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DIPLOMOVÁ PRÁCE

Kuželočelní převodovka pro RIG

Autor: **Bc. Lenka KARLOVÁ**

Vedoucí práce: **Doc. Ing. Jaroslav KRÁTKÝ, Ph.D.**

Akademický rok 2013/2014

ZÁPADOČESKÁ UNIVERZITA V PLZNI
Fakulta strojní
Akademický rok: **2013/2014**

ZADÁNÍ DIPLOMOVÉ PRÁCE

(PROJEKTU, UMĚLECKÉHO DÍLA, UMĚLECKÉHO VÝKONU)

Jméno a příjmení:	**Bc. Lenka KARLOVÁ**
Osobní číslo:	**S12N0053K**
Studijní program:	**N2301 Strojní inženýrství**
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Název tématu:	**Kuželočelní řaditelná převodovka pro rig**
Zadávající katedra:	**Katedra konstruování strojů**

Zásady pro vypracování:

Základní požadavky:
Navrhnout a provést konstrukční výpočty kuželočelní převodovky. Navržené řešení musí splňovat specifikované požadavky zadavatele.

Základní technické údaje:
Technické parametry jsou uvedeny v příloze zadání.

Osnova diplomové práce:

1. Vypracování konstrukčního návrhu včetně systematické specifikace požadavků a koncepčních variant, výběr optimálního řešení.
2. Zjištění klíčových vlastností konstrukčního návrhu s potřebnými technickými výpočty.
3. Vypracování potřebné technické dokumentace.
4. Komplexní zhodnocení.

Rozsah grafických prací:	**dle potřeby**
Rozsah pracovní zprávy:	**50-70 stran A4**
Forma zpracování diplomové práce:	**tištěná/elektronická**

Seznam odborné literatury:

HOSNEDL, S., KRÁTKÝ, J. *Příručka strojního inženýra: obecné strojní části 1.* **Praha: Computer Press, 1999**

KRÁTKÝ, J., KRÓNEROVÁ, E., HOSNEDL, S. *Obecné strojní části 2.* **Plzeň: ZČU, 2011**

MORAVEC, V. *Konstrukce strojů a zařízení II. : čelní ozubená kola : teorie, výpočet, konstrukce, výroba, kontrola.* **Ostrava: Montanex, 2001**

Podkladový materiál, výkresy, katalogy, apod. poskytnuté zadavatelem úkolu.

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Konzultant diplomové práce:	**Ing. Michal Bouda** WIKOW GEAR, s.r.o., Plzeň
Datum zadání diplomové práce:	**23. září 2013**
Termín odevzdání diplomové práce:	**23. května 2014**

Doc. Ing. Jiří Staněk, CSc.
děkan

L.S.

Západočeská univerzita v Plzni
Fakulta strojní

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vedoucí katedry

V Plzni dne 23. září 2013

Prohlášení o autorství

Předkládám tímto k posouzení a obhajobě diplomovou práci, zpracovanou na závěr studia na Fakultě strojní Západočeské univerzity v Plzni.
Prohlašuji, že jsem tuto diplomovou práci vypracovala samostatně, s použitím odborné literatury a pramenů, uvedených v seznamu, který je součástí této diplomové práce.

V Plzni dne: ……. **. . . . . .**
podpis autora

ANOTAČNÍ LIST DIPLOMOVÉ PRÁCE

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STRUČNÝ POPIS **ZAMĚŘENÍ, TÉMA, CÍL POZNATKY A PŘÍNOSY**	Diplomová práce obsahuje návrh převodovky pro naviják lan na ropné plošině ve dvou variantách. Výpočty sloužící k návrhu převodových prvků, hřídelí a uložení hřídelí byly provedeny pomocí výpočetního programu KISSsoft 2013. Pro modelování a výpočet modální analýzy, pevnostní a deformační analýzy byl použit Inventor Professional 2013.
KLÍČOVÁ SLOVA	převodovka, převodový poměr, soukolí, modální analýza, pevnostní analýza, deformační analýza

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BRIEF DESCRIPTION **TOPIC, GOAL, RESULTS AND CONTRIBUTIONS**	The thesis contains a proposal for gear winch ropes on an oil platform in two variants. Calculations use to design transmission elements, shaft and shaft were performed using the computer program KISSsoft. For modeling and calculation of modal analysis, strength and deformation analysis was used Inventor Professional 2013.
KEY WORDS	gearbox, gear ratio, gear, modal analysis, stress analysis, strain analysis

Poděkování

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Obsah

1. Úvod ... 5
2. Představení zadavatele ... 5
2.1. Ukázky z výrobní náplně Wikov Gear, Plzeň ... 7
2.2. Ropná plošina ... 9
3. Upřesnění zadání ... 10
3.1. Požadavky zadavatele ... 11
3.2. Požadované zatěžovací stavy ... 12
4. Převodovka ... 13
4.1. Členění převodovek ... 14
4.2. Vlastnosti výrobků ... 15
4.3. Stavební struktura převodovky ... 15
5. Návrh převodovky ... 21
5.1. Rozdělení zatěžovacích stavů ... 21
5.2. Varianty kinematických schémat ... 21
5.3. Návrh modulů a počtu zubů ... 23
5.4. Model návrhu ... 26
5.4.1. Softwary použité při řešení ... 26
6. Návrh a kontrola jednotlivých souhmotí s využitím programu KISSsoft ... 29
6.1. Soukolí ... 29
6.2. Hřídele ... 29
6.3. Spojovací prvky ... 32
7. Upravená geometrie ... 33
8. Porovnání převodovky typu C, typu KC se stejným motorem a typu KC se stejným výstupním momentem ... 36
9. Modely soukolí ve 3D ... 38
9.1. Původní řešení ... 43
9.2. Převodovka upravená dle požadavků na tuhost ... 45
9.3. Upravená převodovka s jiným uložením vstupního hřídele ... 46
9.4. Porovnání půdorysů jednotlivých řešení ... 47
9.5. Pohled do dělicí roviny variant převodovky typu C ... 48
9.6. Pohled do dělicí roviny variant převodovky typu KC ... 49
10. Pevnostní, deformační a modální analýza skříně převodovky ... 50
10.1. Pevnostní a deformační analýza skříně ... 50
10.2. Modální analýza převodovky ... 52
10.3. Porovnání frekvencí ... 54
11. Závěr ... 57
12. Literatura ... 58

Seznam použitých veličin a jednotek

označení	jednotky	význam
a	[mm]	osová vzdálenost
b	[mm]	šířka kola
d	[mm]	průměr roztečné kružnice
d_a	[mm]	průměr hlavové kružnice
d_f	[mm]	průměr patní kružnice
c	[-]	materiálová konstanta
h_a	[mm]	výška hlavy zubu
h_f	[mm]	výška paty zubu
i	[-]	převod
m	[mm]	modul
M_t	[Nm, kNm]	točivý moment
n_1	[min^{-1}]	otáčky
η	[-]	účinnost
P	[W, kW]	výkon
Q	[l]	objem
t	[mm]	rozteč
v	[ms^{-1}]	rychlost
ν	[mm^2s^{-1}]	viskozita
x	[mm]	korekce
ψ	[-]	materiálová konstanta
z	[-]	počet zubů;

Seznam obrázků

Obr. 2-1 Mgr. Martin Wichterle 5
Obr. 2-2 Instalace převodovky pohonu kolesa korečkového velkorypadla 7
Obr. 2-3 Šneko-planetové převodovky v pohonech velkorypadel a bagrů [9] 7
Obr. 2-4 Pohon cementárenského kulového mlýnu [12] 8
Obr. 2-5 Kuželová převodovka pro požární pohon čerpadla [18] 8
Obr. 2-6 Čelní převodovka pro naviják kotevního lana [18] 9
Obr. 2-7 Rozdělení typů ropných plošin [15] 9
Obr. 2-8 Různé typy plovoucích ropných plošin 10
Obr. 3-1 Obrysové rozměry převodovky typu C; vstupní a výstupní hřídel jsou rovnoběžně 11
Obr. 3-2 Obrysové rozměry převodovky typu KC; vstupní a výstupní hřídel jsou kolmé 12
Obr. 4-1 Základní schéma převodového mechanizmu 13
Obr. 4-2 Kinematické schéma převodovky s rotačním výstupním pohybem 13
Obr. 4-4 Mazání ložiska broděním(vlevo) a mazacím kroužkem 17
Obr. 4-5 Mazání ložiska nuceným oběhem oleje (vlevo), mazání vstřikováním (uprostřed) . 17
Obr. 4-3 Ruční mazání 17
Obr. 4-6 Montážní sada chladiče oleje 18
Obr. 4-7 Těsnění rotujících dílů [4, 7, 13, 17] 20
Obr. 4-8 Princip těsnění pomocí O-kroužku [16] 20
Obr. 5-1 Kinematické schéma převodovky typu C 21
Obr. 5-2 Kinematické schéma převodovky typu KC s nakupovanou převodovkou 22
Obr. 5-3 Možná umístění kuželového soukolí 22

Obr. 5-4 Sestavení prvního návrhu – varianta s rovnoběžným uspořádáním hřídelů 26
Obr. 5-5 Umístění vstupního hřídele pro typ C a typ KC 28
Obr. 6-1 Varianta uložení Hřídele 0 29
Obr. 6-2 Varianta Hřídele I pro rovnoběžné uspořádání hřídelů 30
Obr. 6-3 Varianta Hřídele I pro kolmé uspořádání hřídelů 30
Obr. 6-4 Hřídel II 31
Obr. 6-5 Hřídel III 31
Obr. 6-6 Hřídel IV 32
Obr. 7-1 Vzhled motoru 35
Obr. 9-1 3D model kuželového soukolí Klingelnberg 38
Obr. 9-2 Kuželové soukolí 38
Obr. 9-3 3D model soukolí Klingelnberg – jiné uložení 39
Obr. 9-4 Kuželové soukolí se soudečkovým a párovým kuželíkovým ložiskem 39
Obr. 9-5 3D model soukolí 1,2; soukolí 3,4; přesuvná spojka 40
Obr. 9-6 Osová vzdálenost soukolí 1,2 a 3,4 40
Obr. 9-7 3D model soukolí 5,6 41
Obr. 9-8 Osová vzdálenost soukolí 5,6 41
Obr. 9-9 3D model výstupního hřídele a soukolí 7,8 42
Obr. 9-10 Osová vzdálenost soukolí 7,8 42
Obr. 9-11 3D model původního návrhu univerzální skříně 43
Obr. 9-12 Původní návrh univerzální skříně bez víka 43
Obr. 9-13 Pohled do dělicí roviny obou typů převodovky při původním návrhu 44
Obr. 9-14 Pohled na 3D model upravené převodovky typu KC 45
Obr. 9-15 Pohled do dělicí roviny upravené převodovky typu KC 45
Obr. 9-16 Pohled na 3D model upravené převodovky typu KC – jiné uložení vstupního hřídele 46
Obr. 9-17 Pohled do dělicí roviny. Do skříně umístěna převodovka typu KC 46
Obr. 9-18 Pohled do dělicí roviny. Do skříně umístěna převodovka typu C 46
Obr. 9-19 Rozměry jednotlivých návrhů 47
Obr. 9-20 Pohled do dělicí roviny modelu převodovky typu C jednotlivých návrhů 48
Obr. 9-21 Pohled do dělicí roviny převodovky typu KC jednotlivých návrhů 49
Obr. 10-1 Příprava modelu pro pevnostní a deformační analýzu 50
Obr. 10-2 Napětí Von Mises 50
Obr. 10-3 Výsledky deformační analýzy skříně 51
Obr. 10-4 Náhrada modelů komponent 52
Obr. 10-5 3D model s náhradami komponent a jeho zasíťování 52
Obr. 10-6 První vlastní tvar kmitu 53
Obr. 10-7 Sedmý vlastní tvar kmitu 53

Seznam tabulek

Tab. 3-1 Údaje zadání 10
Tab. 3-2 Rozměry převodovky typu C v mm (označené v Obr. 3-1) 11
Tab. 3-3 Rozměry převodovky typu KC v mm (označené v Obr. 3-2) 12
Tab. 5-1 První návrh ozubení (jeden zatěžovací stav a rovnoběžná vzájemná poloha hřídelů) 25
Tab. 5-2 Zatěžovací stavy pro první návrh soukolí 25

Tab. 5-3 První návrh ozubení (jeden zatěžovací stav a vzájemná poloha hřídelů kolmá) 27
Tab. 5-4 Zatěžovací stavy pro první návrh soukolí (kolmá poloha hřídelů) 27
Tab. 5-5 Dovolené hodnoty průhybu podle doporučení softwaru MITCalc 28
Tab. 6-1 Mechanické vlastnosti oceli udávané dodavatelem [10] 32
Tab. 7-1 Upravená geometrie (vyznačená tučně); vzájemná poloha hřídelů rovnoběžná 33
Tab. 7-2 Změny v zatěžovacích stavech vyvolané změnou geometrie kol (typ C) 33
Tab. 7-3 Upravená geometrie (vyznačená tučně); vzájemná poloha hřídelů kolmá 34
Tab. 7-4 Zatěžovací stavy při užití stejného motoru na vstupu (poloha hřídelů kolmá) 34
Tab. 7-5 Zatěžovací stavy při požadavku stejného momentu na výstupu 34
Tab. 7-6 Porovnání čtyř sledovaných parametrů 35
Tab. 7-7 Vliv kmitočtu sítě na potřebnou velikost motoru [8] 35
Tab. 10-1 Hodnoty zubových frekvencí v Hz 55
Tab. 10-2 Hodnoty vlastních frekvencí převodovky 55
Tab. 11-1 Sledované parametry pro řešené možnosti 57

1. Úvod

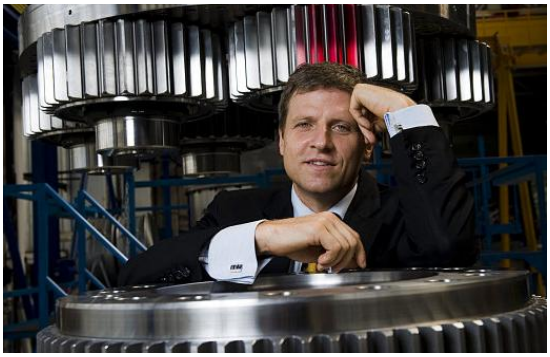
Cílem této diplomové práce je navrhnout převodovku ve dvou variantách podle zadaných parametrů a požadavků zadavatele. Převodovka bude pracovat na ropné plošině plovoucí v moři. Bude sloužit k pohonu navijáku lan, která plošinu kotví a vyrovnávají její polohu.

2. Představení zadavatele

Zadavatelem diplomové práce je firma Wikov Gear, Tylova 1/57, 301 00 Plzeň, která je součástí holdingu Wikov Industry. Jde o významnou firmu, která je pokračovatelem části bývalého koncernu Škoda a má tak tradici ve strojírenství více než 125 let a ve výrobě ozubených kol a převodovek více než 80 let. Holdingová společnost Wikov Industry má následující strukturu

- Wikov Industry je holdingová skupina s ředitelstvím v Praze.
- Wikov MGI konstruuje a vyrábí speciální převodovky pro široké spektrum průmyslových aplikací, kolejová vozidla a větrné turbíny.
- Wikov Gear vyrábí velké převodovky a díly převodovek pro těžební průmysl, cementárny a průmysl těžby ropy a plynu.
- Wikov Wind poskytuje kompletní dodávky větrných elektráren včetně stavby a servisování.
- ORBITAL2 je konstrukční kancelář především pro aplikace větrných elektráren.
- Wikov China je naše zastupitelská kancelář v Číně.
- Wikov Sázavan je výrobní závod specializující se na výrobu strojních celků a precizní obrábění jejich komponent.

Firma má obchodní zastoupení v Bulharsku, Indii, Indonésii, Íránu, Korei, Nizozemí, Belgii, Lucembursku, Rusku, Singapuru, Turecku, USA a Kanadě.



Obr. 2-1 Mgr. Martin Wichterle

Jednatelem společnosti Wikov Industry a zároveň jediným akcionářem je dle Obchodního rejstříku (ke dni 27.4.2014) Mgr. Martin Wichterle [19], vnuk špičkového českého chemika prof. Otty Wichterleho (vynálezce např. kontaktních čoček) a pravnuk zakladatele významných strojíren v Prostějově, kde se vyráběly parní lokomotivy, zemědělské stroje a automobily.

Wikov Gear je výrobní závod s cca 150 zaměstnanci specializující se na:

- Design a výrobu převodovek pro:
  - Tepelné elektrárny
  - Povrchové doly
  - Cementárny a zpracování minerálů
  - Průmysl těžby ropy a plynu
  - Cukrovary
  - Chemický průmysl
- Design a výrobu rychloběžných převodovek
- Výrobu kuželových kol s ozubením Klingelnberg do průměru 1150 mm (lapované a HPG)
- Výrobu profilově broušených ozubených kol s přímým vnitřním a vnějším ozubením do průměru 2500 mm
- Výrobu frézovaných ozubených dílů do průměru 3500 mm

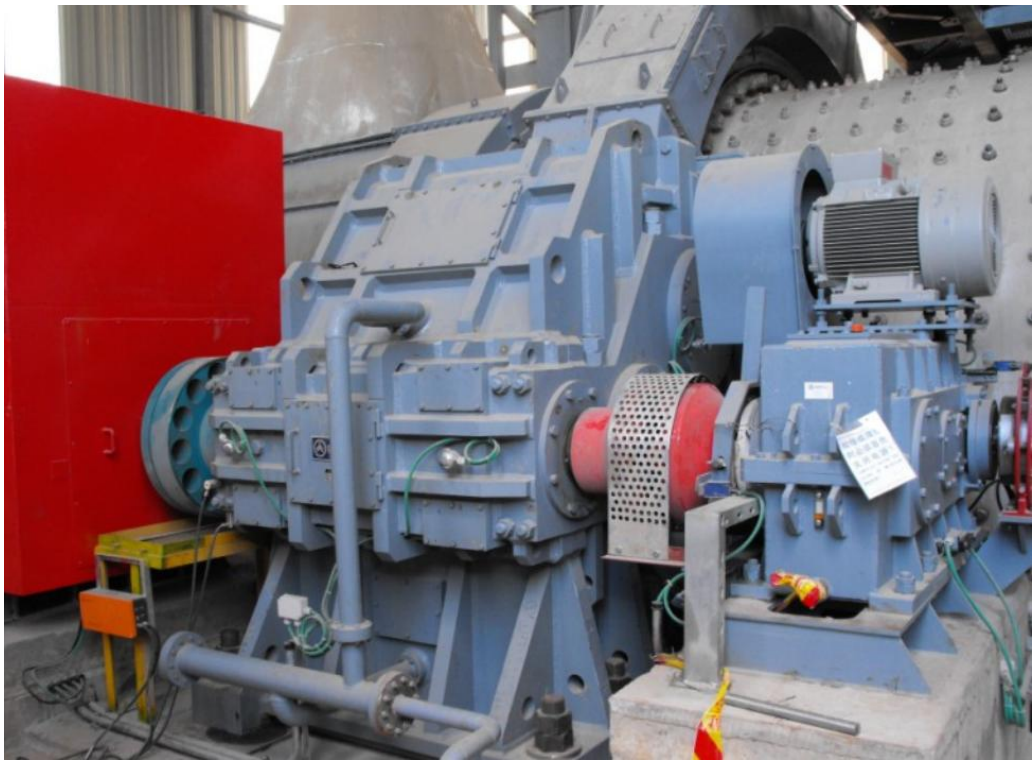
Pro odvětví Těžba ropy a plynu a Loďařský průmysl firma dodává

- Převodovky pro tyto aplikace:
  - kotevní, uvazovací, tažné či kombinované vrátky
  - naviják vrtného systému
  - čerpadlo hasicího zařízení
  - kalové čerpadlo
  - hlavice vrtného systému
  - převodovky pohonu lodí s hydraulickým ovládáním propeleru
  - přesná ozubená kola s čelním ozubením do průměru 2500 mm – dle DIN3961 do přesnosti IT4 (3)
- Rychloběžné převodovky pro:
  - pohon plynových turbín
  - pohon turbokompresorů
  - pohon čerpadel
  - pohon motor/generátor
- Sady ozubených kol pro dieselové motory:
  - dělená kola pro klikové hřídele
  - rozvodová kola
- Sady cyklopaloidních soukolí Klingelnberg do průměru talířového kola až 1150 mm pro thrustery
- Přejímky produktů u renomovaných přejímacích společností, jako jsou např.: BV, DNV, LRS, GL, ABS, KR, a další

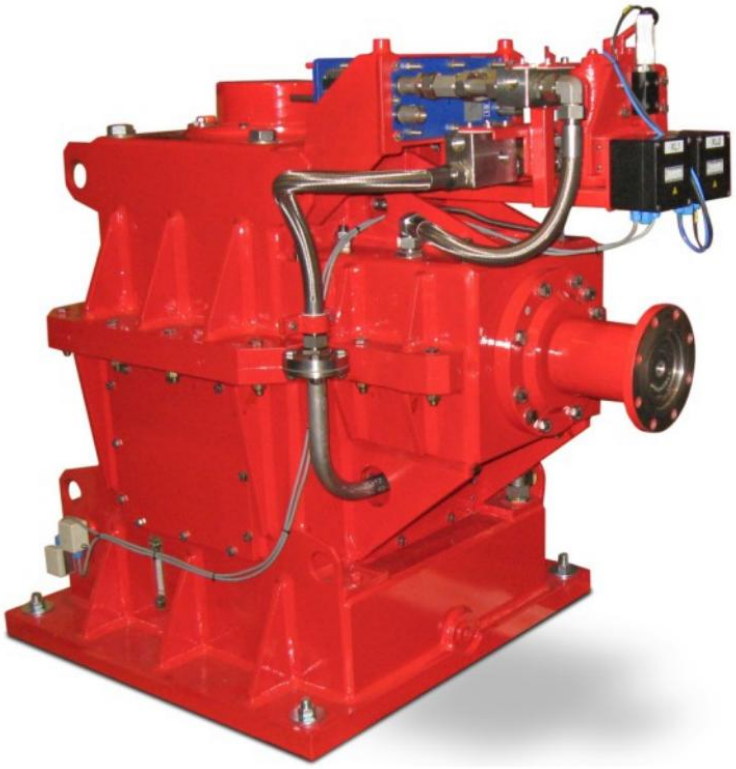
2.1. Ukázky z výrobní náplně Wikov Gear, Plzeň

Obr. 2-2 Instalace převodovky pohonu kolesa korečkového velkorypadla

Obr. 2-3 Šneko-planetové převodovky v pohonech velkorypadel a bagrů [9]



Obr. 2-4 Pohon cementárenského kulového mlýnu [12]

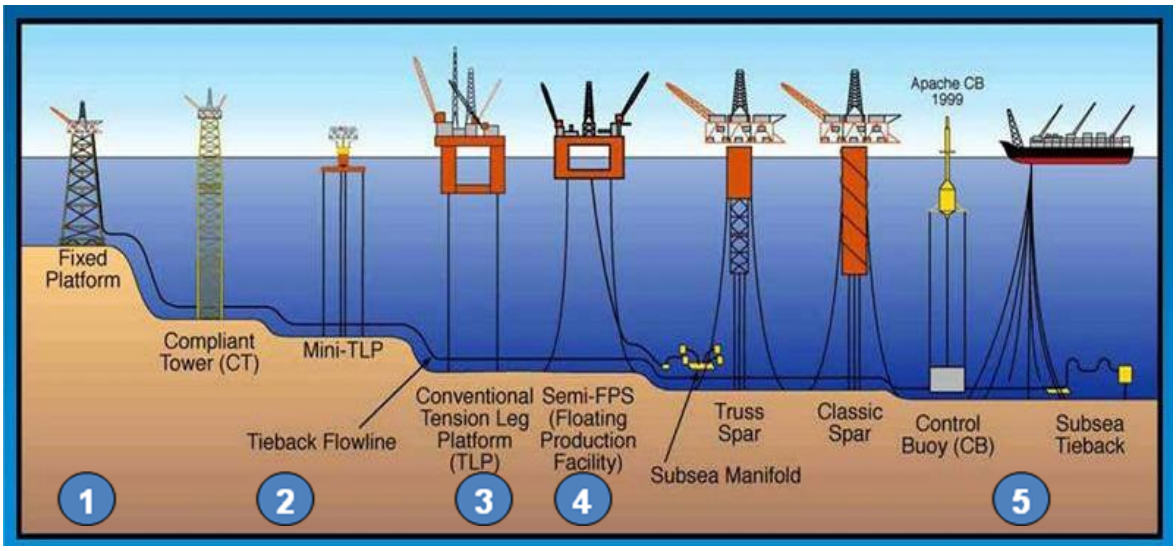


Obr. 2-5 Kuželová převodovka pro požární pohon čerpadla [18]

Obr. 2-6 Čelní převodovka pro naviják kotevního lana [18]

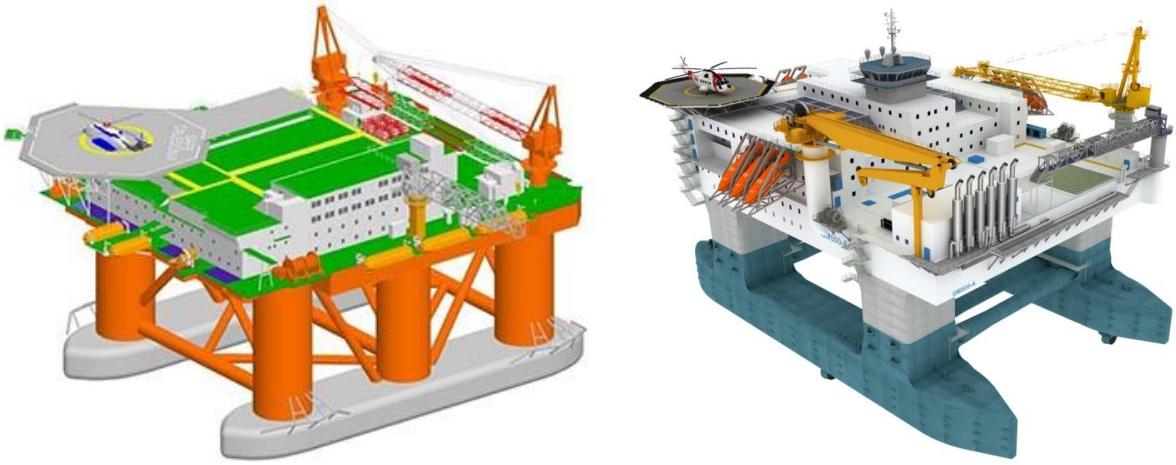
2.2. Ropná plošina

Ropná (vrtná) plošina je specializované technické zařízení určené k těžbě ropy, které je ukotvené k mořskému dnu.



Obr. 2-7 Rozdělení typů ropných plošin [15]

1. **Pevná plošina** - zabetonována do mořského dna, použitelná do hloubky 500 m
2. **Jack-up plošina** - vybavena vlastními vysouvacími nohami, použitelná do hloubky 120 až 150 m
3. **Volná nebo mobilní plošina** - ukotvená lany ke dnu, použitelná do hloubky 900 m
4. **Poloponorná plošina** - nadnášena pontony a ukotvena ke dnu, použitelná do hloubky 3200 m
5. **Vrtací souprava na lodi** - je použitelná do hloubky 3700 m



Obr. 2-8 Různé typy plovoucích ropných plošin

3. Upřesnění zadání

Úkolem práce je navrhnout konstrukci redukční převodovky pro činnost lodního manipulačního navijáku lana podle požadavků zadavatelské firmy. Točivý moment se přenáší z převodovky drážkováním vždy pouze na jednom ze dvou konců výstupního hřídele. Jako pohon je určen elektrický motor. Točivý moment je z motoru přenášen pomocí pera.

Životnost je požadována 2400 hodin. Odpovídá době životnosti plošiny 20 let. 20 % doby je převodovka zatížena 100 % maximálního zatížení, 80 % doby životnosti je zatížena do výše 70 % max. zatížení. 50% provozní doby tvoří reverzní chod.

Převodovka bude mazána broděním s použitím syntetického oleje typu PG (na bázi polyglykolů). Při poklesu teploty oleje pod 15°C se použije ohřívač oleje, který je možné odstranit bez vypuštění oleje. Teplota oleje nesmí překročit 65°C. K chlazení slouží vodní chladič ve formě spirály z nerezové oceli.

Skříň navrhnout univerzální pro uspořádání hřídelů vstupu a výstupu rovnoběžně (pro převodovku typu C) i kolmo (pro převodovku typu KC).

Převodovka typu C i typu KC má mít dvě výstupní rychlosti. Řadicí mechanismus, který bude použitý, už je využíván u jiných výrobků firmy a není součástí řešení této práce.

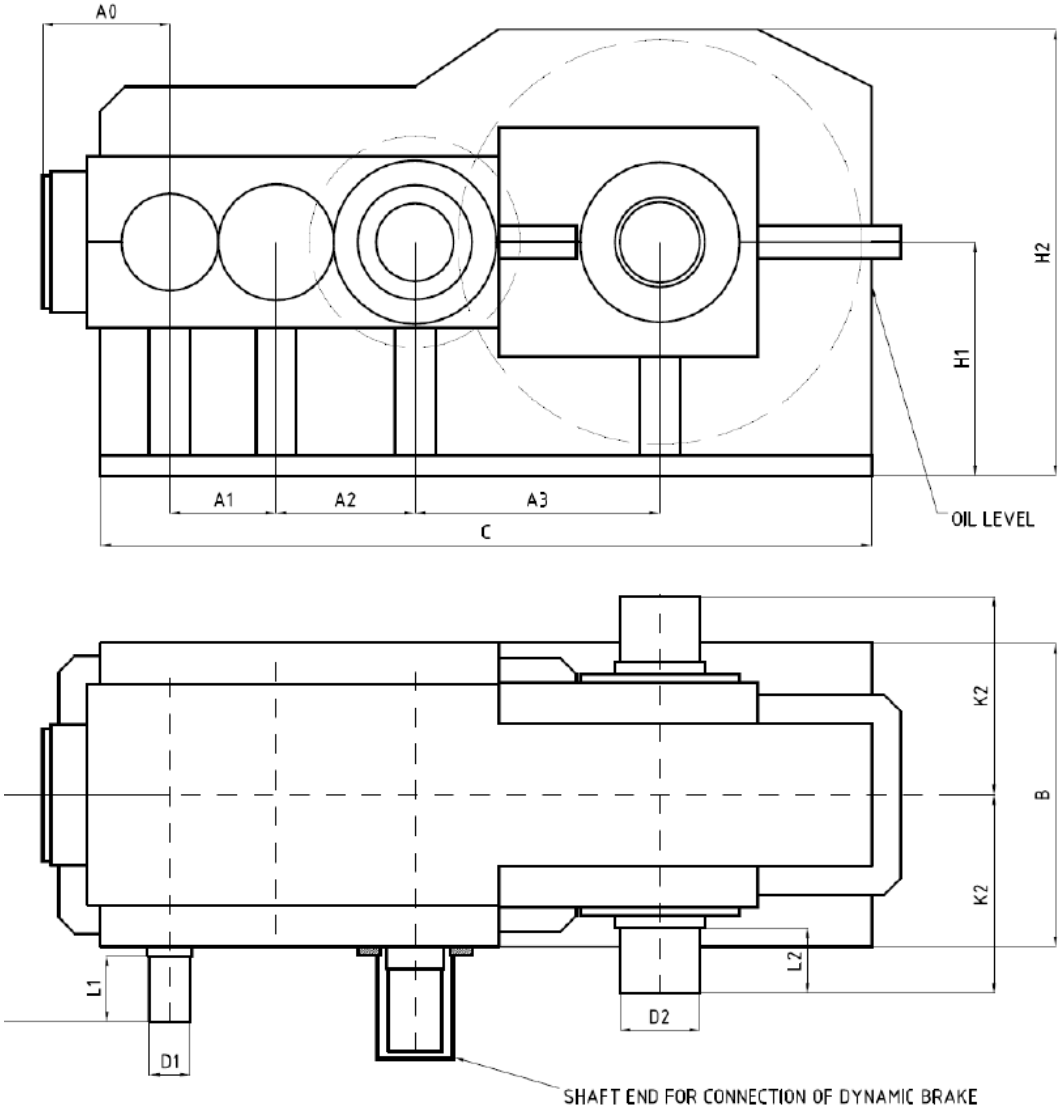
Na výrobu ozubených kol použít přednostně materiál 18CrNiMo7-6.

Převod	i	54,485 / 14,825
Moment	Mt [Nm]	6.000
Vstupní otáčky	n_1[min^{-1}]	800
Výstupní otáčky	n_2[min^{-1}]	14,68 / 53,96
Hmotnost	m [kg]	6900
Množství oleje	Q [l]	400
Viskozita oleje	ν [mm^2s^{-1} / 40°C]	150
Typ oleje	Shell Omala SGX	
Typ maziva	Shell Alvania EP2	

Tab. 3-1 Údaje zadání

3.1. Požadavky zadavatele

Součástí zadání je orientační požadavek na rozměry skříně. Zadavatel chce používat jednu univerzální skříň pro dva typy převodovek. Na prvním obrázku je rámcová představa skříně převodovky s rovnoběžně uloženými hřídeli (typ C). Průměr vstupního hřídele je 100 mm a délka přesahující skříň je 160 mm. Výsledný převod má být uskutečněn pomocí tří převodů. Osové vzdálenosti budou stejné u obou typů převodovky. Je určena délka, šířka a výška skříně. Výstupní hřídel bude na obou koncích drážkovaný (260x5x50), délka pro spojení bude 200 mm. Výstupní hřídel přesahuje symetricky obrysy skříně o 180 mm na každé straně. Na obrázku je určeno místo pro připojení dynamické brzdy na třetím hřídeli. Je to jen jedna z možností brzdění a pro řešení této práce bude hřídel překrytý víčkem. Přibližné rozměry jsou v tabulce pod obrázkem.

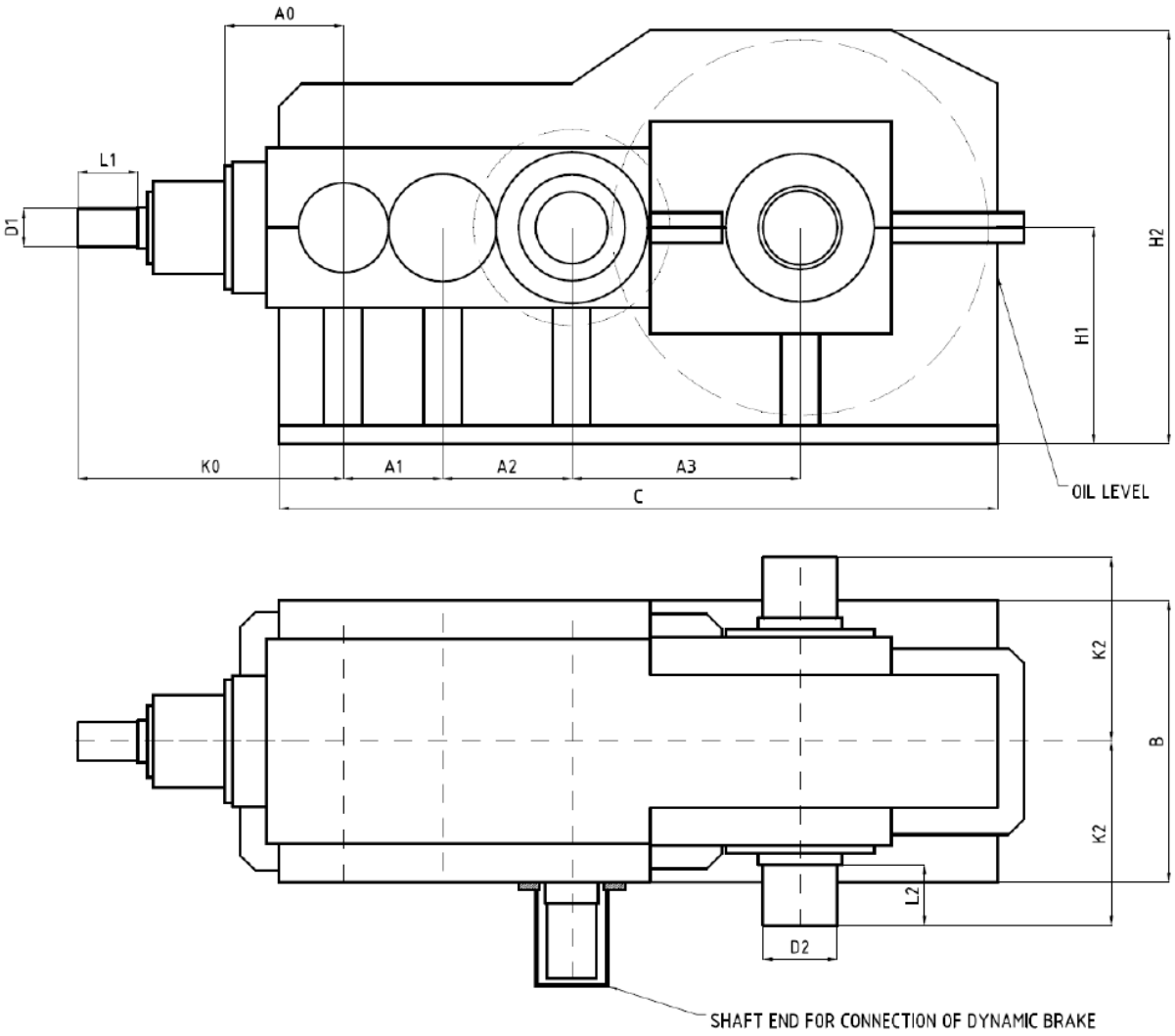


Obr. 3-1 Obrysové rozměry převodovky typu C; vstupní a výstupní hřídel jsou rovnoběžně

A0	A1	A2	A3	B	C	H1	H2	K2	D1	L1	D2	L2
340	300	465	750	780	2615	720	1380	570	100	160	260x5x50	200

Tab. 3-2 Rozměry převodovky typu C v mm (označené v Obr. 3-1)

Typ převodovky KC (Obr. 3-2) vychází z předchozího typu C. Je rozšířen o vstupní hřídel, který je kolmý ke stávajícím (kolmý k výstupnímu). Osa vstupního hřídele má ležet v dělicí rovině skříně a v ose převodovky. Původní vstupní hřídel nemá nepřesahovat obrys skříně. Ostatní rozměry zůstávají stejné jako u typu C.



Obr. 3-2 Obrysové rozměry převodovky typu KC; vstupní a výstupní hřídel jsou kolmé

A0	A1	A2	A3	B	C	H1	H2	K2	D1	L1	D2	L2
340	300	465	750	780	2615	720	1380	570	100	160	260x5x50	200

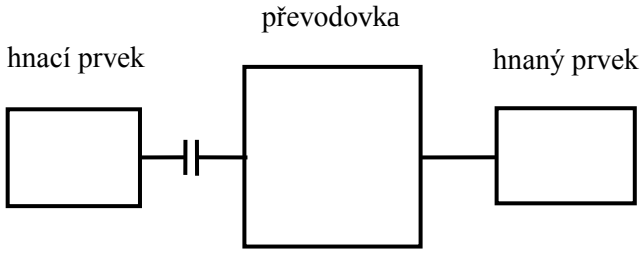
Tab. 3-3 Rozměry převodovky typu KC v mm (označené v Obr. 3-2)

3.2. Požadované zatěžovací stavy

Celková doba životnosti je rozdělena v poměru 1:4. Dvacet procent času bude převodovka zatížena na 100% výkonu; osmdesát procent času bude zátěž 70%. Polovinu obou časů bude tvořit reverzní chod.

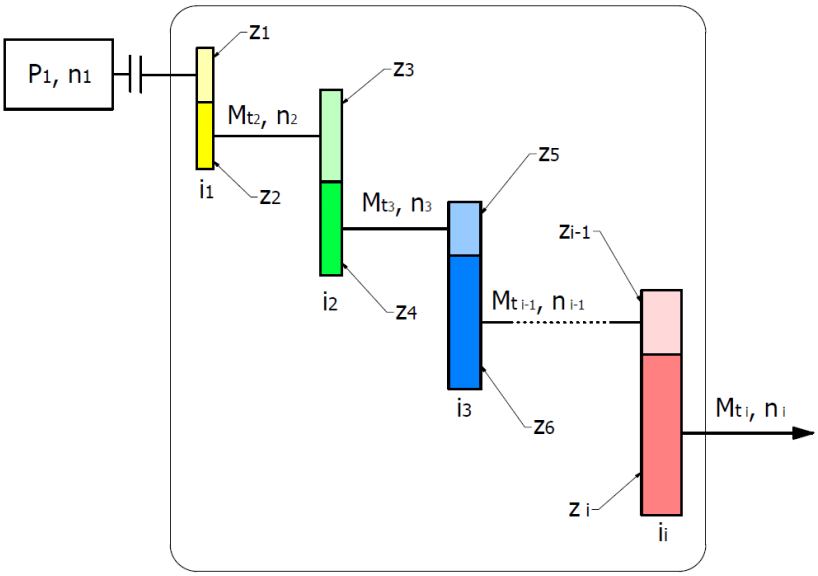
4. Převodovka

Převodovka umožňuje mechanický převod. Je to technické zařízení, které realizuje změnu rotačního pohybu na rotační pohyb s jinou úhlovou rychlostí a točivým momentem. Může umožnit nastavení jednoho nebo více převodových stupňů. Převodovka je součástí pohonného systému. Vytváří kinematickou a silovou vazbu mezi vstupním a výstupním členem.
Převodovky rozdělujeme na převodovky se stálým převodovým poměrem a na převodovky s proměnlivým převodovým poměrem (variátory).
Je-li výstupní rychlost nižší než vstupní, jde o převodovky redukční. V opačném případě říkáme převodovkám multiplikátory.



Obr. 4-1 Základní schéma převodového mechanizmu

Hnací prvek představuje spalovací motor, turbomotor, hydromotor, elektromotor nebo ruční klika.
Výstupní pohyb převodovky může být rotační nebo posuvný.
Funkčními parametry převodovky jsou příkon (nebo vstupní točivý moment), výstupní otáčky (nebo posuvová rychlost na výstupu), celkový převodový poměr, celková účinnost a životnost.
Rozměrovými parametry jsou rozměry připevnění k základu a vzájemná poloha vstupní a výstupní osy.
Provozními parametry jsou provozní teplota, počet rozběhů za čas a zatěžovací spektrum.



Obr. 4-2 Kinematické schéma převodovky s rotačním výstupním pohybem

4.1. Členění převodovek

4.1.1. Podle kinematiky

- rotační ⟶ rotační
  vstupní energie do převodovky je přenášena rotačním pohybem hřídele, výstupní energie je přenášena rotačním pohybem hřídele, ale s jinou charakteristikou, (jiné otáčky / jiný kroutící moment / jiný směr otáčení)
- rotační ⟶ lineární
  vstupní energie do převodovky je přenášena rotačním pohybem hřídele, výstupní energie je přenášena lineárním pohybem (posuvem)
- lineární ⟶ lineární
  vstupní energie do převodovky je přenášena lineárním pohybem (posuvem), výstupní energie je přenášena lineárním pohybem (posuvem)
- rotační ⟶ periodický
  vstup do převodovky vykonává rotační pohyb, výstup převodovky vykonává periodický rotační (kývavý) pohyb nebo periodický posuvný pohyb (tam-zpět)

4.1.2. Podle funkce

- lineární
  výstup převodovky je vždy lineárně úměrný poloze vstupu, např. úhlu natočení hřídele
- nelineární
  výstup převodovky vykonává pohyb, který není přímo úměrný vstupu převodovky (spojitý, nelineární) případně může být výstup z převodovky přerušovaný (nespojitý, nelineární).

4.1.3. Podle přenosu energie

- obousměrné
  vstup a výstup převodovky je možno zaměnit (zpravidla u jednoduchého soukolí).
- jednosměrné
  převodovka má určenou vstupní a výstupní stranu pro přenos energie (zpravidla vícestupňové převodovky).
- samosvorné
  konstrukce převodovky principiálně neumožňuje obousměrný přenos výkonu (např. šroubové a šnekové převodovky). [8]

4.1.4. Podle provedení

- s přímými, šikmými nebo šípovými zuby – rovnoběžné vstupní a výstupní hřídele
- s kuželovým soukolím – různoběžné vstupní a výstupní hřídele
- se šnekovým převodem – kolmé vstupní a výstupní hřídele

4.2. Vlastnosti výrobků

Samotná volba jednotlivých prvků výrobků, tedy i převodovek, se provádí podle různých kritérií. Existuje řada různých vlastností, které lze utřídit do určitých skupin nebo tříd. Vlastnosti se dají dělit na tři skupiny vlastností:

1. **Vlastnosti deskriptivní** – tedy vlastnosti, které daný technický systém popisují zvnějšku – jak objekt vypadá, jako např. jeho tvar, rozměr, materiál a barva
2. **Reaktivní vlastnosti** – což jsou vlastnosti, kterými objekt reaguje na vnější podněty, jeho reakce na okolí. Tuto skupinu vlastností lze dále rozdělit do podtříd:
   a) Fyzikální vlastnosti – lze je popsat fyzikálními veličinami a jsou také měřitelné a kvalifikovatelné fyzikálními jednotkami soustavy SI. Mimo jiné tuhost, pevnost, tvrdost a houževnatost.
   b) Interaktivní vlastnosti – vyjadřují odolnost vůči působení okolního prostředí na objekt jako např. odolnost vůči chemicky agresivnímu prostředí nebo odolnost vůči korozi apod.
   c) Technicko-výrobní vlastnosti – využití objektu v praxi, především vyrobitelnost objektu (např. obrobitelnost), dále vhodnost a možnosti spojení např. svařitelnost

3) **Reflektivní vlastnosti** – vlastnosti, jakými objekt působí zpět na okolí. Jsou to jeho provozní a výrobní vlastnosti; ekonomické, distribuční a legislativní vlastnosti; ergonomické, ekologické a likvidační vlastnosti

4.3. Stavební struktura převodovky

- převodové prvky
  slouží k převodu jednoho typu pohybu na pohyb s jinými parametry (např. úhlová rychlost, točivý moment)
- přenosové prvky
  slouží k přenosu zatížení mezi převodovým prvkem a rámem
- uložení rotačních částí
  slouží k zajištění jednoznačné polohy hřídelů vůči rámu (kriteria při jejich volbě jsou únosnost, životnost, tuhost, vůle, tepelné poměry, mazání)
- Spojovací prvky pro přenos točivého momentu

4.3.1. Převodové prvky

- Ozubené čelní válcové (účinnost převodu asi 0,98)
- Ozubené kuželové (účinnost převodu asi 0,96)
- Ozubené šnekové (účinnost převodu do 0,6)
- Třecí
- Řetězové
- Řemenové
- Převod pohybový šroub – pohybová matice
- Vačkový mechanizmus
- Klikový mechanizmus

4.3.2. Prvky pro přenos zatížení

- Hřídele

4.3.3. Uložení rotačních částí

- Valivá ložiska
- S plošným dotykem - kluzná ložiska
  - hydrostatická ložiska
  - hydrodynamická ložiska

4.3.4. Spojovací prvky pro přenos točivého momentu

- Kolíky
- Pera
- Drážkování
- Nalisování
- Rozpěrné kroužky

4.3.5. Rám – převodová skříň s výztužnými žebry

- Svařenec
- Odlitek
- Kombinace

4.3.6. Prvky zajišťující další funkce

- Mazání
- Chlazení
- Těsnění

Mazání

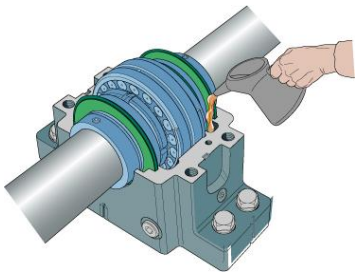
Mazání snižuje třecí odpory a opotřebení funkčních ploch, tím zvyšuje účinnost, přesnost a životnost, a snižuje hlučnost. V převodovkách jsou místa s vyššími nároky na mazání – ložiska, spojky, ozubená kola, vodicí plochy. Jinde stačí přetržité mazání. Způsob mazání dělíme podle počtu mazaných míst na centrální a jednotlivé. Mazat lze pevným mazivem (grafit, teflon) olejem nebo tukem (plastickými mazivy).

Mazací soustavy, kde mazací medium oběhne soustavou jen jednou, nazýváme ztrátové. V uzavřených soustavách obíhá mazivo stále. Soustava může být beztlaková nebo s působícím tlakem [11].

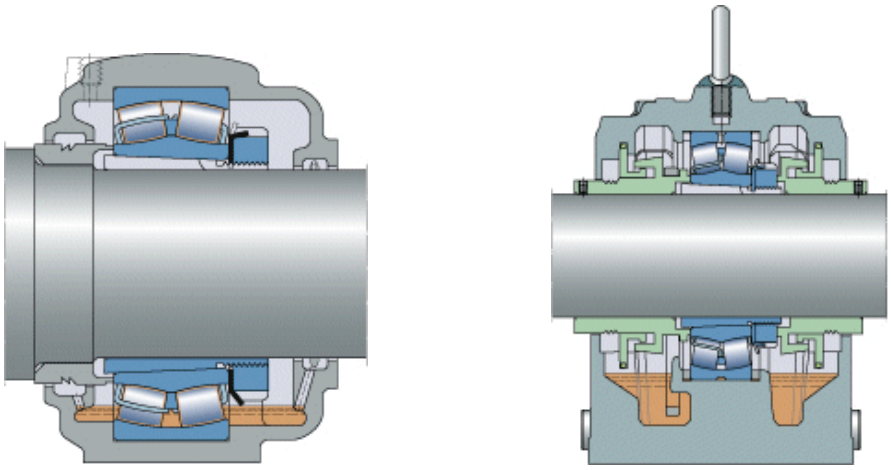
Způsoby nanášení maziva na funkční plochy:

- ruční
  Nalitím maziva do označených maznic.
- kapáním
  Zcela ztrátový systém.
- rozstřikem, broděním
  Některé části jsou částečně ponořeny v oleji Olej svým pohybem nabírají a rozstřikují. Hloubka ponoru je cca polovina výšky zubu. Používá se do obvodové rychlosti 6m/s. Při vyšších rychlostech olej pění a přehřívá se. Šneky do rychlosti 4m/s ponořeny více než z poloviny. Může se stát, že se rozstřikované mazivo nedostane na všechna potřebná místa. Zajištění mazání takových míst můžeme dosáhnout změnou tvaru ploch, od kterých se mazivo odráží, nebo musíme přidat některý další způsob mazání.

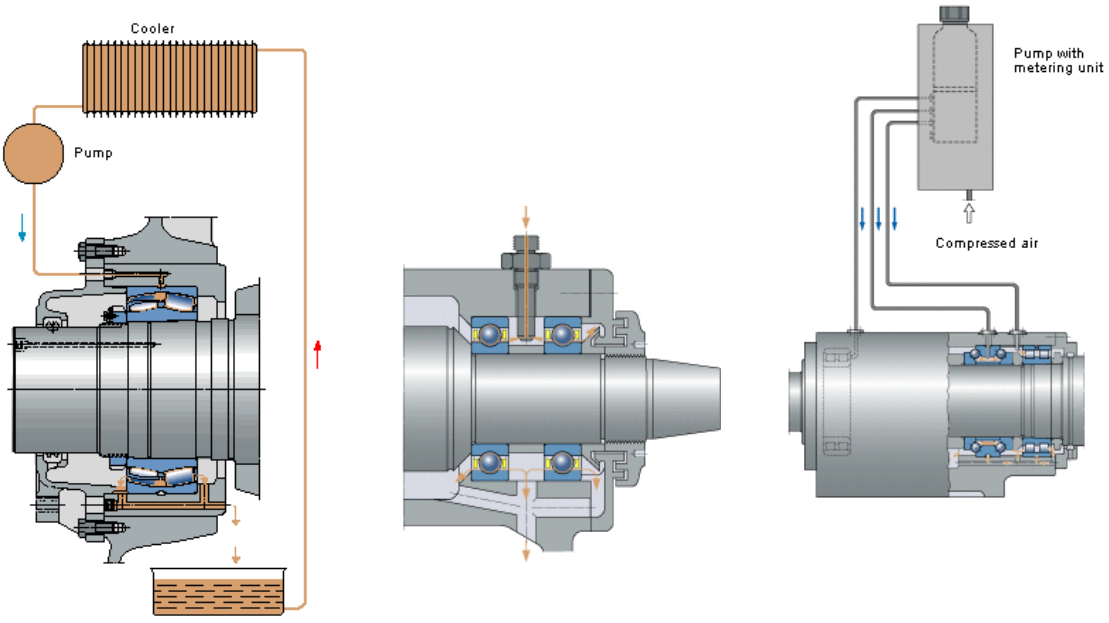
- olejovou mlhou
  Využívá se při vysokých otáčkách. V celém prostoru se díky tlakovému vzduchu tvoří z oleje jemné kapičky.
- oběhové
  Jde o tlakové mazání v uzavřené soustavě, které plní více funkcí, např. chlazení. Tlak zajišťuje ponorné samonasávací čerpadlo s vlastním elektromotorem.



Obr. 4-3 Ruční mazání



Obr. 4-4 Mazání ložiska broděním(vlevo) a mazacím kroužkem



Obr. 4-5 Mazání ložiska nuceným oběhem oleje (vlevo), mazání vstřikováním (uprostřed) a mazání systémem olej-vzduch [7]

Chlazení

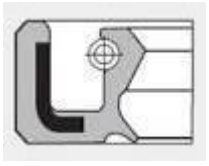
K chlazení přistupujeme proto, že při styku zubů dochází nejen k odvalování, ale také ke skluzům. Ty se podílejí na snížení účinnosti převodovky a projeví se ve formě tepla. Převodový olej je třeba přizpůsobit teplotě převodovky. Ideální teploty v převodovce by byly z hlediska oleje kolem 60° C. Je-li vyšší, je třeba zkrátit interval výměny oleje. Přírůstek teploty o 10°C vede ke snížení doby životnosti oleje o 50%. Naopak snížením teploty o 10°C tato doba vzroste na dvojnásobek.

Obr. 4-6 Montážní sada chladiče oleje

Těsnění

Důvodem k používání těsnění je skutečnost, že nečistoty, které vniknou do soustrojí, mohou být důvodem mechanického poškozování hřídelů a ložisek. To pak vede ke snížení životnosti dílu nebo i celého stroje. Dalším důvodem použití těsnění je zabránění úniku ekologicky nepříznivých médií vně stroje. Těsní se rotující díly, díly, které mají přímočarý posuv nebo navzájem se nepohybující díly.

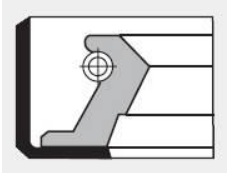
Těsnění pro rotující díly

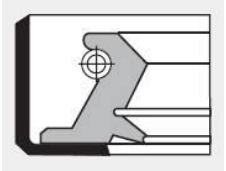


Gufero bez prachovky

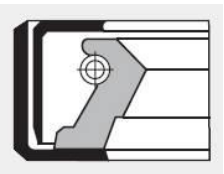
Gufero s prachovkou

Těsnění s jedním těsnícím břitem. Pryžový elastický vnější plášť eliminuje teplotní roztažnost a větší povrchovou drsnost úložného prostoru. Při častější výměně těsnění není nebezpečí poškození zástavbového prostoru. Typ je vhodný pro běžné utěsnění kapalných a plynných médií**.** Ochranná prachovka zabraňuje přístupu prachu a nečistot do vlastního těsnícího místa. Otěr na těsnění snižuje a korozi na hřídeli zabraňuje mazací vazelína v prostoru mezi těsnícím břitem a prachovkou.

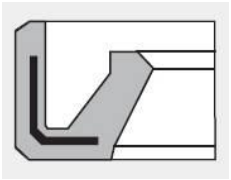




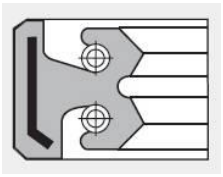
Těsnění s jedním těsnícím břitem. Kovové pouzdro umožňující při montáži snadnější uložení. Vyžaduje přesnější toleranci úložného prostoru, aby bylo dosaženo dokonalého utěsnění i na vnějším plášti.



Těsnění s jedním těsnícím břitem. Je opatřeno kovovým pouzdrem a kovovou výztuží. Pro drsnější provozní podmínky a větší rozměry. Gufero je díky výztuži odolnější vůči chybám při montáži.

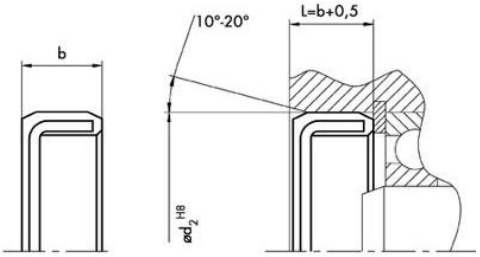


Těsnění s jedním těsnícím břitem**.** Gufera bez tažných pružinek určená pouze pro nenáročná použití**.** Gufera WAO mají vnější pryžový plášť.

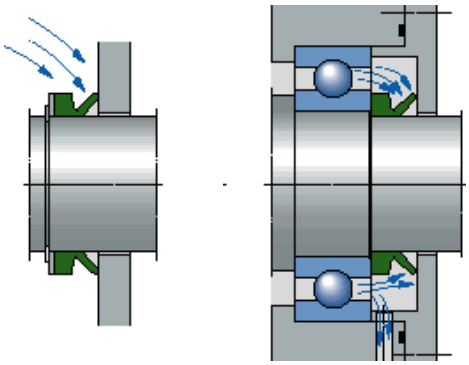


Těsnění se dvěma těsnícími břity k utěsňování dvou médií. Gufera WAD mají vnější pryžový plášť. Těsnění se čtyřmi břity jsou ještě účinnější. Mají nižší tření. Nahrazují těsnění se dvěmi břity pro vyšší otáčky hřídele. Výroba ze vstřikovaného termoplastického elastomeru (TPE).

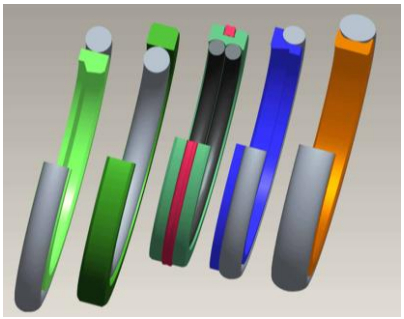
Axiální těsnění se používají především v kombinaci s radiálními těsnicími kroužky hřídele. Používají se jako modulární předřazený těsnicí prvek pro utěsnění před nečistotami, prachem, tukem a proti stříkající vodě z vnějšku. Axiální těsnění se skládají ze dvou složek - z kovového kroužku a z pryže.



Těsnící víčko se používá pro bezpečné utěsnění otvorů pro hřídele. Často v převodovkách. Požadujeme chemickou odolnost vůči olejům a tukům. Střední odolnost proti stárnutí.

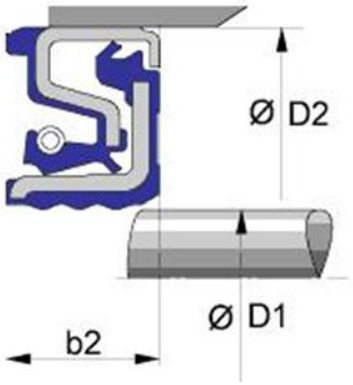


V-kroužky - celopryžová těsnění pro rotující hřídele s kuželovým těsnicím břitem. Montují se a otáčejí s hřídelí. Těsnicí břit v axiálním směru těsní vůči stykové ploše, která je kolmá k hřídeli. V-kroužky lze roztáhnout a mohou být při montáži přetaženy i přes přírubu - výhoda při opravách. Při rychlostech od 8 do 12 m/s musí být axiálně pojištěny. Ochrana proti prachu, popř. stříkající vodě.
Jedna velikost V - kroužku může být použitá i pro více průměrů hřídelí.



Dvoudílné rotační těsnění (Omegat) se skládá z opěrného o-kroužku a PTFE tvarového těsnícího kroužku. Výhodou je možnost kombinace posuvného a rotačního pohybu, a možnost velkého tlakového zatížení těsnění.

Těsnicí kroužky, které se dotýkají rotačních dílů, jsou při provozu zdrojem tepla. Z tohoto důvodu se u rychloběžných převodovek používá labyrint.

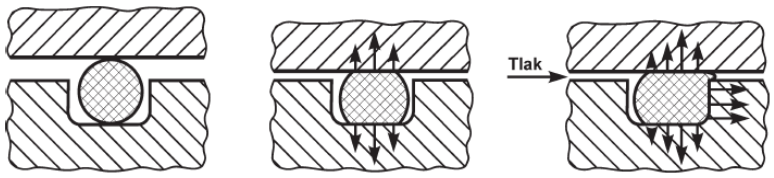


Kazetové těsnění je kompletní jednotka složená z radiálního hřídelového těsnění a protiběžného místa. Racionální řešení se zabudovaným labyrintem proti extrémnímu zatížení nečistotami. Zabudované protioběžné místo odpovídá vysokým požadavkům na dynamické těsnění. Výhodou tohoto těsnění je nenáročnost na opracování hřídele (i jeho možné použití pro poškozené hřídele) a je výrazně prodloužená životnost.

Obr. 4-7 Těsnění rotujících dílů [4, 7, 13, 17]

Těsnění pro statická a dynamická použití

O-kroužky jsou vhodné pro těsnění vzájemně se nepohybujících částí (pod hlavou šroubu, utěsnění víka) nebo při vzájemném axiálním pohybu (píst a pístnice)



Obr. 4-8 Princip těsnění pomocí O-kroužku [16]

5. Návrh převodovky

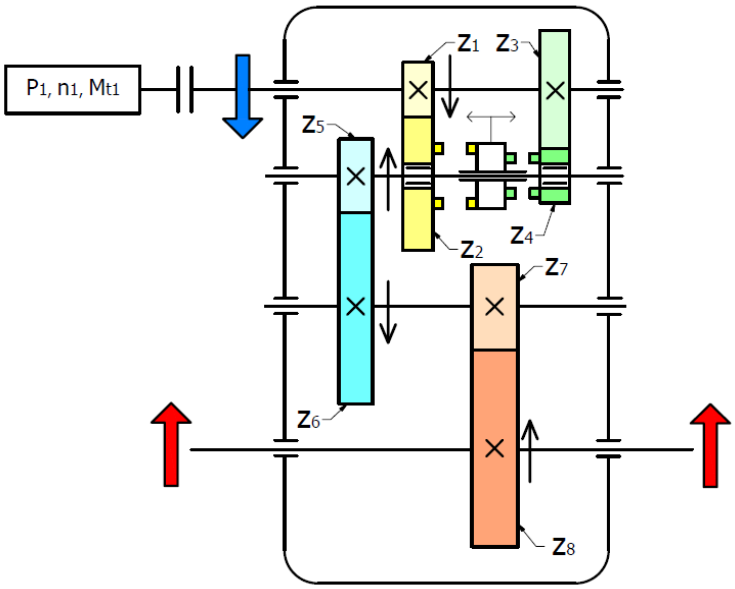
5.1. Rozdělení zatěžovacích stavů

Celková doba životnosti T je rozdělena v poměru 1:4 na dobu T_1 a dobu T_2. Po dobu T_1 bude převodovka zatížena na 100% výkonu; po dobu T_2 bude zátěž 70%. Polovinu doby T_1 i doby T_2 bude tvořit reverzní chod (tj.10 a 40%). V tomto okamžiku jde o 4 zatěžovací stavy. Spojkou na hřídeli II bude zařazen 1. nebo 2. rychlostní stupeň. Rozdělením 4 předchozích stavů dvěma rychlostními stupni dostávám osm zatěžovacích stavů.

100% zatížení	Celková doba provozu T=2400 hodin	Moment na vstupním hřídeli [kNm]	Moment na hřídeli II	
	$T_1 = 2400 \cdot 0{,}2 = 480$		Stupeň	[kNm]
1.	120	6	1.	22,14
2.	120	-6		-22,14
3.	120	6	2.	6
4.	120	-6		-6
70% zatížení	$T_2 = 2400 \cdot 0{,}8 = 1920$			
5.	480	4,2	1.	15,5
6.	480	-4,2		-15,5
7.	480	4,2	2.	4,2
8.	480	-4,2		-4,2

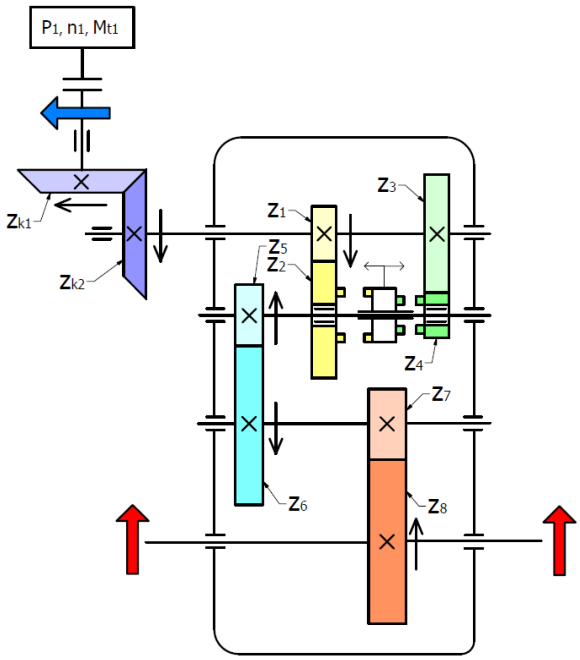
Motor zatím není specifikovaný. Vstupní točivý moment je M_t = 6000 Nm

5.2. Varianty kinematických schémat



Obr. 5-1 Kinematické schéma převodovky typu C

Na základě požadavků zadavatele jsem sestavila návrh kinematického schéma pro typ převodovky C. Všechny hřídele mají vůči sobě navzájem rovnoběžnou polohu. Převodovka má mít dva převodové stupně. To je umožněno dvěma kinematickými cestami. Každá cesta je přes tři soukolí. Jedna kinematická cesta začíná vstupním hřídelem přes soukolí 1,2, soukolí 5,6 a soukolí 7,8 a končí výstupním hřídelem. Druhá kinematická cesta rovněž začíná vstupním hřídelem, ale pokračuje přes soukolí 3,4. Dále je shodná s předchozí cestou (tj. přes soukolí 5,6 a 7,8 na výstupní hřídel). O zařazeném stupni rozhoduje poloha přesuvné spojky.



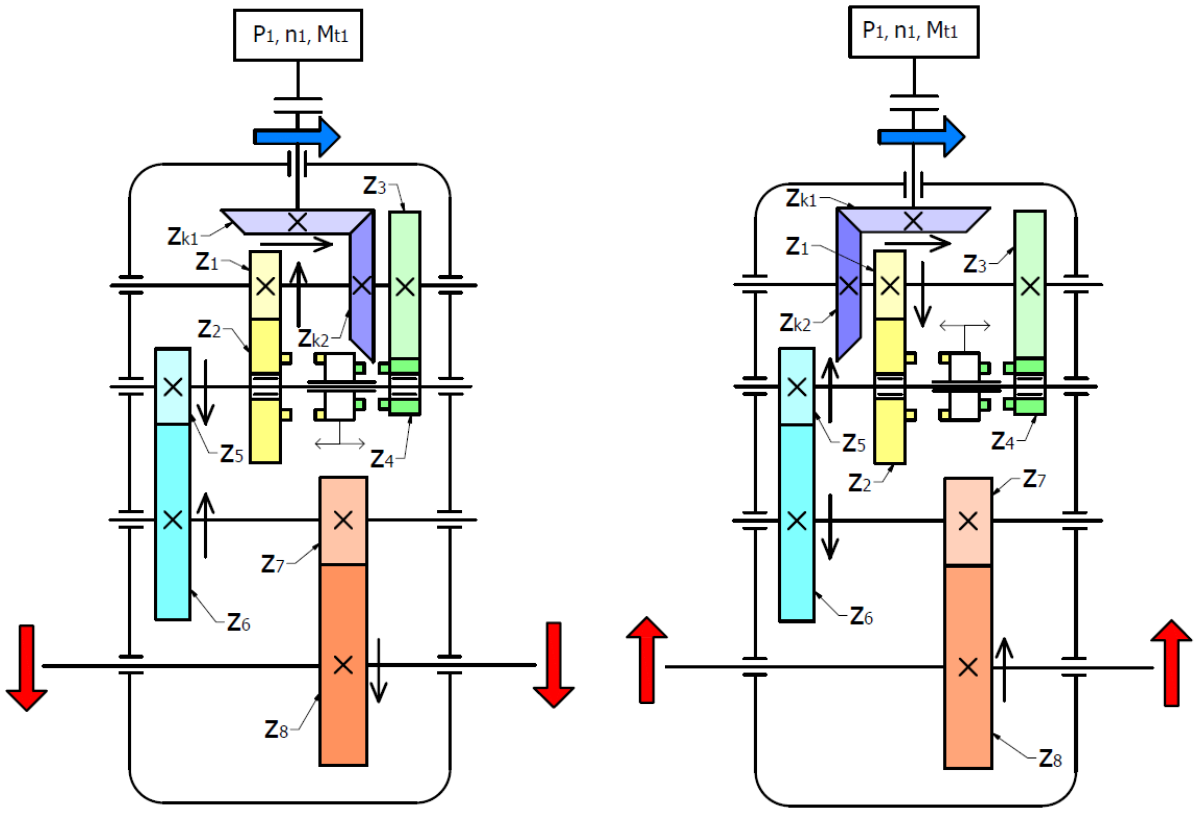
Obr. 5-2 Kinematické schéma převodovky typu KC s nakupovanou převodovkou

Z požadavku zadavatele na stejnou skříň pro oba typy převodovky vyplývá nutnost ponechání základu kinematického schéma převodovky typu C i pro převodovku typu KC, jejíž vstupní hřídel bude umístěný kolmo k výstupnímu hřídeli.

Kolmou polohu hřídelů jsem se rozhodla vyřešit kuželovými koly s převodem 1:1.

Pro rychlou změnu vzájemné polohy hřídelů ze stejného výchozího základu by mohla sloužit nakupovaná převodovka, která by se umístila na současný vstupní hřídel (kinematické schéma je na Obr. 5-2). Tímto řešením by ale došlo k výraznému překročení určených orientačních obrysových rozměrů skříně a nebyl by ani dodržen požadavek na umístění osy vstupního hřídele do osy převodovky a dělicí roviny skříně.

Při dodržení požadavků na umístění vstupního hřídele se jeví jako možné umístění kuželového kola mezi kola 1 a 3 nebo před (viděno zleva) kolo 1(viz Obr. 5-3).



Obr. 5-3 Možná umístění kuželového soukolí

5.3. Návrh modulů a počtu zubů

Kritéria vhodné volby druhu ozubení

- únosnost
- tuhost
- účinnost
- hlučnost
- tlumení

Pro větší únosnost a menší hlučnost volím na čelním ozubení šikmé zuby. Vztahy pro první návrhy ozubení

Informativní modul $m = 7{,}6 \cdot \sqrt[3]{\frac{M_t \cdot \cos\beta}{c \cdot \psi \cdot z_1}}$.

M_t = 6000 Nm
c = 15 (materiálová konstanta pro šlechtěnou ocel, tvrzené boky zubů)
ψ = 20 (volí se podle materiálu, pro tvrzené boky zubů v rozmezí 10 – 20)

$$m = 7{,}6 \cdot \sqrt[3]{\frac{6000 \cdot \cos 15°}{15 \cdot 20 \cdot 17}} \cdot = 7{,}95$$

Volím modul m = 7.

$$a = \frac{d_1 + d_2}{2} = 295\,[\text{mm}] \qquad d_1 = \frac{z_1 \cdot m}{\cos\beta} = \frac{17 \cdot 7}{\cos 15} = 123{,}198[\text{mm}]$$

$$d_2 = 2 \cdot a - d_1 = 2 \cdot 295 - 123{,}198 = 466{,}802[\text{mm}]$$

$$d_2 = \frac{z_2 \cdot m}{\cos\beta} \rightarrow z_2 = \frac{d_2 \cdot \cos\beta}{m} = \frac{466{,}802 \cdot \cos 15°}{7} = 64{,}413 \doteq 64\,\text{zubů}$$

Bachův vzorec $F_{dov} = t \cdot b \cdot c \cdot 1{,}5$; $b = \cdot\psi \cdot m$

$b = \cdot\psi \cdot m = 20 \cdot 7 = 140$
$F_{dov} = \pi \cdot 7 \cdot 140 \cdot 15 \cdot 1{,}5 = 69272[\text{N}]$

Pro první soukolí volím počty zubů $z_1 = 17$, $z_2 = 64$.

Převod $i_1 = \frac{z_2}{z_1} = \frac{64}{17} = 3{,}7647$

Z požadovaného celkového převodu 1. stupně zbyde

$$i = \frac{i_{c1}}{i_1} = \frac{54{,}485}{3{,}764} = 14{,}4753\,.$$

To je téměř stejná hodnota převodu jako u 2. stupně.

$$i_2 = \frac{i_{c2}}{i} = \frac{14{,}825}{14{,}475} = 1{,}024\,.$$

Moment M_t = 6000 Nm je stejný jako u soukolí 1,2. Modul volím m = 7. Osovou vzdálenost musím rozdělit koly s převodem 1,024. Tedy zhruba na půl. 295 / 2 = 147,5 [mm].

$$d_3 = \frac{z_3 \cdot m}{\cos\beta} = 2 \cdot 147{,}5 = \frac{z_3 \cdot 7}{\cos 15°} \rightarrow z_3 = \frac{295 \cdot \cos 15°}{7} = 40{,}7 \text{ [zubů]}$$

Upravím-li úhel $\beta = 10°$, pak $z_3 = 41{,}5$ zubů

Poměr z_4/z_3 = 41/40 =1,025,
z_4/z_3 = 42/41 =1,024.

Proto volím čelní ozubení se sklonem zubů $\beta = 10°$ a počty zubů z_4=42, z_3=41.

Pro další soukolí se změní točivý moment $M_{s1} = M_1 \cdot i_1 \cdot \eta_1$ [Nm]

$$M_{s1} = 6000 \cdot \frac{z_2}{z_1} \cdot \eta_1 = 6000 \cdot \frac{64}{17} \cdot 0{,}98 = 22\,136{,}5 \doteq 22\,140 \text{[Nm]}$$

$$m = 7{,}6 \cdot \sqrt[3]{\frac{M_t \cdot \cos\beta}{c \cdot \psi \cdot z_1}} \cdot = 7{,}6 \cdot \sqrt[3]{\frac{22140 \cdot \cos 15°}{15 \cdot 20 \cdot 17}} = 12{,}25$$

Volím modul m = 12.

$$d_5 = \frac{z_5 \cdot m}{\cos\beta} = \frac{17 \cdot 12}{\cos 15°} = 211{,}196 \text{ [mm]}$$

a = 455 [mm] $\quad d_6 = 2 \cdot a - d_5 = 2 \cdot 455 - 211{,}196 = 698{,}804 \text{[mm]}$

$$698{,}804 = \frac{z_6 \cdot m}{\cos\beta} \rightarrow z_5 = \frac{698{,}804 \cdot \cos 15°}{12} = 56{,}25 \doteq 56 \text{ [zubů]}$$

Poměr z_6/z_5 = 56/17 =3,294; na poslední převod zbude 4,394.
z_6/z_5 = 57/16 =3,563; na poslední převod zbude 4,063.

Volím počty zubů z_5=16, z_6=57.
Pro třetí soukolí se změní točivý moment $M_{s2} = M_{s1} \cdot i_2 \cdot \eta_2$ [Nm]

$$M_{s2} = 22\,140 \cdot \frac{z_6}{z_5} \cdot \eta_1 = 22\,140 \cdot \frac{57}{16} \cdot 0{,}98 = 77\,296{,}3 \doteq 77\,300 \text{ [Nm]}$$

$$m = 7{,}6 \cdot \sqrt[3]{\frac{M_t \cdot \cos\beta}{c \cdot \psi \cdot z_1}} \cdot = 7{,}6 \cdot \sqrt[3]{\frac{77300 \cdot \cos 15°}{15 \cdot 20 \cdot 17}} = 18{,}59$$

Volím modul m = 18.

$$d_7 = \frac{z_5 \cdot m}{\cos\beta} = \frac{17 \cdot 18}{\cos 15°} = 316{,}795 \text{ [mm]}$$

a = 765 [mm] $\qquad d_8 = 2 \cdot a - d_7 = 2 \cdot 765 - 316{,}795 = 1213{,}205 \left[\text{mm}\right]$

$$1213{,}205 = \frac{z_8 \cdot m}{\cos \beta} \rightarrow z_8 = \frac{1213{,}205 \cdot \cos 15°}{18} = 65{,}10 \doteq 65 \text{ [zubů]}$$

Poměr z_8/z_7 = 65/17 =3,294; celkový převod by byl 44,176.
z_8/z_7 = 65/16 =4,063. Celkový převod bude požadovaných 54,485.

Výstupní moment bude $M = M_{s2} \cdot i_3 \cdot \eta_3 \left[\text{Nm}\right]$

$$M = 77\,300 \cdot \frac{65}{16} \cdot 0{,}98 = 307\,750 \left[\text{Nm}\right]$$

2. stupeň není tolik redukční, točivý moment bude menší, ozubení vypočítané pro 1.stupeň vyhoví.

kolo	z	m [mm]	α [°]	β [°]	b [mm]	Převod i	a [mm]	**1. stupeň** M_t [Nm]	otáčky přísluš. hřídele [1/min]	**2. stupeň** M_t [Nm]	otáčky přísluš. hřídele [1/min]
1	17	7	20	13	202	3,76	295	6 000	800	-	
2	64				118			22 140	212,5	-	
3	41	7	20	10	70	1,02	295	-		6 000	800
4	42				70			-		6 023	780,95
5	16	12	25	14	160	3,56	455	22 140	212,5	6 023	780,95
6	57				148			77 300	59,65	21 029	219,24
7	16	18	20	15	250	4,06	765	77 300	59,65	21 029	219,24
8	65				218			307 750	14,68	83 422	53,96

Tab. 5-1 První návrh ozubení (jeden zatěžovací stav a rovnoběžná vzájemná poloha hřídelů)

Změna otáček $n_2 = \frac{n_1}{i_1} = \frac{n_1 \cdot z_1}{z_2}$

Výkon motoru $P = \frac{M_t \cdot 2 \cdot \pi \cdot n}{60} = \frac{6 \cdot 10^3 \cdot \pi \cdot 800}{30} \doteq 500 \left[\text{kW}\right] \cdot$

	$\frac{T_1}{T_2} = \frac{20}{80}$	Hřídel I (kolo 1, 3. K2)			Hřídel II (kolo 5+2, nebo 5+4)				Hřídel III (kolo 6, 7)			Hřídel IV (kolo 8)		
100% zatížení	T1 hodin 480	M_t [kNm]	Otáčky [1/min]	Výkon [kW]	stupeň	M_t [kNm]	Otáčky [1/min]	Výkon [kW]	M_t [kNm]	Otáčky [1/min]	Výkon [kW]	M_t [kNm]	Otáčky [1/min]	Výkon [kW]
1.	120	6	800	502,7	1 (i=z2/z1)	22,14	212,5	492,6	77,28	59,6	482,8	308	14,6	473
2.	120	-6	-800			-22,14	-212,5		-77,28	-59,6		-308	-14,6	
3.	120	6	800		2 (i=z4/z3)	6	781		21	219,2		83,7	53,9	
4.	120	-6	-800			-6	-781		-21	-219,2		-83,7	-53,9	
70%	T2 hodin 1920													
5.	480	4,2	800	351,9	1 (i=z2/z1)	15,5	212,5	344,8	54,1	59,6	337,9	215,3	14,6	331
6.	480	-4,2	-800			-15,5	-212,5		-54,1	-59,6		-215,3	-14,6	
7.	480	4,2	800		2 (i=z4/z3)	4,2	781		14,7	219,2		58,6	53,9	
8.	480	-4,2	-800			-4,2	-781		-14,7	-219,2		-58,6	-53,9	

Tab. 5-2 Zatěžovací stavy pro první návrh soukolí

5.4. Model návrhu

V této fázi návrhu jsem udělala 3D návrh soukolí, abych získala přehled o možnostech umístění kuželového soukolí. Samotná ozubená kola jsem modelovala podle údajů z Tab. 5-1 a pevnostně kontrolovala na hodnoty z Tab. 5-2. Používala jsem dva softwary, Autodesk Inventor Professional 2013 a KISSsoft 2013.

5.4.1. Softwary použité při řešení

KISSsoft 2013

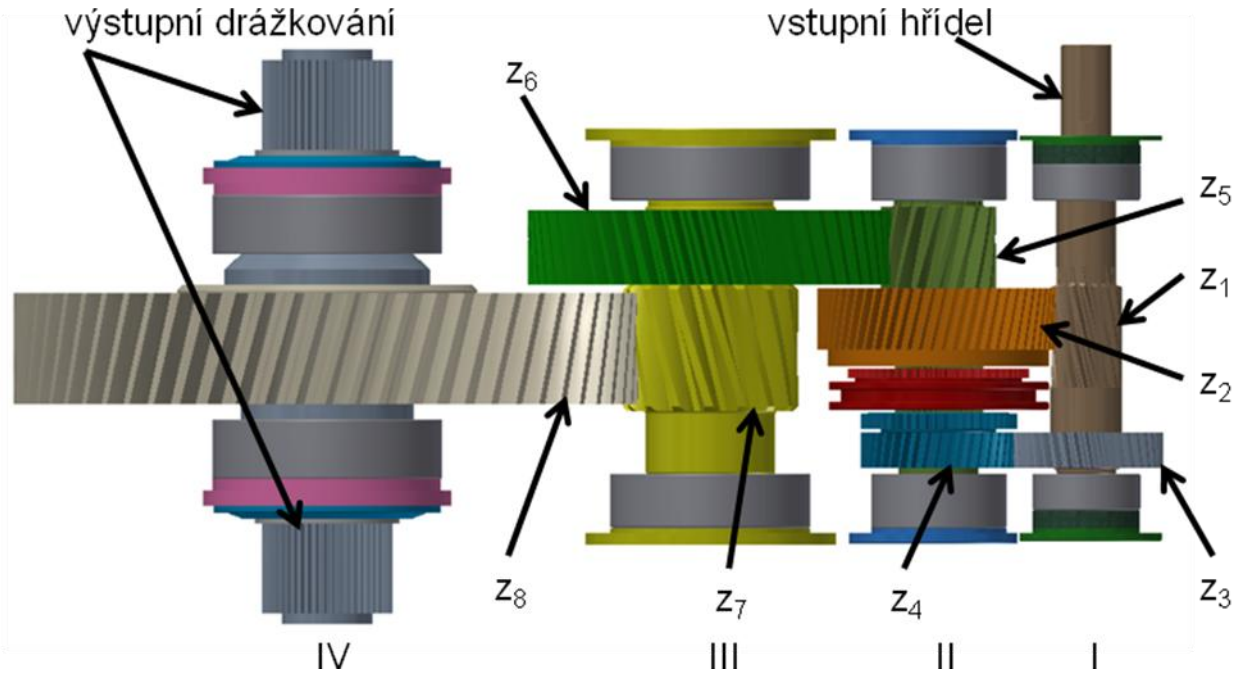
Software je určený pro výpočty. Výsledky výpočtů ozubení, hřídelů s ložisky a spojovacích prvků jsem zařadila do přílohy. Výsledná data jsem dále použila jako vstupy k analýzám provedeným v Inventoru.

Využila jsem skutečnost, že software dokáže vytvořit model navrhovaného počítaného dílu ve formátu *.step. Tímto způsobem jsem získala model kuželového soukolí Klingelnberg pro další použití v Inventoru.

Autodesk Inventor Professional 2013

Software, který jsem použila pro vytvoření modelů jednotlivých částí, včetně ozubených soukolí, k pevnostní, tuhostní a modální analýze a k vytvoření výrobní dokumentace. Základ modelu kuželového soukolí jsem získala z KISSsoftu ve formátu *.step. Inventor totiž umožňuje modelování ozubení s přímými a šikmými zuby, nikoli se zakřivenými.

K vytvoření 3D modelu prvního návrhu soukolí jsem použila Inventor.



Obr. 5-4 Sestavení prvního návrhu – varianta s rovnoběžným uspořádáním hřídelů

Průměr hřídelů jsem přizpůsobila pastorkům, délku hřídelů požadované šířce skříně. Na vstupním hřídeli je drážka pro pero. Pastorek 1 má ozubení ve větší šířce než spoluzabírající kolo 2. Je to z důvodu rozměrů výrobního nástroje. Na hřídeli I je ještě nasazen pastorek 3, který zabírá s kolem 4. Soukolí 1,2 a 3,4 jsou stále v záběru. Kola 2 a 4 jsou uložena na kuličkových ložiskách a k přenosu momentu na druhý hřídel dojde po zasunutí ozubení

spojky, která se pohybuje axiálně po drážkovaném hřídeli. Poloha spojky rozhoduje o celkovém převodu. Lze nastavit 2 převodové stupně. K přenosu momentu a tím i k zařazení převodového stupně a otáčení hřídele II dojde po zasunutí zubů přesuvné spojky (na Obr. 5-4 má červenou barvu) buď do kola 2, nebo na kolo 4. Spoluzabírající část spojky je přišroubována ke kolu a má přímé zuby. Hřídel IV je delší, přesahuje plánovaný obrys skříně a je na obou koncích opatřen drážkováním.

Existují tedy 2 kinematické cesty, každá přes 3 soukolí.
1. rychlostní stupeň je dosažen přes převody z_2/z_1, z_6/z_5 a z_8/z_7
2. rychlostní stupeň je dosažen přes převody z_4/z_3, z_6/z_5 a z_8/z_7

Pro změnu vzájemné polohy vstupního a výstupního hřídele z rovnoběžné na kolmou jsem zvolila kuželové soukolí Klingelnberg s převodem 1:1.

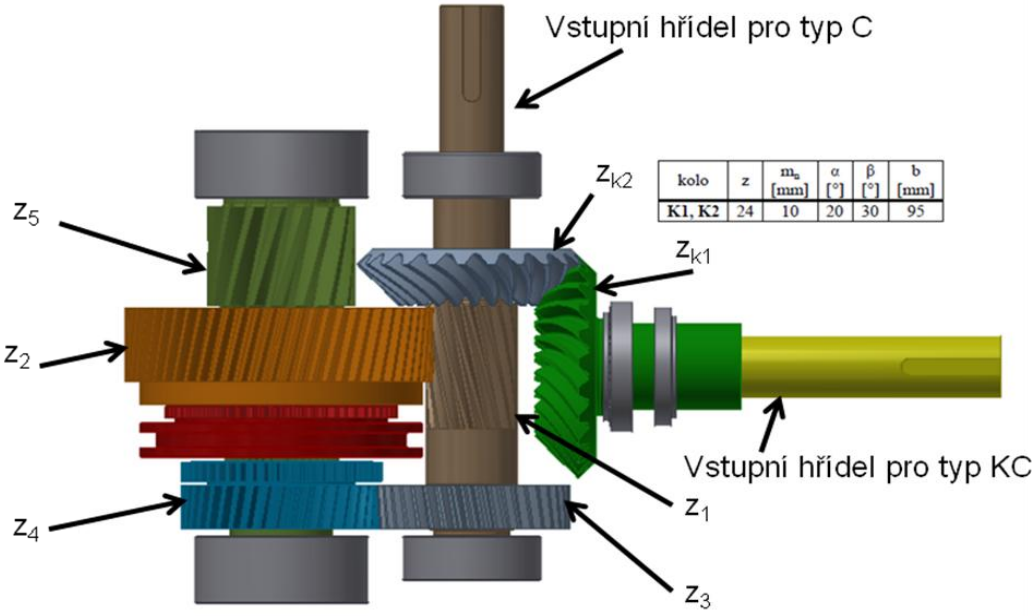
kolo	z	m [mm]	α [°]	β [°]	b [mm]	Převod *i*	a [mm]	**1. stupeň** M_t [kNm]	otáčky přísluš. hřídele [1/min]	**2. stupeň** M_t [kNm]	otáčky přísluš. hřídele [1/min]
K1	24	10	20	30	95	1		6	800	6	800
K2	24				95			5,8	800	5,8	800
1	17	7	20	13	202	3,76	295	5,8	800	-	-
2	64				118			17,4	259	-	-
3	41	7	20	10	70	1,02	295	-		5,8	800
4	42				70			-		5,8	786
5	16	12	25	14	160	3,56	455	17,4	259	5,8	786
6	57				148			61	72,7	20	221
7	16	18	20	15	250	4,06	765	61	72,7	20	54,3
8	65				218			242	17,9	79,8	54,3

Tab. 5-3 První návrh ozubení (jeden zatěžovací stav a vzájemná poloha hřídelů kolmá)

100%	$\frac{T_1}{T_2} = \frac{20}{80}$	Hřídel 0 (kolo K1)			Hřídel I (kolo 1, 3. K2)			Hřídel II (kolo 5+2, nebo 5+4)				Hřídel III (kolo 6, 7)			Hřídel IV (kolo 8)		
	T1 hodin 480	M_t [kNm]	Otáčky [1/min]	M_t [kNm]	M_t [kNm]	Otáčky [1/min]	Výkon [kW]	stupeň	M_t [kNm]	Otáčky [1/min]	Výkon [kW]	M_t [kNm]	Otáčky [1/min]	Výkon [kW]	M_t [kNm]	Otáčky [1/min]	Výkon [kW]
1.	120	6	800	503	5,8	800	483	1 (i=z2/z1)	17,4	259	473	61	72,7	463	242	17,9	454
2.	120	-6	-800		-5,8	-800			-17,4	-259		-61	-72,7		-242	-17,9	
3.	120	6	800		5,8	800		2 (i=z4/z3)	5,8	786		20	221		79,8	54,3	
4.	120	-6	-800		-5,8	-800			-5,8	-786		-20	-221		-79,8	-54,3	
70%	T2 hodin 1920																
5.	480	4,2	800	352	4	800	338	1 (i=z2/z1)	12,2	259	331	42,6	72,7	324	169,5	17,9	318
6.	480	-4,2	-800		-4	-800			-12,2	-259		-42,6	-72,7		-169,5	-17,9	
7.	480	4,2	800		4	800		2 (i=z4/z3)	4,	786		14	221		55,9	54,3	
8.	480	-4,2	-800		-4	-800			-4,	-786		-14	-221		-55,9	-54,3	

Tab. 5-4 Zatěžovací stavy pro první návrh soukolí (kolmá poloha hřídelů)

Při vzájemné kolmé poloze vstupního a výstupního hřídele existují rovněž dvě kinematické cesty. Každá vede přes 4 soukolí. Přibylo kuželové soukolí, zmenšila se celková účinnost.
1. rychlostní stupeň je dosažen přes převody z_{k2}/z_{k1}, z_2/z_1, z_6/z_5 a z_8/z_7
2. rychlostní stupeň je dosažen přes převody z_{k2}/z_{k1}, z_4/z_3, z_6/z_5 a z_8/z_7



Obr. 5-5 Umístění vstupního hřídele pro typ C a typ KC

Z Obr. 5-5 je patrné, že při respektování požadavku zadavatele na umístění osy vstupního hřídele v podélné ose skříně a zároveň v dělicí rovině převodovky je možná jen jedna varianta umístění kuželového soukolí. Pro řešení s kuželovým kolem mezi koly 1 a 3 není v modelu volný prostor. Došlo by ke kolizi s přesouvací spojkou.

Kontrola návrhu průměru hřídele

$$\tau_t = \frac{M_t}{W_k} = \frac{M_t}{\frac{\pi \cdot d^3}{16}} \leq \tau_{dov} \quad \Rightarrow \quad d \doteq \sqrt[3]{\frac{16 \cdot M_t}{\pi \cdot \tau_t}} \,[\mathrm{mm}]$$

Pevnostní kontrola pro hřídel s ozubenými koly

$$F_o = \frac{2 \cdot M_t}{d} \,[\mathrm{N}]$$

Radiální složky sil v ozubení

$$F_r = F_o \cdot tg(\alpha_t) \,[\mathrm{N}]$$

Axiální složky sil v ozubení

$$F_a = F_o \cdot tg(\beta_t) \,[\mathrm{N}]$$

		průhyb
kola (m = modul)	čelní	$y = 0{,}01 \cdot m$
	kuželová, šneková	$y = 0{,}005 \cdot m$
nosník (L = vzdálenost mezi ložisky)	všeobecné	$y = 0{,}0003 \cdot L$
	obráběcí stroje	$y = 0{,}0002 \cdot L$

Tab. 5-5 Dovolené hodnoty průhybu podle doporučení softwaru MITCalc

Na přání zadávající firmy jsem z důvodu dosažení vyšší tuhosti hřídelů provedla úpravy. Následující postup návrhu a kontroly jednotlivých souhmotí je uveden pouze pro upravené řešení.

6. Návrh a kontrola jednotlivých souhmotí s využitím programu KISSsoft

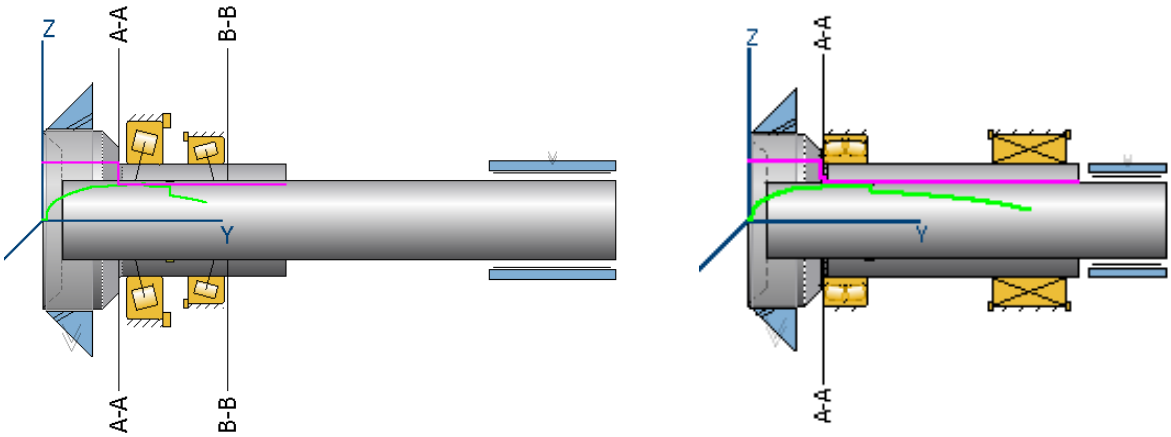
6.1. Soukolí

Původní návrh kuželového soukolí Klingelnberg jsem dělala pomocí programu Inventor Professional 2013, který nezohledňuje zakřivený tvar zubů. Za pomoci softwaru KISSsoft jsem z důvodu zadírání u soukolí změnila počet zubů z 24 na 32 a šířku *b* z 95 mm na 82 mm. Změny čelních soukolí oproti původnímu návrhu vyplynuly ze zadavatelem požadované vyšší tuhosti hřídelů při nutnosti zachování osových vzdáleností. Soukolí 1,2 jsem upravila z převodu 64/17 na 71/23, soukolí 3,4 z převodu 42/41 na 58/57. Ostatní soukolí zůstala beze změny. Výstupy z výpočtů jednotlivých soukolí jsou uvedeny v příloze.

Ozubená kola budou vyrobena z materiálu 18CrNiMo7-6, což je středně legovaná ušlechtilá chrom-nikl-molybdenová ocel k cementování. Tento materiál je vhodný pro velmi namáhané strojní součásti s cementovaným povrchem. Cementovaná vrstva po tepelném zpracování dosahuje na povrchu tvrdosti 62 až 64 HRC, zatímco jádro cementované součásti je i při relativně vysoké pevnosti značně houževnaté. Přísada molybdenu zvyšuje prokalitelnost; ocel prokaluje do hloubky přibližně 60 mm. Je vhodná pro dynamicky namáhané součásti.

6.2. Hřídele

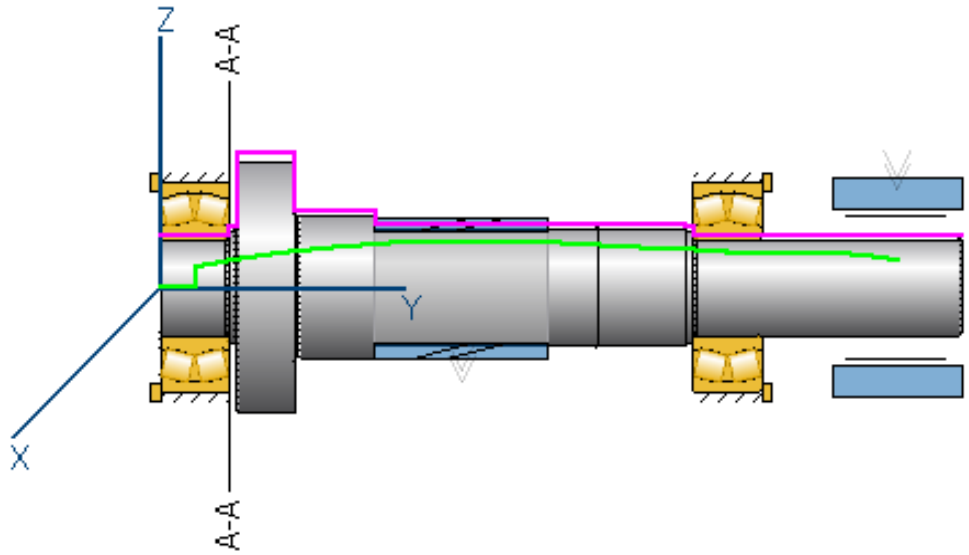
V návrhu hřídele 0 (zajištění kolmé polohy vstupního a výstupního hřídele) jsem uvažovala dvě možná uložení; se dvěma kuželíkovými ložisky SKF 30228 J2 a SKF 32028 X, nebo s dvouřadým soudečkovým ložiskem SKF*23030 CC/W33 a párovým kuželíkovým ložiskem v provedení čely k sobě SKF 32030 X/DF. Obrys pro případné modifikování velikosti z hlediska dimenzování na pevnost (nastaveno redukované napětí 100 MPa) se na obrázcích zobrazuje jako zelená čára, pro dimenzování z hlediska ohybu (nastaven průhyb 0,1 mm) jako čára v barvě magenta (purpurová).



Obr. 6-1 Varianta uložení Hřídele 0
se dvěma kuželíkovými ložisky na soudečkovém a párovém kuželíkovém ložisku

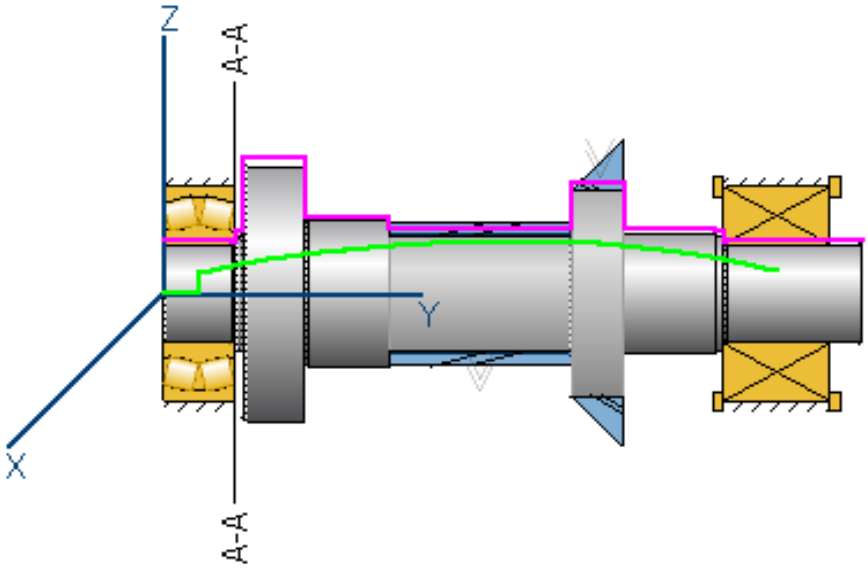
U hlediska montáže bude lepší uložení varianta s použitím soudečkového a párového kuželíkového ložiska.

Hřídel I jsem počítala také ve dvou variantách. První varianta pro převodovku typu C uvažuje převislý konec hřídele pro připojení motoru z boku skříně. Je uložen ve dvou dvouřadých soudečkových ložiskách SKF*22322E.



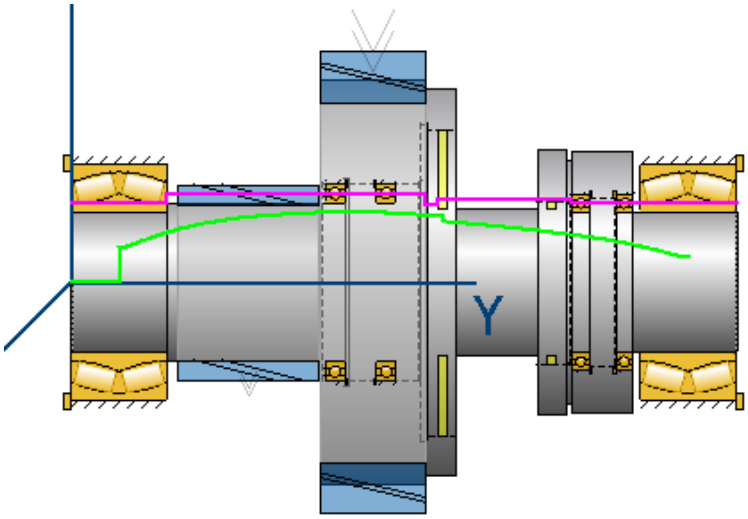
Obr. 6-2 Varianta Hřídele I pro rovnoběžné uspořádání hřídelů

Druhá varianta Hřídele I je pro typ převodovky KC (vstupní a výstupní hřídel k sobě kolmé). Levé ložisko je dvouřadé soudečkové SKF*22322E. Na hřídeli přibylo kuželové kolo a to si vynutilo použití párového kuželíkového ložiska Koyo 46T 30322 JR/93 (v provedení zády k sobě)



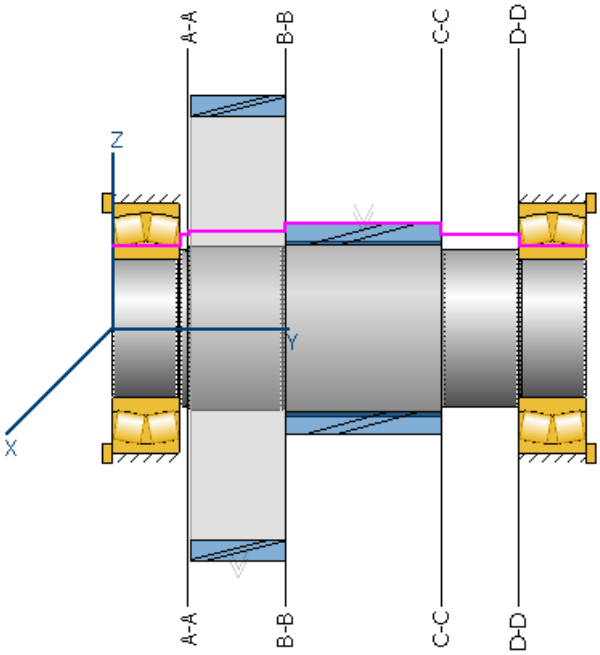
Obr. 6-3 Varianta Hřídele I pro kolmé uspořádání hřídelů

Při konzultaci po prvním návrhu požadoval zadavatel z důvodu případných modifikací ozubení větší tuhost Hřídele II tak, aby koeficient $K_{H\beta}$ u pastorku dosahoval hodnoty v rozsahu 1,1 – 1,3. Výpočtový model se stavem po změnách obsahuje pastorek (5), větší kolo (2) uložené na dvou vnitřních kuličkových ložiskách SKF 61836, menší kolo (4) uložené na dvou kuličkových ložiskách SKF 61832. Samotný hřídel je uložen na dvou soudečkových ložiskách SKF*24132 CC/W33. Spojka je zjednodušena na dva spojovací elementy. Zjednodušený výpočtový model je na Obr. 6-4.



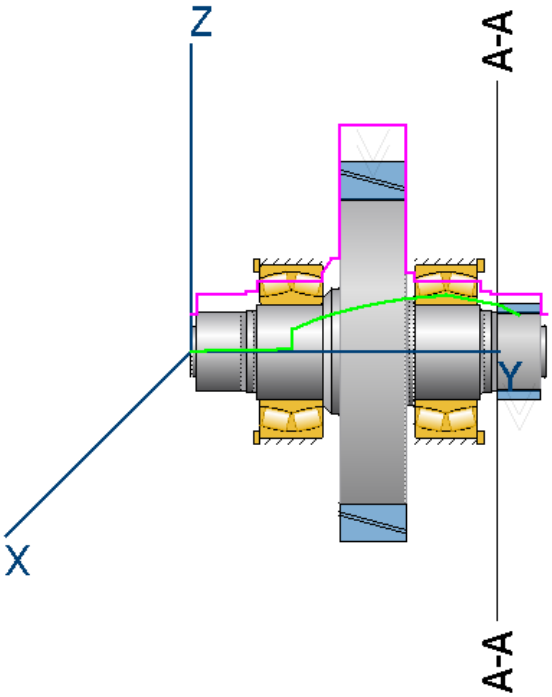
Obr. 6-4 Hřídel II

Hřídel III nese kolo (6) a pastorek (7). Je uložen na dvou kuželíkových ložiskách SKF*22244 CC/W33.



Obr. 6-5 Hřídel III

Hřídel IV jsem také z důvodu větší tuhosti upravila. Nově má větší průměr, což se neprojeví na kole, ale na uložení a drážkování na koncích hřídele. Hřídel je uložen na dvou kuželíkových ložiskách SKF*23268 CA/W33



Obr. 6-6 Hřídel IV

Při výpočtech jsem nejprve uvažovala zatěžovací stavy (i reverzní). Pak jsem určila první čtyři vlastní frekvence souhmotí hřídelů, které jsem později použila při posouzení možného ovlivnění vlastní frekvence skříně. Výsledky výpočtů jsou v příloze.

6.3.Spojovací prvky

Pero

Výpočet pera pro přenos momentu z kola na hřídel je v příloze. Software KISSsoft upozorňuje, že materiálové vlastnosti oceli 18CrNiMo7-6 jsou dané pouze orientačně: R_m = 600 MPa, R_p = 425 MPa, E = 2,06.10^{5}MPa, ρ = 7830 kg/m^3.
Nepodařilo se mě získat lépe vypovídající hodnoty. Dodavatel (Tab. 6-1) uvádí hodnoty jen do průměru 100 mm. Firma Poldi dodává i větší průměry, ale na svých stránkách materiálové vlastnosti uvádí jen slovně.

Bohdan Bolzano

Vlastnosti ocelí k cementování podle EN10084

Přehled vlastností oceli 18CrNiMo7-6 1.6587

Mechanické vlastnosti v jádře referenčního vzorku po kalení a popuštění při 150-200 °C (uvedené hodnoty nejsou součástí EN 10084) [1)]	Průměr mm	Rp0,2 min MPa	Rm MPa
	d ≤ 11	980	1230 – 1520
	11< d ≤ 25	735	980 – 1320
	25 < d ≤ 50	640	885 - 1080
	50 < d ≤ 100	490	685 - 980

Tab. 6-1 Mechanické vlastnosti oceli udávané dodavatelem [10]

Drážkování

Drážkování jsem použila k přenosu točivého momentu na hřídel II (přesuvná spojka) a na koncích výstupního hřídele. Výpočty jsou v příloze.

Nalisování

Nalisováním jsou upevněna kola 2, 6 a 8. Výsledky výpočtů jsou přiloženy v příloze.

7. Upravená geometrie

Na základě požadavku zadavatele na větší tuhost hřídelů z důvodu modifikace ozubení a s využitím výpočetního programu KISSsoft jsem změnila geometrii ozubení soukolí 1,2 a soukolí 3,4.

kolo	z	m [mm]	α [°]	β [°]	b [mm]	Převod *i*	a [mm]	**1. stupeň** M_t [kNm]	otáčky přísluš. hřídele [1/min]	**2. stupeň** M_t [kNm]	otáčky přísluš. hřídele [1/min]
1	**23**	**6**	20	**14**	202	**3,09**	295	6	800	-	
2	**71**				118			18,15	259	-	
3	**57**	**5**	20	**13**	70	1,02	295	-		6	800
4	**58**				70			-		5,98	786
5	16	12	25	14	160	3,56	455	18,15	259	5,98	786
6	57				148			63,37	73	20,89	221
7	16	18	20	15	250	4,06	765	63,37	73	20,89	221
8	65				218			252.29	18	83,16	54

Tab. 7-1 Upravená geometrie (vyznačená tučně); vzájemná poloha hřídelů rovnoběžná

Převod i_1 se změnil z poměru 64/17 = 3,7647 na poměr 71/23 = 3,0869 a převod i_2 z poměru 42/41 = 1,0244 na poměr 58/57 = 1,0175. Změny se promítly v točivém momentu a otáčkách jednotlivých stupňů.

	$\frac{T_1}{T_2} = \frac{20}{80}$	Hřídel I (kolo 1, 3.)			Hřídel II (kolo 5+2, nebo 5+4)				Hřídel III (kolo 6, 7)			Hřídel IV (kolo 8)		
100%	T1 hodin 480	M_t [kNm]	Otáčky [1/min]	Výkon [kW]	stupeň	M_t [kNm]	Otáčky [1/min]	Výkon [kW]	M_t [kNm]	Otáčky [1/min]	Výkon [kW]	M_t [kNm]	Otáčky [1/min]	Výkon [kW]
1.	120	6	800	502,7	1 (i=z2/z1)	18,2	259	493	63,4	72,7	483	252	17,9	473
2.	120	-6	-800			-18,2	-259		-63,4	-72,7		-252	-17,9	
3.	120	6	800		2 (i=z4/z3)	6	786		21	221		83	54,3	
4.	120	-6	-800			-6	-786		-21	-221		-83	-54,3	
70%	T2 hodin 1920													
5.	480	4,2	800	351,9	1 (i=z2/z1)	12,7	259	345	44,4	72,7	338	177	17,9	331
6.	480	-4,2	-800			-12,7	-259		-44,4	-72,7		-177	-17,9	
7.	480	4,2	800		2 (i=z4/z3)	4,2	786		14,6	221		58	54,3	
8.	480	-4,2	-800			-4,2	-786		-14,6	-221		-58	-54,3	

Tab. 7-2 Změny v zatěžovacích stavech vyvolané změnou geometrie kol (typ C)

S přidáním kuželového soukolí (vzájemná kolmá poloha vstupního a výstupního hřídele) jsou rozdíly v točivém momentu a otáčkách ještě o něco větší.

kolo	z	m [mm]	α [°]	β [°]	b [mm]	Převod *i*	a [mm]	**1. stupeň** M_t [kNm]	otáčky přísluš. hřídele [1/min]	**2. stupeň** M_t [kNm]	otáčky přísluš. hřídele [1/min]
k1	**32**	**8**	20	30	**82**	1		6	800	6	800
k2	**32**				**82**			5,8	800	5,8	800
1	**23**	**6**	20	**14**	202	**3,09**	295	5,8	800	-	
2	**71**				118			17,4	259	-	
3	**57**	**5**	20	**13**	70	1,02	295	-		5,8	800
4	**58**				70			-		5,8	786
5	16	12	25	14	160	3,56	455	17,4	259	5,8	786
6	57				148			74,2	73	20,2	221
7	16	18	20	15	250	4,06	765	74,2	73	20,2	221
8	65				218			242,2	18	80	54

Tab. 7-3 Upravená geometrie (vyznačená tučně); vzájemná poloha hřídelů kolmá

Změněná geometrie ovlivní parametry převodovky. Buď budu chtít ponechat stejný motor (a tím klesne moment na výstupu), nebo budu požadovat na výstupu stejný moment jako u vzájemné rovnoběžné polohy vstupního a výstupního hřídele (a to vyvolá potřebu jiného motoru nebo použití motoru s regulací výkonu). Při volbě motoru je třeba vědět také údaje o napájecí frekvenci. Naše přenosová soustava pracuje s kmitočtem sítě 50 Hz, ale v zámoří, odkud zřejmě bude koncový zákazník vzhledem k určení převodovky, využívají kmitočet 60 Hz.

	$\frac{T_1}{T_2} = \frac{20}{80}$	Hřídel 0 (kolo K1)			Hřídel I (kolo 1, 3. K2)			Hřídel II (kolo 5+2, nebo 5+4)				Hřídel III (kolo 6, 7)			Hřídel IV (kolo 8)		
100%	T1 hodin 480	M_t [kNm]	Otáčky [1/min]	Výkon [kW]	M_t [kNm]	Otáčky [1/min]	Výkon [kW]	stupeň	M_t [kNm]	Otáčky [1/min]	Výkon [kW]	M_t [kNm]	Otáčky [1/min]	Výkon [kW]	M_t [kNm]	Otáčky [1/min]	Výkon [kW]
1.	120	6	800	502,7	5,8	800	482,5	1 (i=z2/z1)	17,4	259,2	472,9	74,2	72,8	463,5	242,2	17,9	454,1
2.	120	-6	-800		-5,8	-800			-17,4	-259,2		-74,2	-72,8		-242,2	-17,9	
3.	120	6	800		5,8	800		2 (i=z4/z3)	5,6	786,2		20,2	220,7		79,8	54,3	
4.	120	-6	-800		-5,8	-800			-5,6	-786,2		-20,2	-220,7		-79,8	-54,3	
70%	T2 hodin 1920																
5.	480	4,2	800	351,9	4	800	335,1	1 (i=z2/z1)	12,2	259,2	331	51,5	72,8	324,4	169,5	17,9	317,9
6.	480	-4,2	-800		-4	-800			-12,2	-259,2		-51,5	-72,8		-169,5	-17,9	
7.	480	4,2	800		4	800		2 (i=z4/z3)	4	786,2		14	220,7		55,9	54,3	
8.	480	-4,2	-800		-4	-800			-4	-786,2		-14	-220,7		-55,9	-54,3	

Tab. 7-4 Zatěžovací stavy při užití stejného motoru na vstupu (poloha hřídelů kolmá)

	$\frac{T_1}{T_2} = \frac{20}{80}$	Hřídel 0 (kolo K1)			Hřídel I (kolo 1, 3. K2)			Hřídel II (kolo 5+2, nebo 5+4)				Hřídel III (kolo 6, 7)			Hřídel IV (kolo 8)		
100%	T1 hodin 480	M_t [kNm]	Otáčky [1/min]	Výkon [kW]	M_t [kNm]	Otáčky [1/min]	Výkon [kW]	stupeň	M_t [kNm]	Otáčky [1/min]	Výkon [kW]	M_t [kNm]	Otáčky [1/min]	Výkon [kW]	M_t [kNm]	Otáčky [1/min]	Výkon [kW]
1.	120	7,6	800	639	7,3	800	613,6	1 (i=z2/z1)	22,2	259,2	601,4	77,4	72,8	589,3	308	17,9	577,6
2.	120	-7,6	-800		-7,3	-800			-22,2	-259,2		-77,4	-72,8		-308	-17,9	
3.	120	7,6	800		7,3	800		2 (i=z4/z3)	7,3	786,2		25,5	220,7		101,5	54,3	
4.	120	-7,6	-800		-7,3	-800			-7,3	-786,2		-25,5	-220,7		-101,5	-54,3	
70%	T2 hodin 1920																
5.	480	5,3	800	447	5,1	800	429,6	1 (i=z2/z1)	15,5	259,2	421	54,15	72,8	412,5	215,6	17,9	404,3
6.	480	-5,3	-800		-5,1	-800			-15,5	-259,2		-54,15	-72,8		-215,6	-17,9	
7.	480	5,3	800		5,1	800		2 (i=z4/z3)	5,1	786,2		17,85	220,7		71,07	54,3	
8.	480	-5,3	-800		-5,1	-800			-5,1	-786,2		-17,85	-220,7		-71,07	-54,3	

Tab. 7-5 Zatěžovací stavy při požadavku stejného momentu na výstupu

Sledované parametry		**První návrh**	**Stejný motor**	**Stejný výstupní moment**
Převod	*i*	54,485 / 14,825	44,676 / 14,727	44,676 / 14,727
Moment	Mt [Nm]	6.000	6.000	7.600
Vstupní otáčky	n_1[min^{-1}]	800	800	800
Výstupní otáčky	n_2[min^{-1}]	14,68 / 53,96	17,91 / 54,32	17,91 / 54,32

Tab. 7-6 Porovnání čtyř sledovaných parametrů

Na příkladu třífázového asynchronního motoru nakrátko je patrné, jak kmitočet ovlivní výkon, jmenovité otáčky a moment.

Obr. 7-1 Vzhled motoru

Třífázový asynchronní motor nakrátko je určen k pohonu průmyslových zařízení, např. ventilátorů, čerpadel, obráběcích strojů, lisů apod. Lze je používat pro prostředí mírného klimatu, ve zvláštních provedeních i v jiných klimatických podmínkách. K širšímu průmyslovému využití a rozšíření aplikačních možností v elektrických pohonech pracovních strojů a zařízení jsou řady asynchronních motorů s kotvou nakrátko odvozeny modifikované řady a speciální provedení motorů.

Technické parametry motoru

Velikost	160 - 450
Rozsah výkonů	4 – 900 kW
Počet pólů	2, 4, 6, 8
Tvar	IM B3, IM B5. IM B35
Frekvence	50 / 60 Hz
Krytí	IP 55
Jmen. napětí nad 3kW	400VD / 690VY, 50Hz//460VD

Kostra	Šedá litina
Pro teplotu okolí	-20°C až +40°C
Třída izolace	F
Pro nadmoř. výšku	Do 1000 m
Pro trvalé zatížení	S1
Standardní nátěr	RAL 7030

6 - pólové, otáčky 1000 min^{-1} ***400V / 50 Hz***

Velikost	Jmenovitý výkon při 50 / 60 Hz	Jmenovité otáčky při 50 / 60 Hz	Účinnost	Účinník při 50 Hz	Jmenovitý proud při 400V/50Hz	Jmenovitý moment	Poměrný záběrný proud	Poměrný záběrný moment	Poměrný moment zvratu	Moment setrvačnosti	Hmotnost
typ	KW	min^{-1}	%	cosφ	A	Nm	I_A / I_N	T_A / T_N	T_K / T_N	J kgm^2	kg
ACM 400 LC-6	500/600	994/1193	96,1	0,86	871	4804	5,72	1,86	2,19	7,57	3866
ACM 400 LD-6	560/672	994/1193	96,1	0,86	977	5380	5,88	1,95	2,22	8,26	4140
ACM 450 MA-6	500/600	994/1193	96,0	0,86	874	4785	5,99	1,61	2,34	49,3	3886
ACM 450 MB-6	560/672	994/1193	96,1	0,86	978	5355	5,89	1,64	2,32	54,1	4203
ACM 450 LA-6	630/756	994/1193	96,1	0,86	1097	6025	5,99	1,65	2,30	60,6	4620
ACM 450 LB-6	710/852	994/1193	95,9	0,86	1235	6790	6,13	1,71	2,33	67,9	5080
ACM 450 LC-6	800/960	995/1194	96,5	0,87	1381	7680	5,47	1,52	2,06	67,9	5080

Tab. 7-7 Vliv kmitočtu sítě na potřebnou velikost motoru [8]

8. Porovnání převodovky typu C, typu KC se stejným motorem a typu KC se stejným výstupním momentem

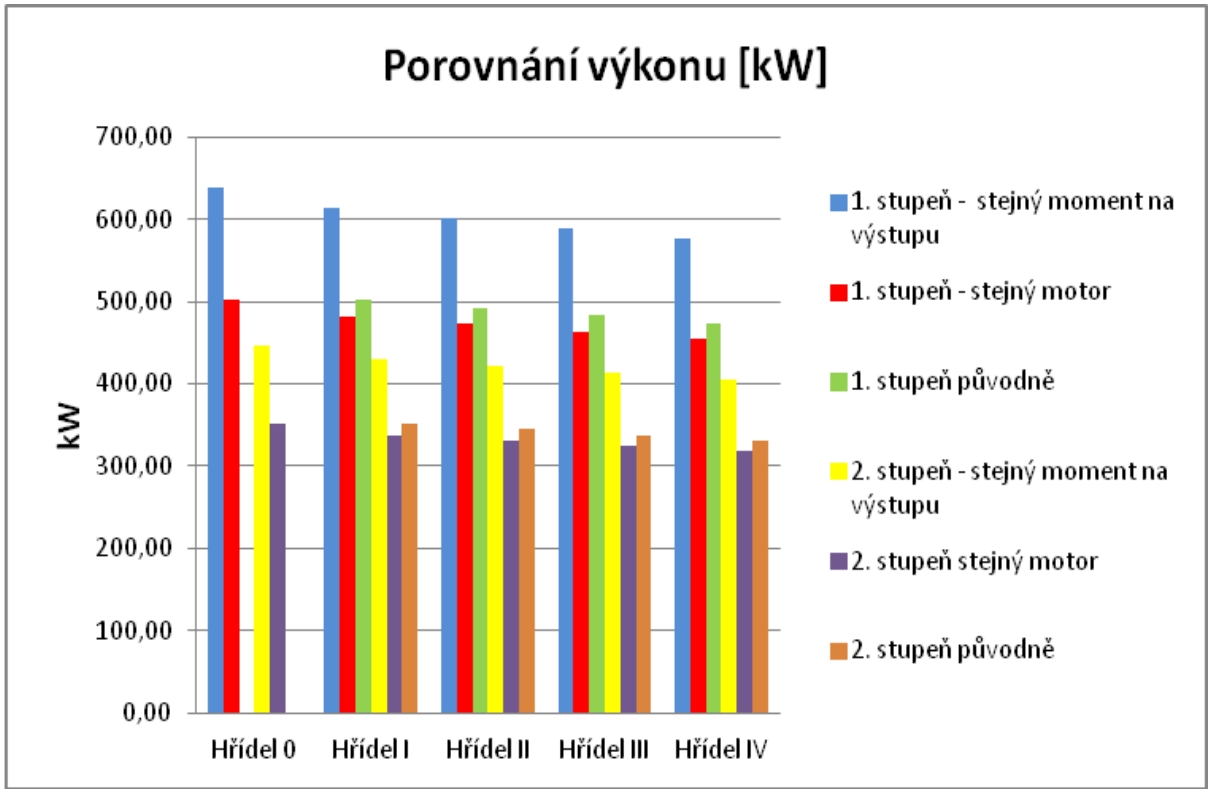
Každá z provedených kinematických změn má vliv na změnu výkonu.
V Grafu 1 jsou znázorněné hodnoty výkonu na jednotlivých hřídelích. Převodovka má dva převodové stupně. Barevné sloupce ilustrují rozdíly mezi původní převodovkou typu C a dvěma pohledy na převodovku typu KC.

Význam barev v grafu

Postupně z leva je použitá barva u každého hřídele nejprve pro 1. převodový stupeň modrá pro převodovku KC s požadavkem stejného momentu na výstupu, červená pro převodovku KC s ponechaným stejným motorem, zelená je první návrh pro převodovku typu C.

Následují hodnoty pro druhý stupeň. Žlutá pro převodovku typu KC s požadavkem na zachování stejného momentu jako u typu C, fialové jsou hodnoty pro případ stejného motoru na vstupu a hnědá barva znázorňuje výkon převodovky typu C.

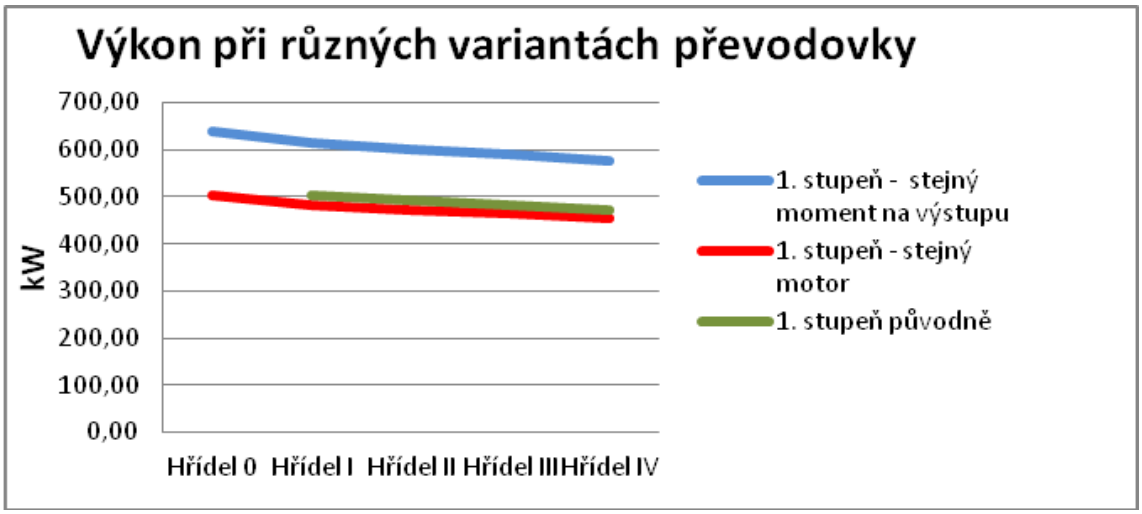
U hřídele 0 zelený a hnědý sloupec chybí. Je to proto, že v převodovce typu C hřídel 0 není.



Graf 1 Porovnání výkonu na jednotlivých hřídelích pro různá řešení převodovky

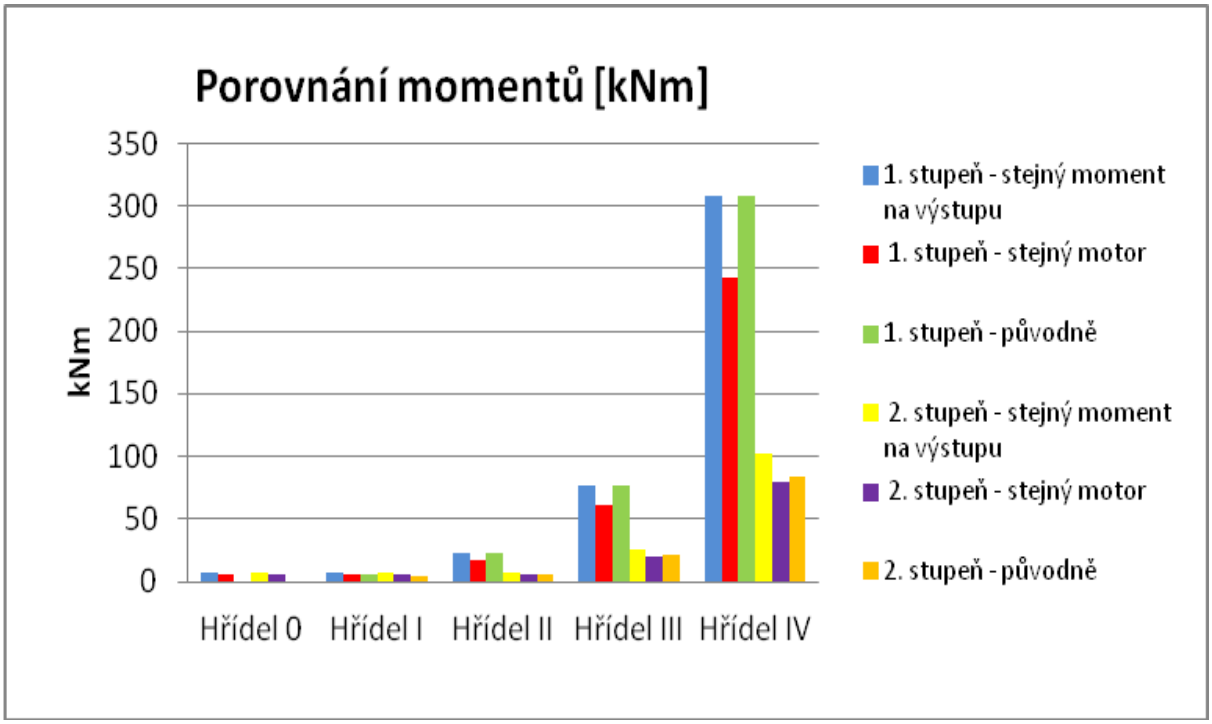
Celkově vidíme největší rozdíly výkonu u 1. převodového stupně (s větší redukcí otáček) mezi požadavkem na stejný motor a požadavkem na stejný výstupní moment. Na poklesu výkonu se podílí vložení kuželového soukolí asi čtyřmi procenty a změna geometrie vyvolaná požadavkem větší tuhosti asi dvaceti pěti procenty. Kdybychom tedy chtěli, vzhledem k použití převodovky pro naviják lan, zachovat stejný výstupní moment, jako má původní rovnoběžné uspořádání hřídelů, vedlo by to pravděpodobně k potřebě jiného motoru.

V následujícím grafu jsou stejná data jako v grafu 1 vykreslena jako spojitý pokles výkonu původního řešení převodovky typu C a poklesy převodovky typu KC. Pro lepší názornost je uveden jen první převodový stupeň a barvy jsou stejné jako v grafu 1. Zelený graf začíná opět až u hřídele I, protože původní převodovka typu C hřídel 0 nemá.



Graf 2 Pokles výkonu pro 1. převodový stupeň v závislosti na typu převodovky

Při porovnání z hlediska momentů, je z grafu 3 vidět zřetelný pokles momentu na výstupním hřídeli IV při stejném motoru na vstupu oproti požadavku na stejný výstupní moment. Zelený a oranžový sloupec u Hřídele 0 nejsou; převodovka typu C Hřídel 0 neobsahuje.



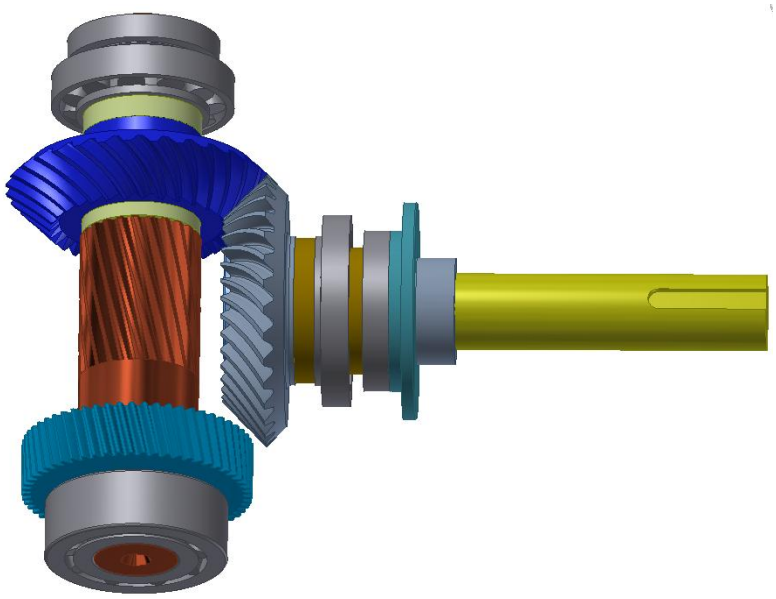
Graf 3 Točivé momenty v závislosti na typu převodovky

Převodovka typu KC má, při zachování stejného motoru na vstupu jako u převodovky typu C, nižší výstupní točivý moment. Vložení kuželového soukolí se podílí na poklesu cca 4%, vlivem upravené kinematiky čelních ozubení jde o pokles o dalších cca 25%.

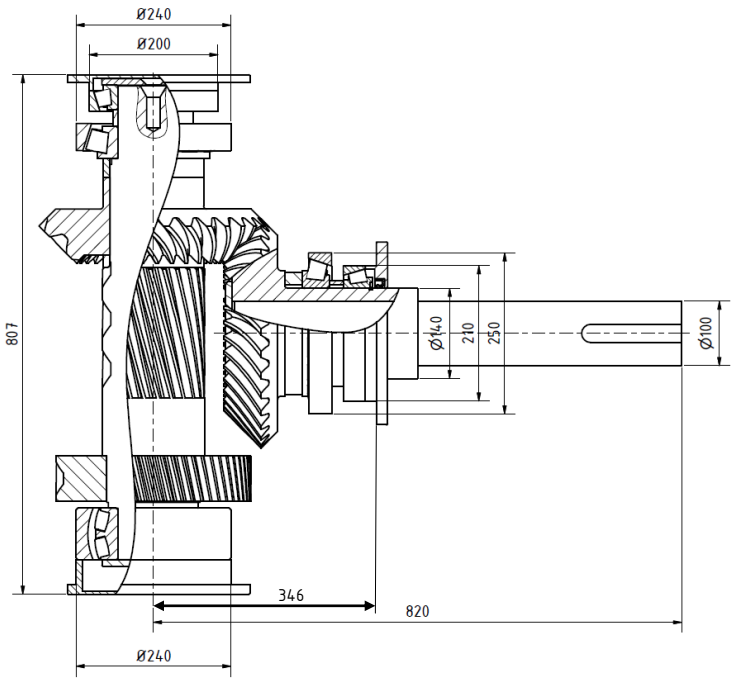
9. Modely soukolí ve 3D

3D modely jsem získala pomocí softwaru Inventor Professional 2013. Jsou modelovány pro nejméně příznivý zatěžovací stav, tj. respektování stejného momentu na výstupu pro převodovku typu C a KC. Inventor neumožňuje výpočet ani modelování kuželového soukolí Klingelnberg, proto jsem převzala model kuželového soukolí ve formátu *.step z KISSsoftu.

Na následujícím obrázku modelu kuželového soukolí je vstupní hřídel v kolmé poloze ke zbylým hřídelům, kuželové soukolí Klingelnberg s převodem 1:1, pastorky 1 a 3.

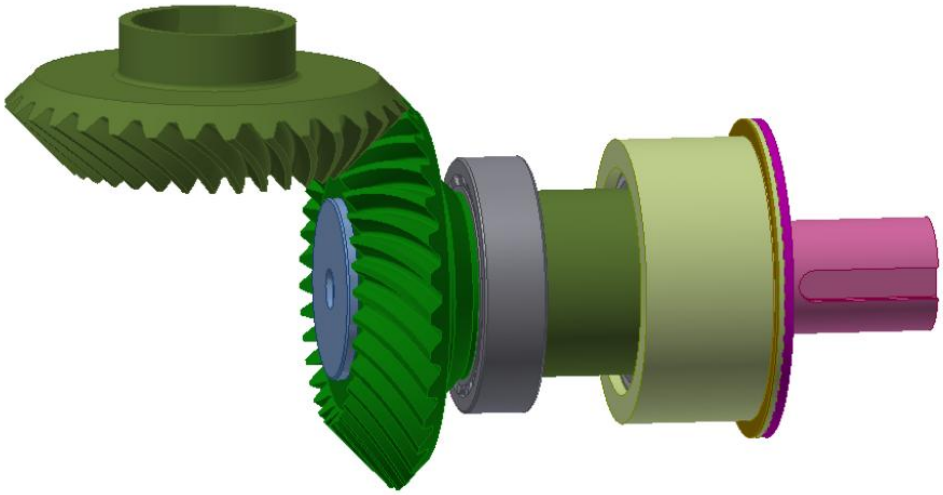


Obr. 9-1 3D model kuželového soukolí Klingelnberg; na Hřídeli 0 dvě kuželíková ložiska

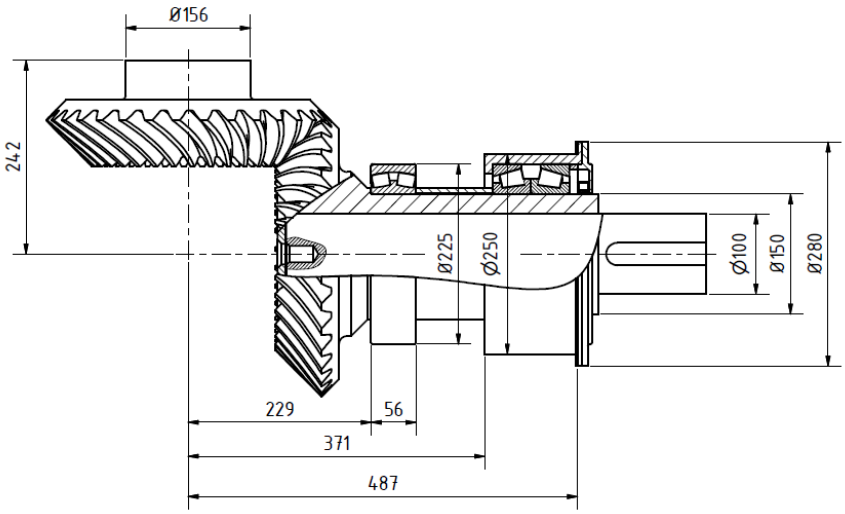


Obr. 9-2 Kuželové soukolí

Ustavování kuželových kol do záběru bude snazší, když bude kuželový pastorek uložen pomocí soudečkového a párového kuželíkového ložiska, jak je tomu na Obr. 9-3. Je to ale náročnější z pohledu potřebného prostoru. Celkové rozměry skříní s různým uložením hřídelů jsou srovnány v této práci později.

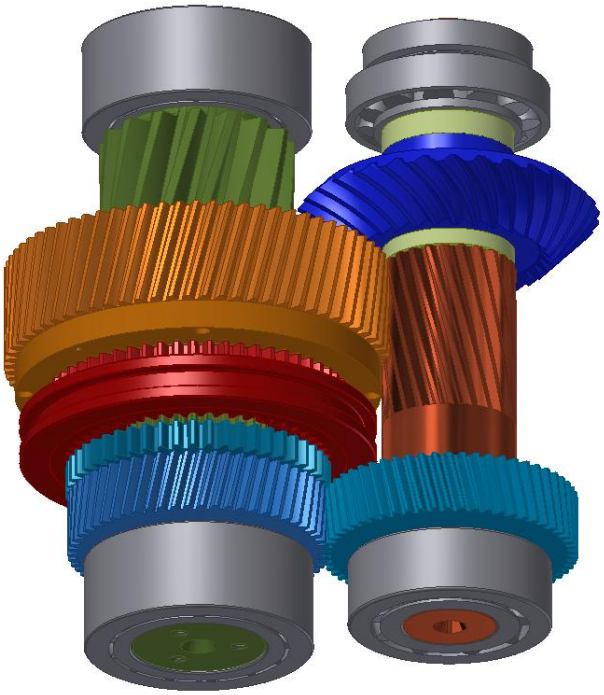


**Obr. 9-3 3D model soukolí Klingelnberg – jiné uložení;
na Hřídeli 0 je soudečkové a párové kuželíkové ložisko**

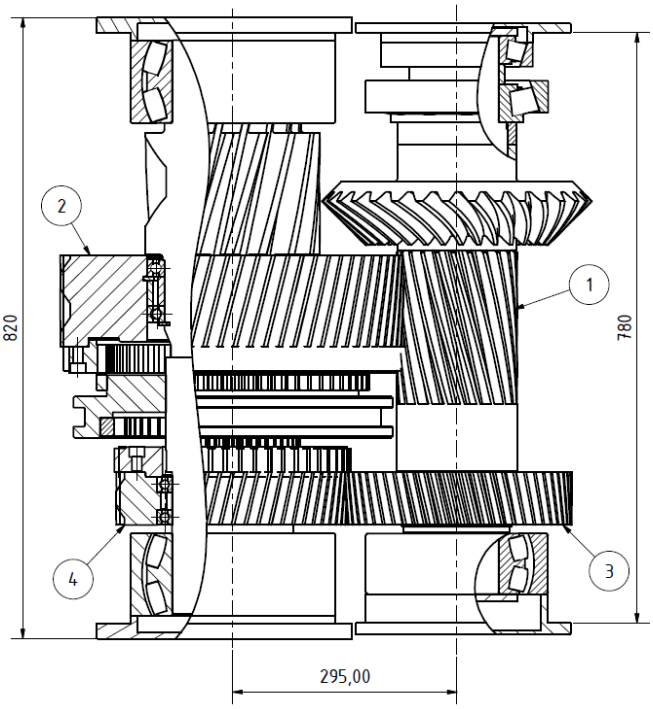


Obr. 9-4 Kuželové soukolí se soudečkovým a párovým kuželíkovým ložiskem

Na Obr. 9-5 je hřídel I s kuželovým kolem pro převodovku typu KC. Součástí hřídele je pastorek 1. Na hřídel je také nasazeno kolo 3. Na hřídeli II jsou kola 2 a 4 a přesouvací spojka. Na kolech 2 a 4 jsou přišroubovány čelní ozubené objímky s přímými zuby, které střídavě, podle zařazeného převodového stupně, jsou a nejsou v záběru s ozubením spojky.

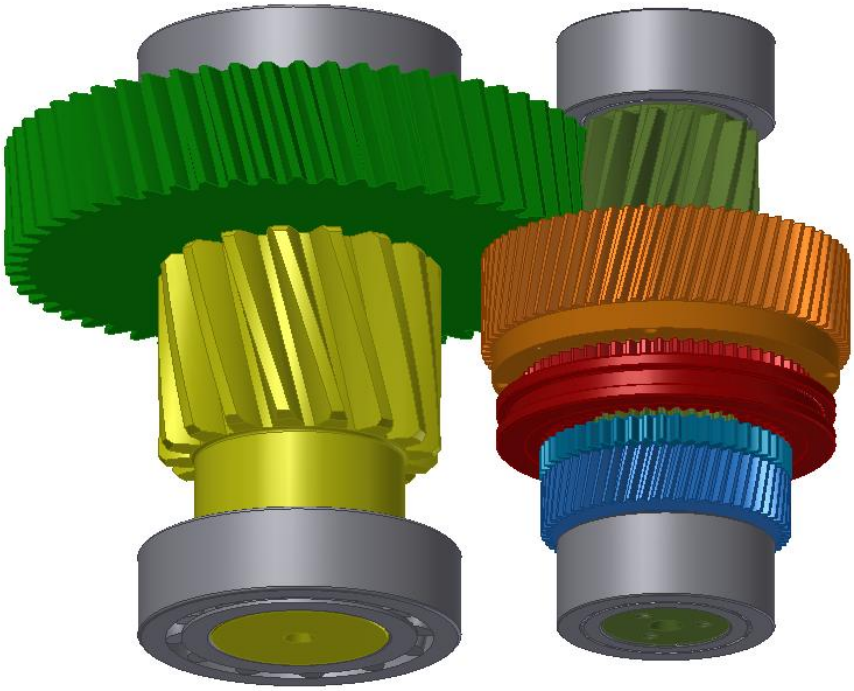


Obr. 9-5 3D model soukolí 1,2; soukolí 3,4; přesuvná spojka

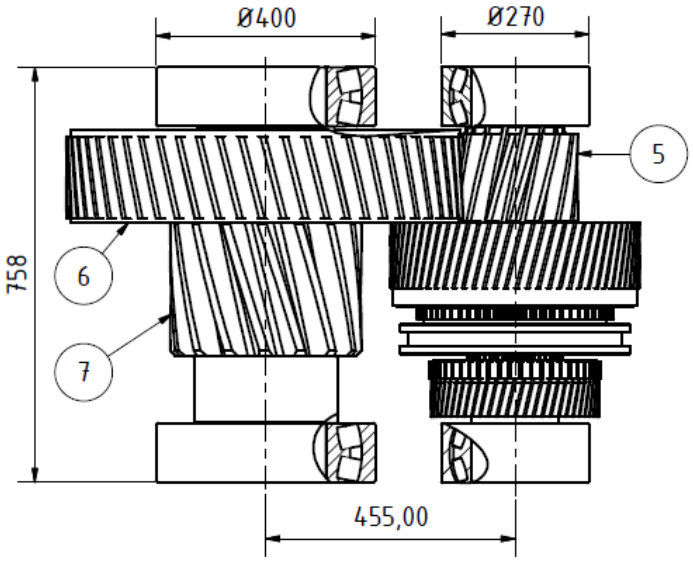


Obr. 9-6 Osová vzdálenost soukolí 1,2 a 3,4

Soukolí 5,6 je pro oba převodové stupně společné a jeho model je na Obr. 9-7.

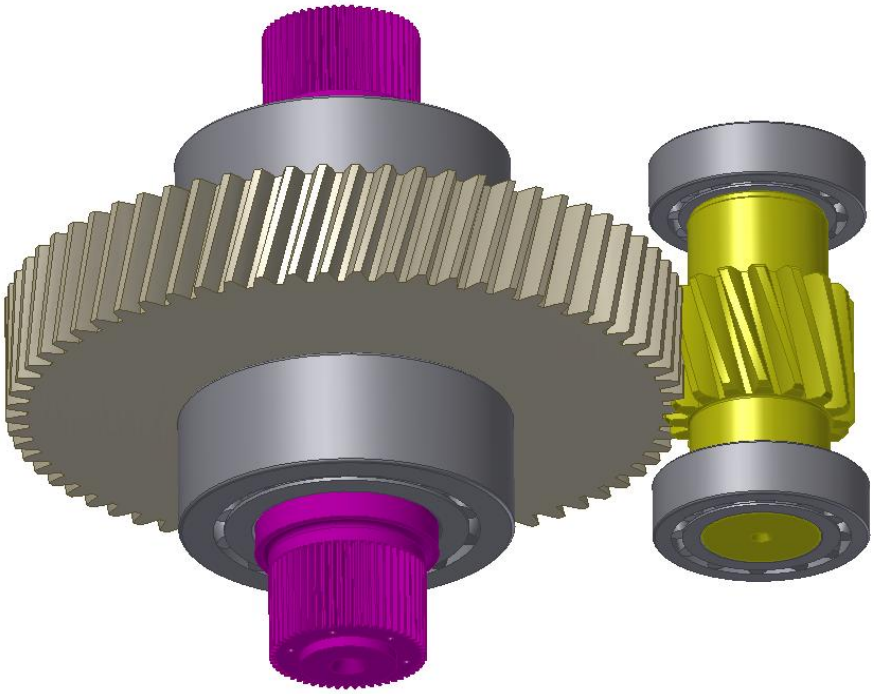


Obr. 9-7 3D model soukolí 5,6

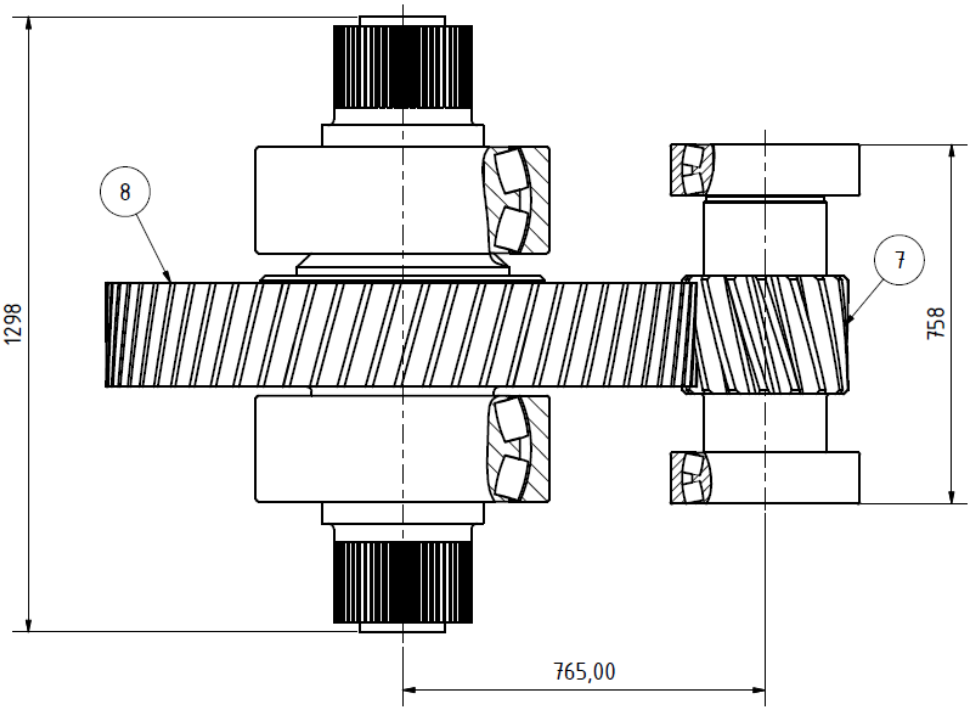


Obr. 9-8 Osová vzdálenost soukolí 5,6

Posledním převodem převodovky je soukolí 7,8 na Obr. 9-9. Výstupní hřídel, na kterém je nasazeno kolo 8, přesahuje souměrně obrysy skříně. Jeho oba konce jsou opatřeny drážkováním.



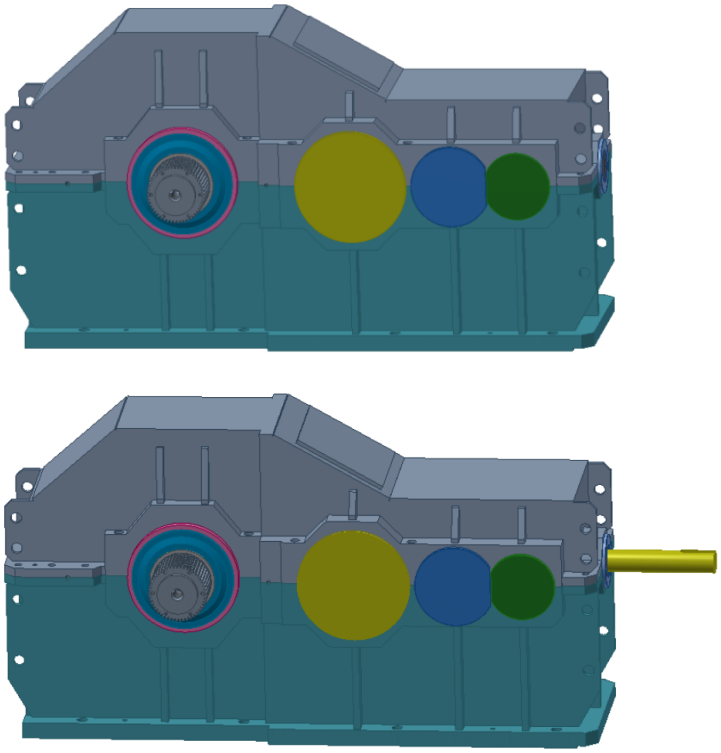
Obr. 9-9 3D model výstupního hřídele a soukolí 7,8



Obr. 9-10 Osová vzdálenost soukolí 7,8

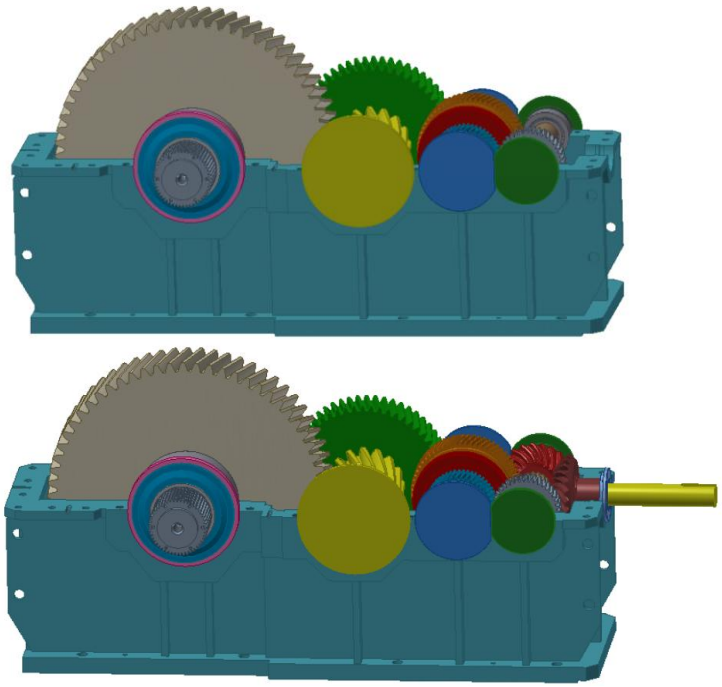
9.1. Původní řešení

Na Obr. 9-11 je původní návrh převodovky v univerzální skříni před úpravami. Nahoře je typ C. Otvor pro kolmý vstupní hřídel je zakrytý víčkem. Na dolním obrázku je otvor využitý pro vstupní hřídel poháněj ící kuželové soukolí.



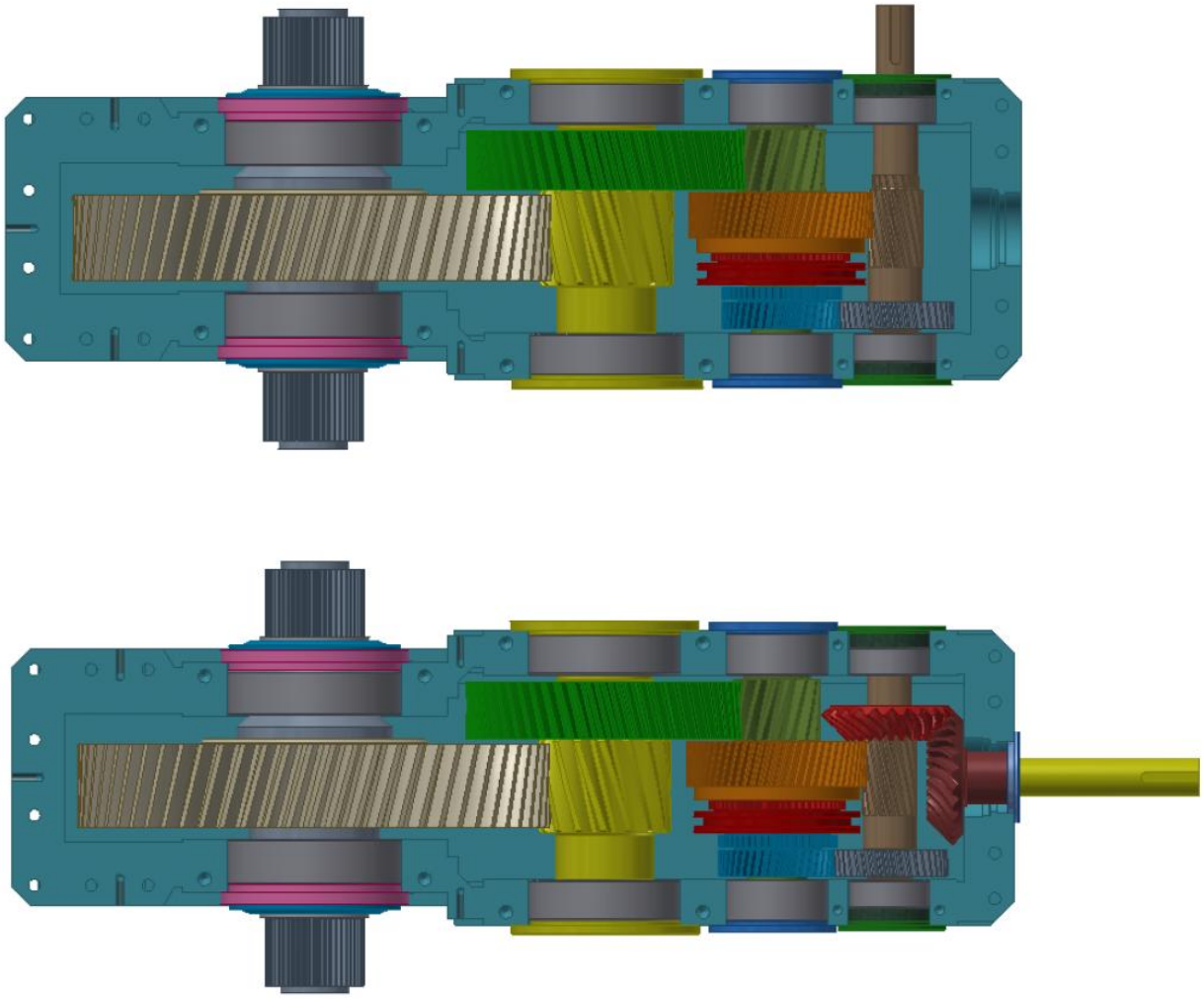
Obr. 9-11 3D model původního návrhu univerzální skříně

Na 3D modelu bez víka je na dolním obrázku oproti hornímu navíc kuželové soukolí a kolmý vstupní hřídel.



Obr. 9-12 Původní návrh univerzální skříně bez víka

Na Obr. 9-13. je pohled do dělicí roviny převodovky typu C a převodovky typu KC.

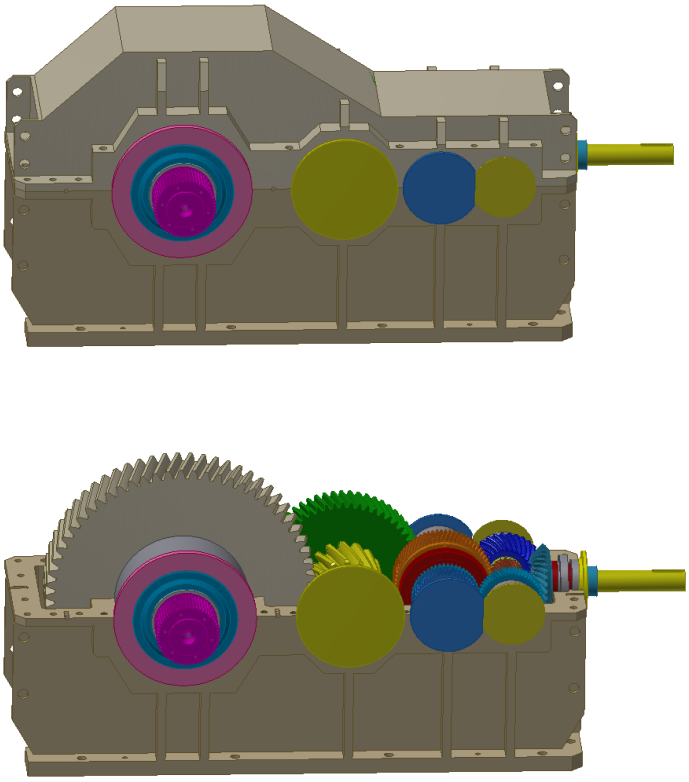


Obr. 9-13 Pohled do dělicí roviny obou typů převodovky při původním návrhu

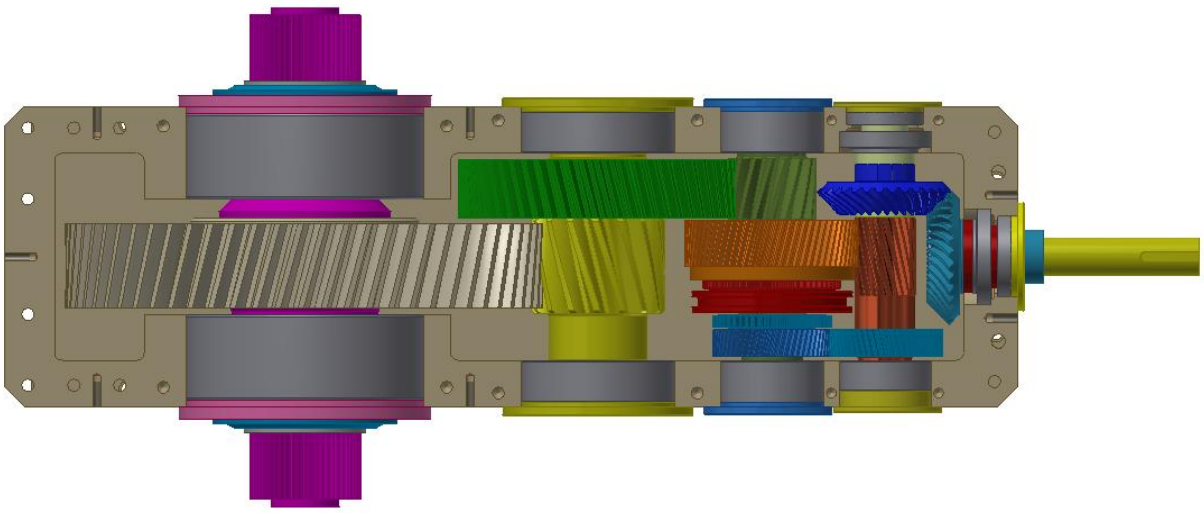
Tento návrh nesplnil přání zadavatele ohledně tuhosti hřídelů.

9.2. Převodovka upravená dle požadavků na tuhost

Po požadovaném zvětšení tuhosti prvního a čtvrtého hřídele a změně velikosti ložisek jsem upravila rozměry skříně. Na Obr. 9-14 je 3D model upravené převodovky, na Obr. 9-15 je pohled do dělicí roviny této upravené převodovky. Oproti původnímu návrhu jsou i jiná čelní soukolí 1,2; 3,4 a kuželové soukolí.



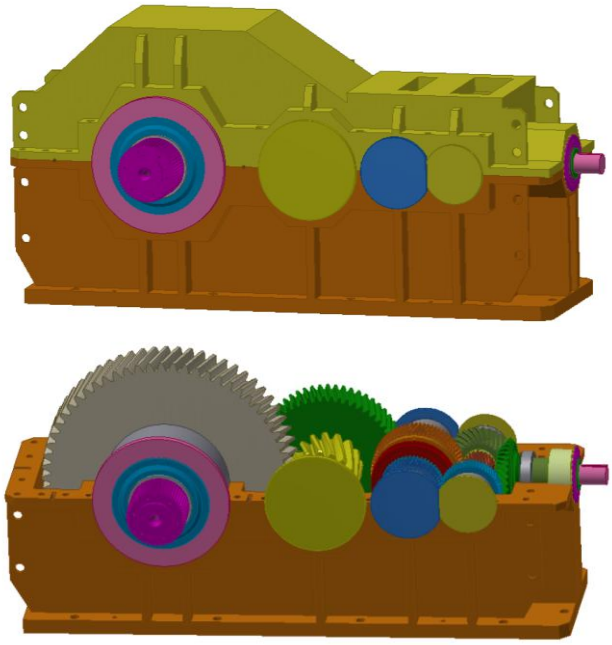
Obr. 9-14 Pohled na 3D model upravené převodovky typu KC



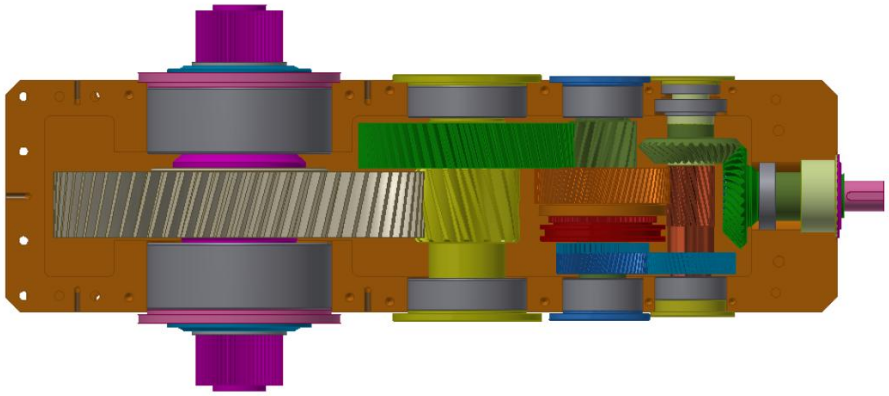
Obr. 9-15 Pohled do dělicí roviny upravené převodovky typu KC

9.3.Upravená převodovka s jiným uložením vstupního hřídele

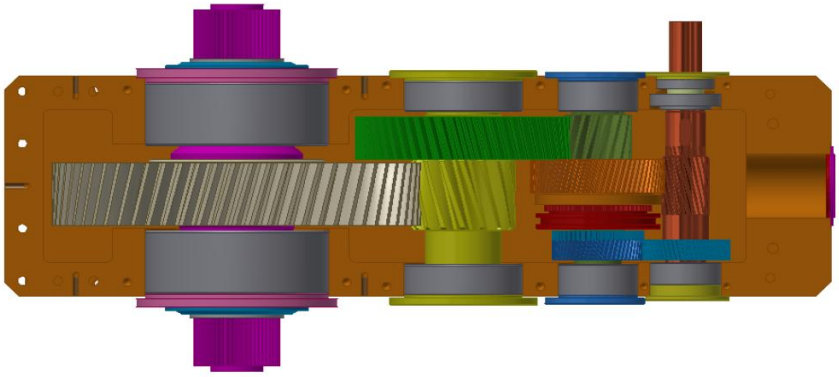
Následující návrh vychází z tuhostně zesíleného (upraveného) návrhu, ale uložení vstupního hřídele je s ohledem na snazší montáž řešeno soudečkovým ložiskem spolu s párovým kuželíkovým ložiskem. Uvedená varianta je z hlediska uložení nejlepší, ale nedodržuje obrysové rozměry skříně uvedené zadavatelem.



Obr. 9-16 Pohled na 3D model upravené převodovky typu KC – jiné uložení vstupního hřídele



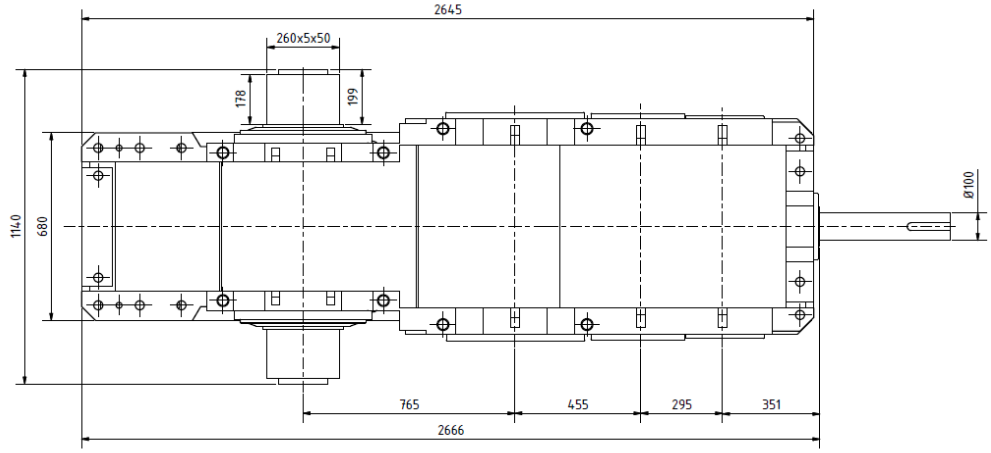
Obr. 9-17 Pohled do dělicí roviny. Do skříně umístěna převodovka typu KC



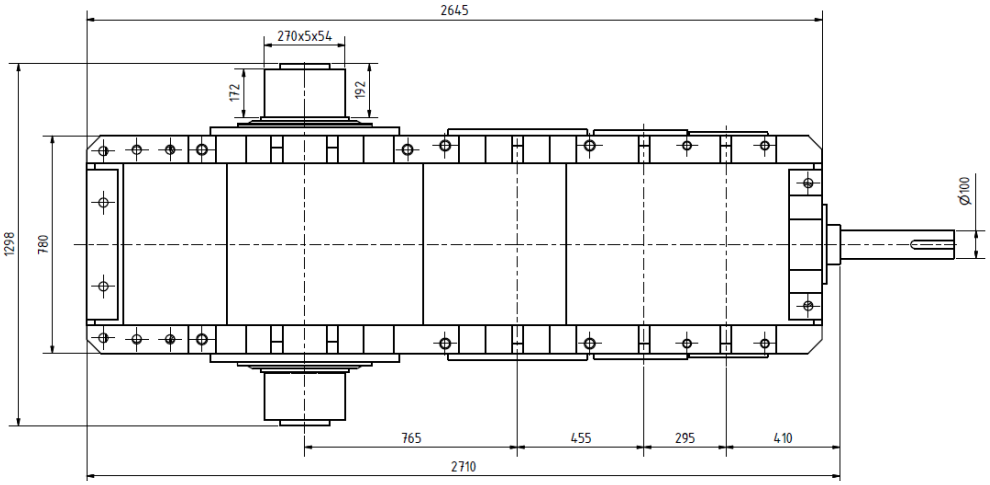
Obr. 9-18 Pohled do dělicí roviny. Do skříně umístěna převodovka typu C

9.4.Porovnání půdorysů jednotlivých řešení

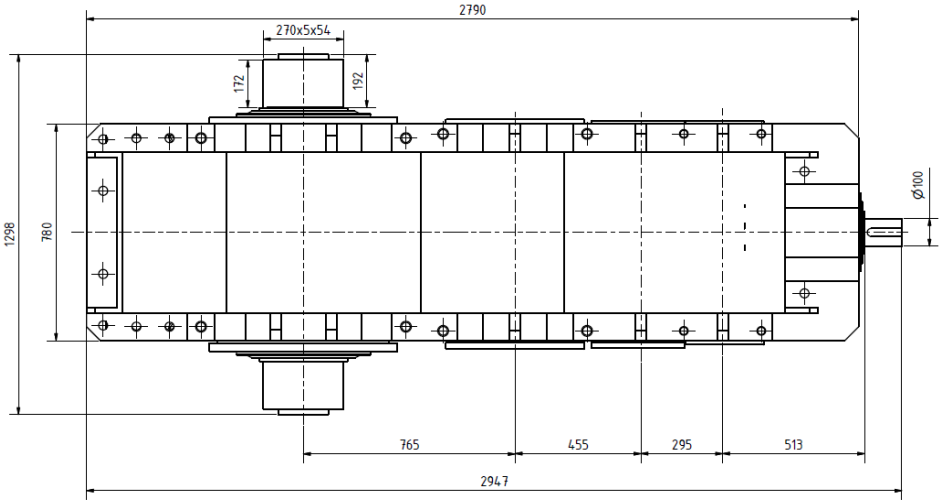
- Původní návrh



- Návrh po upravení tuhosti hřídelů



- Návrh po upravení tuhosti hřídelů a po změně uložení vstupního hřídele

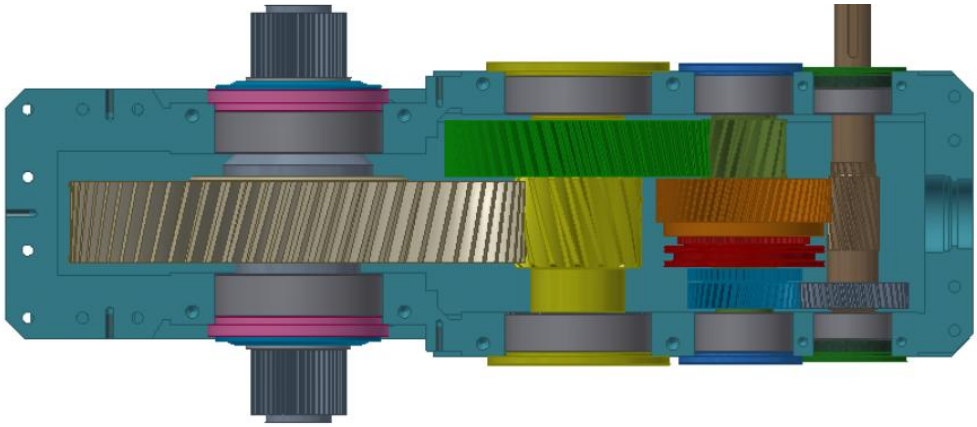


Obr. 9-19 Rozměry jednotlivých návrhů

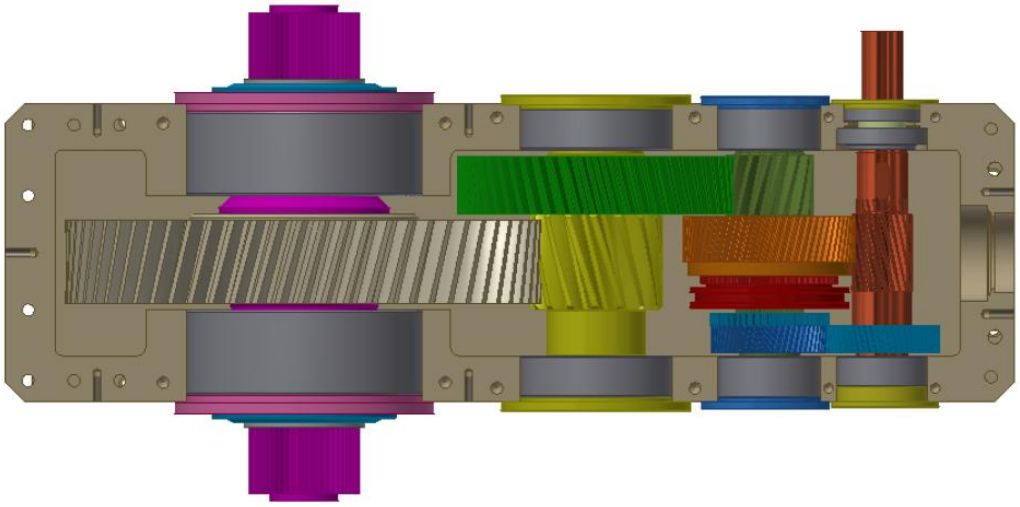
Řešení, které vyhovuje tuhostně a bude u něj snadněji probíhat montáž kuželového soukolí, má ze všech variant největší obrysové rozměry.

9.5.Pohled do dělicí roviny variant převodovky typu C

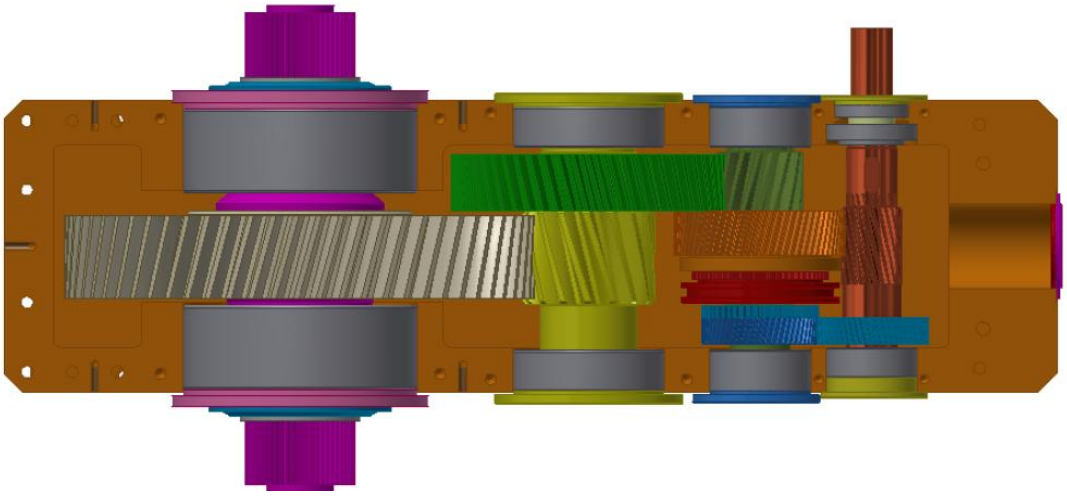
- Původní návrh



- Návrh po upravení tuhosti hřídelů



- Návrh po upravení tuhosti hřídelů a po změně uložení vstupního hřídele pro typ KC

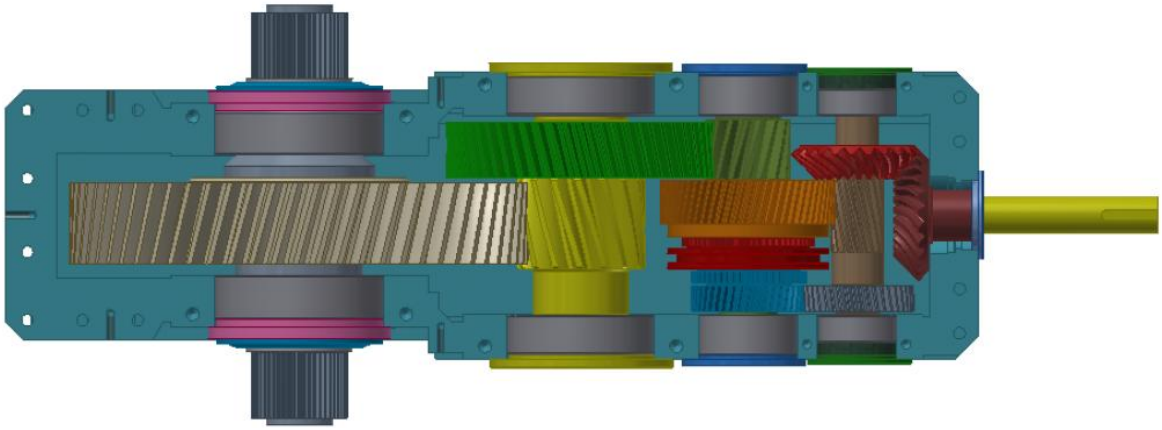


Obr. 9-20 Pohled do dělicí roviny modelu převodovky typu C jednotlivých návrhů

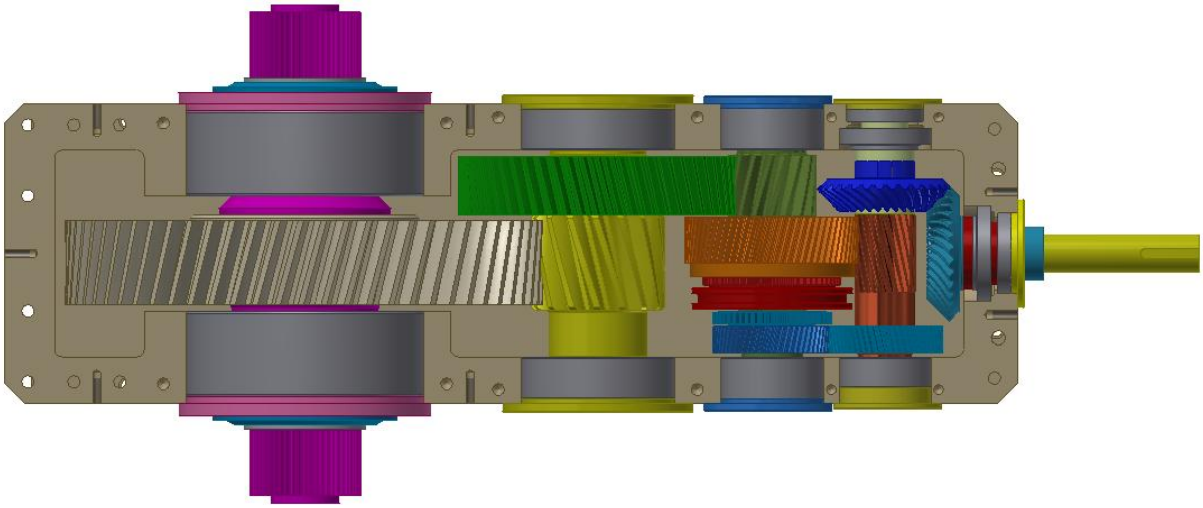
Na pohledech po upravení tuhosti hřídelů jsem zesílené hřídele I a IV barevně odlišila od původního řešení.

9.6.Pohled do dělicí roviny variant převodovky typu KC

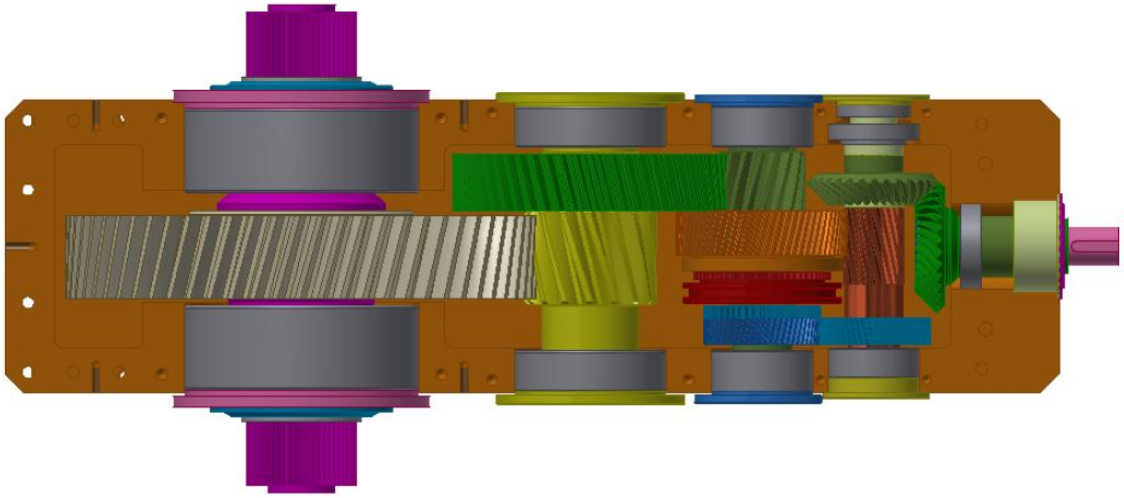
- Původní návrh



- Návrh po upravení tuhosti hřídelů a změně počtu zubů kuželového soukolí



- Návrh po upravení tuhosti hřídele a uložení vstupního hřídele u typu KC



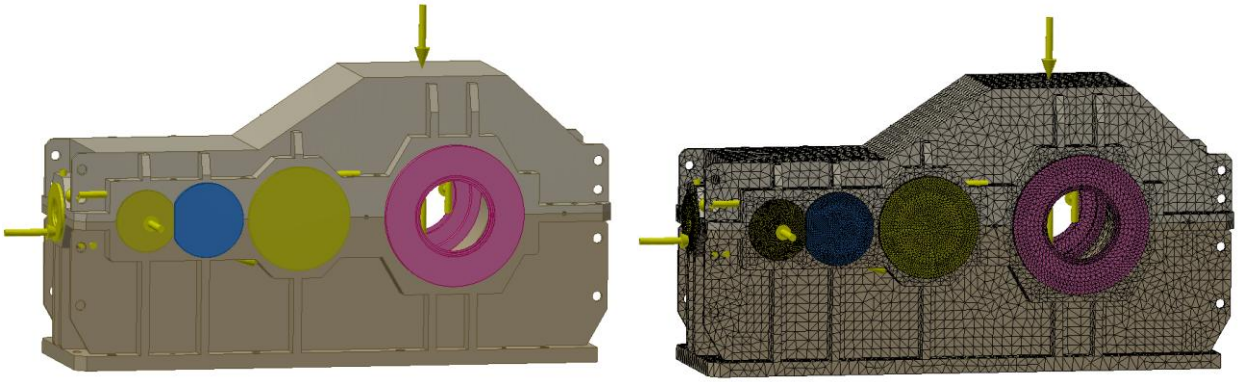
Obr. 9-21 Pohled do dělicí roviny převodovky typu KC jednotlivých návrhů

Kuželové soukolí je v každém návrhu jiné. V původním má 24 zubů. V dalších návrzích je shodně po 32 zubech, ale vstupní hřídel je rozdílný.

10. Pevnostní, deformační a modální analýza skříně převodovky

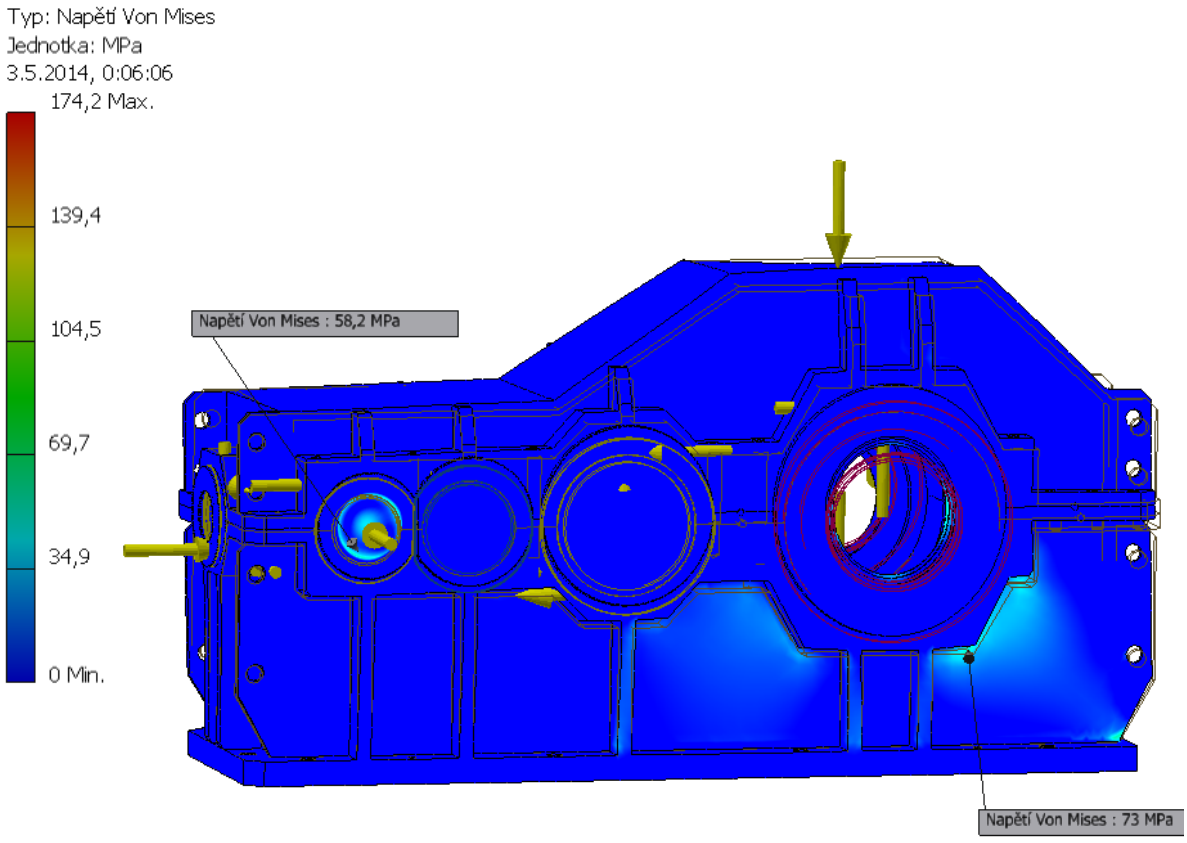
10.1. Pevnostní a deformační analýza skříně

Příprava pro spuštění výpočtu v softwaru Inventor Professional 2013 spočívala v použití vany a víka skříně. Otvory pro hřídele jsem osadila víčky. Podle údajů o reakcích v ložiskách z výpočtu KISSsoftem jsem umístila příslušné síly do modelu. Přidala jsem působení gravitace a model zasíťovala (Obr. 10-1).



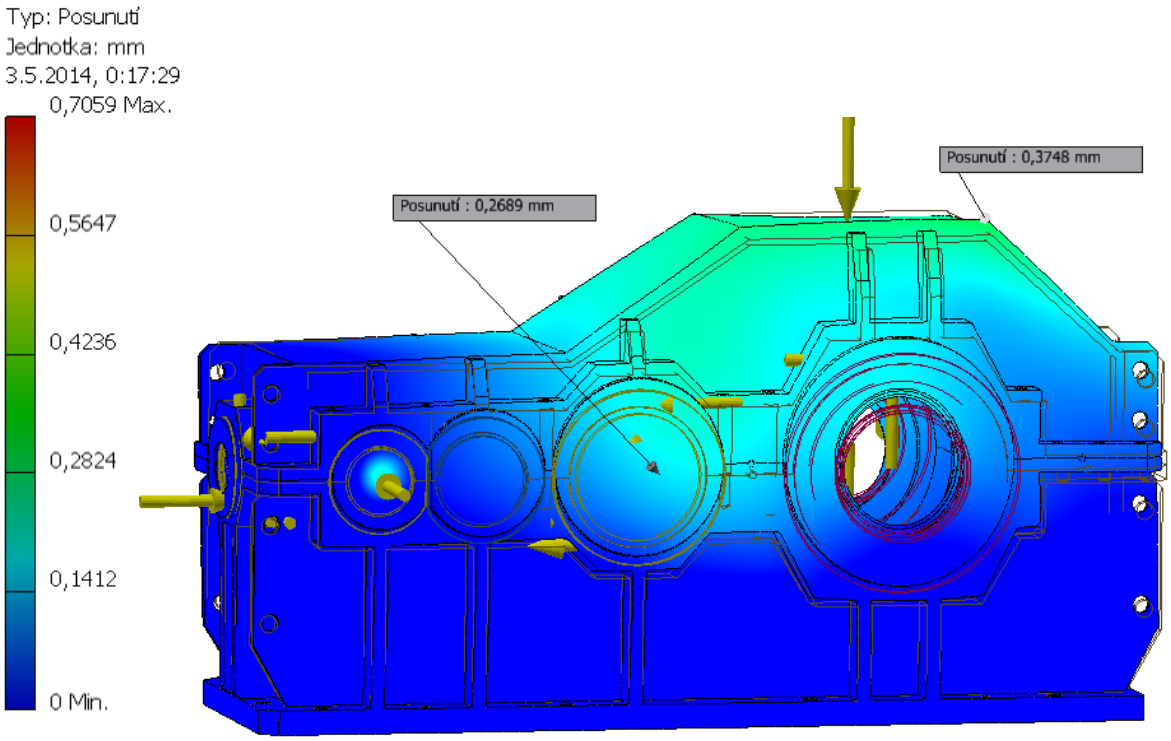
Obr. 10-1 Příprava modelu pro pevnostní a deformační analýzu

Výsledky pevnostní analýzy



Obr. 10-2 Napětí Von Mises

Výsledky deformační analýzy



Obr. 10-3 Výsledky deformační analýzy skříně

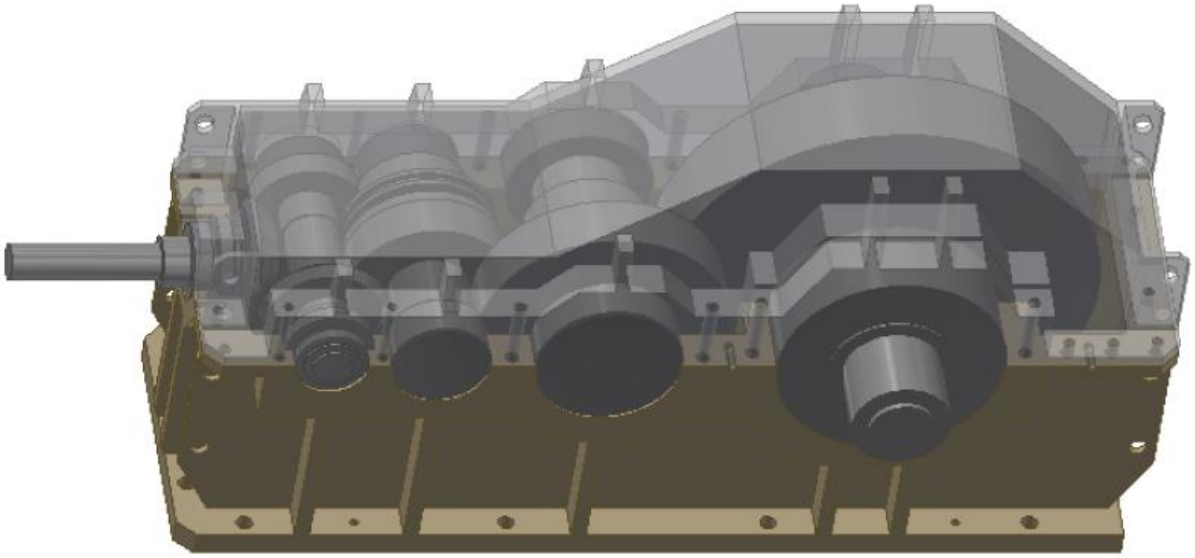
Napětí Von Mises deformační analýza jsou dva nejčastěji využívané. Celá zpráva z analýzy je uvedena v příloze. Materiálové hodnoty použité při výpočtu jsou: mez kluzu R_e = 207 MPa, mez pevnosti R_m = 345 MPa, modul pružnosti E = 2,2.10^5 MPa odpovídají oceli obvyklých jakostí vhodné ke svařování třídy 11.

Návrh skříně pevnostně vyhovuje s bezpečností proti mezi kluzu cca 2,8. Červeně vykreslená maxima jsou na hranách víčka výstupního hřídele a vykazují hodnotu 174,2 MPa. Je to způsobeno odstraněním zaoblení hran v rámci zjednodušení geometrie pro výpočtový model. Hrany se tak staly koncentrátorem napětí. Ve skutečnosti tam špičky napětí nebudou.

Výsledky deformační analýzy jsou ovlivněny zjednodušením modelu pro výpočet. Skříň navíc ještě vyztuží díly, které nebyly součástí řešení této DP, ale ve skutečnosti budou k převodovce připojeny (např. hydromotor pro pohon přesouvací spojky a kryty připojení konců výstupního hřídele k navijáku lana). Velikosti posunutí jsou vyhovující.

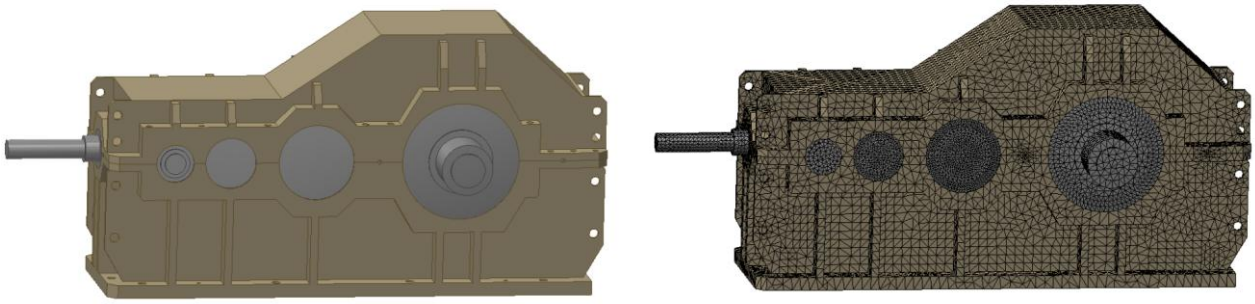
10.2. Modální analýza převodovky

V rámci přípravy pro provedení modální analýzy jsem nahradila modely jednotlivých vnitřních komponent převodovky jinými, velmi zjednodušenými. Odstranila jsem malá zaoblení a zkosení, ozubení jsem nahradila válci se stejnými průměry, jako jsou průměry roztečných kružnic. Šrouby spojující víko a vanu skříně jsem odstranila. V modelu není rovněž počítáno s olejovou náplní převodovky.



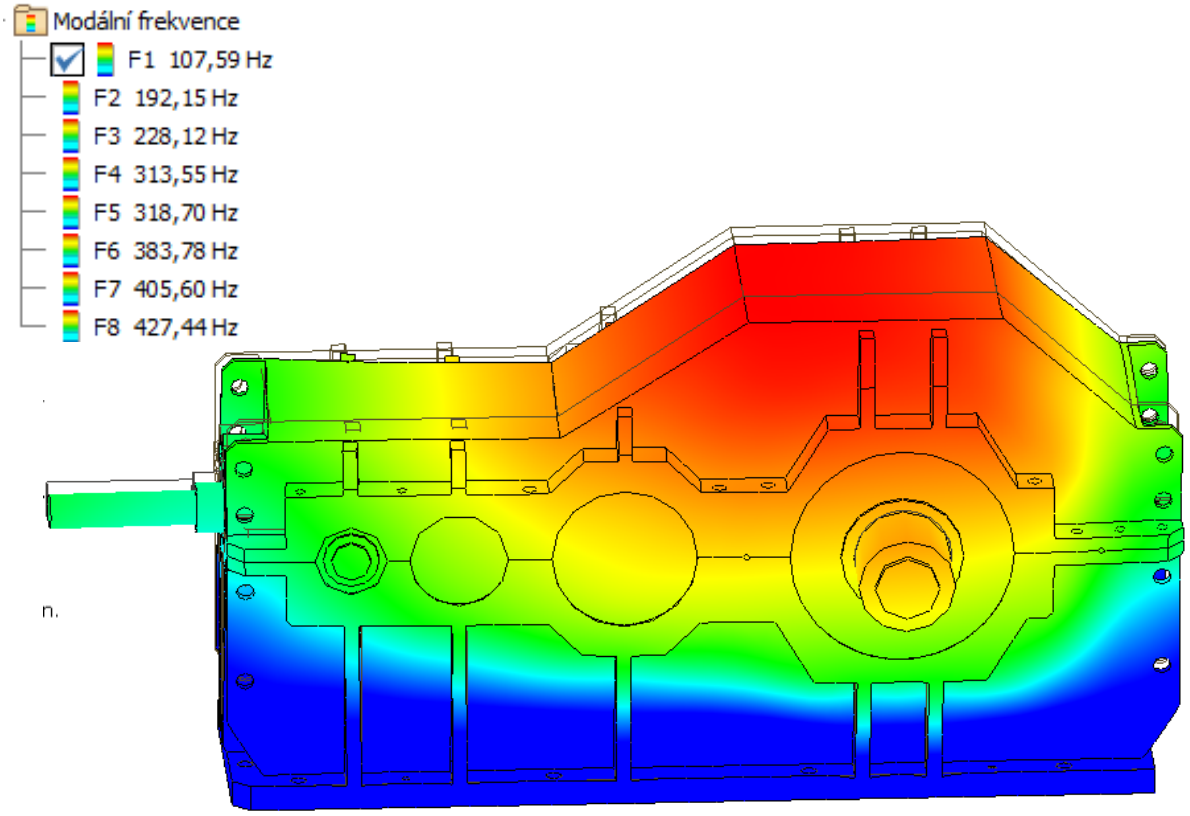
Obr. 10-4 Náhrada modelů komponent

Poté jsem provedla zasíťování modelu podobně jako pro předchozí výpočet.



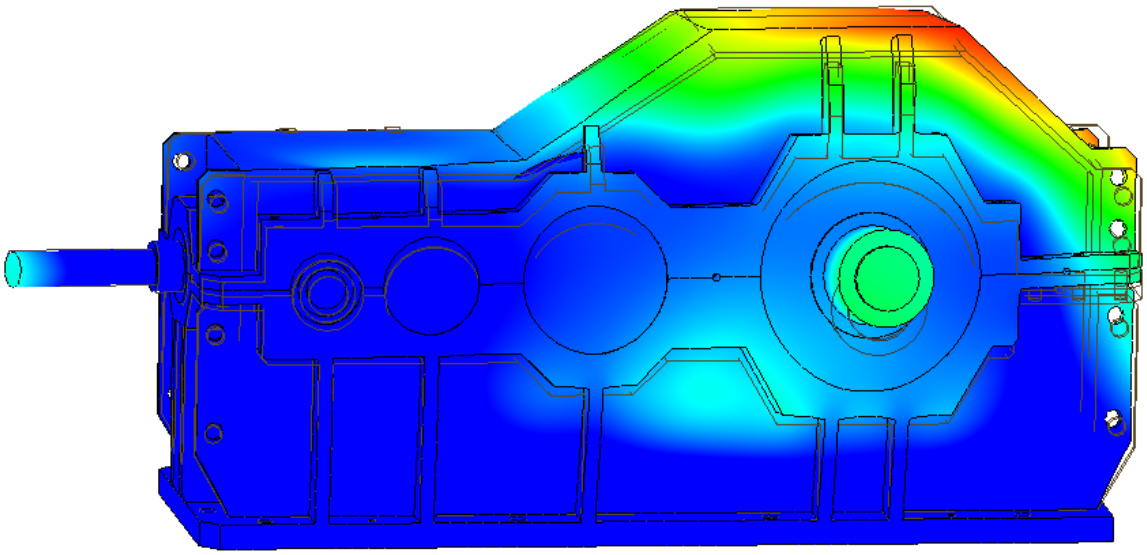
Obr. 10-5 3D model s náhradami komponent a jeho zasíťování

Výsledky modální analýzy



Obr. 10-6 První vlastní tvar kmitu

Řešením modální analýzy jsem získala informace o vlastních frekvencích převodovky (Obr. 10-6), které jsem dále využila pro srovnání s vlastními frekvencemi hřídelů a se zubovými frekvencemi. Součástí výsledků jsou i krátké animace vlastních tvarů kmitů. Celková zpráva z analýzy je zařazena do přílohy. Zde jsem vybrala pro ilustraci znázornění prvního a sedmého vlastního tvaru kmitu.



Obr. 10-7 Sedmý vlastní tvar kmitu

10.3. Porovnání frekvencí

Porovnání frekvencí děláme z toho důvodu, abychom předešli nepříznivým stavům rezonance. Stav, kdy se budicí frekvence příliš blíží vlastní frekvenci má za následek enormní růst působících sil a může vést k poškození součásti nebo celého zařízení.

Vlastní frekvence Hřídele 0 s dvouřadým soudečkovým ložiskem SKF*23030 CC/W33 a párovým kuželíkovým ložiskem v provedení čely k sobě SKF 32030 X/DF.

č.	[Hz]	Kritické otáčky [min-1]	
1.	0,00	0,00	Rigid body station Y „Shaft 1“
2.	415,19	24911,17	Bending YZ „Shaft 2“
3.	1391,19	83471,29	Bending YZ „Shaft 1“
4.	1934,02	116041,00	Axial „Shaft 1“

Vlastní frekvence Hřídele 0 se dvěma kuželíkovými ložisky SKF 30228 J2 a SKF 32028 X

č.	[Hz]	Kritické otáčky [min-1]	
1.	0,00	0,00	Rigid body station Y „Shaft 2“
2.	214,13	12847,99	Bending YZ „Shaft 2“
3.	1204,77	72286,11	Bending XY „Shaft 2“
4.	1422,86	85371,72	Torsion „Shaft 2“

Vlastní frekvence Hřídele I pro převodovku typu C

č.	[Hz]	Kritické otáčky [min-1]	
1.	0,00	0,00	Rigid body station Y „Shaft 1“
2.	527,87	31671,69	Bending XY „Shaft 1“, Bending YZ „Shaft 1“
3.	905,66	54339,78	Bending XY „Shaft 1“, Bending YZ „Shaft 1“
4.	1604,65	96279,28	Torsion „Shaft 1“

Vlastní frekvence Hřídele I pro převodovku typu KC

č.	[Hz]	Kritické otáčky [min-1]	
1.	0,00	0,00	Rigid body station Y „Shaft 1“
2.	579,37	34762,39	Bending YZ „Shaft 1“, Bending XY „Shaft 1“
3.	1291,11	77466,59	Torsion „Shaft 1“
4.	1458,67	87520,42	Axial „Shaft 1“

Vlastní frekvence Hřídele II

č.	[Hz]	Kritické otáčky [min-1]	
1.	0,00	0,00	Rigid body station Y „Shaft“
2.	0,01	0,61	Rigid body station Y „Shaft 3“ (zástupce kola 4)
3.	409,71	24582,57	Bending YZ „Shaft“, Bending XY „Shaft“
4.	852,31	51138,56	Bending XY „Shaft“

Vlastní frekvence Hřídele III

č.	[Hz]	Kritické otáčky [min-1]	
1.	0,00	1,99	Rigid body station Y „Shaft III“
2.	111,79	6707,13	Axial „Shaft III“
3.	514,75	30884,89	Bending XY „Shaft III“
4.	651,13	39067,58	Bending YZ „Shaft III“

Vlastí frekvence Hřídele IV

č.	[Hz]	Kritické otáčky [min-1]	
1.	0,00	0,00	Rigid body station Y „Shaft 1“
2.	767,64	46058,48	Bending YZ „Shaft 1“
3.	838,98	50339,05	Bending XY „Shaft 1“
4.	1124,13	67448,08	Axial „Shaft 1“

Z vlastních frekvencí jsem pro další porovnání vybrala jen ty, které by bylo v provozu reálně možné dosáhnout. Maximální otáčky jsou 800 ot/min. Vlastní frekvence dosažené při vyšších otáčkách jsem do porovnání nezahrnula.

Zubové frekvence vznikaní nárážením boků zubů při záběru s protikolem. Zubové frekvence jsem spočítala ze vztahu

$$f_z = \frac{z \cdot n}{60} \,[\mathrm{Hz}].$$

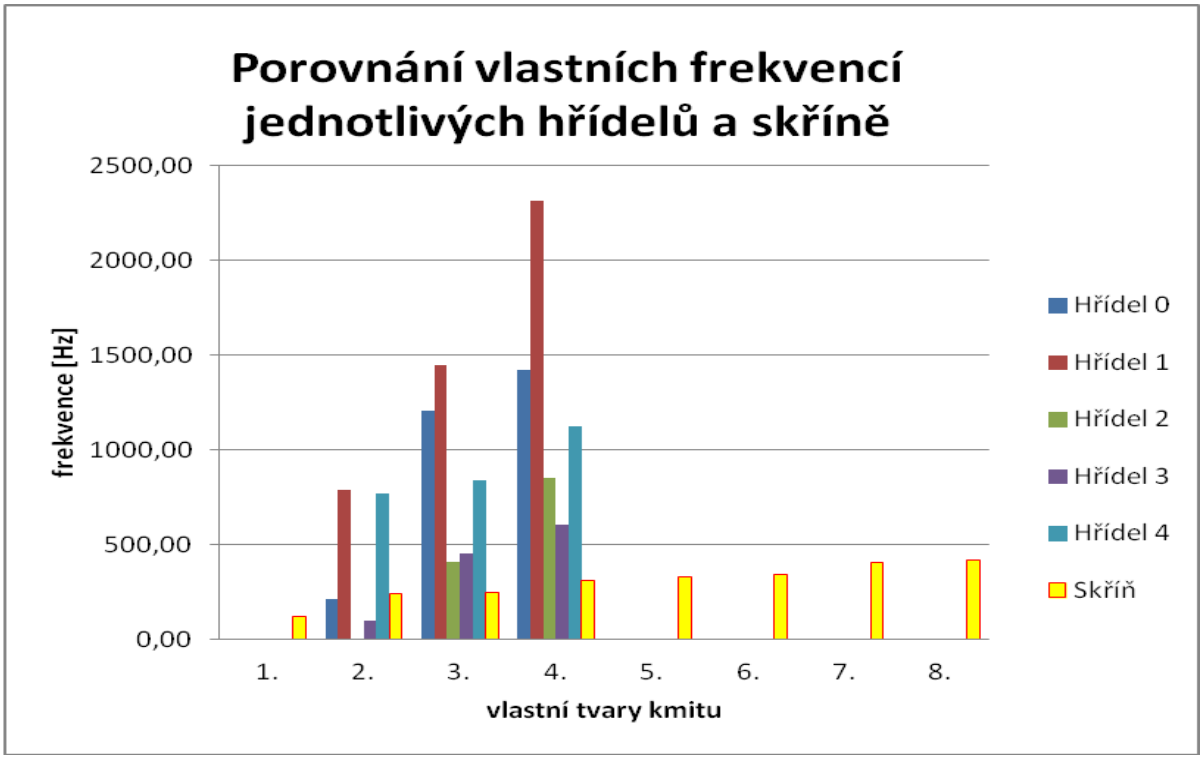
Zubové frekvence [Hz]					
Soukolí	**K1, K2**	**1, 2**	**3 ,4**	**5, 6**	**7, 8**
1.stupeň	426,67	306,67	-	67,41	18,92
2.stupeň	426,67	-	760	209,65	57,40

Tab. 10-1 Hodnoty zubových frekvencí v Hz

Vlastní frekvence převodovky [Hz]							
1.	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**
107,53	192,13	228,1	313,77	318,77	383,72	405,60	427,56

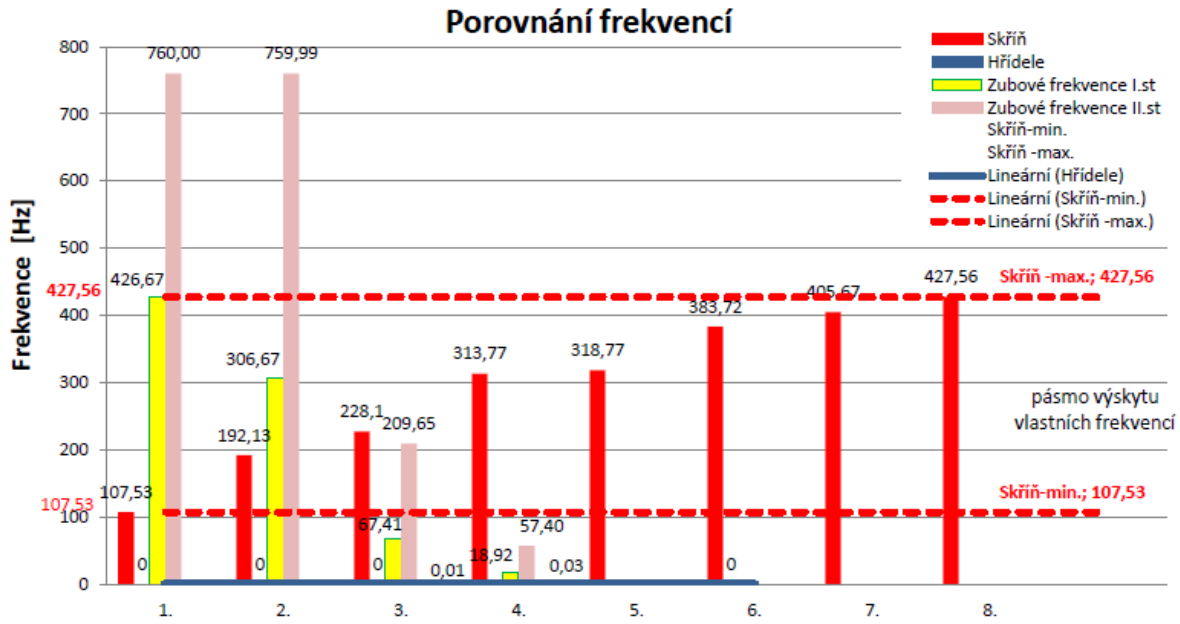
Tab. 10-2 Hodnoty vlastních frekvencí převodovky

Graf 4 ukazuje, které hřídele by se mohly podílet na buzení skříně. K zubovým frekvencím zde nepřihlížím.



Graf 4 Porovnání vlastních frekvencí skříně s vlastními frekvencemi hřídelů

Graf 5 zahrnuje frekvence skříně, hřídelů a zubové frekvence. Pásmo, kde se vyskytují vlastní frekvence skříně, je vyznačeno dvěma vodorovnými linkami. Hodnoty vlastní frekvence při jednotlivých tvarech kmitu jsou vyznačeny červeným sloupcem. Hodnoty hřídelů jsou nízké a v grafu se projevili jen jako linka u vodorovné osy. Zubové frekvence při 1. převodovém stupni jsou vyznačeny růžově, zubové frekvence vznikající při druhém převodovém stupni jsou znázorněny žlutým sloupcem.



Graf 5 Porovnání vlastních frekvencí skříně, hřídelů a zubových frekvencí

Zubové frekvence a vlastní frekvence skříně jsou rozdílné. Pro přesnější posouzení by bylo třeba uvažovat se všemi částmi převodovky.

11. Závěr

Úkolem diplomové práce bylo navrhnout převodovky, které se liší polohou vstupní a výstupní osy (rovnoběžné hřídele a kolmé hřídele). Další požadavek byl na co největší počet společných dílů, tj. aby se převodovky lišily jen na vstupní části a vlastní těleso skříně se lišilo jen v detailech.

Ze zadaných parametrů jsem navrhla první varianty čelní a kuželové převodovky. Po následné konzultaci se zadavatelem vznikl požadavek na zvýšení tuhosti hřídelů na vstupu i výstupu převodovky.

Finální návrh je patrný z kapitoly 9 (část 9.2 a 9.3). Převodovku typu KC jsem navrhla ve dvou variantách uložení vstupního hřídele. Hlavní parametry jednotlivých variant jsou uvedeny v Tab. 11-1.

Sledované parametry		**První návrh**	**Stejný motor**	**Stejný výstupní moment**
Převod	i	54,485 / 14,825	44,676 / 14,727	44,676 / 14,727
Moment	Mt [Nm]	6.000	6.000	7.600
Vstupní otáčky	n_1 [min^{-1}]	800	800	800
Výstupní otáčky	n_2 [min^{-1}]	14,68 / 53,96	17,91 / 54,32	17,91 / 54,32

Tab. 11-1 Sledované parametry pro řešené možnosti

Po navržení řešení jsem zjistila kompletní vlastnosti převodové skříně (pevnost a tuhost) a provedla jsem analýzu převodovky metodou MKP a výsledky porovnala.
Výsledné navržené převodovky jsou ve formě 3D uvedené v diplomové práci. Pro ilustraci jsou v příloze výkresy ve 2D. V příloze jsou také výsledky výpočtů.

Návrh konstrukčního řešení splňuje zadané parametry a požadavky na zvýšenou tuhost.

12. Literatura

Knižní publikace

[1] BARTOŠ, J. a kol. *Strojnické tabulky*, Praha: SNTL 1971

[2] HOSNEDL, S., KRÁTKÝ J. *Příručka strojního inženýra, obecné strojní části 1*, Praha: Computer Press, 1999

[3] KRÁTKÝ, J., KRÓNEROVÁ, E. *Obecné strojní části 2 : základní a složené převodové mechanismy*, Plzeň: Západočeská univerzita 2011

Internetové zdroje

[4] *Gufera. http://www.prumex.cz/gufera*, 2014

[5] HOSNEDL, S. *Specifikace požadavků. https://courseware.zcu.cz/wps/PA_Courseware/DownloadDokumentu?id=15207*

[6] LAŠOVÁ, V. *Základy stavby obráběcích strojů. http://www.zcu.cz/pracoviste/vyd/online/Zaklady_stavby.pdf*, Plzeň, ZČU-KKS, 2012

[7] *Ložiska. http://www.skf.com/cz/products/bearings-units-housings/index.html* , 2014

[8] *Motory řady ACM, http://www.motorgear.cz/elektromotory-acmotoren-acm*, 2014

[9] *Povrchové a hlubinné doly, Mechanické převodovky a ozubená kola pro důlní průmysl www.wikov.cz/pages_data/cz_doly_cz.pdf*, 2007

[10] *Přehled vlastností oceli 18CrNiMo7-6. http://pririicka.bolzano.cz/cz/technicka-podpora/techprirI/tycovaocel/ocelikcementovani/18CrNiMo7-6/* 2014

[11] *Převodovka. http://cs.wikipedia.org/wiki/P%C5%99evodovka#mw-navigation#mw-navigation*, 2014

[12] *Převodovky pro cementárny a průmysl zpracování minerálů http://www.wikov.cz/pages_data/cz_cement_cz.pdf*, 2014

[13] *Rotační hřídelové těsnění. http://www.bohemiaseal.cz*, 2014

[14] ŠEVČÍK, M. *Mazání zapouzdřených převodovek. http://old.uk.fme.vutbr.cz/kestazeni/tribologie/4r_2006/prezentace_4r_sevcik.pdf*, Brno, VUT, 2006

[15] *Technet. http://technet.idnes.cz/pomohl-ze-zeme-vyrvat-miliardy-barelu-ropy-aneb-cech-na-ropne-plosine-122-/*, 2010

[16] *Těsnicí prvky. http://www.abeltechnik.cz/rubena/tesnici_prvky.pdf*, 2014

[17] *Těsnění. http://www.elotechnik.cz/*, 2014

[18] *Těžba ropy a plynu, loďařský průmysl, http://www.wikov.cz/pages_data/cz_oil_gas_en.pdf* , 2014

[19] *Veřejný rejstřík a sbírka listin. https://or.justice.cz/ias/ui/rejstrik-$firma*, 2014

Seznam příloh

Příloha č.1 Výsledky výpočtů soukolí
Příloha č.2 Výsledky výpočtů hřídelů a jejich uložení
Příloha č. 3 Výsledky výpočtů spojovacích prvků
Příloha č.4 Zpráva z pevnostní analýzy – výběr

Výkresová dokumentace

DP-KKS-2014-01 Převodovka KC
DP-KKS-2014-02 Pastorek 1

PŘÍLOHA č. 1

Výsledky výpočtů soukolí

KISSsoft Release 03/2013

KISSsoft evaluation

File

Name : Kuželová_kola_32z_b82
Changed by: karlova am: 02.05.2014 um: 12:00:51

Important hint: At least one warning has occurred during the calculation:
1-> Calculation of the profile shift coefficient for
balanced sliding is inaccurate!

BEVEL-GEAR-CALCULATION (BEVEL-GEAR-PAIR)

Drawing or article number:
Gear 1: 0.000.0
Gear 2: 0.000.0

Strength calculation with load spectrum
Required service life (h): 2400.00

Load spectrum

Nominal Power [P] 502.6548 kW
Application factor [KA] 1.00

Load spectrum : Own Input
Number of element in the Load spectrum: 2
Reference gear: 1

i	[%]	[kW]	[1/min]	[Nm]	KV	KHb	Kgam	YM1	YM2	Oil°
1	20.00000	502.6548	800.0000	6000.0000	1.0703	1.8750	1.0000	1.0000	1.0000	70
2	80.00000	351.8584	800.0000	4200.0000	1.0888	1.8750	1.0000	1.0000	1.0000	70

Woehler line (S-N curve) at the fatigue stress according: according to standard

Notice:
Calculation-method according to:
- ISO 6336, part 6
During the calculation al the load-coefficients (ISO6336: KV, KHb, KFb; AGMA2001: Knu, Km, ..)
for each load spectrum element are calculated separately.

Safety root: 3.01 3.01
Safety flank: 2.31 2.31

Safety scuffing (Integral) 3.26
(Safety against scuffing/micropitting/EHT is indicated for the weakest element of the load spectrum.)

ONLY AS INFORMATION: CALCULATION WITH REFERENCE POWER

Calculation method Bevel gear Klingelnberg Cyclo-Palloid KN3028/KN3030 V1.2
Geometry calculation according ISO 23509:2006, method 3
Uniform depth, fig 3 (Klingelnberg)
Manufacture process: grinded/hard toothed
Spiral toothing
Face hobbing (continuing indexing method)

		------- GEAR 1	-------- GEAR 2 -------
Power (kW)	[P]	502.65	
Speed (1/min)	[n]	800.0	800.0
Rotation direction, wheel 1, viewed on cone tip:		right	
Torque (Nm)	[T]	6000.0	6000.0
Gear driving (+) / driven (-)		+	-
Application factor	[KA]	1.00	
Required service life	[H]	2400.00	

1. TOOTH GEOMETRY AND MATERIAL

		------- GEAR 1	-------- GEAR 2 -------
Hypoid offset (mm)	[a]	0.000	
Shaft angle (°)	[Sigma]	90.0000	
Mean normal module (mm)	[mmn]	7.7676	
Pressure angle at normal section (°)	[alfn]	20.0000	
Mean spiral angle (°)	[betm]	30.0000	
Hand of gear		right	left
Number of teeth	[z]	32	32
Facewidth (mm)	[b]	82.00	82.00
Assumed and measured contact pattern width (mm)	[be]	69.70	69.70
Accuracy grade according to DIN 3965	[Q-DIN3965]	6	6
Internal diameter gearbody (mm)	[di]	0.000	0.000
Pitch apex to front of gear blank (mm)	[yi]	121.770	121.770
Pitch apex to back of gear blank (mm)	[yo]	188.945	188.945
H misalignment (P misalignment) (µm)	[DeltaH]	0.000	
G misalignment (µm)	[DeltaG]	0.000	
V misalignment (E misalignment) (µm)	[DeltaV]	0.000	

Material

Gear 1:	18CrNiMo7-6, Case-carburized steel, case-hardened ISO 6336-5 Figure 9/10 (MQ), core strength >=30HRC		
Gear 2:	18CrNiMo7-6, Case-carburized steel, case-hardened ISO 6336-5 Figure 9/10 (MQ), core strength >=30HRC		
Surface hardness		HRC 61	HRC 61
Fatigue strength. tooth root stress (N/mm²)	[sigFlim]	500.00	500.00
Fatigue strength for Hertzian pressure (N/mm²)	[sigHlim]	1500.00	1500.00
Tensile strength (N/mm²)	[Rm]	1200.00	1200.00
Yield point (N/mm²)	[Rp]	850.00	850.00
Young's modulus (N/mm²)	[E]	206000	206000
Poisson's ratio	[ny]	0.300	0.300
Mean roughness, Ra, tooth flank (µm)	[RAH]	0.60	0.60
Mean roughness height, Rz, flank (µm)	[RZH]	4.80	4.80
Mean roughness height, Rz, root (µm)	[RZF]	20.00	20.00

Tool or reference profile of gear 1 :			
Reference profile	1.25 / 0.30 / 1.0 Cyclo-Palloid		
Dedendum coefficient	[hfP*]		1.250
Root radius factor	[rhofP*]		0.300
Addendum coefficient	[haP*]		1.000
Tip radius factor	[rhoaP*]		0.000
Tip form height coefficient	[hFaP*]		0.000
Protuberance height factor	[hprP*]		0.000
Protuberance angle	[alfprP]		0.000
Ramp angle	[alfKP]		0.000
		not topping	

Tool or reference profile of gear 2 :			
Reference profile	1.25 / 0.30 / 1.0 Cyclo-Palloid		
Dedendum coefficient	[hfP*]		1.250
Root radius factor	[rhofP*]		0.300
Addendum coefficient	[haP*]		1.000
Tip radius factor	[rhoaP*]		0.000
Tip form height coefficient	[hFaP*]		0.000
Protuberance height factor	[hprP*]		0.000
Protuberance angle	[alfprP]		0.000
Ramp angle	[alfKP]		0.000
		not topping	

Summary of reference profile gears:			
Dedendum reference profile (in module)	[hfP*]	1.250	1.250
Root radius reference profile (in module)	[rofP*]	0.300	0.300
Addendum reference profile (in module)	[haP*]	1.000	1.000
Protuberance height coefficient (in module)	[hprP*]	0.000	0.000
Protuberance angle (°)	[alfprP]	0.000	0.000
Tip form height coefficient (in module)	[hFaP*]	0.000	0.000
Ramp angle (°)	[alfKP]	0.000	0.000

Type of profile modification:
none (only running-in)

Tip relief (µm)	[Ca]	2.0	2.0

No modification at tip circle

Lubrication type		oil injection lubrication
Type of oil		Oil: ISO-VG 220
Lubricant base		Mineral-oil base
Kinem. viscosity oil at 40 °C (mm²/s)	[nu40]	220.00
Kinem. viscosity oil at 100 °C (mm²/s)	[nu100]	17.50
FZG test A/8.3/90 (ISO 14635-1:2006)	[FZGtestA]	12
Specific density at 15 °C (kg/dm³)	[roOil]	0.895
Oil temperature (°C)	[TS]	70.000

		------- GEAR 1 --------	GEAR 2 -------
Overall transmission ratio	[itot]	-1.000	
Gear ratio	[u]	1.000	
Outer spiral angle (°)	[bete]	40.4264	40.4264
Mean spiral angle (°)	[betm]	30.0000	30.0000
Inner spiral angle (°)	[beti]	18.8265	18.8265
Pinion offset angle in axial plane (°)	[zetm]	0.0000	

Pinion offset angle in pitch plane (°)	[zetmp]		0.0000	
Offset in pitch plane (mm)	[ap]		0.000	
Outer normal module (mm)	[men]		8.2071	
Outer transverse module (mm)	[met]	10.7813		10.7813
Mean normal module (mm)	[mmn]		7.7676	
Mean transverse module (mm)	[mmt]	8.9693		8.9693
Inner normal module (mm)	[min]		6.7744	
Inner transverse module (mm)	[mit]	7.1573		7.1573
Sum of profile shift coefficients	[xhm1+xhm2]		0.0000	
Profile shift coefficient	[xhm]	0.0000		0.0000
Undercut boundary	[xGrenz]	-1.5859		
Profile shift coef. for balanced sliding	[xGleit]	0.0828		
Tooth thickness modification coefficient	[xsmn]	0.0000		-0.0000
Outer pitch diameter (mm)	[de]	345.000		345.000
Outer tip diameter (mm)	[dae]	355.985		355.985
Outer root diameter (mm)	[dfe]	331.269		331.269
Mean pitch diameter (mm)	[dm]	287.017		287.017
Mean tip diameter (mm)	[dam]	298.002		298.002
Mean root diameter (mm)	[dfm]	273.286		273.286
Inner pitch diameter (mm)	[di]	229.034		229.034
Inner tip diameter (mm)	[dai]	240.020		240.020
Inner root diameter (mm)	[dfi]	215.303		215.303
Addendum (mm)	[hae]	7.768		7.768
(mm)	[ham]	7.768		7.768
(mm)	[hai]	7.768		7.768
Dedendum (mm)	[hfe]	9.710		9.710
(mm)	[hfm]	9.710		9.710
(mm)	[hfi]	9.710		9.710
Tooth height (mm)	[he]	17.477		17.477
(mm)	[hm]	17.477		17.477
(mm)	[hi]	17.477		17.477
Working depth (mm)	[whe]		15.535	
(mm)	[whm]		15.535	
(mm)	[whi]		15.535	
Tip clearance (mm)	[ce]	1.942		1.942
(mm)	[cm]	1.942		1.942
(mm)	[ci]	1.942		1.942
Outer cone distance (mm)	[Re]	243.952		243.952
Mean cone distance (mm)	[Rm]	202.952		202.952
Inner cone distance (mm)	[Ri]	161.952		161.952
Pitch angle (°)	[delta]	45.0000		45.0000
Face angle (°)	[dela]	45.0000		45.0000
Addendum angle (°)	[thea=dela-delta]	0.0000		0.0000
Root angle (°)	[delf]	45.0000		45.0000
Dedendum angle (°)	[thef=delta-delf]	0.0000		0.0000
Distance along axis to crossing point (mm)	[txo]	167.007		167.007
(mm)	[txi]	109.025		109.025
Distance apex to crossing point (mm)	[tz]	0.000		-0.000
(mm)	[tzF]	10.985		10.985
(mm)	[tzR]	-13.731		-13.731
Distance in axial direction to the cone tip (mm)	[ye]	172.500		172.500
(mm)	[yae]	167.007		167.007
(mm)	[yai]	109.025		109.025
Theoretical tip clearance (mm)	[c]	1.942		1.942

Effective tip clearance (mm)	[c.e/i]	1.942 / 1.942	1.942 / 1.942

According to Klingelnberg instruction for bevel gears:

Transverse contact ratio	[epsa]	1.404
Overlap ratio	[epsb]	1.671

****** **Virtual spur gear toothing** ******

Pressure angle at normal section (°)	[alfnv]	20.0000	
Pressure angle at pitch circle (°)	[alftv]	22.7959	
Base helix angle (°)	[betbv]	28.0243	
Virtual centre distance (mm)	[av]	405.904	
Working transverse pressure angle (°)	[alfwtv]	22.7959	
Number of teeth	[zv]	45.255	45.255
Gear ratio	[uv]	1.000	
Theoretical tip clearance (mm)	[c]	1.942	1.942
Effective tip clearance (mm)	[c.e/i]	1.942 / 1.942	1.942 / 1.942
Reference diameter (mm)	[dv]	405.904	405.904
Base diameter (mm)	[dbv]	374.199	374.199
Tip diameter (mm)	[dav]	421.439	421.439
Tip form diameter (mm)	[dFav]	421.439	421.439
Operating pitch diameter (mm)	[dwv]	405.904	405.904
Root diameter (mm)	[dfv]	386.485	386.485
Active root diameter (mm)	[dNfv]	393.172	393.172
Root form diameter (mm)	[dFfv]	391.489	391.489
Virtual gear no. of teeth	[znv]	67.060	67.060
Maximum sliding speed at tip (m/s)	[vga]	2.168	2.168
Pitch on reference circle (mm)	[ptv]	28.178	
Base pitch (mm)	[pbtv]	25.977	
Transverse pitch on contact-path (mm)	[petv]	25.977	
Length of path of contact (mm)	[gav]	36.604	

Virtual cylindrical gear (ISO 10300:2001, Annex A):

Referenced to facewidth	[bveff]	82.000
Transverse contact ratio	[epsva]	1.409
Overlap ratio	[epsvb]	1.680
Total contact ratio	[epsvg]	2.193

(DIN 3991: epsva = 1.409, epsvb = 1.428, epsvg = 2.837)

Characteristic values for sizing	[Re2/b2]	2.975
	[b2/mmn]	10.557

2. FACTORS OF GENERAL INFLUENCE

		------- GEAR 1 --------	GEAR 2 -------
Nominal circum. force at pitch circle (N)	[Fmt]	41809.3	41809.3
		Drive side	
Axial force (N)	[Fa]	29493.5	-4643.7
Radial force (N)	[Fr]	-4643.7	29493.5
Normal force (N)	[Fnorm]	51375.6	51375.6
Axial force (%)	[Fa/Ft]	70.543	-11.107
Radial force (%)	[Fr/Ft]	-11.107	70.543

Remarks:

Forces if rotation goes in opposite direction (coast side):

Axial force (N)	[Fa]	-4643.7	29493.5
Radial force (N)	[Fr]	29493.5	-4643.7

Normal force (N)	[Fnorm]	51375.6	51375.6
Axial force (%)	[Fa/Ft]	-11.107	70.543
Radial force (%)	[Fr/Ft]	70.543	-11.107
Tangent.load at p.c.d.per mm (N/mm) (N/mm)	[w]	599.85	
Circumferential speed pitch d.. (m/sec)	[v]	12.02	12.02
Singular tooth stiffness (N/mm*µm)	[c']	14.00	
Meshing stiffness (N/mm*µm)	[cg]	20.00	
Single pitch deviation (µm)	[fp]	16.00	16.00
Running-in value y.a (µm)	[ya]	1.20	
Reduced mass (kg/mm)	[mRed]	0.143	
Resonance speed (min-1)	[nE1]	3524	
Under critical range - resonance ratio	[N]	0.227	
Dynamic factor	[KV]	1.07	
Mounting factor	[KHbbe]	1.25	
Face load factor - flank	[KHb]	1.88	
- Tooth root	[KFb]	1.88	
- Scuffing	[KBb]	1.88	
Transverse load factor - flank	[KHa]	1.01	
- Tooth root	[KFa]	1.01	
- Scuffing	[KBa]	1.01	
Helical load factor scuffing	[Kbg]	1.27	
Number of load cycles (in mio.)	[NL]	115.200	115.200

3. TOOTH ROOT STRENGTH

		------- GEAR 1 --------	GEAR 2 -------
Calculation of Tooth form coefficients according method: C			
(Calculate tooth shape coefficient YF with addendum mod. x)			
Manufacture process: hobbing			
Tooth form factor	[YF]	2.28	2.28
Stress correction factor	[YS]	1.84	1.84
Bending lever arm (mm)	[hF]	15.05	15.05
Working angle (grd)	[alfh]	23.49	23.49
Tooth thickness at root (mm)	[sFn]	17.31	17.31
Tooth root radius (mm)	[roF]	3.19	3.19
(hF* = 1.938/ 1.938 sFn* = 2.229/ 2.229 roF* = 0.411/ 0.411)			
Contact ratio factor	[Yeps]	0.66	
Helical load factor	[Ybet]	0.75	
Effective facewidth (mm)	[b]	69.70	69.70
Bevel gear factor (root)	[YK]	1.000	
Nominal stress at tooth root (N/mm²)	[sigF0]	161.94	161.94
Tooth root stress (N/mm²)	[sigF]	328.87	328.87

Permissible bending stress at root of Test-gear			
Support factor	[YdrelT]	1.002	1.002
Surface factor	[YRrelT]	1.015	1.015
Size coefficient (Tooth root)	[YX]	0.972	0.972
Finite life factor	[YNT]	1.000	1.000

	[YdrelT*YRrelT*YX*YNT]	0.989	0.989
Alternating bending coefficient	[YM]	1.000	1.000
Stress correction factor	[Yst]	2.00	
Yst*sigFlim (N/mm²)	[sigFE]	1000.00	1000.00
Permissible tooth root stress (N/mm²)	[sigFP=sigFG/SFmin]	706.32	706.32
Limit strength tooth root (N/mm²)	[sigFG]	988.84	988.84
Required safety	[SFmin]	1.40	1.40

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		------- GEAR 1	-------- GEAR 2 -------
Zone factor	[ZH]	2.22	
Elasticity coefficient (N.5/mm)	[ZE]	189.81	
Contact ratio factor	[Zeps]	0.842	
Helix angle factor	[Zbet]	0.931	
Bevel gear factor (flank)	[ZK]	0.850	
Nominal flank pressure (N/mm²)	[sigH0]	483.45	
Effective flank pressure (N/mm²)	[sigH]	688.93	

Lubrication coefficient at NL	[ZL]	1.000	1.000
(calculation with lubricant temperature 70°C)			
Speed coefficient at NL	[ZV]	1.000	1.000
Roughness coefficient at NL	[ZR]	1.000	1.000
Material pairing coefficient at NL	[ZW]	1.000	1.000
Finite life factor	[ZNT]	1.000	1.000
	[ZL*ZV*ZR*ZNT]	1.000	1.000
Small amount of pitting permissible (0=no, 1=yes)		0	0
Size coefficient (flank)	[ZX]	1.000	1.000
Permissible surface pressure (N/mm²)	[sigHP=sigHG/SHmin]	1500.00	1500.00
Limit strength pitting (N/mm²)	[sigHG]	1500.00	1500.00

Safety for surface pressure at operating pitch circle	[SHw]	2.18	2.18
Single tooth contact factor	[ZB/ZD]	1.00	1.00
Flank pressure (N/mm²)	[sigHB/D]	688.93	688.93

5. STRENGTH AGAINST SCUFFING

Calculation method according to Klingelnberg

Lubrication coefficient (for lubrication type)	[XS]	1.200	
Relative structure coefficient (Scuffing)	[XWrelT]	1.000	
Thermal contact factor (N/mm/s^.5/K)	[BM]	13.780	13.780
Relevant tip relief (µm)	[Ca]	2.00	2.00
Optimal tip relief (µm)	[Ceff]	25.49	
Ca taken as optimal in the calculation (0=no, 1=yes)		0	0
Effective facewidth (mm)	[beff]	69.700	
Applicable circumferential force/facewidth (N/mm)	[wBt]	1545.961	
Pressure angle factor (eps1: 0.705, eps2: 0.705)	[Xalfbet]	0.992	

Integral temperature-criteria		
Tooth mass temperature (°C)	[theM-C]	84.58
theM-C = theoil + XS*0.70*theflaint	[theflaint]	17.36

Integral scuffing temperature (°C)	[theSint]	360.78
Flash factor (°K*N^-.75*s^.5*m^-.5*mm)	[XM]	50.058
Contact ratio factor	[Xeps]	0.306
Dynamic viscosity (mPa*s)	[etaOil]	41.90 (70.0 °C)
Averaged coefficient of friction	[mym]	0.036
Geometry factor	[XBE]	0.168
Meshing factor	[XQ]	1.000
Tip relief factor	[XCa]	1.008
Integral tooth flank temperature (°C)	[theint]	110.62

6. ALLOWANCES FOR TOOTH THICKNESS

		------- GEAR 1 --------	GEAR 2 -------
Tooth thickness deviation		No backlash	No backlash
Tooth thickness allowance (normal section) (mm)	[As.e/i]	0.000 / 0.000	0.000 / 0.000
Circumferential backlash (mm)	[jmt]	-0.000 / -0.000	
(mm)	[jet]	-0.000 / -0.000	
Normal backlash (mm)	[jmn]	-0.000 / -0.000	
(mm)	[jen]	-0.000 / -0.000	

7. GEAR ACCURACY

		------- GEAR 1 --------	GEAR 2 --
According to DIN 3965:1986:			
Accuracy grade	[Q-DIN3965]	6	6
Total cumulative pitch deviation (µm)	[Fp]	59.00	59.00
Concentricity deviation (µm)	[Fr]	45.00	45.00
Tangential tooth-to-tooth composite deviation (µm)			
	[fi']	27.00	27.00
Total tangential composite deviation (µm)	[Fi']	66.00	66.00
According to Klingelnberg:			
Single pitch deviation (µm)	[fp]	16.00	16.00

8. MANUFACTURING ACCORDING KLINGELNBERG-PLANT STANDARD KN 3028

Machine type		AMK635	
Maximal machining distance (mm)	[MdGrenz]	280.0000	
Machine distance (mm)	[Md]	206.4939	
Cutter radius (mm)	[R, rc0]	170.00	
Number of cutter blade groups	[z0]	5.00	
Cutter blade module (mm)	[m0]	7.00	
Cutter edge radius (module) (module)	[roa0*]	0.333	0.333
Angle modification (°)	[thek]	0.0000	-0.0000
Reference diameter (mm)	[de]	345.00	345.00
Tooth no of plane gear	[ZP]	45.2548	
Base circle radius (mm)	[ro]	185.9492	
Outer spiral angle (°)	[bete]	40.4264	
Helix angle at tooth middle (°)	[betm]	30.0000	
Inner spiral angle (°)	[beti]	18.8265	
Outer normal module (mm)	[men]	8.2071	
Outer transverse module (mm)	[met]	10.7813	
Inner normal module (mm)	[min]	6.7744	
Inner transverse module (mm)	[mit]	7.1573	

Undercut limit (mm)	[Rv]		139.5807	
Spacewidth at tooth root at RY2 (mm)	[efny]	5.84		5.84
Spacewidth at tooth root at RE2 (mm)	[efne]	5.82		5.82
Spacewidth at tooth root at RI2 (mm)	[efni]	3.57		3.57
Head width of universal cutter (mm)	[sa0]		2.41	
Profile shift at inner diameter	[xi]	0.0000		
Tooth tip height (mm)	[ha]	7.768		7.768
Tooth height (mm)	[H]	17.477		17.477
Tooth tip thickness Middle (mm)	[sanm]	6.146		6.146
Tooth tip thickness inside (mm)	[sani]	4.354		4.354
Tip relief coefficient inside	[k]	0.000		0.000
Width of Tip relief (mm)	[bk]	0.000		0.000
Tip reduction cone angle (°)	[delak]	45.0000		0.0000
Virtual gear no. of teeth	[zn]	67.060		67.060
Transverse contact ratio	[epsa]		1.404	
Overlap ratio	[epsb]		1.671	

Dimensions according to Klingelnberg: (mm)	[dae]	355.985	355.985
(mm)	[dai]	240.020	240.020
(mm)	[(dai)k]	240.020	240.020
(mm)	[LH]	172.500	172.500
(mm)	[LA]	57.983	57.983
(mm)	[LAK]	57.983	57.983
(mm)	[LW]	109.025	109.025
(mm)	[LWK]	109.025	109.025

9. DETERMINATION OF TOOTHFORM

Data for the tooth form calculation :
Data not available.

10. ADDITIONAL DATA

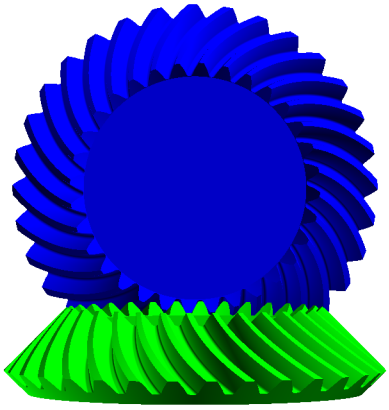
Input data for calculating the gear measurements according to ISO 23509:2006
Data of type 1 (according to table 3, ISO 23509:2006):
xhm1= 0.0000 khap= 1.0000 khfp= 1.2500 xsmn= 0.0000
Data of type 2 (according to table 3, ISO 23509:2006):
cham= 0.5000 kd= 2.0000 kc= 0.1250 kt= 0.0000

Calculation according to
Wech

Coefficient of friction	[mum]	0.031
Compound velocity (m/s)	[vSigm]	13.974
Loss factor	[HV]	0.080
Power loss from gear load (kW)	[PVZ]	1.237
Meshing efficiency (%)	[etaz]	99.754

Wech-Data: VR = 0.745 VS = 1.000 VZ = 0.931
XL = 1.000 Kgm = 0.000 (0.200)
ronC = 44.54 mm (16.00 mm) Fn*Cos(betb2)/b2 = 553.07 N/mm
etaOil(Oil) = 41.90 mPa*s VSigm = 13.97 m/s

Weight - calculated with da (kg)	[Mass]	32.065	32.065



Right flank (Gear 1): Drive flank, Left flank (Gear 1): Coast flankRotate independently to the left: Drive flank, Rotate independently to the right: Coast flankRotation angle to make flank contact: 0.0000° (Right flank), 0.0000° (Left flank)Rotation steps for flank alignment: 0.0000 (Right flank), 0.0000 (Left flank)(Calculated values assuming the center of pinion tooth is positioned at the center of gear tooth space without axial adjustments.)The contact can be controlled with the contact lines. Pinion and gear are to be meshing well, both should be produced based on the 3D-model.Mounting distance (Gear 1, Gear 2): 188.9454 mm, 188.9454 mmThis is the distance in axial direction from the pitch apex to the back of the gear blank.

Figure: Tooth system

End of Report	lines:	509

KISSsoft Release 03/2013

KISSsoft evaluation

File

Name : Soukoli_1_2_2_stavy
Changed by: karlova am: 02.05.2014 um: 11:56:03

CALCULATION OF A HELICAL GEAR PAIR

Drawing or article number:
Gear 1: 0.000.0
Gear 2: 0.000.0

Strength calculation with load spectrum
Required service life (h): 2400.00

Load spectrum

Nominal Power [P] 502.6548 kW
Application factor [KA] 1.00

Load spectrum : Own Input
Number of element in the Load spectrum: 2
Reference gear: 1

i	[%]	[kW]	[1/min]	[Nm]	KV	KHb	Kgam	YM1	YM2	Oil°
1	20.00000	502.6548	800.0000	6000.0000	1.0173	1.1582	1.0000	1.0000	1.0000	70
2	80.00000	351.8584	800.0000	4200.0000	1.0216	1.2251	1.0000	1.0000	1.0000	70

Woehler line (S-N curve) at the fatigue stress according: according to standard

Notice:
Calculation-method according to:
- ISO 6336, part 6
During the calculation al the load-coefficients (ISO6336: KV, KHb, KFb; AGMA2001: Knu, Km, ..)
for each load spectrum element are calculated separately.

Safety root: 2.73 2.40
Safety flank: 1.62 1.74

Safety scuffing (Integral) 3.00
Safety scuffing (Flash) 1.90
(Safety against scuffing/micropitting/EHT is indicated for the weakest element of the load spectrum.)

ONLY AS INFORMATION: CALCULATION WITH REFERENCE POWER

Calculation method DIN 3990:1987 Method B

		GEAR 1	GEAR 2
Power (kW)	[P]	502.655	
Speed (1/min)	[n]	800.0	259.2
Torque (Nm)	[T]	6000.0	18521.7
Application factor	[KA]	1.00	
Required service life	[H]	2400.00	
Gear driving (+) / driven (-)		+	-

1. TOOTH GEOMETRY AND MATERIAL

(geometry calculation according to DIN 3960:1987)

		GEAR 1	GEAR 2
Center distance (mm)	[a]	295.000	
Centre distance tolerance	ISO 286:2010 Measure js7		
Normal module (mm)	[mn]	6.0000	
Pressure angle at normal section (°)	[alfn]	20.0000	
Helix angle at reference circle (°)	[beta]	14.0000	
Number of teeth	[z]	23	71
Facewidth (mm)	[b]	202.00	118.00
Hand of gear		right	left
Accuracy grade	[Q-DIN 3961:1978]	6	6
Inner diameter (mm)	[di]	0.00	0.00
Inner diameter of gear rim (mm)	[dbi]	0.00	0.00

Material

Gear 1: 18CrNiMo7-6, Case-carburized steel, case-hardened
ISO 6336-5 Figure 9/10 (MQ), core strength >=30HRC

Gear 2: 18CrNiMo7-6, Case-carburized steel, case-hardened
ISO 6336-5 Figure 9/10 (MQ), core strength >=30HRC

		GEAR 1	GEAR 2
Surface hardness		HRC 61	HRC 61
Fatigue strength. tooth root stress (N/mm²)	[sigFlim]	500.00	500.00
Fatigue strength for Hertzian pressure (N/mm²)	[sigHlim]	1500.00	1500.00
Tensile strength (N/mm²)	[Rm]	1200.00	1200.00
Yield point (N/mm²)	[Rp]	850.00	850.00
Young's modulus (N/mm²)	[E]	206000	206000
Poisson's ratio	[ny]	0.300	0.300
Mean roughness, Ra, tooth flank (µm)	[RAH]	0.60	0.60
Mean roughness height, Rz, flank (µm)	[RZH]	4.80	4.80
Mean roughness height, Rz, root (µm)	[RZF]	20.00	20.00

Tool or reference profile of gear 1 :
Reference profile (Own input) 1.25 / 0.25 / 1.0 ISO 53.2:1997 Profil C

Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.250
Addendum coefficient	[haP*]	1.000
Tip radius factor	[rhoaP*]	0.000
Tip form height coefficient	[hFaP*]	0.000
Protuberance height factor	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Ramp angle	[alfKP]	0.000

not topping

Tool or reference profile of gear	2 :	
Reference profile (Own input)	1.25 / 0.25 / 1.0 ISO 53.2:1997 Profil C	
Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.250
Addendum coefficient	[haP*]	1.000
Tip radius factor	[rhoaP*]	0.000
Tip form height coefficient	[hFaP*]	0.000
Protuberance height factor	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Ramp angle	[alfKP]	0.000
	not topping	

Summary of reference profile gears:

Dedendum reference profile (in module)	[hfP*]	1.250	1.250
Root radius reference profile (in module)	[rofP*]	0.250	0.250
Addendum reference profile (in module)	[haP*]	1.000	1.000
Protuberance height coefficient (in module)	[hprP*]	0.000	0.000
Protuberance angle (°)	[alfprP]	0.000	0.000
Tip form height coefficient (in module)	[hFaP*]	0.000	0.000
Ramp angle (°)	[alfKP]	0.000	0.000

Type of profile modification:
none (only running-in)

Tip relief (µm)	[Ca]	2.0	2.0

Lubrication type		oil bath lubrication
Type of oil		Oil: ISO-VG 220
Lubricant base		Mineral-oil base
Kinem. viscosity oil at 40 °C (mm²/s)	[nu40]	220.00
Kinem. viscosity oil at 100 °C (mm²/s)	[nu100]	17.50
FZG test A/8.3/90 (ISO 14635-1:2006)	[FZGtestA]	12
Specific density at 15 °C (kg/dm³)	[roOil]	0.895
Oil temperature (°C)	[TS]	70.000

		------- GEAR 1	-------- GEAR 2 --
Overall transmission ratio	[itot]	-3.087	
Gear ratio	[u]	3.087	
Transverse module (mm)	[mt]	6.184	
Pressure angle at pitch circle (°)	[alft]	20.562	
Working transverse pressure angle (°)	[alfwt]	22.715	
	[alfwt.e/i]	22.727 /	22.703
Working pressure angle at normal section (°)	[alfwn]	22.089	
Helix angle at operating pitch circle (°)	[betaw]	14.202	
Base helix angle (°)	[betab]	13.140	
Reference centre distance (mm)	[ad]	290.633	
Sum of profile shift coefficients	[Summexi]	0.7649	
Profile shift coefficient	[x]	0.0000	0.7649
Tooth thickness (Arc) (module) (module)	[sn*]	1.5708	2.1276
Tip alteration (mm)	[k*mn]	-0.222	-0.222
Reference diameter (mm)	[d]	142.225	439.041
Base diameter (mm)	[db]	133.164	411.072
Tip diameter (mm)	[da]	153.781	459.776
(mm)	[da.e/i]	153.781 / 153.771	459.776 / 459.766
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / -0.010	0.000 / -0.010
Tip form diameter (mm)	[dFa]	153.781	459.776
(mm)	[dFa.e/i]	153.781 / 153.771	459.776 / 459.766

Active tip diameter (mm)	[dNa.e/i]	153.781 /	153.771	459.776 /	459.766
Operating pitch diameter (mm)	[dw]	144.362		445.638	
(mm)	[dw.e/i]	144.374 /	144.349	445.678 /	445.599
Root diameter (mm)	[df]	127.225		433.220	
Generating Profile shift coefficient	[xE.e/i]	-0.0218/	-0.0332	0.7351/	0.7214
Manufactured root diameter with xE (mm)	[df.e/i]	126.964 /	126.826	432.863 /	432.698
Theoretical tip clearance (mm)	[c]	1.500		1.500	
Effective tip clearance (mm)	[c.e/i]	1.792 /	1.652	1.730 /	1.604
Active root diameter (mm)	[dNf]	134.951		437.900	
(mm)	[dNf.e/i]	134.976 /	134.929	437.953 /	437.853
Root form diameter (mm)	[dFf]	133.784		435.315	
(mm)	[dFf.e/i]	133.715 /	133.680	434.981 /	434.828
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	0.648 /	0.607	1.563 /	1.436
Addendum (mm)	[ha=mn*(haP*+x)]	5.778		10.367	
(mm)	[ha.e/i]	5.778 /	5.773	10.367 /	10.362
Dedendum (mm)	[hf=mn*(hfP*-x)]	7.500		2.911	
(mm)	[hf.e/i]	7.631 /	7.699	3.089 /	3.172
Roll angle at dFa (°)	[xsi_dFa.e/i]	33.093 /	33.085	28.705 /	28.702
Roll angle to dNa (°)	[xsi_dNa.e/i]	33.093 /	33.085	28.705 /	28.702
Roll angle to dNf (°)	[xsi_dNf.e/i]	9.484 /	9.359	21.057 /	21.016
Roll angle at dFf (°)	[xsi_dFf.e/i]	5.215 /	5.047	19.824 /	19.758
Tooth height (mm)	[H]	13.278		13.278	
Virtual gear no. of teeth	[zn]	24.996		77.161	
Normal tooth thickness at tip cyl. (mm)	[san]	4.562		4.296	
(mm)	[san.e/i]	4.465 /	4.406	4.165 /	4.098
Normal spacewidth at root cylinder (mm)	[efn]	0.000		4.019	
(mm)	[efn.e/i]	0.000 /	0.000	4.029 /	4.034
Max. sliding velocity at tip (m/s)	[vga]	1.174		1.878	
Specific sliding at the tip	[zetaa]	0.364		0.672	
Specific sliding at the root	[zetaf]	-2.048		-0.573	
Sliding factor on tip	[Kga]	0.194		0.311	
Sliding factor on root	[Kgf]	-0.311		-0.194	
Pitch on reference circle (mm)	[pt]	19.427			
Base pitch (mm)	[pbt]	18.189			
Transverse pitch on contact-path (mm)	[pet]	18.189			
Lead height (mm)	[pz]	1792.065		5532.027	
Axial pitch (mm)	[px]	77.916			
Length of path of contact (mm)	[ga, e/i]	27.514 (	27.582 /	27.426)	
Length T1-A, T2-A (mm)	[T1A, T2A]	10.943(	10.875/	11.021)	102.973(102.973/ 102.962)
Length T1-B (mm)	[T1B, T2B]	20.268(	20.268/	20.258)	93.647(93.580/ 93.725)
Length T1-C (mm)	[T1C, T2C]	27.873(	27.856/	27.889)	86.043(85.992/ 86.093)
Length T1-D (mm)	[T1D, T2D]	29.132(	29.064/	29.210)	84.784(84.784/ 84.773)
Length T1-E (mm)	[T1E, T2E]	38.457(	38.457/	38.447)	75.458(75.391/ 75.536)
Length T1-T2 (mm)	[T1T2]	113.915 (	113.848 /	113.983)	
Diameter of single contact point B (mm)	[d-B]	139.197(	139.197/	139.191)	451.730(451.674/ 451.794)
Diameter of single contact point D (mm)	[d-D]	145.352(	145.298/	145.415)	444.672(444.672/ 444.664)
Addendum contact ratio	[eps]	0.582(	0.583/	0.580)	0.931(0.934/ 0.927)
Minimal length of contact line (mm)	[Lmin]	164.366			

Transverse contact ratio	[eps_a]	1.513		
Transverse contact ratio with allowances	[eps_a.e/m/i]	1.516 /	1.512 /	1.508
Overlap ratio	[eps_b]	1.514		
Total contact ratio	[eps_g]	3.027		
Total contact ratio with allowances	[eps_g.e/m/i]	3.031 /	3.027 /	3.022

2. FACTORS OF GENERAL INFLUENCE

		GEAR 1	GEAR 2
Nominal circum. force at pitch circle (N)	[Ft]		84373.5
Axial force (N)	[Fa]		21036.7
Radial force (N)	[Fr]		31649.6
Normal force (N)	[Fnorm]		92537.2
Tangent.load at p.c.d.per mm (N/mm) (N/mm)	[w]		715.03
Only as information: Forces at operating pitch circle:			
Nominal circumferential force (N)	[Ftw]		83124.5
Axial force (N)	[Faw]		21036.7
Radial force (N)	[Frw]		34798.0
Circumferential speed pitch d.. (m/sec)	[v]		5.96
Running-in value (µm)	[yp]		0.8
Running-in value (µm)	[yf]		0.8
Correction coefficient	[CM]		0.800
Gear body coefficient	[CR]		1.000
Reference profile coefficient	[CBS]		0.975
Material coefficient	[E/Est]		1.000
Singular tooth stiffness (N/mm/µm)	[c']		14.019
Meshing stiffness (N/mm/µm)	[cg]		19.410
Reduced mass (kg/mm)	[mRed]		0.06180
Resonance speed (min-1)	[nE1]		7358
Resonance ratio (-)	[N]		0.109
Subcritical range			
Running-in value (µm)	[ya]		0.8
Bearing distance l of pinion shaft (mm)	[l]		404.000
Distance s of pinion shaft (mm)	[s]		40.400
Outside diameter of pinion shaft (mm)	[dsh]		129.300
Load according to Figure 6.8, DIN 3990-1:1987 (0:6.8a, 1:6.8b, 2:6.8c, 3:6.8d, 4:6.8e)	[-]		4
Coefficient K' according to Figure 6.8, DIN 3990-1:1987	[K']		-1.00
Without support effect			
Tooth trace deviation (active) (µm)	[Fby]		11.86
from deformation of shaft (µm)	[fsh*B1]		16.59
Tooth trace: with end relief			
Position of Contact pattern: favorable			
from production tolerances (µm)	[fma*B2]		7.70
Tooth trace deviation, theoretical (µm)	[Fbx]		13.95
Running-in value (µm)	[yb]		2.09
Dynamic factor	[KV]		1.017
Face load factor - flank	[KHb]		1.158
- Tooth root	[KFb]		1.139
- Scuffing	[KBb]		1.158
Transverse load factor - flank	[KHa]		1.000
- Tooth root	[KFa]		1.000
- Scuffing	[KBa]		1.000
Helical load factor scuffing	[Kbg]		1.285
Number of load cycles (in mio.)	[NL]	115.200	37.318

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: B
(Calculate tooth shape coefficient YF with addendum mod. x)

		------- GEAR 1	-------- GEAR 2 --
Tooth form factor	[YF]	1.59	1.13
Stress correction factor	[YS]	1.96	2.92
Working angle (°)	[alfFen]	19.07	22.63
Bending lever arm (mm)	[hF]	6.38	6.50
Tooth thickness at root (mm)	[sFn]	12.03	14.25
Tooth root radius (mm)	[roF]	2.89	1.55

(hF* = 1.063/ 1.083 sFn* = 2.006/ 2.376 roF* = 0.481/ 0.259 dsFn = 129.17/ 434.67 alfsFn = 30.00/ 30.00)

Contact ratio factor	[Yeps]	1.000	
Helical load factor	[Ybet]	0.883	
Effective facewidth (mm)	[beff]	130.00	118.00
Nominal stress at tooth root (N/mm²)	[sigF0]	297.99	347.03
Tooth root stress (N/mm²)	[sigF]	345.32	402.15
Permissible bending stress at root of Test-gear			
Support factor	[YdrelT]	0.996	1.017
Surface factor	[YRrelT]	0.957	0.957
Size coefficient (Tooth root)	[YX]	0.990	0.990
Finite life factor	[YNT]	1.000	1.000
[YdrelT*YRrelT*YX*YNT]		0.943	0.963
Alternating bending coefficient	[YM]	1.000	1.000
Stress correction factor	[Yst]	2.00	
Yst*sigFlim (N/mm²)	[sigFE]	1000.00	1000.00
Permissible tooth root stress (N/mm²)	[sigFP=sigFG/SFmin]	673.81	688.12
Limit strength tooth root (N/mm²)	[sigFG]	943.33	963.37
Required safety	[SFmin]	1.40	1.40
Safety for Tooth root stress	[SF=sigFG/sigF]	2.73	2.40
Transmittable power (kW)	[kWRating]	980.81	860.09

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		------- GEAR 1	-------- GEAR 2 --
Zone factor	[ZH]	2.304	
Elasticity coefficient (N^.5/mm)	[ZE]	189.812	
Contact ratio factor	[Zeps]	0.813	
Helix angle factor	[Zbet]	0.985	
Effective facewidth (mm)	[beff]	118.00	
Nominal flank pressure (N/mm²)	[sigH0]	903.52	
Surface pressure at operating pitch circle (N/mm²)	[sigHw]	980.74	
Single tooth contact factor	[ZB,ZD]	1.00	1.00
Flank pressure (N/mm²)	[sigH]	980.74	980.74
Lubrication coefficient at NL	[ZL]	1.020	1.019
Speed coefficient at NL	[ZV]	0.986	0.987
Roughness coefficient at NL	[ZR]	0.991	0.992
Material pairing coefficient at NL	[ZW]	1.000	1.000
Finite life factor	[ZNT]	1.000	1.022
	[ZL*ZV*ZR*ZNT]	0.997	1.020
Small amount of pitting permissible (0=no, 1=yes)		0	0

Size coefficient (flank)	[ZX]	1.000	1.000
Permissible surface pressure (N/mm²)	[sigHP=sigHG/SHmin]	1495.97	1529.63
Limit strength pitting (N/mm²)	[sigHG]	1495.97	1529.63
Safety for surface pressure at operating pitch circle			
	[SHw]	1.53	1.56
Required safety	[SHmin]	1.00	1.00
Transmittable power (kW)	[kWRating]	1169.52	1222.74

4b. MICROPITTING ACCORDING TO ISO TR 15144-1:2010

Calculation did not run. (Lubricant: Load stage micropitting test is unknown.)

5. STRENGTH AGAINST SCUFFING

Calculation method according to
DIN 3990:1987

Lubrication coefficient (for lubrication type)	[XS]	1.000	
Relative structure coefficient (Scuffing)	[XWrelT]	1.000	
Thermal contact factor (N/mm/s^.5/K)	[BM]	13.780	13.780
Relevant tip relief (µm)	[Ca]	2.00	2.00
Optimal tip relief (µm)	[Ceff]	36.84	
Ca taken as optimal in the calculation (0=no, 1=yes)		0	0
Effective facewidth (mm)	[beff]	118.000	
Applicable circumferential force/facewidth (N/mm)			
	[wBt]	1082.326	
Pressure angle factor (eps1: 0.582, eps2: 0.931)	[Xalfbet]	1.011	
Flash temperature-criteria			
Tooth mass temperature (°C)	[theM-B]	127.06	
theM-B = theoil + XS*0.47*theflamax	[theflamax]	121.40	
Scuffing temperature (°C)	[theS]	408.58	
Coordinate gamma (point of highest temp.)	[Gamma]	-0.607	
[Gamma.A]=-0.607 [Gamma.E]=0.380			
Highest contact temp. (°C)	[theB]	248.46	
Flash factor (°K*N^-.75*s^.5*m^-.5*mm)	[XM]	50.058	
Geometry factor	[XB]	0.439	
Load sharing factor	[XGam]	0.333	
Dynamic viscosity (mPa*s)	[etaM]	7.67 (127.1 °C)	
Coefficient of friction	[mym]	0.147	
Integral temperature-criteria			
Tooth mass temperature (°C)	[theM-C]	91.10	
theM-C = theoil + XS*0.70*theflaint	[theflaint]	30.15	
Integral scuffing temperature (°C)	[theSint]	408.58	
Flash factor (°K*N^-.75*s^.5*m^-.5*mm)	[XM]	50.058	
Contact ratio factor	[Xeps]	0.401	
Dynamic viscosity (mPa*s)	[etaOil]	41.90 (70.0 °C)	
Averaged coefficient of friction	[mym]	0.075	
Geometry factor	[XBE]	0.177	
Meshing factor	[XQ]	0.973	
Tip relief factor	[XCa]	1.023	

Integral tooth flank temperature (°C)	[theint]	136.32

6. MEASUREMENTS FOR TOOTH THICKNESS

		------- GEAR 1 --------	GEAR 2 --
Tooth thickness deviation		DIN 3967 cd25	DIN 3967 cd25
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.095 / -0.145	-0.130 / -0.190
Number of teeth spanned	[k]	3.000	10.000
Base tangent length (no backlash) (mm)	[Wk]	46.388	177.913
Actual base tangent length ('span') (mm)	[Wk.e/i]	46.299 / 46.252	177.791 / 177.734
Diameter of contact point (mm)	[dMWk.m]	140.583	446.034
Theoretical diameter of ball/pin (mm)	[DM]	10.274	10.774
Eff. Diameter of ball/pin (mm)	[DMeff]	10.500	11.000
Theor. dim. centre to ball (mm)	[MrK]	78.548	232.023
Actual dimension centre to ball (mm)	[MrK.e/i]	78.438 / 78.379	231.873 / 231.804
Diameter of contact point (mm)	[dMMr.m]	142.385	448.297
Diametral measurement over two balls without clearance (mm)	[MdK]	156.754	463.935
Actual dimension over balls (mm)	[MdK.e/i]	156.534 / 156.418	463.636 / 463.498
Diametral measurement over rolls without clearance (mm)	[MdR]	157.095	464.046
Actual dimension over rolls (mm)	[MdR.e/i]	156.875 / 156.759	463.747 / 463.609
Chordal tooth thickness (no backlash) (mm)	['sn]	9.419	12.764
Actual chordal tooth thickness (mm)	['sn.e/i]	9.324 / 9.274	12.634 / 12.574
Reference chordal height from da.m (mm)	[ha]	5.922	10.452
Tooth thickness (Arc) (mm)	[sn]	9.425	12.765
(mm)	[sn.e/i]	9.330 / 9.280	12.635 / 12.575
Backlash free center distance (mm)	[aControl.e/i]	294.718 /294.580	
Backlash free center distance, allowances (mm)	[jta]	-0.282 / -0.420	
dNf.i with aControl (mm)	[dNf0.i]	134.613	437.151
Reserve (dNf0.i-dFf.e)/2 (mm)	[cF0.i]	0.449	1.085
Centre distance allowances (mm)	[Aa.e/i]	0.026 / -0.026	
Circumferential backlash from Aa (mm)	[jtw_Aa.e/i]	0.022 / -0.022	
Radial clearance (mm)	[jrw]	0.446 / 0.256	
Circumferential backlash (transverse section) (mm)	[jtw]	0.372 / 0.214	
Torsional angle for fixed gear 1 (°)		0.0971 / 0.0558	
Normal backlash (mm)	[jnw]	0.339 / 0.195	

7. GEAR ACCURACY

		------- GEAR 1 --------	GEAR 2 --
According to DIN 3961:1978:			
Accuracy grade	[Q-DIN3961]	6	6
Profile form deviation (µm)	[ff]	10.00	10.00
Profile slope deviation (µm)	[fHa]	7.00	7.00
Total profile deviation (µm)	[Ff]	13.00	13.00
Helix form deviation (µm)	[ffb]	14.00	12.00
Helix slope deviation (µm)	[fHb]	11.00	11.00
Total helix deviation (µm)	[Fb]	18.00	16.00
Normal base pitch deviation (µm)	[fpe]	9.00	10.00

Single pitch deviation (µm)	[fp]	9.00	10.00
Difference between adjacent pitches (µm)	[fu]	11.00	12.00
Total cumulative pitch deviation (µm)	[Fp]	34.00	40.00
Cumulative circular pitch deviation over z/8 pitches (µm)	[Fpz/8]	22.00	25.00
Concentricity deviation (µm)	[Fr]	25.00	28.00
Tooth Thickness Variation (µm)	[Rs]	15.00	16.00
Total radial composite deviation (µm)	[Fi"]	28.00	32.00
Radial tooth-to-tooth composite deviation (µm)	[fi"]	12.00	14.00
Total tangential composite deviation (µm)	[Fi']	38.00	42.00
Tangential tooth-to-tooth composite deviation (µm)	[fi']	15.00	16.00

Axis alignment tolerances (recommendation acc. ISO TR 10064:1992, Quality		6)
Maximum value for deviation error of axis (µm)	[fSigbet]	30.81 (Fb= 18.00)
Maximum value for inclination error of axes (µm)	[fSigdel]	61.63

8. ADDITIONAL DATA

Torsional stiffness (MNm/rad)	[cr]	10.2		96.8
Mean coeff. of friction (acc. Niemann)	[mum]		0.054	
Wear sliding coef. by Niemann	[zetw]		0.837	
Power loss from gear load (kW)	[PVZ]		3.512	
(Meshing efficiency (%)	[etaz]		99.301)	
Weight - calculated with da (kg)	[Mass]	29.377		153.400
Total weight (kg)	[Mass]		182.777	
Moment of inertia (System referenced to wheel 1):				
calculation without consideration of the exact tooth shape				
single gears ((da+df)/2...di) (kg*m²)	[TraeghMom]	0.06023		3.59796
System ((da+df)/2...di) (kg*m²)	[TraeghMom]		0.43779	

9. DETERMINATION OF TOOTHFORM

Data for the tooth form calculation :
Data not available.

REMARKS:
- Specifications with [.e/i] imply: Maximum [e] and Minimal value [i] with consideration of all tolerances
  Specifications with [.m] imply: Mean value within tolerance
- For the backlash tolerance, the center distance tolerances and the tooth thickness deviation are taken into account. Shown is the maximal and the minimal backlash corresponding the largest resp. the smallest allowances
  The calculation is done for the Operating pitch circle..
- Details of calculation method:
  cg according to method B
  KV according to method B
  KHb, KFb according method C
  KHa, KFa according to method B

End of Report lines: 506

KISSsoft Release 03/2013

KISSsoft evaluation

File

Name : P_Soukoli_3_4
Changed by: karlova am: 02.05.2014 um: 12:08:00

CALCULATION OF A HELICAL GEAR PAIR

Drawing or article number:
Gear 1: 0.000.0
Gear 2: 0.000.0

Strength calculation with load spectrum
Required service life (h): 2400.00

Load spectrum

Nominal Power [P] 502.6548 kW
Application factor [KA] 1.00

Load spectrum : Own Input
Number of element in the Load spectrum: 2
Reference gear: 1

i	[%]	[kW]	[1/min]	[Nm]	KV	KHb	Kgam	YM1	YM2	Oil°
1	20.00000	502.6548	800.0000	6000.0000	1.0806	1.0725	1.0000	1.0000	1.0000	70
2	80.00000	351.8584	800.0000	4200.0000	1.1010	1.1016	1.0000	1.0000	1.0000	70

Woehler line (S-N curve) at the fatigue stress according: according to standard

Notice:
Calculation-method according to:
- ISO 6336, part 6
During the calculation al the load-coefficients (ISO6336: KV, KHb, KFb; AGMA2001: Knu, Km, ..)
for each load spectrum element are calculated separately.

Safety root: 2.79 2.78
Safety flank: 2.12 2.12

Safety scuffing (Integral) 3.75
Safety scuffing (Flash) 8.30
(Safety against scuffing/micropitting/EHT is indicated for the weakest element of the load spectrum.)

ONLY AS INFORMATION: CALCULATION WITH REFERENCE POWER

Calculation method DIN 3990:1987 Method B

		GEAR 1	GEAR 2
Power (kW)	[P]	502.655	
Speed (1/min)	[n]	800.0	786.2
Torque (Nm)	[T]	6000.0	6105.3
Application factor	[KA]	1.00	
Required service life	[H]	2400.00	
Gear driving (+) / driven (-)		+	-

1. TOOTH GEOMETRY AND MATERIAL

(geometry calculation according to DIN 3960:1987)

		GEAR 1	GEAR 2
Center distance (mm)	[a]	295.000	
Centre distance tolerance	ISO 286:2010 Measure js7		
Normal module (mm)	[mn]	5.0000	
Pressure angle at normal section (°)	[alfn]	20.0000	
Helix angle at reference circle (°)	[beta]	13.0000	
Number of teeth	[z]	57	58
Facewidth (mm)	[b]	70.00	70.00
Hand of gear		left	right
Accuracy grade	[Q-DIN 3961:1978]	6	6
Inner diameter (mm)	[di]	0.00	0.00
Inner diameter of gear rim (mm)	[dbi]	0.00	0.00

Material

Gear 1: 18CrNiMo7-6, Case-carburized steel, case-hardened
ISO 6336-5 Figure 9/10 (MQ), core strength >=30HRC

Gear 2: 18CrNiMo7-6, Case-carburized steel, case-hardened
ISO 6336-5 Figure 9/10 (MQ), core strength >=30HRC

		GEAR 1	GEAR 2
Surface hardness		HRC 61	HRC 61
Fatigue strength. tooth root stress (N/mm²)	[sigFlim]	500.00	500.00
Fatigue strength for Hertzian pressure (N/mm²)	[sigHlim]	1500.00	1500.00
Tensile strength (N/mm²)	[Rm]	1200.00	1200.00
Yield point (N/mm²)	[Rp]	850.00	850.00
Young's modulus (N/mm²)	[E]	206000	206000
Poisson's ratio	[ny]	0.300	0.300
Mean roughness, Ra, tooth flank (µm)	[RAH]	0.60	0.60
Mean roughness height, Rz, flank (µm)	[RZH]	4.80	4.80
Mean roughness height, Rz, root (µm)	[RZF]	20.00	20.00

Tool or reference profile of gear 1 :

Reference profile	1.25 / 0.25 / 1.0 ISO 53.2:1997 Profil C	
Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.250
Addendum coefficient	[haP*]	1.000
Tip radius factor	[rhoaP*]	0.000
Tip form height coefficient	[hFaP*]	0.000
Protuberance height factor	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Ramp angle	[alfKP]	0.000
		not topping

Tool or reference profile of gear 2 :		
Reference profile 1.25 / 0.25 / 1.0 ISO 53.2:1997 Profil C		
Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.250
Addendum coefficient	[haP*]	1.000
Tip radius factor	[rhoaP*]	0.000
Tip form height coefficient	[hFaP*]	0.000
Protuberance height factor	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Ramp angle	[alfKP]	0.000
	not topping	

Summary of reference profile gears:			
Dedendum reference profile (in module)	[hfP*]	1.250	1.250
Root radius reference profile (in module)	[rofP*]	0.250	0.250
Addendum reference profile (in module)	[haP*]	1.000	1.000
Protuberance height coefficient (in module)	[hprP*]	0.000	0.000
Protuberance angle (°)	[alfprP]	0.000	0.000
Tip form height coefficient (in module)	[hFaP*]	0.000	0.000
Ramp angle (°)	[alfKP]	0.000	0.000

Type of profile modification:
none (only running-in)

Tip relief (µm)	[Ca]	2.0	2.0

Lubrication type		oil bath lubrication
Type of oil		Oil: ISO-VG 220
Lubricant base		Mineral-oil base
Kinem. viscosity oil at 40 °C (mm²/s)	[nu40]	220.00
Kinem. viscosity oil at 100 °C (mm²/s)	[nu100]	17.50
FZG test A/8.3/90 (ISO 14635-1:2006)	[FZGtestA]	12
Specific density at 15 °C (kg/dm³)	[roOil]	0.895
Oil temperature (°C)	[TS]	70.000

		------- GEAR 1	-------- GEAR 2 --
Overall transmission ratio	[itot]	-1.018	
Gear ratio	[u]	1.018	
Transverse module (mm)	[mt]	5.132	
Pressure angle at pitch circle (°)	[alft]	20.483	
Working transverse pressure angle (°)	[alfwt]	20.450	
	[alfwt.e/i]	20.464 /	20.437
Working pressure angle at normal section (°)	[alfwn]	19.968	
Helix angle at operating pitch circle (°)	[betaw]	12.997	
Base helix angle (°)	[betab]	12.204	
Reference centre distance (mm)	[ad]	295.062	
Sum of profile shift coefficients	[Summexi]	-0.0125	
Profile shift coefficient	[x]	-0.0030	-0.0095
Tooth thickness (Arc) (module) (module)	[sn*]	1.5686	1.5639
Tip alteration (mm)	[k*mn]	0.000	0.000
Reference diameter (mm)	[d]	292.497	297.628
Base diameter (mm)	[db]	274.004	278.811
Tip diameter (mm)	[da]	302.467	307.533
(mm)	[da.e/i]	302.467 / 302.457	307.533 / 307.523
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / -0.010	0.000 / -0.010
Tip form diameter (mm)	[dFa]	302.467	307.533
(mm)	[dFa.e/i]	302.467 / 302.457	307.533 / 307.523

Active tip diameter (mm)	[dNa.e/i]	302.467 /	302.457	307.533 /	307.523
Operating pitch diameter (mm)	[dw]	292.435		297.565	
(mm)	[dw.e/i]	292.461 /	292.409	297.591 /	297.539
Root diameter (mm)	[df]	279.967		285.033	
Generating Profile shift coefficient	[xE.e/i]	-0.0387/	-0.0552	-0.0452/	-0.0617
Manufactured root diameter with xE (mm)	[df.e/i]	279.610 /	279.445	284.676 /	284.511
Theoretical tip clearance (mm)	[c]	1.250		1.250	
Effective tip clearance (mm)	[c.e/i]	1.542 /	1.403	1.542 /	1.403
Active root diameter (mm)	[dNf]	284.448		289.530	
(mm)	[dNf.e/i]	284.494 /	284.408	289.576 /	289.490
Root form diameter (mm)	[dFf]	283.115		288.173	
(mm)	[dFf.e/i]	282.860 /	282.744	287.917 /	287.800
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	0.875 /	0.774	0.888 /	0.787
Addendum (mm)	[ha=mn*(haP*+x)]	4.985		4.953	
(mm)	[ha.e/i]	4.985 /	4.980	4.953 /	4.948
Dedendum (mm)	[hf=mn*(hfP*-x)]	6.265		6.297	
(mm)	[hf.e/i]	6.444 /	6.526	6.476 /	6.558
Roll angle at dFa (°)	[xsi_dFa.e/i]	26.785 /	26.780	26.668 /	26.664
Roll angle to dNa (°)	[xsi_dNa.e/i]	26.785 /	26.780	26.668 /	26.664
Roll angle to dNf (°)	[xsi_dNf.e/i]	16.006 /	15.938	16.075 /	16.009
Roll angle at dFf (°)	[xsi_dFf.e/i]	14.685 /	14.586	14.762 /	14.665
Tooth height (mm)	[H]	11.250		11.250	
Virtual gear no. of teeth	[zn]	61.236		62.310	
Normal tooth thickness at tip cyl. (mm)	[san]	3.937		3.946	
(mm)	[san.e/i]	3.808 /	3.741	3.816 /	3.750
Normal spacewidth at root cylinder (mm)	[efn]	3.976		3.970	
(mm)	[efn.e/i]	4.023 /	4.046	4.017 /	4.039
Max. sliding velocity at tip (m/s)	[vga]	2.153		2.143	
Specific sliding at the tip	[zetaa]	0.401		0.401	
Specific sliding at the root	[zetaf]	-0.670		-0.670	
Sliding factor on tip	[Kga]	0.176		0.175	
Sliding factor on root	[Kgf]	-0.175		-0.176	
Pitch on reference circle (mm)	[pt]	16.121			
Base pitch (mm)	[pbt]	15.102			
Transverse pitch on contact-path (mm)	[pet]	15.102			
Lead height (mm)	[pz]	3980.217		4050.045	
Axial pitch (mm)	[px]	69.828			
Length of path of contact (mm)	[ga, e/i]	25.861 (	25.936 /	25.763)	
Length T1-A, T2-A (mm)	[T1A, T2A]	38.185(	38.111/	38.272)	64.887(64.887/ 64.875)
Length T1-B (mm)	[T1B, T2B]	48.945(	48.945/	48.933)	54.127(54.053/ 54.213)
Length T1-C (mm)	[T1C, T2C]	51.088(	51.051/	51.125)	51.984(51.947/ 52.022)
Length T1-D (mm)	[T1D, T2D]	53.287(	53.213/	53.374)	49.785(49.785/ 49.773)
Length T1-E (mm)	[T1E, T2E]	64.047(	64.047/	64.035)	39.025(38.951/ 39.111)
Length T1-T2 (mm)	[T1T2]	103.072 (	102.997 /	103.146)	
Diameter of single contact point B (mm)	[d-B]	290.965(	290.965/	290.957)	299.090(299.036/ 299.152)
Diameter of single contact point D (mm)	[d-D]	294.001(	293.947/	294.063)	296.057(296.057/ 296.049)
Addendum contact ratio	[eps]	0.858(	0.861/	0.855)	0.854(0.857/ 0.851)
Minimal length of contact line (mm)	[Lmin]	122.518			
Transverse contact ratio	[eps_a]	1.712			
Transverse contact ratio with allowances	[eps_a.e/m/i]	1.717 /	1.712 /	1.706	
Overlap ratio	[eps_b]	1.002			
Total contact ratio	[eps_g]	2.715			
Total contact ratio with allowances	[eps_g.e/m/i]	2.720 /	2.714 /	2.708	

2. FACTORS OF GENERAL INFLUENCE

		------- GEAR 1	-------- GEAR 2 --
Nominal circum. force at pitch circle (N)	[Ft]		41026.1
Axial force (N)	[Fa]		9471.6
Radial force (N)	[Fr]		15325.1
Normal force (N)	[Fnorm]		44807.5
Tangent.load at p.c.d.per mm (N/mm) (N/mm)	[w]		586.09
Only as information: Forces at operating pitch circle:			
Nominal circumferential force (N)	[Ftw]		41034.8
Axial force (N)	[Faw]		9471.6
Radial force (N)	[Frw]		15301.8
Circumferential speed pitch d.. (m/sec)	[v]		12.25
Running-in value (µm)	[yp]		0.8
Running-in value (µm)	[yf]		0.8
Correction coefficient	[CM]		0.800
Gear body coefficient	[CR]		1.000
Reference profile coefficient	[CBS]		0.975
Material coefficient	[E/Est]		1.000
Singular tooth stiffness (N/mm/µm)	[c']		14.077
Meshing stiffness (N/mm/µm)	[cg]		21.599
Reduced mass (kg/mm)	[mRed]		0.14980
Resonance speed (min-1)	[nE1]		2012
Resonance ratio (-)	[N]		0.398
Subcritical range			
Running-in value (µm)	[ya]		0.8
Bearing distance l of pinion shaft (mm)	[l]		140.000
Distance s of pinion shaft (mm)	[s]		14.000
Outside diameter of pinion shaft (mm)	[dsh]		70.000
Load according to Figure 6.8, DIN 3990-1:1987 (0:6.8a, 1:6.8b, 2:6.8c, 3:6.8d, 4:6.8e)	[-]		4
Coefficient K' according to Figure 6.8, DIN 3990-1:1987	[K']		-1.00
Without support effect			
Tooth trace deviation (active) (µm)	[Fby]		4.25
from deformation of shaft (µm)	[fsh*B1]		5.49
Tooth without tooth trace modification			
Position of Contact pattern: favorable			
from production tolerances (µm)	[fma*B2]		10.00
Tooth trace deviation, theoretical (µm)	[Fbx]		5.00
Running-in value (µm)	[yb]		0.75
Dynamic factor	[KV]		1.081
Face load factor - flank	[KHb]		1.072
- Tooth root	[KFb]		1.061
- Scuffing	[KBb]		1.072
Transverse load factor - flank	[KHa]		1.032
- Tooth root	[KFa]		1.032
- Scuffing	[KBa]		1.032
Helical load factor scuffing	[Kbg]		1.256
Number of load cycles (in mio.)	[NL]	115.200	113.214

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: B
(Calculate tooth shape coefficient YF with addendum mod. x)

		------- GEAR 1	-------- GEAR 2 --
Tooth form factor	[YF]	1.17	1.18
Stress correction factor	[YS]	2.37	2.37
Working angle (°)	[alfFen]	19.11	19.11
Bending lever arm (mm)	[hF]	4.78	4.79
Tooth thickness at root (mm)	[sFn]	11.08	11.09
Tooth root radius (mm)	[roF]	2.03	2.03

(hF* = 0.956/ 0.958 sFn* = 2.217/ 2.218 roF* = 0.405/ 0.405 dsFn = 281.48/ 286.55 alfsFn = 30.00/ 30.00)

Contact ratio factor	[Yeps]	1.000	
Helical load factor	[Ybet]	0.892	
Effective facewidth (mm)	[beff]	70.00	70.00
Nominal stress at tooth root (N/mm²)	[sigF0]	290.96	291.17
Tooth root stress (N/mm²)	[sigF]	344.20	344.44
Permissible bending stress at root of Test-gear			
Support factor	[YdrelT]	1.002	1.002
Surface factor	[YRrelT]	0.957	0.957
Size coefficient (Tooth root)	[YX]	1.000	1.000
Finite life factor	[YNT]	1.000	1.000
[YdrelT*YRrelT*YX*YNT]		0.959	0.959
Alternating bending coefficient	[YM]	1.000	1.000
Stress correction factor	[Yst]	2.00	
Yst*sigFlim (N/mm²)	[sigFE]	1000.00	1000.00
Permissible tooth root stress (N/mm²)	[sigFP=sigFG/SFmin]	684.88	684.88
Limit strength tooth root (N/mm²)	[sigFG]	958.83	958.83
Required safety	[SFmin]	1.40	1.40
Safety for Tooth root stress	[SF=sigFG/sigF]	2.79	2.78
Transmittable power (kW)	[kWRating]	1000.18	999.48

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		------- GEAR 1	-------- GEAR 2 --
Zone factor	[ZH]	2.444	
Elasticity coefficient (N^.5/mm)	[ZE]	189.812	
Contact ratio factor	[Zeps]	0.764	
Helix angle factor	[Zbet]	0.987	
Effective facewidth (mm)	[beff]	70.00	
Nominal flank pressure (N/mm²)	[sigH0]	697.51	
Surface pressure at operating pitch circle (N/mm²)	[sigHw]	762.90	
Single tooth contact factor	[ZB,ZD]	1.00	1.00
Flank pressure (N/mm²)	[sigH]	762.90	762.90
Lubrication coefficient at NL	[ZL]	1.020	1.020
Speed coefficient at NL	[ZV]	1.006	1.006
Roughness coefficient at NL	[ZR]	0.991	0.991
Material pairing coefficient at NL	[ZW]	1.000	1.000
Finite life factor	[ZNT]	1.000	1.000
	[ZL*ZV*ZR*ZNT]	1.017	1.017
Small amount of pitting permissible (0=no, 1=yes)		0	0

Size coefficient (flank)	[ZX]	1.000	1.000
Permissible surface pressure (N/mm²)	[sigHP=sigHG/SHmin]	1525.45	1525.45
Limit strength pitting (N/mm²)	[sigHG]	1525.45	1525.45
Safety for surface pressure at operating pitch circle			
	[SHw]	2.00	2.00
Required safety	[SHmin]	1.00	1.00
Transmittable power (kW)	[kWRating]	2009.70	2009.70

4b. MICROPITTING ACCORDING TO ISO TR 15144-1:2010

Calculation did not run. (Lubricant: Load stage micropitting test is unknown.)

5. STRENGTH AGAINST SCUFFING

Calculation method according to
DIN 3990:1987

Lubrication coefficient (for lubrication type)	[XS]	1.000	
Relative structure coefficient (Scuffing)	[XWrelT]	1.000	
Thermal contact factor (N/mm/s^.5/K)	[BM]	13.780	13.780
Relevant tip relief (µm)	[Ca]	2.00	2.00
Optimal tip relief (µm)	[Ceff]	27.13	
Ca taken as optimal in the calculation (0=no, 1=yes)		0	0
Effective facewidth (mm)	[beff]	70.000	
Applicable circumferential force/facewidth (N/mm)	[wBt]	880.351	
Pressure angle factor (eps1: 0.858, eps2: 0.854)	[Xalfbet]	0.979	
Flash temperature-criteria			
Tooth mass temperature (°C)	[theM-B]	83.04	
theM-B = theoil + XS*0.47*theflamax	[theflamax]	27.74	
Scuffing temperature (°C)	[theS]	408.58	
Coordinate gamma (point of highest temp.) [Gamma.A]=-0.253 [Gamma.E]=0.254	[Gamma]	-0.253	
Highest contact temp. (°C)	[theB]	110.78	
Flash factor (°K*N^-.75*s^.5*m^-.5*mm)	[XM]	50.058	
Geometry factor	[XB]	0.185	
Load sharing factor	[XGam]	0.333	
Dynamic viscosity (mPa*s)	[etaM]	25.76 (83.0 °C)	
Coefficient of friction	[mym]	0.067	
Integral temperature-criteria			
Tooth mass temperature (°C)	[theM-C]	82.37	
theM-C = theoil + XS*0.70*theflaint	[theflaint]	17.68	
Integral scuffing temperature (°C)	[theSint]	408.58	
Flash factor (°K*N^-.75*s^.5*m^-.5*mm)	[XM]	50.058	
Contact ratio factor	[Xeps]	0.248	
Dynamic viscosity (mPa*s)	[etaOil]	41.90 (70.0 °C)	
Averaged coefficient of friction	[mym]	0.058	
Geometry factor	[XBE]	0.185	
Meshing factor	[XQ]	1.000	
Tip relief factor	[XCa]	1.017	

Integral tooth flank temperature (°C)	[theint]	108.89

6. MEASUREMENTS FOR TOOTH THICKNESS

		------- GEAR 1 --------	GEAR 2 --
Tooth thickness deviation		DIN 3967 cd25	DIN 3967 cd25
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.130 / -0.190	-0.130 / -0.190
Number of teeth spanned	[k]	7.000	7.000
Base tangent length (no backlash) (mm)	[Wk]	100.233	100.286
Actual base tangent length ('span') (mm)	[Wk.e/i]	100.110 / 100.054	100.164 / 100.107
Diameter of contact point (mm)	[dMWk.m]	290.942	295.491
Theoretical diameter of ball/pin (mm)	[DM]	8.436	8.431
Eff. Diameter of ball/pin (mm)	[DMeff]	9.000	9.000
Theor. dim. centre to ball (mm)	[MrK]	152.985	155.522
Actual dimension centre to ball (mm)	[MrK.e/i]	152.822 / 152.747	155.359 / 155.284
Diameter of contact point (mm)	[dMMr.m]	293.316	298.397
Diametral measurement over two balls without clearance (mm)	[MdK]	305.856	311.045
Actual dimension over balls (mm)	[MdK.e/i]	305.531 / 305.381	310.719 / 310.568
Diametral measurement over rolls without clearance (mm)	[MdR]	305.969	311.045
Actual dimension over rolls (mm)	[MdR.e/i]	305.644 / 305.493	310.719 / 310.568
Chordal tooth thickness (no backlash) (mm)	['sn]	7.842	7.819
Actual chordal tooth thickness (mm)	['sn.e/i]	7.712 / 7.652	7.689 / 7.629
Reference chordal height from da.m (mm)	[ha]	5.032	4.999
Tooth thickness (Arc) (mm)	[sn]	7.843	7.819
(mm)	[sn.e/i]	7.713 / 7.653	7.689 / 7.629
Backlash free center distance (mm)	[aControl.e/i]	294.641 /294.474	
Backlash free center distance, allowances (mm)	[jta]	-0.359 / -0.526	
dNf.i with aControl (mm)	[dNf0.i]	283.649	288.727
Reserve (dNf0.i-dFf.e)/2 (mm)	[cF0.i]	0.395	0.405
Centre distance allowances (mm)	[Aa.e/i]	0.026 / -0.026	
Circumferential backlash from Aa (mm)	[jtw_Aa.e/i]	0.019 / -0.019	
Radial clearance (mm)	[jrw]	0.552 / 0.333	
Circumferential backlash (transverse section) (mm)	[jtw]	0.409 / 0.247	
Torsional angle for fixed gear 1 (°)		0.1576 / 0.0952	
Normal backlash (mm)	[jnw]	0.375 / 0.227	

7. GEAR ACCURACY

		------- GEAR 1 --------	GEAR 2 --
According to DIN 3961:1978:			
Accuracy grade	[Q-DIN3961]	6	6
Profile form deviation (µm)	[ff]	10.00	10.00
Profile slope deviation (µm)	[fHa]	7.00	7.00
Total profile deviation (µm)	[Ff]	13.00	13.00
Helix form deviation (µm)	[ffb]	8.00	8.00
Helix slope deviation (µm)	[fHb]	10.00	10.00
Total helix deviation (µm)	[Fb]	13.00	13.00
Normal base pitch deviation (µm)	[fpe]	10.00	10.00

Single pitch deviation (µm)	[fp]	10.00	10.00
Difference between adjacent pitches (µm)	[fu]	12.00	12.00
Total cumulative pitch deviation (µm)	[Fp]	40.00	40.00
Cumulative circular pitch deviation over z/8 pitches (µm)	[Fpz/8]	25.00	25.00
Concentricity deviation (µm)	[Fr]	28.00	28.00
Tooth Thickness Variation (µm)	[Rs]	16.00	16.00
Total radial composite deviation (µm)	[Fi"]	32.00	32.00
Radial tooth-to-tooth composite deviation (µm)	[fi"]	14.00	14.00
Total tangential composite deviation (µm)	[Fi']	42.00	42.00
Tangential tooth-to-tooth composite deviation (µm)	[fi']	16.00	16.00

Axis alignment tolerances (recommendation acc. ISO TR 10064:1992, Quality		6)
Maximum value for deviation error of axis (µm)	[fSigbet]	15.00 (Fb= 15.00)
Maximum value for inclination error of axes (µm)	[fSigdel]	30.00

8. ADDITIONAL DATA

Torsional stiffness (MNm/rad)	[cr]	28.4		29.4
Mean coeff. of friction (acc. Niemann)	[mum]		0.037	
Wear sliding coef. by Niemann	[zetw]		0.687	
Power loss from gear load (kW)	[PVZ]		1.568	
(Meshing efficiency (%)	[etaz]		99.688)	
Weight - calculated with da (kg)	[Mass]	39.383		40.713
Total weight (kg)	[Mass]		80.096	
Moment of inertia (System referenced to wheel 1):				
calculation without consideration of the exact tooth shape				
single gears ((da+df)/2...di) (kg*m²)	[TraeghMom]	0.38583		0.41341
System ((da+df)/2...di) (kg*m²)	[TraeghMom]		0.78511	

9. DETERMINATION OF TOOTHFORM

Data for the tooth form calculation :

Calculation of Gear 1

Tooth form, Gear 1, Step 1: automatic (final treatment)
haP*= 1.043, hfP*= 1.250, rofP*= 0.250

Calculation of Gear 2

Tooth form, Gear 2, Step 1: automatic (final treatment)
haP*= 1.043, hfP*= 1.250, rofP*= 0.250

REMARKS:

- Specifications with [.e/i] imply: Maximum [e] and Minimal value [i] with consideration of all tolerances
  Specifications with [.m] imply: Mean value within tolerance
- For the backlash tolerance, the center distance tolerances and the tooth thickness deviation are taken into account. Shown is the maximal and the minimal backlash corresponding the largest resp. the smallest allowances
  The calculation is done for the Operating pitch circle..
- Details of calculation method:

cg according to method B
KV according to method B
KHb, KFb according method C
KHa, KFa according to method B

End of Report lines: 515

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Name : P_Soukoli_5_6
Changed by: karlova am: 02.05.2014 um: 12:08:55

CALCULATION OF A HELICAL GEAR PAIR

Drawing or article number:
Gear 1: 0.000.0
Gear 2: 0.000.0

Strength calculation with load spectrum
Required service life (h): 2400.00

Load spectrum

Nominal Power [P] 502.6548 kW
Application factor [KA] 1.00

Load spectrum : Own Input
Number of element in the Load spectrum: 2
Reference gear: 2

i	[%]	[kW]	[1/min]	[Nm]	KV	KHb	Kgam	YM1	YM2	Oil°
1	20.00000	502.6548	59.6491	80470.5843	1.0074	1.0500	1.0000	1.0000	1.0000	70
2	80.00000	351.8584	59.6491	56329.4090	1.0086	1.0500	1.0000	1.0000	1.0000	70

Woehler line (S-N curve) at the fatigue stress according: according to standard

Notice:
Calculation-method according to:
- ISO 6336, part 6
During the calculation al the load-coefficients (ISO6336: KV, KHb, KFb; AGMA2001: Knu, Km, ..)
for each load spectrum element are calculated separately.

Safety root: 2.66 2.66
Safety flank: 1.48 1.59

Safety scuffing (Integral) 2.59
Safety scuffing (Flash) 1.70
(Safety against scuffing/micropitting/EHT is indicated for the weakest element of the load spectrum.)

ONLY AS INFORMATION: CALCULATION WITH REFERENCE POWER

Calculation method DIN 3990:1987 Method B

		GEAR 1	GEAR 2
Power (kW)	[P]	502.655	
Speed (1/min)	[n]	212.5	59.6
Torque (Nm)	[T]	22588.2	80470.6
Application factor	[KA]	1.00	
Required service life	[H]	2400.00	
Gear driving (+) / driven (-)		+	-

1. TOOTH GEOMETRY AND MATERIAL

(geometry calculation according to DIN 3960:1987)

		GEAR 1	GEAR 2
Center distance (mm)	[a]	455.000	
Centre distance tolerance	ISO 286:2010 Measure js7		
Normal module (mm)	[mn]	12.0000	
Pressure angle at normal section (°)	[alfn]	25.0000	
Helix angle at reference circle (°)	[beta]	14.0000	
Number of teeth	[z]	16	57
Facewidth (mm)	[b]	160.00	148.00
Hand of gear		left	right
Accuracy grade	[Q-DIN 3961:1978]	6	6
Inner diameter (mm)	[di]	0.00	0.00
Inner diameter of gear rim (mm)	[dbi]	0.00	0.00

Material

Gear 1: 18CrNiMo7-6, Case-carburized steel, case-hardened
ISO 6336-5 Figure 9/10 (MQ), core strength >=30HRC

Gear 2: 18CrNiMo7-6, Case-carburized steel, case-hardened
ISO 6336-5 Figure 9/10 (MQ), core strength >=30HRC

		GEAR 1	GEAR 2
Surface hardness		HRC 61	HRC 61
Fatigue strength. tooth root stress (N/mm²)	[sigFlim]	500.00	500.00
Fatigue strength for Hertzian pressure (N/mm²)	[sigHlim]	1500.00	1500.00
Tensile strength (N/mm²)	[Rm]	1200.00	1200.00
Yield point (N/mm²)	[Rp]	850.00	850.00
Young's modulus (N/mm²)	[E]	206000	206000
Poisson's ratio	[ny]	0.300	0.300
Mean roughness, Ra, tooth flank (µm)	[RAH]	0.60	0.60
Mean roughness height, Rz, flank (µm)	[RZH]	4.80	4.80
Mean roughness height, Rz, root (µm)	[RZF]	20.00	20.00

Tool or reference profile of gear 1 :

Reference profile	1.25 / 0.25 / 1.0 ISO 53.2:1997 Profil C	
Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.250
Addendum coefficient	[haP*]	1.000
Tip radius factor	[rhoaP*]	0.000
Tip form height coefficient	[hFaP*]	0.000
Protuberance height factor	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Ramp angle	[alfKP]	0.000
		not topping

Tool or reference profile of gear 2 :		
Reference profile 1.25 / 0.25 / 1.0 ISO 53.2:1997 Profil C		
Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.250
Addendum coefficient	[haP*]	1.000
Tip radius factor	[rhoaP*]	0.000
Tip form height coefficient	[hFaP*]	0.000
Protuberance height factor	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Ramp angle	[alfKP]	0.000
	not topping	

Summary of reference profile gears:			
Dedendum reference profile (in module)	[hfP*]	1.250	1.250
Root radius reference profile (in module)	[rofP*]	0.250	0.250
Addendum reference profile (in module)	[haP*]	1.000	1.000
Protuberance height coefficient (in module)	[hprP*]	0.000	0.000
Protuberance angle (°)	[alfprP]	0.000	0.000
Tip form height coefficient (in module)	[hFaP*]	0.000	0.000
Ramp angle (°)	[alfKP]	0.000	0.000

Type of profile modification:			
none (only running-in)			
Tip relief (µm)	[Ca]	2.0	2.0

Lubrication type	oil bath lubrication	
Type of oil	Oil: ISO-VG 220	
Lubricant base	Mineral-oil base	
Kinem. viscosity oil at 40 °C (mm²/s)	[nu40]	220.00
Kinem. viscosity oil at 100 °C (mm²/s)	[nu100]	17.50
FZG test A/8.3/90 (ISO 14635-1:2006)	[FZGtestA]	12
Specific density at 15 °C (kg/dm³)	[roOil]	0.895
Oil temperature (°C)	[TS]	70.000

		------- GEAR 1	-------- GEAR 2 --
Overall transmission ratio	[itot]	-3.563	
Gear ratio	[u]	3.563	
Transverse module (mm)	[mt]	12.367	
Pressure angle at pitch circle (°)	[alft]	25.668	
Working transverse pressure angle (°)	[alfwt]	26.594	
	[alfwt.e/i]	26.602 /	26.586
Working pressure angle at normal section (°)	[alfwn]	25.898	
Helix angle at operating pitch circle (°)	[betaw]	14.107	
Base helix angle (°)	[betab]	12.665	
Reference centre distance (mm)	[ad]	451.409	
Sum of profile shift coefficients	[Summexi]	0.3043	
Profile shift coefficient	[x]	0.4800	-0.1757
Tooth thickness (Arc) (module) (module)	[sn*]	2.0185	1.4070
Tip alteration (mm)	[k*mn]	-0.061	-0.061
Reference diameter (mm)	[d]	197.878	704.940
Base diameter (mm)	[db]	178.351	635.375
Tip diameter (mm)	[da]	233.276	724.602
(mm)	[da.e/i]	233.276 / 233.266	724.602 / 724.592
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / -0.010	0.000 / -0.010
Tip form diameter (mm)	[dFa]	233.276	724.602
(mm)	[dFa.e/i]	233.276 / 233.266	724.602 / 724.592

Active tip diameter (mm)	[dNa.e/i]	233.276 /	233.266	724.602 /	724.592
Operating pitch diameter (mm)	[dw]	199.452		710.548	
(mm)	[dw.e/i]	199.466 /	199.438	710.597 /	710.499
Root diameter (mm)	[df]	179.398		670.724	
Generating Profile shift coefficient	[xE.e/i]	0.4715/	0.4670	-0.1913/	-0.1985
Manufactured root diameter with xE (mm)	[df.e/i]	179.194 /	179.087	670.348 /	670.177
Theoretical tip clearance (mm)	[c]	3.000		3.000	
Effective tip clearance (mm)	[c.e/i]	3.310 /	3.156	3.192 /	3.071
Active root diameter (mm)	[dNf]	187.863		685.387	
(mm)	[dNf.e/i]	187.914 /	187.819	685.445 /	685.334
Root form diameter (mm)	[dFf]	185.512		677.218	
(mm)	[dFf.e/i]	185.383 /	185.316	676.918 /	676.782
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	1.299 /	1.218	4.332 /	4.208
Addendum (mm)	[ha=mn*(haP*+x)]	17.699		9.831	
(mm)	[ha.e/i]	17.699 /	17.694	9.831 /	9.826
Dedendum (mm)	[hf=mn*(hfP*-x)]	9.240		17.108	
(mm)	[hf.e/i]	9.342 /	9.395	17.296 /	17.382
Roll angle at dFa (°)	[xsi_dFa.e/i]	48.304 /	48.299	31.413 /	31.411
Roll angle to dNa (°)	[xsi_dNa.e/i]	48.304 /	48.299	31.413 /	31.411
Roll angle to dNf (°)	[xsi_dNf.e/i]	19.013 /	18.916	23.190 /	23.163
Roll angle at dFf (°)	[xsi_dFf.e/i]	16.248 /	16.168	21.055 /	21.020
Tooth height (mm)	[H]	26.939		26.939	
Virtual gear no. of teeth	[zn]	17.323		61.712	
Normal tooth thickness at tip cyl. (mm)	[san]	3.610		7.384	
(mm)	[san.e/i]	3.508 /	3.441	7.210 /	7.123
Normal spacewidth at root cylinder (mm)	[efn]	6.655		6.472	
(mm)	[efn.e/i]	6.713 /	6.745	6.512 /	6.531
Max. sliding velocity at tip (m/s)	[vga]	0.870		0.431	
Specific sliding at the tip	[zetaa]	0.520		0.396	
Specific sliding at the root	[zetaf]	-0.657		-1.084	
Sliding factor on tip	[Kga]	0.392		0.194	
Sliding factor on root	[Kgf]	-0.194		-0.392	
Pitch on reference circle (mm)	[pt]	38.853			
Base pitch (mm)	[pbt]	35.019			
Transverse pitch on contact-path (mm)	[pet]	35.019			
Lead height (mm)	[pz]	2493.308		8882.410	
Axial pitch (mm)	[px]	155.832			
Length of path of contact (mm)	[ga, e/i]	45.670 (	45.740 /	45.581)	
Length T1-A, T2-A (mm)	[T1A, T2A]	29.511(	29.441/	29.592)	174.174(174.174/ 174.164)
Length T1-B (mm)	[T1B, T2B]	40.162(	40.162/	40.154)	163.523(163.453/ 163.602)
Length T1-C (mm)	[T1C, T2C]	44.643(	44.628/	44.659)	159.042(158.987/ 159.097)
Length T1-D (mm)	[T1D, T2D]	64.530(	64.460/	64.611)	139.155(139.155/ 139.144)
Length T1-E (mm)	[T1E, T2E]	75.181(	75.181/	75.173)	128.504(128.434/ 128.582)
Length T1-T2 (mm)	[T1T2]	203.685 (	203.615 /	203.756)	
Diameter of single contact point B (mm)	[d-B]	195.604(	195.604/	195.597)	714.605(714.541/ 714.677)
Diameter of single contact point D (mm)	[d-D]	220.149(	220.067/	220.244)	693.655(693.655/ 693.647)
Addendum contact ratio	[eps]	0.872(	0.872/	0.871)	0.432(0.434/ 0.430)
Minimal length of contact line (mm)	[Lmin]	192.239			

Transverse contact ratio	[eps_a]	1.304		
Transverse contact ratio with allowances	[eps_a.e/m/i]	1.306 /	1.304 /	1.302
Overlap ratio	[eps_b]	0.950		
Total contact ratio	[eps_g]	2.254		
Total contact ratio with allowances	[eps_g.e/m/i]	2.256 /	2.254 /	2.251

2. FACTORS OF GENERAL INFLUENCE

		------- GEAR 1 --------	GEAR 2 --
Nominal circum. force at pitch circle (N)	[Ft]		228304.9
Axial force (N)	[Fa]		56922.8
Radial force (N)	[Fr]		109719.4
Normal force (N)	[Fnorm]		259618.3
Tangent.load at p.c.d.per mm (N/mm) (N/mm)	[w]		1542.60
Only as information: Forces at operating pitch circle:			
Nominal circumferential force (N)	[Ftw]		226502.9
Axial force (N)	[Faw]		56922.8
Radial force (N)	[Frw]		113392.7
Circumferential speed pitch d.. (m/sec)	[v]		2.20
Running-in value (µm)	[yp]		1.1
Running-in value (µm)	[yf]		1.3
Correction coefficient	[CM]		0.800
Gear body coefficient	[CR]		1.000
Reference profile coefficient	[CBS]		1.073
Material coefficient	[E/Est]		1.000
Singular tooth stiffness (N/mm/µm)	[c']		14.758
Meshing stiffness (N/mm/µm)	[cg]		18.124
Reduced mass (kg/mm)	[mRed]		0.15971
Resonance speed (min-1)	[nE1]		6358
Resonance ratio (-)	[N]		0.033
Subcritical range			
Running-in value (µm)	[ya]		1.1
Bearing distance l of pinion shaft (mm)	[l]		320.000
Distance s of pinion shaft (mm)	[s]		32.000
Outside diameter of pinion shaft (mm)	[dsh]		160.000
Load according to Figure 6.8, DIN 3990-1:1987 (0:6.8a, 1:6.8b, 2:6.8c, 3:6.8d, 4:6.8e)	[-]		4
Coefficient K' according to Figure 6.8, DIN 3990-1:1987	[K']		-1.00
Without support effect			
Tooth trace deviation (active) (µm)	[Fby]		6.60
from deformation of shaft (µm)	[fsh*B1]		7.76
Tooth without tooth trace modification			
Position of Contact pattern: favorable			
from production tolerances (µm)	[fma*B2]		11.00
Tooth trace deviation, theoretical (µm)	[Fbx]		7.77
Running-in value (µm)	[yb]		1.17
Dynamic factor	[KV]		1.007
Face load factor - flank	[KHb]		1.050
- Tooth root	[KFb]		1.041
- Scuffing	[KBb]		1.050
Transverse load factor - flank	[KHa]		1.000
- Tooth root	[KFa]		1.000
- Scuffing	[KBa]		1.000
Helical load factor scuffing	[Kbg]		1.167
Number of load cycles (in mio.)	[NL]	30.600	8.589

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: B
(Calculate tooth shape coefficient YF with addendum mod. x)

		------- GEAR 1	-------- GEAR 2 --
Tooth form factor	[YF]	1.24	1.43
Stress correction factor	[YS]	2.46	2.10
Working angle (°)	[alfFen]	30.72	25.30
Bending lever arm (mm)	[hF]	14.62	16.37
Tooth thickness at root (mm)	[sFn]	28.41	28.66
Tooth root radius (mm)	[roF]	4.01	5.41

(hF* = 1.218/ 1.364 sFn* = 2.367/ 2.388 roF* = 0.334/ 0.451 dsFn = 182.16/ 674.60 alfsFn = 30.00/ 30.00)

Contact ratio factor	[Yeps]	1.000	
Helical load factor	[Ybet]	0.889	
Effective facewidth (mm)	[beff]	160.00	148.00
Nominal stress at tooth root (N/mm²)	[sigF0]	322.31	343.75
Tooth root stress (N/mm²)	[sigF]	337.97	360.46
Permissible bending stress at root of Test-gear			
Support factor	[YdrelT]	1.009	1.001
Surface factor	[YRrelT]	0.957	0.957
Size coefficient (Tooth root)	[YX]	0.930	0.930
Finite life factor	[YNT]	1.000	1.000
	[YdrelT*YRrelT*YX*YNT]	0.898	0.891
Alternating bending coefficient	[YM]	1.000	1.000
Stress correction factor	[Yst]	2.00	
Yst*sigFlim (N/mm²)	[sigFE]	1000.00	1000.00
Permissible tooth root stress (N/mm²)	[sigFP=sigFG/SFmin]	641.34	636.44
Limit strength tooth root (N/mm²)	[sigFG]	897.87	891.01
Required safety	[SFmin]	1.40	1.40
Safety for Tooth root stress	[SF=sigFG/sigF]	2.66	2.47
Transmittable power (kW)	[kWRating]	953.83	887.50

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		------- GEAR 1	-------- GEAR 2 --
Zone factor	[ZH]	2.190	
Elasticity coefficient (N^.5/mm)	[ZE]	189.812	
Contact ratio factor	[Zeps]	0.879	
Helix angle factor	[Zbet]	0.985	
Effective facewidth (mm)	[beff]	148.00	
Nominal flank pressure (N/mm²)	[sigH0]	1138.06	
Surface pressure at operating pitch circle (N/mm²)	[sigHw]	1170.48	
Single tooth contact factor	[ZB,ZD]	1.00	1.00
Flank pressure (N/mm²)	[sigH]	1172.82	1170.48
Lubrication coefficient at NL	[ZL]	1.018	1.014
Speed coefficient at NL	[ZV]	0.968	0.975
Roughness coefficient at NL	[ZR]	1.003	1.002
Material pairing coefficient at NL	[ZW]	1.000	1.000
Finite life factor	[ZNT]	1.038	1.143
	[ZL*ZV*ZR*ZNT]	1.026	1.133
Small amount of pitting permissible (0=no, 1=yes)		0	0

Size coefficient (flank)	[ZX]	0.991	0.993
Permissible surface pressure (N/mm²)	[sigHP=sigHG/SHmin]	1525.10	1686.58
Limit strength pitting (N/mm²)	[sigHG]	1525.10	1686.58
Safety for surface pressure at operating pitch circle			
	[SHw]	1.30	1.44
Required safety	[SHmin]	1.00	1.00
Transmittable power (kW)	[kWRating]	849.96	1043.64

4b. MICROPITTING ACCORDING TO ISO TR 15144-1:2010

Calculation did not run. (Lubricant: Load stage micropitting test is unknown.)

5. STRENGTH AGAINST SCUFFING

Calculation method according to
DIN 3990:1987

Lubrication coefficient (for lubrication type)	[XS]	1.000	
Relative structure coefficient (Scuffing)	[XWrelT]	1.000	
Thermal contact factor (N/mm/s^.5/K)	[BM]	13.780	13.780
Relevant tip relief (µm)	[Ca]	2.00	2.00
Optimal tip relief (µm)	[Ceff]	85.11	
Ca taken as optimal in the calculation (0=no, 1=yes)		0	0
Effective facewidth (mm)	[beff]	148.000	
Applicable circumferential force/facewidth (N/mm)			
	[wBt]	1904.229	
Pressure angle factor (eps1: 0.872, eps2: 0.432)	[Xalfbet]	1.076	
Flash temperature-criteria			
Tooth mass temperature (°C)	[theM-B]	133.69	
theM-B = theoil + XS*0.47*theflamax	[theflamax]	135.51	
Scuffing temperature (°C)	[theS]	408.58	
Coordinate gamma (point of highest temp.)	[Gamma]	0.445	
[Gamma.A]=-0.339 [Gamma.E]=0.684			
Highest contact temp. (°C)	[theB]	269.19	
Flash factor (°K*N^-.75*s^.5*m^-.5*mm)	[XM]	50.058	
Geometry factor	[XB]	0.200	
Load sharing factor	[XGam]	1.000	
Dynamic viscosity (mPa*s)	[etaM]	6.69 (133.7 °C)	
Coefficient of friction	[mym]	0.136	
Integral temperature-criteria			
Tooth mass temperature (°C)	[theM-C]	98.02	
theM-C = theoil + XS*0.70*theflaint	[theflaint]	40.02	
Integral scuffing temperature (°C)	[theSint]	408.58	
Flash factor (°K*N^-.75*s^.5*m^-.5*mm)	[XM]	50.058	
Contact ratio factor	[Xeps]	0.295	
Dynamic viscosity (mPa*s)	[etaOil]	41.90 (70.0 °C)	
Averaged coefficient of friction	[mym]	0.095	
Geometry factor	[XBE]	0.293	
Meshing factor	[XQ]	1.000	
Tip relief factor	[XCa]	1.018	

Integral tooth flank temperature (°C)	[theint]	158.05	

6. MEASUREMENTS FOR TOOTH THICKNESS

		------- GEAR 1 --------	GEAR 2 --
Tooth thickness deviation		DIN 3967 cd25	DIN 3967 cd25
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.095 / -0.145	-0.175 / -0.255
Number of teeth spanned	[k]	3.000	9.000
Base tangent length (no backlash) (mm)	[Wk]	95.957	308.840
Actual base tangent length ('span') (mm)	[Wk.e/i]	95.871 / 95.826	308.682 / 308.609
Diameter of contact point (mm)	[dMWk.m]	201.381	703.124
Theoretical diameter of ball/pin (mm)	[DM]	25.297	20.834
Eff. Diameter of ball/pin (mm)	[DMeff]	28.000	22.000
Theor. dim. centre to ball (mm)	[MrK]	127.920	367.100
Actual dimension centre to ball (mm)	[MrK.e/i]	127.849 / 127.812	366.919 / 366.837
Diameter of contact point (mm)	[dMMr.m]	211.767	702.344
Diametral measurement over two balls without clearance (mm)	[MdK]	255.841	733.929
Actual dimension over balls (mm)	[MdK.e/i]	255.699 / 255.624	733.569 / 733.404
Diametral measurement over rolls without clearance (mm)	[MdR]	255.841	734.199
Actual dimension over rolls (mm)	[MdR.e/i]	255.699 / 255.624	733.839 / 733.674
Chordal tooth thickness (no backlash) (mm)	['sn]	24.168	16.882
Actual chordal tooth thickness (mm)	['sn.e/i]	24.073 / 24.023	16.707 / 16.627
Reference chordal height from da.m (mm)	[ha]	18.394	9.924
Tooth thickness (Arc) (mm)	[sn]	24.221	16.884
(mm)	[sn.e/i]	24.126 / 24.076	16.709 / 16.629
Backlash free center distance (mm)	[aControl.e/i]	454.720 /454.584	
Backlash free center distance, allowances (mm)	[jta]	-0.280 / -0.416	
dNf.i with aControl (mm)	[dNf0.i]	187.287	684.691
Reserve (dNf0.i-dFf.e)/2 (mm)	[cF0.i]	0.952	3.886
Centre distance allowances (mm)	[Aa.e/i]	0.032 / -0.032	
Circumferential backlash from Aa (mm)	[jtw_Aa.e/i]	0.032 / -0.032	
Radial clearance (mm)	[jrw]	0.447 / 0.249	
Circumferential backlash (transverse section) (mm)	[jtw]	0.447 / 0.249	
Torsional angle for fixed gear 1 (°)		0.0727 / 0.0405	
Normal backlash (mm)	[jnw]	0.393 / 0.219	

7. GEAR ACCURACY

		------- GEAR 1 --------	GEAR 2 --
According to DIN 3961:1978:			
Accuracy grade	[Q-DIN3961]	6	6
Profile form deviation (µm)	[ff]	18.00	18.00
Profile slope deviation (µm)	[fHa]	12.00	12.00
Total profile deviation (µm)	[Ff]	21.00	21.00
Helix form deviation (µm)	[ffb]	12.00	12.00
Helix slope deviation (µm)	[fHb]	11.00	11.00
Total helix deviation (µm)	[Fb]	16.00	16.00
Normal base pitch deviation (µm)	[fpe]	13.00	14.00

Single pitch deviation (µm)	[fp]	13.00	14.00
Difference between adjacent pitches (µm)	[fu]	16.00	18.00
Total cumulative pitch deviation (µm)	[Fp]	40.00	52.00
Cumulative circular pitch deviation over z/8 pitches (µm)	[Fpz/8]	25.00	33.00
Concentricity deviation (µm)	[Fr]	32.00	40.00
Tooth Thickness Variation (µm)	[Rs]	19.00	23.00
Total radial composite deviation (µm)	[Fi"]	34.00	42.00
Radial tooth-to-tooth composite deviation (µm)	[fi"]	16.00	19.00
Total tangential composite deviation (µm)	[Fi']	49.00	58.00
Tangential tooth-to-tooth composite deviation (µm)	[fi']	24.00	25.00

Axis alignment tolerances (recommendation acc. ISO TR 10064:1992, Quality		6)
Maximum value for deviation error of axis (µm)	[fSigbet]	20.54 (Fb= 19.00)
Maximum value for inclination error of axes (µm)	[fSigdel]	41.08

8. ADDITIONAL DATA

Torsional stiffness (MNm/rad)	[cr]	21.3		270.7
Mean coeff. of friction (acc. Niemann)	[mum]		0.063	
Wear sliding coef. by Niemann	[zetw]		0.625	
Power loss from gear load (kW)	[PVZ]		5.249	
(Meshing efficiency (%)	[etaz]		98.956)	
Weight - calculated with da (kg)	[Mass]	53.544		477.872
Total weight (kg)	[Mass]		531.416	
Moment of inertia (System referenced to wheel 1):				
calculation without consideration of the exact tooth shape				
single gears ((da+df)/2...di) (kg*m²)	[TraeghMom]	0.22237		26.91688
System ((da+df)/2...di) (kg*m²)	[TraeghMom]		2.34325	

9. DETERMINATION OF TOOTHFORM

Data for the tooth form calculation :
Data not available.

REMARKS:
- Specifications with [.e/i] imply: Maximum [e] and Minimal value [i] with consideration of all tolerances
  Specifications with [.m] imply: Mean value within tolerance
- For the backlash tolerance, the center distance tolerances and the tooth thickness deviation are taken into account. Shown is the maximal and the minimal backlash corresponding the largest resp. the smallest allowances
  The calculation is done for the Operating pitch circle..
- Details of calculation method:
  cg according to method B
  KV according to method B
  KHb, KFb according method C
  KHa, KFa according to method B

End of Report lines: 506

KISSsoft Release 03/2013

KISSsoft evaluation

File

Name : Soukoli_7_8_2_stavy
Changed by: karlova am: 02.05.2014 um: 11:58:37

CALCULATION OF A HELICAL GEAR PAIR

Drawing or article number:
Gear 1: 0.000.0
Gear 2: 0.000.0

Strength calculation with load spectrum
Required service life (h): 2400.00

Load spectrum

Nominal Power [P] 502.6548 kW
Application factor [KA] 1.00

Load spectrum : Own Input
Number of element in the Load spectrum: 2
Reference gear: 2

i	[%]	[kW]	[1/min]	[Nm]	KV	KHb	Kgam	YM1	YM2	Oil°
1	20.00000	502.6548	14.6829	326911.8738	1.0024	1.2226	1.0000	1.0000	1.0000	70
2	80.00000	351.8584	14.6829	228838.3117	1.0027	1.3178	1.0000	1.0000	1.0000	70

Woehler line (S-N curve) at the fatigue stress according: according to standard

Notice:
Calculation-method according to:
- ISO 6336, part 6
During the calculation al the load-coefficients (ISO6336: KV, KHb, KFb; AGMA2001: Knu, Km, ..)
for each load spectrum element are calculated separately.

Safety root: 2.33 2.36
Safety flank: 1.39 1.57

Safety scuffing (Integral) 2.23
Safety scuffing (Flash) 1.36
(Safety against scuffing/micropitting/EHT is indicated for the weakest element of the load spectrum.)

ONLY AS INFORMATION: CALCULATION WITH REFERENCE POWER

Calculation method DIN 3990:1987 Method B

		------- GEAR 1 --------	GEAR 2 --
Power (kW)	[P]	502.655	
Speed (1/min)	[n]	59.6	14.7
Torque (Nm)	[T]	80470.6	326911.9
Application factor	[KA]	1.00	
Required service life	[H]	2400.00	
Gear driving (+) / driven (-)		+	-

1. TOOTH GEOMETRY AND MATERIAL

(geometry calculation according to DIN 3960:1987)

		------- GEAR 1 --------	GEAR 2 --
Center distance (mm)	[a]	765.000	
Centre distance tolerance	ISO 286:2010 Measure js7		
Normal module (mm)	[mn]	18.0000	
Pressure angle at normal section (°)	[alfn]	20.0000	
Helix angle at reference circle (°)	[beta]	15.0000	
Number of teeth	[z]	16	65
Facewidth (mm)	[b]	250.00	218.00
Hand of gear		left	right
Accuracy grade	[Q-DIN 3961:1978]	6	6
Inner diameter (mm)	[di]	0.00	0.00
Inner diameter of gear rim (mm)	[dbi]	0.00	0.00

Material

Gear 1: 18CrNiMo7-6, Case-carburized steel, case-hardened
ISO 6336-5 Figure 9/10 (MQ), core strength >=30HRC

Gear 2: 18CrNiMo7-6, Case-carburized steel, case-hardened
ISO 6336-5 Figure 9/10 (MQ), core strength >=30HRC

		------- GEAR 1 --------	GEAR 2 --
Surface hardness		HRC 61	HRC 61
Fatigue strength. tooth root stress (N/mm²)	[sigFlim]	500.00	500.00
Fatigue strength for Hertzian pressure (N/mm²)	[sigHlim]	1500.00	1500.00
Tensile strength (N/mm²)	[Rm]	1200.00	1200.00
Yield point (N/mm²)	[Rp]	850.00	850.00
Young's modulus (N/mm²)	[E]	206000	206000
Poisson's ratio	[ny]	0.300	0.300
Mean roughness, Ra, tooth flank (µm)	[RAH]	0.60	0.60
Mean roughness height, Rz, flank (µm)	[RZH]	4.80	4.80
Mean roughness height, Rz, root (µm)	[RZF]	20.00	20.00

Tool or reference profile of gear 1 :

Reference profile	1.25 / 0.25 / 1.0 ISO 53.2:1997 Profil C	
Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.250
Addendum coefficient	[haP*]	1.000
Tip radius factor	[rhoaP*]	0.000
Tip form height coefficient	[hFaP*]	0.000
Protuberance height factor	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Ramp angle	[alfKP]	0.000
		not topping

Tool or reference profile of gear 2 :		
Reference profile 1.25 / 0.25 / 1.0 ISO 53.2:1997 Profil C		
Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.250
Addendum coefficient	[haP*]	1.000
Tip radius factor	[rhoaP*]	0.000
Tip form height coefficient	[hFaP*]	0.000
Protuberance height factor	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Ramp angle	[alfKP]	0.000
	not topping	

Summary of reference profile gears:			
Dedendum reference profile (in module)	[hfP*]	1.250	1.250
Root radius reference profile (in module)	[rofP*]	0.250	0.250
Addendum reference profile (in module)	[haP*]	1.000	1.000
Protuberance height coefficient (in module)	[hprP*]	0.000	0.000
Protuberance angle (°)	[alfprP]	0.000	0.000
Tip form height coefficient (in module)	[hFaP*]	0.000	0.000
Ramp angle (°)	[alfKP]	0.000	0.000

Type of profile modification:			
none (only running-in)			
Tip relief (µm)	[Ca]	2.0	2.0

Lubrication type	oil bath lubrication	
Type of oil	Oil: ISO-VG 220	
Lubricant base	Mineral-oil base	
Kinem. viscosity oil at 40 °C (mm²/s)	[nu40]	220.00
Kinem. viscosity oil at 100 °C (mm²/s)	[nu100]	17.50
FZG test A/8.3/90 (ISO 14635-1:2006)	[FZGtestA]	12
Specific density at 15 °C (kg/dm³)	[roOil]	0.895
Oil temperature (°C)	[TS]	70.000

		------- GEAR 1	-------- GEAR 2 --
Overall transmission ratio	[itot]	-4.063	
Gear ratio	[u]	4.063	
Transverse module (mm)	[mt]	18.635	
Pressure angle at pitch circle (°)	[alft]	20.647	
Working transverse pressure angle (°)	[alfwt]	22.603	
	[alfwt.e/i]	22.610 /	22.596
Working pressure angle at normal section (°)	[alfwn]	21.888	
Helix angle at operating pitch circle (°)	[betaw]	15.195	
Base helix angle (°)	[betab]	14.076	
Reference centre distance (mm)	[ad]	754.716	
Sum of profile shift coefficients	[Summexi]	0.5976	
Profile shift coefficient	[x]	0.4375	0.1601
Tooth thickness (Arc) (module) (module)	[sn*]	1.8892	1.6873
Tip alteration (mm)	[k*mn]	-0.472	-0.472
Reference diameter (mm)	[d]	298.160	1211.273
Base diameter (mm)	[db]	279.009	1133.475
Tip diameter (mm)	[da]	348.964	1252.093
(mm)	[da.e/i]	348.964 / 348.954	1252.093 / 1252.083
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / -0.010	0.000 / -0.010
Tip form diameter (mm)	[dFa]	348.964	1252.093
(mm)	[dFa.e/i]	348.964 / 348.954	1252.093 / 1252.083

Active tip diameter (mm)	[dNa.e/i]	348.964 / 348.954	1252.093 / 1252.083
Operating pitch diameter (mm)	[dw]	302.222	1227.778
(mm)	[dw.e/i]	302.238 / 302.206	1227.842 / 1227.714
Root diameter (mm)	[df]	268.908	1172.037
Generating Profile shift coefficient	[xE.e/i]	0.4275/ 0.4230	0.1418/ 0.1342
Manufactured root diameter with xE (mm)	[df.e/i]	268.551 / 268.386	1171.377 / 1171.103
Theoretical tip clearance (mm)	[c]	4.500	4.500
Effective tip clearance (mm)	[c.e/i]	5.012 / 4.789	4.806 / 4.638
Active root diameter (mm)	[dNf]	284.591	1194.983
(mm)	[dNf.e/i]	284.637 / 284.550	1195.054 / 1194.917
Root form diameter (mm)	[dFf]	281.718	1181.272
(mm)	[dFf.e/i]	281.579 / 281.517	1180.747 / 1180.529
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	1.560 / 1.485	7.263 / 7.085
Addendum (mm)	[ha=mn*(haP*+x)]	25.402	20.410
(mm)	[ha.e/i]	25.402 / 25.397	20.410 / 20.405
Dedendum (mm)	[hf=mn*(hfP*-x)]	14.626	19.618
(mm)	[hf.e/i]	14.804 / 14.887	19.948 / 20.085
Roll angle at dFa (°)	[xsi_dFa.e/i]	43.041 / 43.038	26.889 / 26.888
Roll angle to dNa (°)	[xsi_dNa.e/i]	43.041 / 43.038	26.889 / 26.888
Roll angle to dNf (°)	[xsi_dNf.e/i]	11.566 / 11.475	19.141 / 19.119
Roll angle at dFf (°)	[xsi_dFf.e/i]	7.795 / 7.699	16.719 / 16.680
Tooth height (mm)	[H]	40.028	40.028
Virtual gear no. of teeth	[zn]	17.606	71.524
Normal tooth thickness at tip cyl. (mm)	[san]	9.189	14.357
(mm)	[san.e/i]	9.045 / 8.969	14.114 / 14.006
Normal spacewidth at root cylinder (mm)	[efn]	0.000	13.328
(mm)	[efn.e/i]	0.000 / 0.000	13.386 / 13.411
Max. sliding velocity at tip (m/s)	[vga]	0.364	0.234
Specific sliding at the tip	[zetaa]	0.556	0.572
Specific sliding at the root	[zetaf]	-1.335	-1.250
Sliding factor on tip	[Kga]	0.385	0.248
Sliding factor on root	[Kgf]	-0.248	-0.385
Pitch on reference circle (mm)	[pt]	58.543	
Base pitch (mm)	[pbt]	54.783	
Transverse pitch on contact-path (mm)	[pet]	54.783	
Lead height (mm)	[pz]	3495.796	14201.673
Axial pitch (mm)	[px]	218.487	
Length of path of contact (mm)	[ga, e/i]	76.753 (76.857 / 76.629)	
Length T1-A, T2-A (mm)	[T1A, T2A]	28.044(27.940/ 28.160)	265.975(265.975/ 265.964)
Length T1-B (mm)	[T1B, T2B]	50.014(50.014/ 50.006)	244.005(243.901/ 244.118)
Length T1-C (mm)	[T1C, T2C]	58.078(58.057/ 58.098)	235.942(235.858/ 236.025)
Length T1-D (mm)	[T1D, T2D]	82.827(82.723/ 82.943)	211.192(211.192/ 211.180)
Length T1-E (mm)	[T1E, T2E]	104.797(104.797/ 104.789)	189.222(189.118/ 189.335)
Length T1-T2 (mm)	[T1T2]	294.019 (293.915 / 294.124)	
Diameter of single contact point B (mm)	[d-B]	296.398(296.398/ 296.392)	1234.066(1233.984/1234.155)
Diameter of single contact point D (mm)	[d-D]	324.481(324.374/ 324.599)	1209.617(1209.617/1209.609)
Addendum contact ratio	[eps]	0.853(0.853/ 0.852)	0.548(0.550/ 0.546)
Minimal length of contact line (mm)	[Lmin]	314.579	

Transverse contact ratio	[eps_a]	1.401
Transverse contact ratio with allowances	[eps_a.e/m/i]	1.403 / 1.401 / 1.399
Overlap ratio	[eps_b]	0.998
Total contact ratio	[eps_g]	2.399
Total contact ratio with allowances	[eps_g.e/m/i]	2.401 / 2.399 / 2.397

2. FACTORS OF GENERAL INFLUENCE

		------- GEAR 1	-------- GEAR 2 --
Nominal circum. force at pitch circle (N)	[Ft]		539782.3
Axial force (N)	[Fa]		144634.2
Radial force (N)	[Fr]		203395.2
Normal force (N)	[Fnorm]		594687.8
Tangent.load at p.c.d.per mm (N/mm) (N/mm)	[w]		2476.07
Only as information: Forces at operating pitch circle:			
Nominal circumferential force (N)	[Ftw]		532526.1
Axial force (N)	[Faw]		144634.2
Radial force (N)	[Frw]		221698.9
Circumferential speed pitch d.. (m/sec)	[v]		0.93
Running-in value (µm)	[yp]		1.3
Running-in value (µm)	[yf]		1.7
Correction coefficient	[CM]		0.800
Gear body coefficient	[CR]		1.000
Reference profile coefficient	[CBS]		0.975
Material coefficient	[E/Est]		1.000
Singular tooth stiffness (N/mm/µm)	[c']		13.900
Meshing stiffness (N/mm/µm)	[cg]		18.081
Reduced mass (kg/mm)	[mRed]		0.33637
Resonance speed (min-1)	[nE1]		4376
Resonance ratio (-)	[N]		0.014
Subcritical range			
Running-in value (µm)	[ya]		1.3
Bearing distance l of pinion shaft (mm)	[l]		500.000
Distance s of pinion shaft (mm)	[s]		50.000
Outside diameter of pinion shaft (mm)	[dsh]		250.000
Load according to Figure 6.8, DIN 3990-1:1987 (0:6.8a, 1:6.8b, 2:6.8c, 3:6.8d, 4:6.8e)	[-]		4
Coefficient K' according to Figure 6.8, DIN 3990-1:1987	[K']		-1.00
Without support effect			
Tooth trace deviation (active) (µm)	[Fby]		61.10
from deformation of shaft (µm)	[fsh*B1]		57.10
Tooth without tooth trace modification			
Position of Contact pattern: favorable			
from production tolerances (µm)	[fma*B2]		11.00
Tooth trace deviation, theoretical (µm)	[Fbx]		67.10
Running-in value (µm)	[yb]		6.00
Dynamic factor	[KV]		1.002
Face load factor - flank	[KHb]		1.223
- Tooth root	[KFb]		1.179
- Scuffing	[KBb]		1.223
Transverse load factor - flank	[KHa]		1.000
- Tooth root	[KFa]		1.000
- Scuffing	[KBa]		1.000
Helical load factor scuffing	[Kbg]		1.204
Number of load cycles (in mio.)	[NL]	8.589	2.114

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: B
(Calculate tooth shape coefficient YF with addendum mod. x)

		------- GEAR 1	-------- GEAR 2 --
Tooth form factor	[YF]	1.34	1.47
Stress correction factor	[YS]	2.36	2.29
Working angle (°)	[alfFen]	24.50	21.30
Bending lever arm (mm)	[hF]	18.97	22.98
Tooth thickness at root (mm)	[sFn]	38.49	40.96
Tooth root radius (mm)	[roF]	6.28	6.36

(hF* = 1.054/ 1.277 sFn* = 2.139/ 2.275 roF* = 0.349/ 0.353 dsFn = 273.30/1177.09 alfsFn = 30.00/ 30.00)

Contact ratio factor	[Yeps]	1.000	
Helical load factor	[Ybet]	0.875	
Effective facewidth (mm)	[beff]	250.00	218.00
Nominal stress at tooth root (N/mm²)	[sigF0]	331.79	403.79
Tooth root stress (N/mm²)	[sigF]	392.14	477.23

Permissible bending stress at root of Test-gear			
Support factor	[YdrelT]	1.005	1.011
Surface factor	[YRrelT]	0.957	0.959
Size coefficient (Tooth root)	[YX]	0.870	0.875
Finite life factor	[YNT]	1.000	1.041
	[YdrelT*YRrelT*YX*YNT]	0.837	0.883
Alternating bending coefficient	[YM]	1.000	1.000
Stress correction factor	[Yst]	2.00	
Yst*sigFlim (N/mm²)	[sigFE]	1000.00	1000.00
Permissible tooth root stress (N/mm²)	[sigFP=sigFG/SFmin]	597.57	630.92
Limit strength tooth root (N/mm²)	[sigFG]	836.60	883.29
Required safety	[SFmin]	1.40	1.40
Safety for Tooth root stress	[SF=sigFG/sigF]	2.13	1.85
Transmittable power (kW)	[kWRating]	765.99	664.53

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		------- GEAR 1	-------- GEAR 2 --
Zone factor	[ZH]	2.307	
Elasticity coefficient (N^.5/mm)	[ZE]	189.812	
Contact ratio factor	[Zeps]	0.845	
Helix angle factor	[Zbet]	0.983	
Effective facewidth (mm)	[beff]	218.00	
Nominal flank pressure (N/mm²)	[sigH0]	1169.85	
Surface pressure at operating pitch circle (N/mm²)	[sigHw]	1295.04	
Single tooth contact factor	[ZB,ZD]	1.00	1.00
Flank pressure (N/mm²)	[sigH]	1295.21	1295.04

Lubrication coefficient at NL	[ZL]	1.014	1.010
Speed coefficient at NL	[ZV]	0.967	0.977
Roughness coefficient at NL	[ZR]	1.012	1.008
Material pairing coefficient at NL	[ZW]	1.000	1.000
Finite life factor	[ZNT]	1.143	1.270
	[ZL*ZV*ZR*ZNT]	1.133	1.263
Small amount of pitting permissible (0=no, 1=yes)		0	0

Size coefficient (flank)	[ZX]	0.971	0.980
Permissible surface pressure (N/mm²)	[sigHP=sigHG/SHmin]	1651.21	1857.50
Limit strength pitting (N/mm²)	[sigHG]	1651.21	1857.50
Safety for surface pressure at operating pitch circle			
	[SHw]	1.28	1.43
Required safety	[SHmin]	1.00	1.00
Transmittable power (kW)	[kWRating]	816.95	1034.09

4b. MICROPITTING ACCORDING TO ISO TR 15144-1:2010

Calculation did not run. (Lubricant: Load stage micropitting test is unknown.)

5. STRENGTH AGAINST SCUFFING

Calculation method according to
DIN 3990:1987

Lubrication coefficient (for lubrication type)	[XS]	1.000	
Relative structure coefficient (Scuffing)	[XWrelT]	1.000	
Thermal contact factor (N/mm/s^.5/K)	[BM]	13.780	13.780
Relevant tip relief (µm)	[Ca]	2.00	2.00
Optimal tip relief (µm)	[Ceff]	136.95	
Ca taken as optimal in the calculation (0=no, 1=yes)		0	0
Effective facewidth (mm)	[beff]	218.000	
Applicable circumferential force/facewidth (N/mm)			
	[wBt]	3652.481	
Pressure angle factor (eps1: 0.853, eps2: 0.548)	[Xalfbet]	1.009	
Flash temperature-criteria			
Tooth mass temperature (°C)	[theM-B]	149.51	
theM-B = theoil + XS*0.47*theflamax	[theflamax]	169.18	
Scuffing temperature (°C)	[theS]	408.58	
Coordinate gamma (point of highest temp.)	[Gamma]	0.426	
[Gamma.A]=-0.517 [Gamma.E]=0.804			
Highest contact temp. (°C)	[theB]	318.69	
Flash factor (°K*N^-.75*s^.5*m^-.5*mm)	[XM]	50.058	
Geometry factor	[XB]	0.189	
Load sharing factor	[XGam]	1.000	
Dynamic viscosity (mPa*s)	[etaM]	4.95 (149.5 °C)	
Coefficient of friction	[mym]	0.206	
Integral temperature-criteria			
Tooth mass temperature (°C)	[theM-C]	105.90	
theM-C = theoil + XS*0.70*theflaint	[theflaint]	51.28	
Integral scuffing temperature (°C)	[theSint]	408.58	
Flash factor (°K*N^-.75*s^.5*m^-.5*mm)	[XM]	50.058	
Contact ratio factor	[Xeps]	0.272	
Dynamic viscosity (mPa*s)	[etaOil]	41.90 (70.0 °C)	
Averaged coefficient of friction	[mym]	0.133	
Geometry factor	[XBE]	0.330	
Meshing factor	[XQ]	1.000	
Tip relief factor	[XCa]	1.016	

Integral tooth flank temperature (°C)	[theint]	182.82

6. MEASUREMENTS FOR TOOTH THICKNESS

		------- GEAR 1 --------	GEAR 2 --
Tooth thickness deviation		DIN 3967 cd25	DIN 3967 cd25
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.130 / -0.190	-0.240 / -0.340
Number of teeth spanned	[k]	3.000	9.000
Base tangent length (no backlash) (mm)	[Wk]	142.685	471.737
Actual base tangent length ('span') (mm)	[Wk.e/i]	142.563 / 142.507	471.511 / 471.417
Diameter of contact point (mm)	[dMWk.m]	311.385	1222.250
Theoretical diameter of ball/pin (mm)	[DM]	35.868	30.645
Eff. Diameter of ball/pin (mm)	[DMeff]	40.000	35.000
Theor. dim. centre to ball (mm)	[MrK]	189.483	637.264
Actual dimension centre to ball (mm)	[MrK.e/i]	189.372 / 189.321	636.976 / 636.856
Diameter of contact point (mm)	[dMMr.m]	318.306	1225.525
Diametral measurement over two balls without clearance (mm)	[MdK]	378.966	1274.165
Actual dimension over balls (mm)	[MdK.e/i]	378.744 / 378.641	1273.590 / 1273.350
Diametral measurement over rolls without clearance (mm)	[MdR]	378.966	1274.527
Actual dimension over rolls (mm)	[MdR.e/i]	378.744 / 378.641	1273.952 / 1273.712
Chordal tooth thickness (no backlash) (mm)	['sn]	33.942	30.369
Actual chordal tooth thickness (mm)	['sn.e/i]	33.812 / 33.752	30.129 / 30.029
Reference chordal height from da.m (mm)	[ha]	26.305	20.585
Tooth thickness (Arc) (mm)	[sn]	34.006	30.372
(mm)	[sn.e/i]	33.876 / 33.816	30.132 / 30.032
Backlash free center distance (mm)	[aControl.e/i]	764.533 /764.330	
Backlash free center distance, allowances (mm)	[jta]	-0.467 / -0.670	
dNf.i with aControl (mm)	[dNf0.i]	283.923	1193.882
Reserve (dNf0.i-dFf.e)/2 (mm)	[cF0.i]	1.172	6.567
Centre distance allowances (mm)	[Aa.e/i]	0.040 / -0.040	
Circumferential backlash from Aa (mm)	[jtw_Aa.e/i]	0.033 / -0.033	
Radial clearance (mm)	[jrw]	0.710 / 0.427	
Circumferential backlash (transverse section) (mm)	[jtw]	0.589 / 0.355	
Torsional angle for fixed gear 1 (°)		0.0558 / 0.0336	
Normal backlash (mm)	[jnw]	0.535 / 0.322	

7. GEAR ACCURACY

		------- GEAR 1 --------	GEAR 2 --
According to DIN 3961:1978:			
Accuracy grade	[Q-DIN3961]	6	6
Profile form deviation (µm)	[ff]	23.00	23.00
Profile slope deviation (µm)	[fHa]	15.00	15.00
Total profile deviation (µm)	[Ff]	28.00	28.00
Helix form deviation (µm)	[ffb]	14.00	14.00
Helix slope deviation (µm)	[fHb]	11.00	11.00
Total helix deviation (µm)	[Fb]	18.00	18.00
Normal base pitch deviation (µm)	[fpe]	17.00	18.00

Single pitch deviation (µm)	[fp]	17.00	18.00
Difference between adjacent pitches (µm)	[fu]	21.00	23.00
Total cumulative pitch deviation (µm)	[Fp]	49.00	61.00
Cumulative circular pitch deviation over z/8 pitches (µm)	[Fpz/8]	31.00	38.00
Concentricity deviation (µm)	[Fr]	40.00	48.00
Tooth Thickness Variation (µm)	[Rs]	23.00	28.00
Total radial composite deviation (µm)	[Fi"]	42.00	50.00
Radial tooth-to-tooth composite deviation (µm)	[fi"]	20.00	23.00
Total tangential composite deviation (µm)	[Fi']	61.00	71.00
Tangential tooth-to-tooth composite deviation (µm)	[fi']	31.00	32.00

Axis alignment tolerances (recommendation acc. ISO TR 10064:1992, Quality		6)
Maximum value for deviation error of axis (µm)	[fSigbet]	27.52 (Fb=24.00)
Maximum value for inclination error of axes (µm)	[fSigdel]	55.05

8. ADDITIONAL DATA

Torsional stiffness (MNm/rad)	[cr]	76.7		1266.0
Mean coeff. of friction (acc. Niemann)	[mum]		0.071	
Wear sliding coef. by Niemann	[zetw]		0.787	
Power loss from gear load (kW)	[PVZ]		5.612	
(Meshing efficiency (%)	[etaz]		98.884)	
Weight - calculated with da (kg)	[Mass]	187.221		2101.750
Total weight (kg)	[Mass]		2288.971	
Moment of inertia (System referenced to wheel 1):				
calculation without consideration of the exact tooth shape				
single gears ((da+df)/2...di) (kg*m²)	[TraeghMom]	1.74553		361.19917
System ((da+df)/2...di) (kg*m²)	[TraeghMom]		23.63121	

9. DETERMINATION OF TOOTHFORM

Data for the tooth form calculation :
Data not available.

REMARKS:
- Specifications with [.e/i] imply: Maximum [e] and Minimal value [i] with consideration of all tolerances
  Specifications with [.m] imply: Mean value within tolerance
- For the backlash tolerance, the center distance tolerances and the tooth thickness deviation are taken into account. Shown is the maximal and the minimal backlash corresponding the largest resp. the smallest allowances
  The calculation is done for the Operating pitch circle..
- Details of calculation method:
  cg according to method B
  KV according to method B
  KHb, KFb according method C
  KHa, KFa according to method B

End of Report lines: 506

PŘÍLOHA č. 2

Výsledky výpočtů hřídelů a jejich uložení

File

Name : Hřídel_0_2_stavy
Changed by: karlova am: 02.05.2014 um: 11:44:10

Important hint: At least one warning has occurred during the calculation:
1-> For shaft with internal diameter the notch factors are limited.
Non of the known calculation methods produces reliable data. It is proposed to use the data for the full shaft and to judge the results conservatively

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label		Shaft 1
Drawing		
Initial position (mm)		0.000
Length (mm)		305.000
Speed (1/min)		800.00
Sense of rotation: clockwise		
Material		18CrNiMo7-6
Young's modulus (N/mm²)		206000.000
Poisson's ratio nu		0.300
Specific weight (kg/m³)		7830.000
Coefficient of thermal expansion	(10^-6/K)	11.500
Temperature (°C)		20.000
Weight of shaft (kg)		36.042
Mass moment of inertia (kg*m²)		0.418
Momentum of mass GD2 (Nm²)		16.401

(Notice: Weight stands for the shaft only without considering the gears)

Label		Shaft 2
Drawing		
Initial position (mm)		25.000
Length (mm)		696.000
Speed (1/min)		800.00
Sense of rotation: clockwise		
Material		18CrNiMo7-6
Young's modulus (N/mm²)		206000.000
Poisson's ratio nu		0.300
Specific weight (kg/m³)		7830.000
Coefficient of thermal expansion	(10^-6/K)	11.500
Temperature (°C)		20.000
Weight of shaft (kg)		42.802
Mass moment of inertia (kg*m²)		0.054
Momentum of mass GD2 (Nm²)		2.099

(Notice: Weight stands for the shaft only without considering the gears)

Position in space (°)	0.000

Regard gears as masses and stiffness	
Consider deformations due to shearing	
Shear correction coefficient	1.100
Contact angle of rolling bearings is considered	
Reference temperature (°C)	20.000

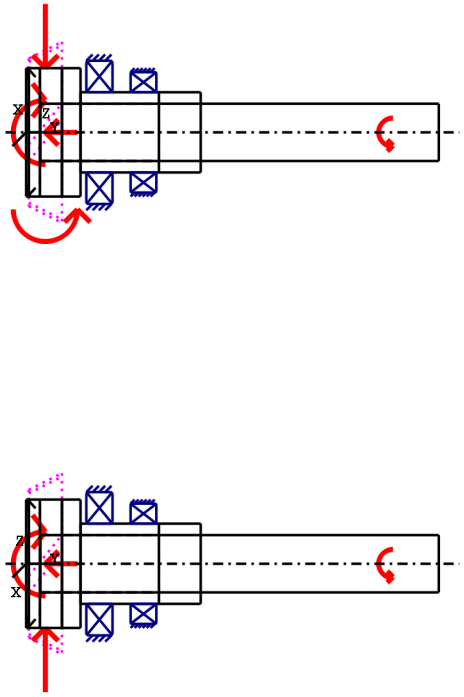


Figure: Load applications

SHAFT DEFINITION (Shaft 1)

Outer contour

Cylinder (Cylinder) y= 0.00...95.00 (mm)
d=224.10 (mm), l=95.00 (mm), Rz= 8.0

Chamfer right (Chamfer right)
l=20.00 (mm), alpha=45.00 (°)

Cylinder (Cylinder) y= 95.00...305.00 (mm)
d=140.00 (mm), l=210.00 (mm), Rz= 8.0

Radius left (Radius left)
r=5.00 (mm), Rz= 8.0

Inner contour

Cone inside (Conical bore) y= 0.00...24.00 (mm)
d1=220.00 (mm), d2=176.32 (mm), l=24.00 (mm)

Cylinder inside (Cylindrical bore) y= 24.00...232.00 (mm)
d=100.00 (mm), l=208.00 (mm)

Forces

Bevel gear (Bevel gear / hypoid gear) y= 33.59 (mm)

Operating pitch diameter	(mm)	287.0170	
Helix angle	(°)	30.0000	left
Half angle of cone	(°)	45.0000	Tip to the left
Working pressure angle at normal section	(°)	20.0000	
Position of contact point	(°)	0.0000	
Face width	(mm)	82.0000	
Axial force (Load spectrum)	(N)	-4643.68/-3250.57	
Shearing force X (Load spectrum)	(N)	-29493.53/-20645.47	
Shearing force Z (Load spectrum)	(N)	41809.37/29266.56	
Bending moment X (Load spectrum)	(N)	0.00/0.00	
Bending moment Z (Load spectrum)	(N)	-666.41/-466.48	

load spectrum,driving (Output):

Element	Frequency (%)	Speed (1/min)	Power (kW)	Torque (Nm)
1	20.0000	800.0	-502.7	-6000.0
2	80.0000	800.0	-351.9	-4200.0

Bearing

Taper roller bearing (single row) SKF 30228J2 (Kuzelikove_leve) y= 128.00 (mm)
Set fixed bearing right
d = 140.000 (mm), D = 250.000 (mm), B = 45.750 (mm), r = 4.000 (mm)
C = 418.000 (kN), C0 = 570.000 (kN), Cu = 58.500 (kN)
The bearing pressure angle will be considered in the calculation
Position (center of pressure) (mm) 103.8750

Taper roller bearing (single row) SKF 32028 X (Kuzelikove_prave) y= 205.00 (mm)
Set fixed bearing left
d = 140.000 (mm), D = 210.000 (mm), B = 45.000 (mm), r = 2.500 (mm)
C = 330.000 (kN), C0 = 565.000 (kN), Cu = 58.500 (kN)
The bearing pressure angle will be considered in the calculation
Position (center of pressure) (mm) 228.5000

SHAFT DEFINITION (Shaft 2)

Outer contour

Cylinder (Cylinder) y= 0.00...696.00 (mm)
d=100.00 (mm), l=696.00 (mm), Rz= 8.0

Inner contour

Forces

Coupling (Coupling / Motor) y= 616.00 (mm)

Eff. Diameter	(mm)	0.0000
Radial force coefficient	(-)	0.0000
Direction of radial force	(°)	0.0000
Axial force coefficient	(-)	0.0000
Length of load application	(mm)	160.0000
Mass	(kg)	0.0000

load spectrum,driven (Input):

Element	Frequency (%)	Speed (1/min)	Power (kW)	Torque (Nm)
1	20.0000	800.0	502.7	6000.0
2	80.0000	800.0	351.9	4200.0

Bearing

CONNECTIONS

Joint, general: Shaft 'Shaft 2' <-> Shaft 'Shaft 1' y= 160.00 (mm)

Degrees of freedom
X: fixed, Y: fixed, Z: fixed
Rx: fixed, Ry: fixed, Rz: fixed

Shaft 'Shaft 1': Bevel gear 'Bevel gear / hypoid gear' (y= 14.2993 (mm)) is taken into account as component of the shaft.
EI (y= 4.5986 (mm)): 1815809.6264 (Nm˳), EI (y= 24.0000 (mm)): 15730430.0599 (Nm˳), m (yS= 15.2207 (mm)): 2.7131 (kg)
Jp: 0.0420 (kg*m˳), Jxx: 0.0211 (kg*m˳), Jzz: 0.0211 (kg*m˳)

Shaft 'Shaft 1': Bevel gear 'Bevel gear / hypoid gear' (y= 43.2907 (mm)) is taken into account as component of the shaft.
EI (y= 24.0000 (mm)): 24492579.3823 (Nm˳), EI (y= 62.5814 (mm)): 24492579.3823 (Nm˳), m (yS= 45.1277 (mm)): 9.6547 (kg)
Jp: 0.1717 (kg*m˳), Jxx: 0.0870 (kg*m˳), Jzz: 0.0870 (kg*m˳)

---

maximum deflection 28.55 µm (Shaft 2, 721.00 (mm))

Center of mass

Shaft 1	189.5	mm
Shaft 2	348.0	mm

Deformation due to torsion

Shaft 1	[phi.t]	0.01	°
Shaft 2	[phi.t]	0.21	°

Probability of failure	[n]	10.00	%
Axial clearance	[uA]	10.00	µm

Rolling bearings, classical calculation (contact angle considered)

Shaft 'Shaft 1' Rolling bearing 'Kuzelikove_leve'

Position (Y-coordinate)	[y]	128.00	mm
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	10180.92	h
Operating viscosity	[nu]	48.88	mm²/s
Reference viscosity	[nu1]	0.00	mm²/s
static safety factor	[S0]	6.85	

	Bearing reaction force			Bearing reaction moment		
	Fx (kN)	Fy (kN)	Fz (kN)	Mx (Nm)	My (Nm)	Mz (Nm)
1	51.474	-29.729	-65.416	1578.166	0.000	1241.819
2	36.032	-20.812	-45.800	1104.915	0.000	869.273

	Displacement of bearing			Misalignment of bearing		
	ux (mm)	uy (mm)	uz (mm)	ux (mrad)	uy (mrad)	uz (mrad)
1	0.0011	-0.0117	-0.0012	-0.050	0.103	-0.046
2	0.0008	-0.0112	-0.0008	-0.035	0.072	-0.032

Shaft 'Shaft 1' Rolling bearing 'Kuzelikove_prave'

Position (Y-coordinate)	[y]	205.00	mm
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	15514.38	h
Operating viscosity	[nu]	48.88	mm²/s
Reference viscosity	[nu1]	0.00	mm²/s
static safety factor	[S0]	13.94	

	Bearing reaction force			Bearing reaction moment		
	Fx (kN)	Fy (kN)	Fz (kN)	Mx (Nm)	My (Nm)	Mz (Nm)
1	-21.981	34.372	24.502	575.790	0.000	516.549
2	-15.387	24.063	17.428	409.556	0.000	361.585

	Displacement of bearing			Misalignment of bearing		
	ux (mm)	uy (mm)	uz (mm)	ux (mrad)	uy (mrad)	uz (mrad)
1	-0.0002	-0.0100	0.0002	-0.011	0.190	-0.009
2	-0.0001	-0.0100	0.0002	-0.008	0.133	-0.007

Bearing 'Joint, general'

Position (Y-coordinate)	[y]	160.00	mm

	Bearing reaction force			Bearing reaction moment		
	Fx (kN)	Fy (kN)	Fz (kN)	Mx (Nm)	My (Nm)	Mz (Nm)
1	0.000	0.000	0.420	89.422	-6000.000	0.000
2	0.000	0.000	0.420	89.422	-4200.000	0.000

	Displacement of bearing			Misalignment of bearing		
	ux (mm)	uy (mm)	uz (mm)	ux (mrad)	uy (mrad)	uz (mrad)
1	0.0000	0.0000	-0.0000	-0.000	0.000	0.000
2	0.0000	0.0000	-0.0000	-0.000	0.000	0.000

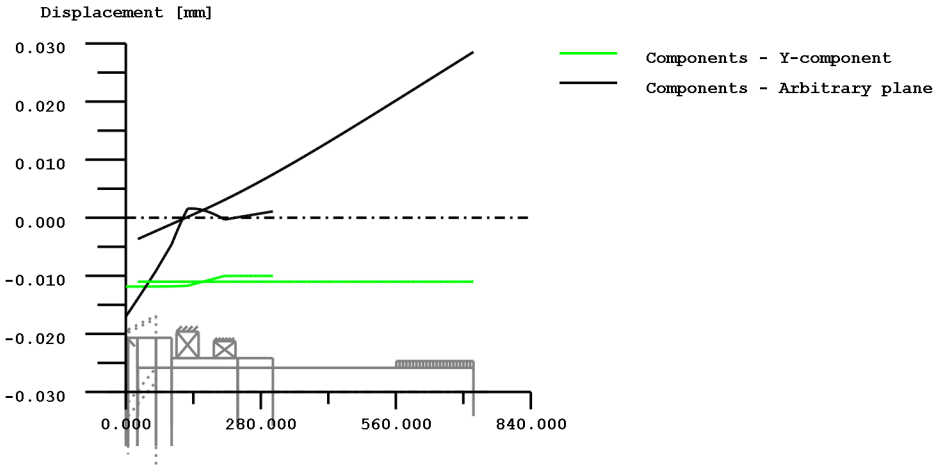
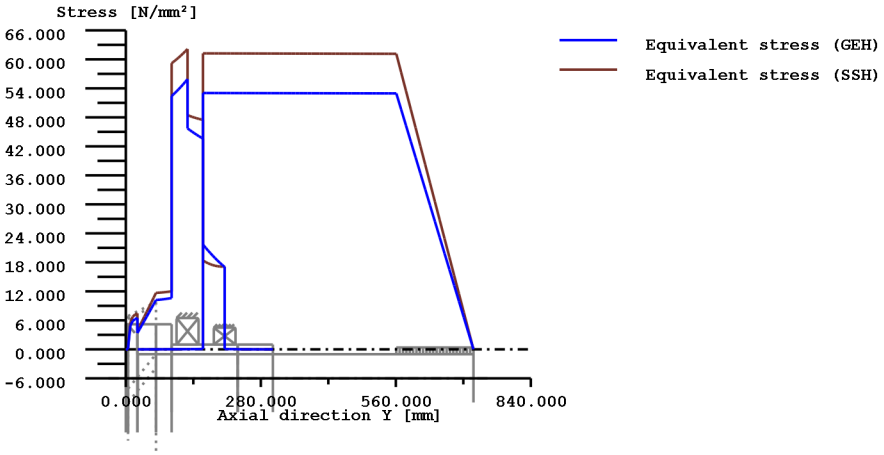


Figure: Displacement (bending etc.) (Arbitrary plane -58.28266122 °)



GEH(von Mises): sigV = ((sigB+sigZ,D)^2 + 3*(tauT+tauS)^2)^1/2SSH(Tresca): sigV = ((sigB-sigZ,D)^2 + 4*(tauT+tauS)^2)^1/2
Figure: Equivalent stress

Strength calculation as specified in

DIN 743:2012

with finite life fatigue strength according to FKM standard and FVA draft

Summary

Label	Shaft 1
Drawing	

Material	18CrNiMo7-6
Material type	Case-carburized steel
Material treatment	case-hardened
Surface treatment	No

Calculation of service strength and static strength
Woehler line (S-N curve) according Miner elementary
Calculation for load case 2 (sig.av/sig.mv = const)

Cross section	Position (Y-Coord) (mm)	
A-A	95.00	Shoulder
B-B	232.00	Smooth shaft

Results:

Cross section	Kfb	Kfsig	K2d	SD	SS	SA
A-A	2.07	0.88	0.80	6.31	11.27	24.36
B-B	1.00	0.88	0.80	10000.00	10000.00	10000.00
Nominal safety:				1.20	1.20	1.20

Abbreviations:
Kfb: Notch factor bending
Kfsig: Surface factor
K2d: Size coefficient bending
SD: Safety endurance limit
SS: Safety against yield point
SA: Safety against incipient crack

The requirements of the safety proof of the shaft are:

satisfied [x] not satisfied [ ]

Design engineer:..... Date:..... Signature:.....

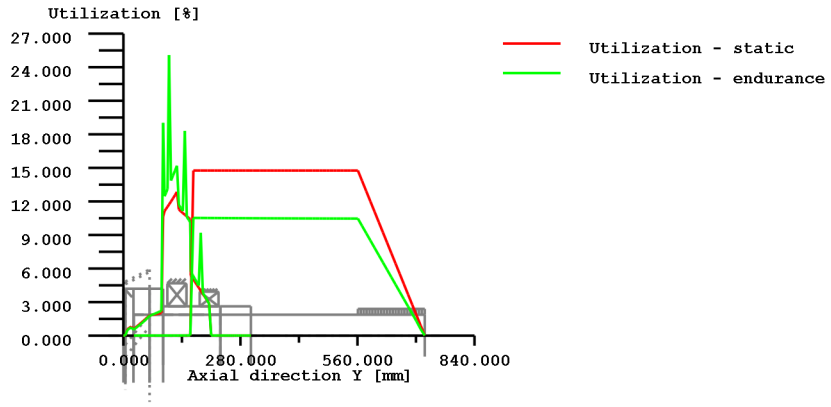


Figure: Strength

Calculation details:

General statements

Label	Shaft 1		
Drawing			
Length (mm)		[l]	305.00
Speed (1/min)		[n]	800.00

Material	18CrNiMo7-6
Material type	Case-carburized steel
Material treatment	case-hardened
Surface treatment	No

	Tension/Compression	Bending	Torsion	Shearing
Load factor static calculation	1.700	1.700	1.700	1.700
Load factor endurance limit	1.000	1.000	1.000	1.000

Reference diameter material (mm)	[dB]	16.00
sigB according DIN 743 (at dB) (N/mm²)	[sigB]	1200.00
sigS according DIN 743 (at dB) (N/mm²)	[sigS]	850.00
[sigzdW] (bei dB) (N/mm²)		480.00
[sigbW] (bei dB) (N/mm²)		600.00
[tautW] (bei dB) (N/mm²)		360.00
Thickness of raw material (mm)	[dWerkst]	230.00

Material data calculated according DIN743/3 with K1(d)
Material strength calculated from size of raw material
Geometric size coefficient K1d calculated from raw material diameter

[sigBeff] (N/mm²)	838.83

[sigSeff] (N/mm²)	594.17
[sigbF] (N/mm²)	653.59
[tautF] (N/mm²)	377.35
[sigBRand] (N/mm²)	2300.00
[sigzdW] (N/mm²)	335.53
[sigbW] (N/mm²)	419.41
[tautW] (N/mm²)	251.65

Service strength for a load spectrum
Woehler line (S-N curve) according Miner elementary

Required life time	[h]	2400.00
Number of load cycles (Mio)	[NL]	115.200

Data of Woehler line (S-N curve) analog to FKM standard:

[ksigma, ktau]	15	25
[kDsigma, kDtau]	0	0
[NDsigma, NDtau]	1e+006	1e+006
[NDsigmaII, NDtauII]	0	0
[DM]	0.3	

Calculation for load case 2 (sig.av/sig.mv = const)

Cross section 'A-A' Shoulder

Comment				
Position (Y-Coordinate) (mm)		[y]		95.00
External diameter (mm)		[da]		140.000
Inner diameter (mm)		[di]		100.000
Notch effect	Shoulder			
[D, r, t] (mm)	224.100	5.000	0.000	
Mean roughness (µm)		[Rz]		8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	2321.8	0.0	3000.0	0.0
Amplitude	2321.8	3557.8	3000.0	50912.0
Maximum value	7894.2	6048.2	10200.0	86550.4
Cross section, moment of resistance: (mm²)				
[A, Wb, Wt, A]	7539.8	199266.7	398533.5	7539.8

Load spectrum, load base values (Mean-value + Amplitude):

Element	Frequency (%)	Tens./Press. (N)	Bending (Nm)	Torsion (Nm)	Shearing (N)
1	20.00	4643.676	3557.782	6000.000	50911.979
2	80.00	3250.573	2487.387	4200.000	35562.514

Stresses: (N/mm²)

[sigzdm, sigbm, taum, tauqm] (N/mm²)	0.308	0.000	7.528	0.000
[sigzda, sigba, taua, tauqa] (N/mm²)	0.308	17.854	7.528	13.261
[sigzdmax,sigbmax,taumax,tauqmax] (N/mm²)	1.047	30.352	25.594	22.545

Technological size influence	[K1(sigB)]	0.699
	[K1(sigS)]	0.699

	Tension/Compression	Bending	Torsion

Stress concentration factor		[alfa]	2.665	2.349	1.712
References stress slope		[G']	0.460	0.460	0.230
Notch sensitivity factor	n	[n]	1.135	1.135	1.096
Notch effect coefficient		[beta]	2.347	2.069	1.563
Geometrical size influence		[K2(d)]	1.000	0.805	0.805
Influence coefficient surface roughness		[KF]	0.876	0.876	0.929
Influence coefficient surface strengthening		[KV]	1.000	1.000	1.000
Total influence coefficient		[K]	2.489	2.713	2.019

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm²)	[sigmV]		13.042	
Equivalent mean stress (N/mm²)	[taumV]		7.530	
Fatigue limit of part (N/mm²)	[sigWK]	134.831	154.615	124.651
Influence coeff. mean stress sensitivity.	[PsisigK]	0.087	0.102	0.080
Permissible amplitude (N/mm²)	[sigADK]	15.076	143.942	115.387
Permissible amplitude (N/mm²)	[sigANK]	15.076	143.942	115.387
Load spectrum factor	[fKoll]	1.000	1.000	1.000
Margin of safety endurance limit	[S]		6.309	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		525.7	

Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.000	1.000
Increase coefficient	[gammaF]	1.100	1.100	1.000
Yield stress of part (N/mm²)	[sigFK]	653.586	653.586	343.043
Margin of safety yield stress	[S]		11.269	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		939.1	

Present margin of safety for proof of avoiding incipient crack on hard surface layers:		
Safety against incipient crack	[S]	24.357
Required safety	[Smin]	1.200
Result (%)	[S/Smin]	2029.8

Cross section 'B-B' Smooth shaft

Comment		
Position (Y-Coordinate) (mm)	[y]	232.00
External diameter (mm)	[da]	140.000
Inner diameter (mm)	[di]	0.000
Notch effect	Smooth shaft	
Mean roughness (µm)	[Rz]	8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	0.0	0.0	0.0	0.0
Amplitude	0.0	3.1	0.0	83.6
Maximum value	0.0	5.4	0.0	142.1
Cross section, moment of resistance: (mm²)				
[A, Wb, Wt, A]	15393.8	269391.6	538783.1	15393.8

Load spectrum, load base values (Mean-value + Amplitude):

Element	Frequency (%)	Tens./Press. (N)	Bending (Nm)	Torsion (Nm)	Shearing (N)
1	20.00	0.000	3.148	0.000	83.607
2	80.00	0.000	3.148	0.000	83.607

Stresses: (N/mm²)					
[sigzdm, sigbm, taum, tauqm] (N/mm²)		0.000	0.000	0.000	0.000
[sigzda, sigba, taua, tauqa] (N/mm²)		0.000	0.012	0.000	0.007
[sigzdmax,sigbmax,taumax,tauqmax] (N/mm²)		0.000	0.020	0.000	0.012
Technological size influence	[K1(sigB)]	0.699			
	[K1(sigS)]	0.699			

		Tension/Compression	Bending	Torsion
Notch effect coefficient	[beta]	1.000	1.000	1.000
Geometrical size influence	[K2(d)]	1.000	0.805	0.805
Influence coefficient surface roughness	[KF]	0.876	0.876	0.929
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	1.141	1.384	1.319

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm²)	[sigmV]		0.000	
Equivalent mean stress (N/mm²)	[taumV]		0.000	
Fatigue limit of part (N/mm²)	[sigWK]	294.023	303.041	190.726
Influence coeff. mean stress sensitivity.	[PsisigK]	0.213	0.220	0.128
Permissible amplitude (N/mm²)	[sigADK]	294.023	303.041	190.726
Permissible amplitude (N/mm²)	[sigANK]	294.023	303.041	190.726
Load spectrum factor	[fKoll]	1.000	1.000	1.000
Margin of safety endurance limit	[S]		10000.000	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		10000.0	

Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.100	1.100
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm²)	[sigFK]	594.169	653.586	377.348
Margin of safety yield stress	[S]		10000.000	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		10000.0	

Present margin of safety for proof of avoiding incipient crack on hard surface layers:		
Safety against incipient crack	[S]	9999.999
Required safety	[Smin]	1.200
Result (%)	[S/Smin]	833333.3

Remarks:

- The shearing force is not considered in the analysis specified in DIN 743.

- Cross section with interference fit:
  The notching factor for the light fit case is no longer defined in DIN 743.
  The values are imported from the FKM-Guideline..

End of Report lines: 507

KISSsoft Release 03/2013

KISSsoft evaluation

File

Name : Hřídel_0_2_stavy_krátky
Changed by: karlova am: 02.05.2014 um: 11:46:57

Important hint: At least one warning has occurred during the calculation:
1-> For shaft with internal diameter the notch factors are limited.
Non of the known calculation methods produces reliable data. It is proposed to use the data for the full shaft and to judge the results conservatively

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label		Shaft 1
Drawing		
Initial position (mm)		0.000
Length (mm)		434.000
Speed (1/min)		800.00
Sense of rotation: clockwise		
Material		18CrNiMo7-6
Young's modulus (N/mm²)		206000.000
Poisson's ratio nu		0.300
Specific weight (kg/m³)		7830.000
Coefficient of thermal expansion	(10^-6/K)	11.500
Temperature (°C)		20.000
Weight of shaft (kg)		57.776
Mass moment of inertia (kg*m²)		0.489
Momentum of mass GD2 (Nm²)		19.179

(Notice: Weight stands for the shaft only without considering the gears)

Label		Shaft 2
Drawing		
Initial position (mm)		25.000
Length (mm)		525.000
Speed (1/min)		800.00
Sense of rotation: clockwise		
Material		18CrNiMo7-6
Young's modulus (N/mm²)		206000.000
Poisson's ratio nu		0.300
Specific weight (kg/m³)		7830.000
Coefficient of thermal expansion	(10^-6/K)	11.500
Temperature (°C)		20.000
Weight of shaft (kg)		32.286
Mass moment of inertia (kg*m²)		0.040
Momentum of mass GD2 (Nm²)		1.584

(Notice: Weight stands for the shaft only without considering the gears)

Position in space (°)	0.000

Regard gears as masses and stiffness	
Consider deformations due to shearing	
Shear correction coefficient	1.100
Contact angle of rolling bearings is considered	
Reference temperature (°C)	20.000

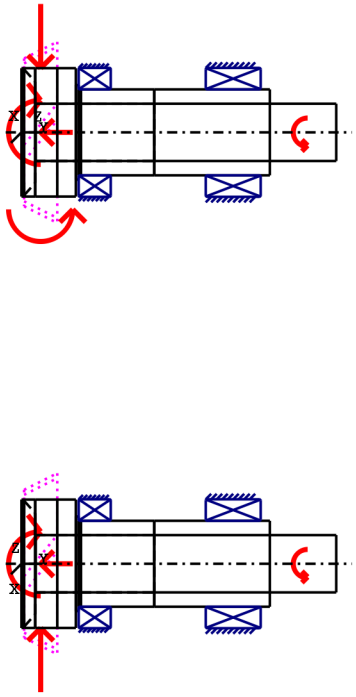


Figure: Load applications

SHAFT DEFINITION (Shaft 1)

Outer contour

Cylinder (Cylinder) y= 0.00...95.00 (mm)
d=224.10 (mm), l=95.00 (mm), Rz= 8.0

Chamfer right (Chamfer right)
l=20.00 (mm), alpha=45.00 (°)

Cylinder (Cylinder) y= 95.00...100.00 (mm)
d=165.00 (mm), l=5.00 (mm), Rz= 8.0

Radius left (Radius left)
r=2.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 100.00...104.00 (mm)
d=149.20 (mm), l=4.00 (mm), Rz= 8.0

Radius left (Radius left)
r=1.00 (mm), Rz= 8.0

Radius right (Radius right)
r=1.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 104.00...434.00 (mm)
d=150.00 (mm), l=330.00 (mm), Rz= 8.0

Inner contour

Cone inside (Conical bore) y= 0.00...24.00 (mm)
d1=220.00 (mm), d2=176.32 (mm), l=24.00 (mm)

Cylinder inside (Cylindrical bore) y= 24.00...232.00 (mm)
d=100.00 (mm), l=208.00 (mm)

Forces

Bevel gear (Bevel gear / hypoid gear) y= 33.59 (mm)

Operating pitch diameter	(mm)	287.0170	
Helix angle	(°)	30.0000	left
Half angle of cone	(°)	45.0000	Tip to the left
Working pressure angle at normal section	(°)	20.0000	
Position of contact point	(°)	0.0000	
Face width	(mm)	82.0000	
Axial force (Load spectrum)	(N)	-4643.68/-3250.57	
Shearing force X (Load spectrum)	(N)	-29493.53/-20645.47	
Shearing force Z (Load spectrum)	(N)	41809.37/29266.56	
Bending moment X (Load spectrum)	(N)	0.00/0.00	
Bending moment Z (Load spectrum)	(N)	-666.41/-466.48	

load spectrum,driving (Output):

Element	Frequency (%)	Speed (1/min)	Power (kW)	Torque (Nm)
1	20.0000	800.0	-502.7	-6000.0
2	80.0000	800.0	-351.9	-4200.0

Bearing

Spherical roller bearings SKF *23030CC/W33 (Soudeckove) y= 128.00 (mm)
Free bearing
d = 150.000 (mm), D = 225.000 (mm), B = 56.000 (mm), r = 2.100 (mm)
C = 510.000 (kN), C0 = 750.000 (kN), Cu = 73.500 (kN)
Bearing clearance DIN 620:1988 C0 (140.00 µm)

Taper roller bearing (paired) (X,TDI) SKF 32030 X/DF (Kuzelikove) y= 370.00 (mm)
Fixed bearing
d = 150.000 (mm), D = 225.000 (mm), B = 96.000 (mm), r = 2.500 (mm)
C = 644.000 (kN), C0 = 1320.000 (kN), Cu = 132.000 (kN)

SHAFT DEFINITION (Shaft 2)

Outer contour

Cylinder (Cylinder) y= 0.00...525.00 (mm)

d=100.00 (mm), l=525.00 (mm), Rz= 8.0

Inner contour

Forces

Coupling (Coupling / Motor) y= 475.00 (mm)

Eff. Diameter	(mm)	0.0000
Radial force coefficient	(-)	0.0000
Direction of radial force	(°)	0.0000
Axial force coefficient	(-)	0.0000
Length of load application	(mm)	100.0000
Mass	(kg)	0.0000

load spectrum,driven (Input):

Element	Frequency (%)	Speed (1/min)	Power (kW)	Torque (Nm)
1	20.0000	800.0	502.7	6000.0
2	80.0000	800.0	351.9	4200.0

Bearing

CONNECTIONS

Joint, general: Shaft 'Shaft 2' <-> Shaft 'Shaft 1' y= 160.00 (mm)

Degrees of freedom

X: fixed, Y: fixed, Z: fixed

Rx: fixed, Ry: fixed, Rz: fixed

Shaft 'Shaft 1': Bevel gear 'Bevel gear / hypoid gear' (y= 14.2993 (mm)) is taken into account as component of the shaft.
EI (y= 4.5986 (mm)): 1815809.6264 (Nm˳), EI (y= 24.0000 (mm)): 15730430.0599 (Nm˳), m (yS= 15.2207 (mm)): 2.7131 (kg)
Jp: 0.0420 (kg*m˳), Jxx: 0.0211 (kg*m˳), Jzz: 0.0211 (kg*m˳)

Shaft 'Shaft 1': Bevel gear 'Bevel gear / hypoid gear' (y= 43.2907 (mm)) is taken into account as component of the shaft.
EI (y= 24.0000 (mm)): 24492579.3823 (Nm˳), EI (y= 62.5814 (mm)): 24492579.3823 (Nm˳), m (yS= 45.1277 (mm)): 9.6547 (kg)
Jp: 0.1717 (kg*m˳), Jxx: 0.0870 (kg*m˳), Jzz: 0.0870 (kg*m˳)

---

maximum deflection 130.12 µm (Shaft 1, 0.00 (mm))

Center of mass

Shaft 1	244.3	mm
Shaft 2	262.5	mm

Deformation due to torsion

Shaft 1	[phi.t]	0.01	°
Shaft 2	[phi.t]	0.15	°

Probability of failure	[n]	10.00	%
Axial clearance	[uA]	10.00	µm

Rolling bearings, classical calculation (contact angle considered)

Shaft 'Shaft 1' Rolling bearing 'Soudeckove'

Position (Y-coordinate)	[y]	128.00	mm
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	31891.02	h
Operating viscosity	[nu]	48.88	mm²/s
Reference viscosity	[nu1]	0.00	mm²/s
static safety factor	[S0]	10.38	

	Bearing reaction force			Bearing reaction moment		
	Fx (kN)	Fy (kN)	Fz (kN)	Mx (Nm)	My (Nm)	Mz (Nm)
1	43.753	0.000	-57.470	0.000	0.000	0.000
2	30.627	0.000	-40.034	0.000	0.000	0.000

	Displacement of bearing			Misalignment of bearing		
	ux (mm)	uy (mm)	uz (mm)	ux (mrad)	uy (mrad)	uz (mrad)
1	-0.0414	-0.0104	0.0564	-0.325	0.073	-0.252
2	-0.0415	-0.0103	0.0563	-0.297	0.051	-0.228

Shaft 'Shaft 1' Rolling bearing 'Kuzelikove'

Position (Y-coordinate)	[y]	370.00	mm
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	> 1000000	h
Operating viscosity	[nu]	48.88	mm²/s
Reference viscosity	[nu1]	0.00	mm²/s
static safety factor	[S0]	46.42	

	Bearing reaction force			Bearing reaction moment		
	Fx (kN)	Fy (kN)	Fz (kN)	Mx (Nm)	My (Nm)	Mz (Nm)
1	-14.260	4.644	16.666	0.000	0.000	0.000
2	-9.982	3.251	11.773	0.000	0.000	0.000

	Displacement of bearing			Misalignment of bearing		
	ux (mm)	uy (mm)	uz (mm)	ux (mrad)	uy (mrad)	uz (mrad)
1	0.0000	-0.0100	-0.0000	-0.216	0.133	-0.156
2	0.0000	-0.0100	-0.0000	-0.221	0.093	-0.161

Bearing 'Joint, general'

Position (Y-coordinate)	[y]	160.00	mm

	Bearing reaction force			Bearing reaction moment		
	Fx (kN)	Fy (kN)	Fz (kN)	Mx (Nm)	My (Nm)	Mz (Nm)
1	0.000	0.000	0.317	40.376	-6000.000	0.000
2	0.000	0.000	0.317	40.376	-4200.000	0.000

	Displacement of bearing	Misalignment of bearing

	ux (mm)	uy (mm)	uz (mm)	ux (mrad)	uy (mrad)	uz (mrad)
1	0.0000	0.0000	-0.0000	-0.000	0.000	0.000
2	0.0000	0.0000	-0.0000	-0.000	0.000	0.000

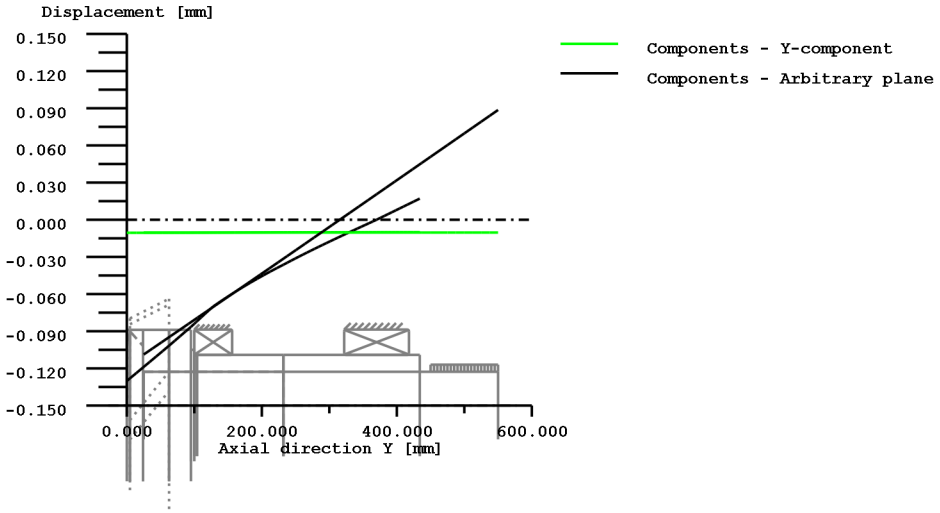
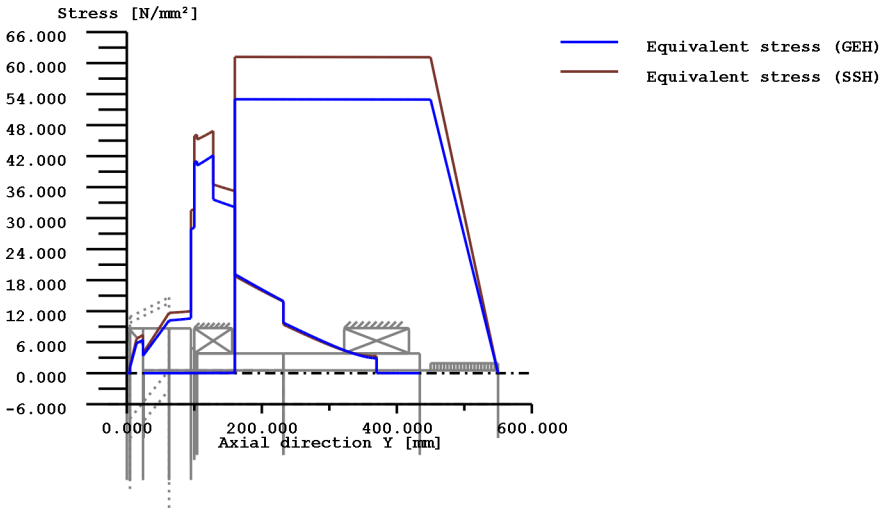


Figure: Displacement (bending etc.) (Arbitrary plane -52.95998969 °)



GEH(von Mises): sigV = ((sigB+sigZ,D)^2 + 3*(tauT+tauS)^2)^1/2SSH(Tresca): sigV = ((sigB-sigZ,D)^2 + 4*(tauT+tauS)^2)^1/2
Figure: Equivalent stress

Strength calculation as specified in

DIN 743:2012

with finite life fatigue strength according to FKM standard and FVA draft

Summary

Label	Shaft 1
Drawing	

Material	18CrNiMo7-6
Material type	Case-carburized steel
Material treatment	case-hardened
Surface treatment	No

Calculation of service strength and static strength
Woehler line (S-N curve) according Miner elementary
Calculation for load case 2 (sig.av/sig.mv = const)

Cross section	Position (Y-Coord) (mm)	
A-A	100.00	Shoulder

Results:

Cross section	Kfb	Kfsig	K2d	SD	SS	SA
A-A	2.67	0.88	0.80	6.50	14.62	21.38
Nominal safety:				1.20	1.20	1.20

Abbreviations:
Kfb: Notch factor bending
Kfsig: Surface factor
K2d: Size coefficient bending
SD: Safety endurance limit
SS: Safety against yield point
SA: Safety against incipient crack

The requirements of the safety proof of the shaft are:

satisfied [x] not satisfied [ ]

Design engineer:..... Date:..... Signature:.....

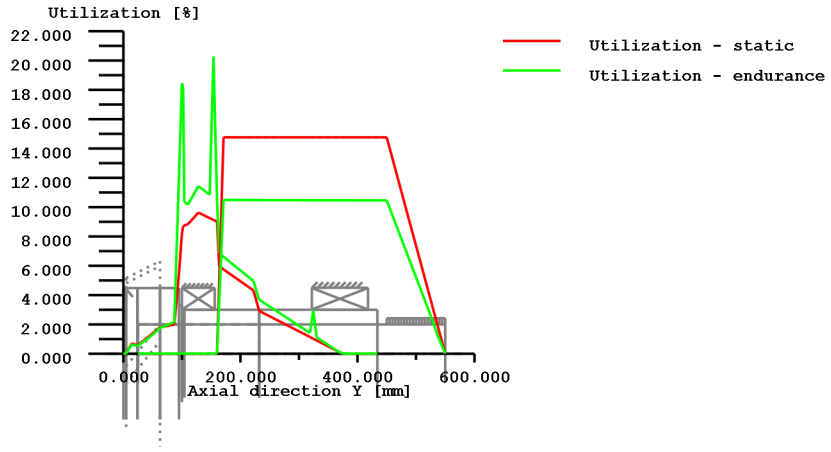


Figure: Strength

Calculation details:

General statements

Label	Shaft 1		
Drawing			
Length (mm)		[l]	434.00
Speed (1/min)		[n]	800.00

Material	18CrNiMo7-6
Material type	Case-carburized steel
Material treatment	case-hardened
Surface treatment	No

	Tension/Compression	Bending	Torsion	Shearing
Load factor static calculation	1.700	1.700	1.700	1.700
Load factor endurance limit	1.000	1.000	1.000	1.000

Reference diameter material (mm)	[dB]	16.00
sigB according DIN 743 (at dB) (N/mm²)	[sigB]	1200.00
sigS according DIN 743 (at dB) (N/mm²)	[sigS]	850.00
[sigzdW] (bei dB) (N/mm²)		480.00
[sigbW] (bei dB) (N/mm²)		600.00
[tautW] (bei dB) (N/mm²)		360.00
Thickness of raw material (mm)	[dWerkst]	230.00

Material data calculated according DIN743/3 with K1(d)
Material strength calculated from size of raw material
Geometric size coefficient K1d calculated from raw material diameter

[sigBeff] (N/mm²)	838.83

[sigSeff] (N/mm²)	594.17
[sigbF] (N/mm²)	653.59
[tautF] (N/mm²)	377.35
[sigBRand] (N/mm²)	2300.00
[sigzdW] (N/mm²)	335.53
[sigbW] (N/mm²)	419.41
[tautW] (N/mm²)	251.65

Service strength for a load spectrum

Woehler line (S-N curve) according	Miner elementary		
Required life time	[h]	2400.00	
Number of load cycles (Mio)	[NL]	115.200	
Data of Woehler line (S-N curve) analog to FKM standard:			
[ksigma, ktau]	15	25	
[kDsigma, kDtau]	0	0	
[NDsigma, NDtau]	1e+006	1e+006	
[NDsigmaII, NDtauII]	0	0	
[DM]	0.3		

Calculation for load case 2 (sig.av/sig.mv = const)

Cross section 'A-A' Shoulder

Comment				
Position (Y-Coordinate) (mm)	[y]	100.00		
External diameter (mm)	[da]	149.200		
Inner diameter (mm)	[di]	100.000		
Notch effect	Shoulder			
[D, r, t] (mm)	165.000	1.000	0.000	
Mean roughness (µm)	[Rz]	8.000		

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	2321.8	0.0	3000.0	0.0
Amplitude	2321.8	3809.6	3000.0	50907.9
Maximum value	7894.2	6476.3	10200.0	86543.5
Cross section, moment of resistance: (mm²)				
[A, Wb, Wt, A]	9629.5	260265.9	520531.7	9629.5

Load spectrum, load base values (Mean-value + Amplitude):

Element	Frequency (%)	Tens./Press. (N)	Bending (Nm)	Torsion (Nm)	Shearing (N)
1	20.00	4643.676	3809.579	6000.000	50907.945
2	80.00	3250.573	2663.276	4200.000	35558.484

Stresses: (N/mm²)

[sigzdm, sigbm, taum, tauqm] (N/mm²)	0.241	0.000	5.763	0.000
[sigzda, sigba, taua, tauqa] (N/mm²)	0.241	14.637	5.763	10.309
[sigzdmax,sigbmax,taumax,tauqmax] (N/mm²)	0.820	24.883	19.595	17.525

Technological size influence	[K1(sigB)]	0.699
	[K1(sigS)]	0.699

	Tension/Compression	Bending	Torsion

Stress concentration factor		[alfa]	3.810	3.510	2.190
References stress slope		[G']	2.474	2.474	1.150
Notch sensitivity factor	n	[n]	1.314	1.314	1.214
Notch effect coefficient		[beta]	2.900	2.672	1.804
Geometrical size influence		[K2(d)]	1.000	0.800	0.800
Influence coefficient surface roughness		[KF]	0.876	0.876	0.929
Influence coefficient surface strengthening		[KV]	1.000	1.000	1.000
Total influence coefficient		[K]	3.041	3.479	2.330

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm²)	[sigmV]		9.985	
Equivalent mean stress (N/mm²)	[taumV]		5.765	
Fatigue limit of part (N/mm²)	[sigWK]	110.337	120.540	107.988
Influence coeff. mean stress sensitivity.	[PsisigK]	0.070	0.077	0.069
Permissible amplitude (N/mm²)	[sigADK]	16.111	114.494	101.035
Permissible amplitude (N/mm²)	[sigANK]	16.111	114.494	101.035
Load spectrum factor	[fKoll]	1.000	1.000	1.000
Margin of safety endurance limit	[S]		6.503	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		541.9	

Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.000	1.000
Increase coefficient	[gammaF]	1.150	1.150	1.000
Yield stress of part (N/mm²)	[sigFK]	683.294	683.294	343.043
Margin of safety yield stress	[S]		14.621	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1218.4	

Present margin of safety for proof of avoiding incipient crack on hard surface layers:		
Safety against incipient crack	[S]	21.379
Required safety	[Smin]	1.200
Result (%)	[S/Smin]	1781.5

Remarks:

- The shearing force is not considered in the analysis specified in DIN 743.
- Cross section with interference fit:
  The notching factor for the light fit case is no longer defined in DIN 743.
  The values are imported from the FKM-Guideline..

End of Report lines: 443

KISSsoft Release 03/2013

KISSsoft evaluation

File

Name : Hřídel_0_2_stavy_krátky
Changed by: karlova am: 02.05.2014 um: 10:50:43

Important hint: At least one warning has occurred during the calculation:
1-> For shaft with internal diameter the notch factors are limited.
Non of the known calculation methods produces reliable data. It is proposed to use the data for the full shaft and to judge the results conservatively

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label		Shaft 1
Drawing		
Initial position (mm)		0.000
Length (mm)		434.000
Speed (1/min)		800.00
Sense of rotation: clockwise		
Material		18CrNiMo7-6
Young's modulus (N/mm²)		206000.000
Poisson's ratio nu		0.300
Specific weight (kg/m³)		7830.000
Coefficient of thermal expansion	(10^-6/K)	11.500
Temperature (°C)		20.000
Weight of shaft (kg)		57.776
Mass moment of inertia (kg*m²)		0.489
Momentum of mass GD2 (Nm²)		19.179

(Notice: Weight stands for the shaft only without considering the gears)

Label		Shaft 2
Drawing		
Initial position (mm)		25.000
Length (mm)		525.000
Speed (1/min)		800.00
Sense of rotation: clockwise		
Material		18CrNiMo7-6
Young's modulus (N/mm²)		206000.000
Poisson's ratio nu		0.300
Specific weight (kg/m³)		7830.000
Coefficient of thermal expansion	(10^-6/K)	11.500
Temperature (°C)		20.000
Weight of shaft (kg)		32.286
Mass moment of inertia (kg*m²)		0.040
Momentum of mass GD2 (Nm²)		1.584

(Notice: Weight stands for the shaft only without considering the gears)

Position in space (°)	0.000

Regard gears as masses and stiffness	
Consider deformations due to shearing	
Shear correction coefficient	1.100
Contact angle of rolling bearings is considered	
Reference temperature (°C)	20.000

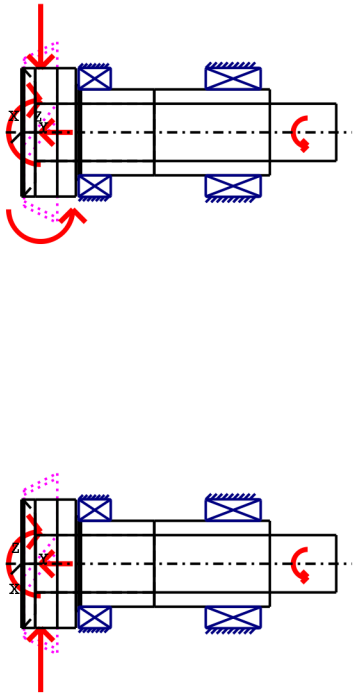


Figure: Load applications

SHAFT DEFINITION (Shaft 1)

Outer contour

Cylinder (Cylinder) y= 0.00...95.00 (mm)
d=224.10 (mm), l=95.00 (mm), Rz= 8.0

Chamfer right (Chamfer right)
l=20.00 (mm), alpha=45.00 (°)

Cylinder (Cylinder) y= 95.00...100.00 (mm)
d=165.00 (mm), l=5.00 (mm), Rz= 8.0

Radius left (Radius left)
r=2.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 100.00...104.00 (mm)
d=149.20 (mm), l=4.00 (mm), Rz= 8.0

Radius left (Radius left)
r=1.00 (mm), Rz= 8.0

Radius right (Radius right)
r=1.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 104.00...434.00 (mm)
d=150.00 (mm), l=330.00 (mm), Rz= 8.0

Inner contour

Cone inside (Conical bore) y= 0.00...24.00 (mm)
d1=220.00 (mm), d2=176.32 (mm), l=24.00 (mm)

Cylinder inside (Cylindrical bore) y= 24.00...232.00 (mm)
d=100.00 (mm), l=208.00 (mm)

Forces

Bevel gear (Bevel gear / hypoid gear) y= 33.59 (mm)

Operating pitch diameter	(mm)	287.0170	
Helix angle	(°)	30.0000	left
Half angle of cone	(°)	45.0000	Tip to the left
Working pressure angle at normal section	(°)	20.0000	
Position of contact point	(°)	0.0000	
Face width	(mm)	82.0000	
Power	(kW)	502.6548	driving (Output)
Torque	(Nm)	-6000.0000	
Axial force	(N)	-4643.6764	
Shearing force X	(N)	-29493.5314	
Shearing force Z	(N)	41809.3702	
Bending moment X	(Nm)	0.0000	
Bending moment Z	(Nm)	-666.4070	

Bearing

Spherical roller bearings SKF *23030CC/W33 (Soudeckove) y= 128.00 (mm)
Free bearing
d = 150.000 (mm), D = 225.000 (mm), B = 56.000 (mm), r = 2.100 (mm)
C = 510.000 (kN), C0 = 750.000 (kN), Cu = 73.500 (kN)
Bearing clearance DIN 620:1988 C0 (140.00 µm)

Taper roller bearing (paired) (X,TDI) SKF 32030 X/DF (Kuzelikove) y= 370.00 (mm)
Fixed bearing
d = 150.000 (mm), D = 225.000 (mm), B = 96.000 (mm), r = 2.500 (mm)
C = 644.000 (kN), C0 = 1320.000 (kN), Cu = 132.000 (kN)

SHAFT DEFINITION (Shaft 2)

Outer contour

Cylinder (Cylinder) y= 0.00...525.00 (mm)
d=100.00 (mm), l=525.00 (mm), Rz= 8.0

Inner contour

Forces

Coupling (Coupling / Motor)			y= 475.00 (mm)
Eff. Diameter	(mm)	0.0000	
Radial force coefficient	(-)	0.0000	
Direction of radial force	(°)	0.0000	
Axial force coefficient	(-)	0.0000	
Length of load application	(mm)	100.0000	
Power	(kW)	502.6548	driven (Input)
Torque	(Nm)	6000.0000	
Mass	(kg)	0.0000	

Bearing

CONNECTIONS

Joint, general: Shaft 'Shaft 2' <-> Shaft 'Shaft 1' y= 160.00 (mm)

Degrees of freedom
X: fixed, Y: fixed, Z: fixed
Rx: fixed, Ry: fixed, Rz: fixed

Shaft 'Shaft 1': Bevel gear 'Bevel gear / hypoid gear' (y= 14.2993 (mm)) is taken into account as component of the shaft.
EI (y= 4.5986 (mm)): 1815809.6264 (Nm˳), EI (y= 24.0000 (mm)): 15730430.0599 (Nm˳), m (yS= 15.2207 (mm)): 2.7131 (kg)
Jp: 0.0420 (kg*m˳), Jxx: 0.0211 (kg*m˳), Jzz: 0.0211 (kg*m˳)

Shaft 'Shaft 1': Bevel gear 'Bevel gear / hypoid gear' (y= 43.2907 (mm)) is taken into account as component of the shaft.
EI (y= 24.0000 (mm)): 24492579.3823 (Nm˳), EI (y= 62.5814 (mm)): 24492579.3823 (Nm˳), m (yS= 45.1277 (mm)): 9.6547 (kg)
Jp: 0.1717 (kg*m˳), Jxx: 0.0870 (kg*m˳), Jzz: 0.0870 (kg*m˳)

---

maximum deflection 130.12 µm (Shaft 1, 0.00 (mm))

Center of mass

Shaft 1	244.3	mm
Shaft 2	262.5	mm

Deformation due to torsion

Shaft 1	[phi.t]	0.01	°
Shaft 2	[phi.t]	0.15	°

Probability of failure	[n]	10.00	%

Axial clearance	[uA]	10.00	µm

Rolling bearings, classical calculation (contact angle considered)

Shaft 'Shaft 1' Rolling bearing 'Soudeckove'

Position (Y-coordinate)	[y]	128.00	mm
Equivalent load	[P]	72.23	kN
Equivalent load	[P0]	72.23	kN
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	14069.04	h
Operating viscosity	[nu]	48.88	mm¿/s
Reference viscosity	[nu1]	0.00	mm¿/s
static safety factor	[S0]	10.38	
Bearing reaction force	[Fx]	43.753	kN
Bearing reaction force	[Fy]	0.000	kN
Bearing reaction force	[Fz]	-57.470	kN
Bearing reaction force	[Fr]	72.230	kN (-52.72°)
Oil level	[H]	103.125	mm
Torque of friction	[Mloss]	17.204	Nm
Power loss	[Ploss]	1441.267	W
Displacement of bearing	[ux]	-0.041	mm
Displacement of bearing	[uy]	-0.010	mm
Displacement of bearing	[uz]	0.056	mm
Displacement of bearing	[ur]	0.070	mm (126.28°)
Misalignment of bearing	[rx]	-0.325	mrad (-1.12')
Misalignment of bearing	[ry]	0.073	mrad (0.25')
Misalignment of bearing	[rz]	-0.252	mrad (-0.86')
Misalignment of bearing	[rr]	0.411	mrad (1.41')

Shaft 'Shaft 1' Rolling bearing 'Kuzelikove'

Position (Y-coordinate)	[y]	370.00	mm
Equivalent load	[P]	28.90	kN
Equivalent load	[P0]	28.43	kN
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	648761.11	h
Operating viscosity	[nu]	48.88	mm¿/s
Reference viscosity	[nu1]	0.00	mm¿/s
static safety factor	[S0]	46.42	
Bearing reaction force	[Fx]	-14.260	kN
Bearing reaction force	[Fy]	4.644	kN
Bearing reaction force	[Fz]	16.666	kN
Bearing reaction force	[Fr]	21.934	kN (130.55°)
Oil level	[H]	103.125	mm
Torque of friction	[Mloss]	22.812	Nm
Power loss	[Ploss]	1911.055	W
Displacement of bearing	[ux]	0.000	mm
Displacement of bearing	[uy]	-0.010	mm
Displacement of bearing	[uz]	-0.000	mm
Displacement of bearing	[ur]	0.000	mm
Misalignment of bearing	[rx]	-0.216	mrad (-0.74')
Misalignment of bearing	[ry]	0.133	mrad (0.46')
Misalignment of bearing	[rz]	-0.156	mrad (-0.54')
Misalignment of bearing	[rr]	0.267	mrad (0.92')

Bearing 'Joint, general'

Position (Y-coordinate)	[y]	160.00	mm
Bearing reaction force	[Fx]	0.000	kN
Bearing reaction force	[Fy]	0.000	kN
Bearing reaction force	[Fz]	0.317	kN
Bearing reaction force	[Fr]	0.317	kN (90°)
Bearing reaction moment	[Mx]	40.38	Nm
Bearing reaction moment	[My]	-6000.00	Nm
Bearing reaction moment	[Mz]	0.00	Nm
Bearing reaction moment	[Mr]	40.38	Nm (0°)
Displacement of bearing	[ux]	0.000	mm
Displacement of bearing	[uy]	0.000	mm
Displacement of bearing	[uz]	-0.000	mm
Displacement of bearing	[ur]	0.000	mm
Misalignment of bearing	[rx]	-0.000	mrad (0')
Misalignment of bearing	[ry]	0.000	mrad (0')
Misalignment of bearing	[rz]	0.000	mrad (0')
Misalignment of bearing	[rr]	0.000	mrad (0')

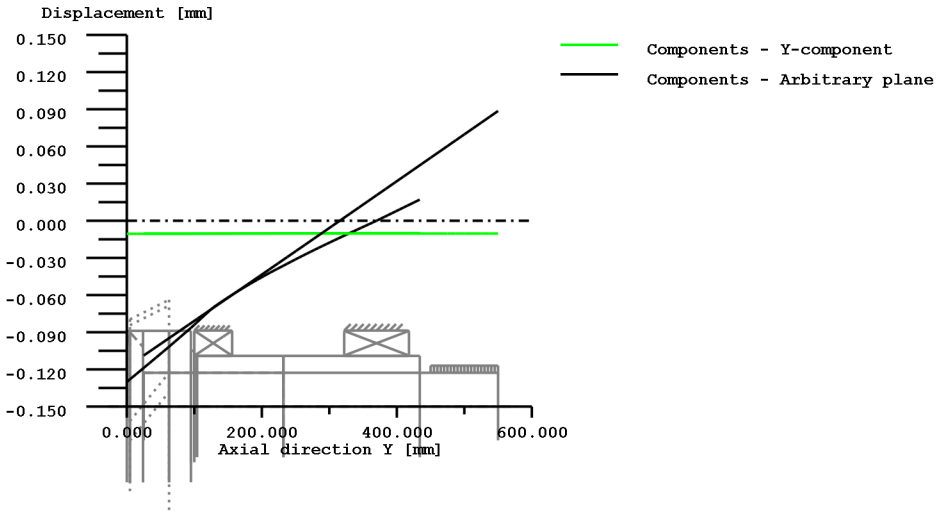
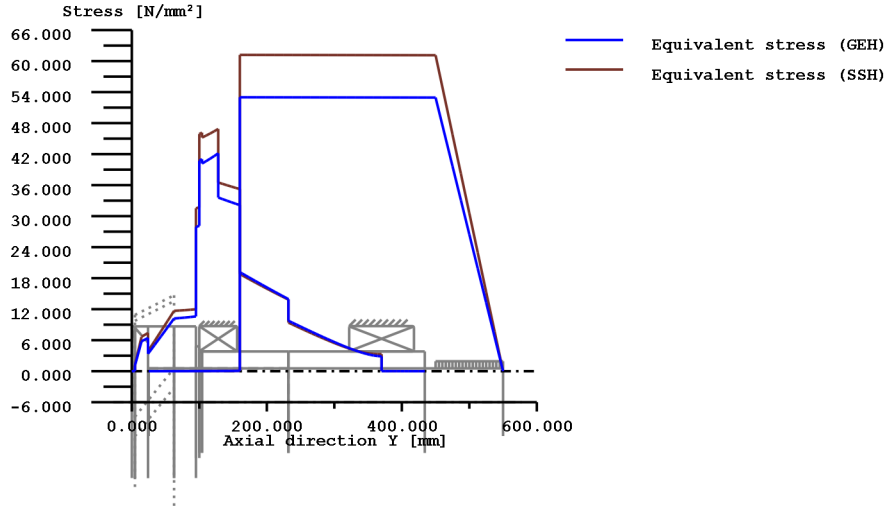


Figure: Displacement (bending etc.) (Arbitrary plane -52.95998969 °)



GEH(von Mises): sigV = ((sigB+sigZ,D)^2 + 3*(tauT+tauS)^2)^1/2SSH(Tresca): sigV = ((sigB-sigZ,D)^2 + 4*(tauT+tauS)^2)^1/2
Figure: Equivalent stress

Eigenfrequencies/Critical speeds

1. Eigenfrequency:	0.00 Hz, Critical speed:	0.00 1/min	Rigid body rotation Y 'Shaft 1'
2. Eigenfrequency:	415.19 Hz, Critical speed:	24911.17 1/min	Bending YZ 'Shaft 2'
3. Eigenfrequency:	1391.19 Hz, Critical speed:	83471.29 1/min	Bending YZ 'Shaft 1'
4. Eigenfrequency:	1934.02 Hz, Critical speed:	116041.00 1/min	Axial 'Shaft 1'

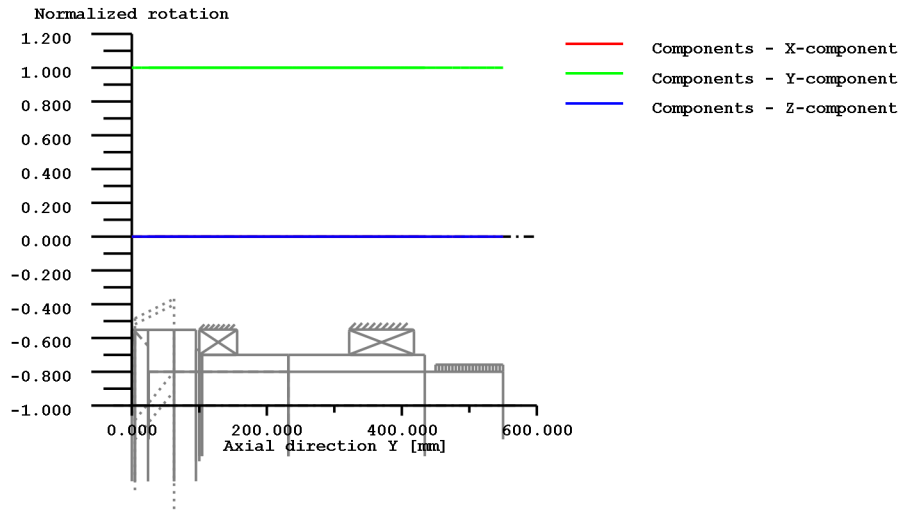


Figure: Eigenfrequencies (Normalized displacement)

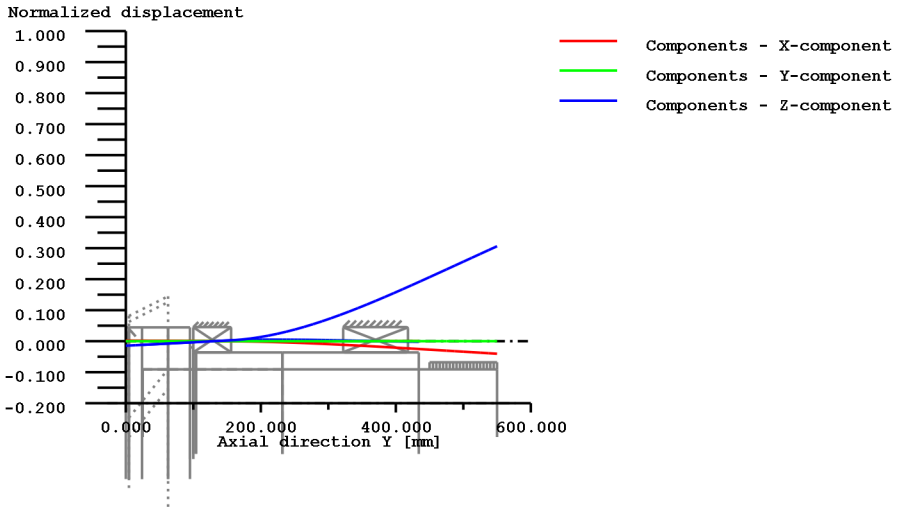


Figure: Eigenfrequencies (Normalized rotation)

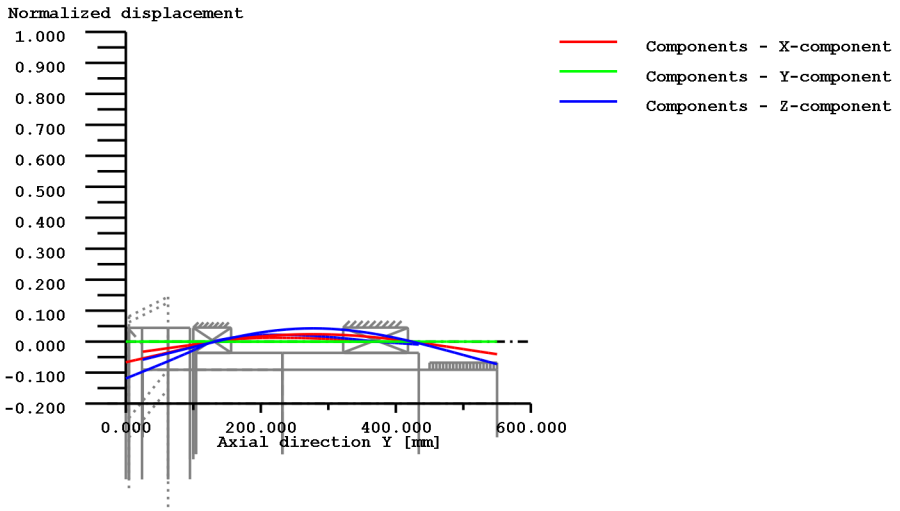


Figure: Eigenfrequencies (Normalized rotation)

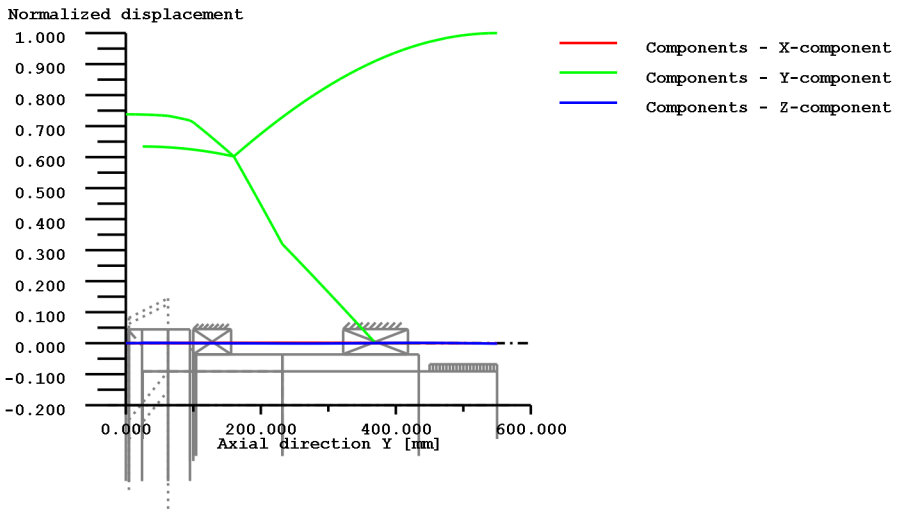


Figure: Eigenfrequencies (Normalized rotation)

Strength calculation as specified in

DIN 743:2012

Summary

Label	Shaft 1
Drawing	

Material	18CrNiMo7-6
Material type	Case-carburized steel
Material treatment	case-hardened
Surface treatment	No

Calculation of endurance limit and the static strength
Calculation for load case 2 (sig.av/sig.mv = const)

Cross section	Position (Y-Coord) (mm)	
A-A	100.00	Shoulder

Results:

Cross section	Kfb	Kfsig	K2d	SD	SS	SA
A-A	2.67	0.88	0.80	6.50	14.62	21.38
Nominal safety:				1.20	1.20	1.20

Abbreviations:
Kfb: Notch factor bending
Kfsig: Surface factor
K2d: Size coefficient bending
SD: Safety endurance limit
SS: Safety against yield point
SA: Safety against incipient crack

The requirements of the safety proof of the shaft are:

satisfied [x] not satisfied [ ]

Design engineer:..... Date:..... Signature:.....

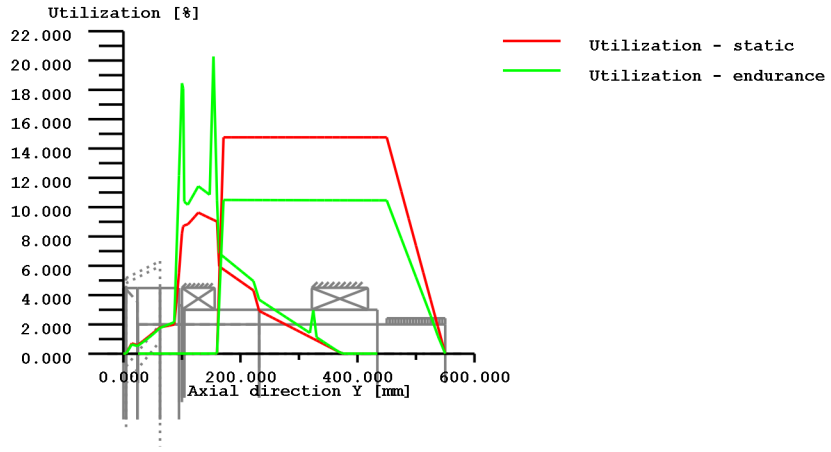


Figure: Strength

Calculation details:

General statements

Label	Shaft 1		
Drawing			
Length (mm)		[l]	434.00
Speed (1/min)		[n]	800.00

Material	18CrNiMo7-6
Material type	Case-carburized steel
Material treatment	case-hardened
Surface treatment	No

	Tension/Compression	Bending	Torsion	Shearing
Load factor static calculation	1.700	1.700	1.700	1.700
Load factor endurance limit	1.000	1.000	1.000	1.000

Reference diameter material (mm)	[dB]	16.00
sigB according DIN 743 (at dB) (N/mm²)	[sigB]	1200.00
sigS according DIN 743 (at dB) (N/mm²)	[sigS]	850.00
[sigzdW] (bei dB) (N/mm²)		480.00
[sigbW] (bei dB) (N/mm²)		600.00
[tautW] (bei dB) (N/mm²)		360.00
Thickness of raw material (mm)	[dWerkst]	230.00

Material data calculated according DIN743/3 with K1(d)
Material strength calculated from size of raw material
Geometric size coefficient K1d calculated from raw material diameter

[sigBeff] (N/mm²)	838.83

[sigSeff] (N/mm²)	594.17
[sigbF] (N/mm²)	653.59
[tautF] (N/mm²)	377.35
[sigBRand] (N/mm²)	2300.00
[sigzdW] (N/mm²)	335.53
[sigbW] (N/mm²)	419.41
[tautW] (N/mm²)	251.65

Endurance limit for single stage use

Calculation for load case 2 (sig.av/sig.mv = const)

Cross section 'A-A' Shoulder

Comment					
Position (Y-Coordinate) (mm)		[y]		100.00	
External diameter (mm)		[da]		149.200	
Inner diameter (mm)		[di]		100.000	
Notch effect	Shoulder				
[D, r, t] (mm)	165.000	1.000	0.000		
Mean roughness (µm)		[Rz]		8.000	

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	2321.8	0.0	3000.0	0.0
Amplitude	2321.8	3809.6	3000.0	50910.7
Maximum value	7894.2	6476.3	10200.0	86548.2
Cross section, moment of resistance: (mm²)				
[A, Wb, Wt, A]	9629.5	260265.9	520531.7	9629.5

Stresses: (N/mm²)					
[sigzdm, sigbm, taum, tauqm] (N/mm²)		0.241	0.000	5.763	0.000
[sigzda, sigba, taua, tauqa] (N/mm²)		0.241	14.637	5.763	10.309
[sigzdmax,sigbmax,taumax,tauqmax] (N/mm²)		0.820	24.883	19.595	17.526
Technological size influence	[K1(sigB)]	0.699			
	[K1(sigS)]	0.699			

		Tension/Compression	Bending	Torsion
Stress concentration factor	[alfa]	3.810	3.510	2.190
References stress slope	[G']	2.474	2.474	1.150
Notch sensitivity factor n	[n]	1.314	1.314	1.214
Notch effect coefficient	[beta]	2.900	2.672	1.804
Geometrical size influence	[K2(d)]	1.000	0.800	0.800
Influence coefficient surface roughness				
	[KF]	0.876	0.876	0.929
Influence coefficient surface strengthening				
	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	3.041	3.479	2.330

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm²)	[sigmV]		9.985	
Equivalent mean stress (N/mm²)	[taumV]		5.765	
Fatigue limit of part (N/mm²)	[sigWK]	110.337	120.540	107.988

Influence coeff. mean stress sensitivity.				
	[PsisigK]	0.070	0.077	0.069
Permissible amplitude (N/mm²)	[sigADK]	16.111	114.494	101.035
Margin of safety endurance limit	[S]		6.503	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		541.9	
Present margin of safety				
for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.000	1.000
Increase coefficient	[gammaF]	1.150	1.150	1.000
Yield stress of part (N/mm²)	[sigFK]	683.294	683.294	343.043
Margin of safety yield stress	[S]		14.621	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1218.4	
Present margin of safety				
for proof of avoiding incipient crack on hard surface layers:				
Safety against incipient crack	[S]		21.379	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1781.5	

Remarks:

- The shearing force is not considered in the analysis specified in DIN 743.
- Cross section with interference fit:
  The notching factor for the light fit case is no longer defined in DIN 743.
  The values are imported from the FKM-Guideline..

End of Report lines: 449

File

Name : Hřídel_0_2_stavy
Changed by: karlova am: 02.05.2014 um: 11:45:08

Important hint: At least one warning has occurred during the calculation:
1-> For shaft with internal diameter the notch factors are limited.
Non of the known calculation methods produces reliable data. It is proposed to use the data for the full shaft and to judge the results conservatively

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label		Shaft 1
Drawing		
Initial position (mm)		0.000
Length (mm)		305.000
Speed (1/min)		800.00
Sense of rotation: clockwise		
Material		18CrNiMo7-6
Young's modulus (N/mm²)		206000.000
Poisson's ratio nu		0.300
Specific weight (kg/m³)		7830.000
Coefficient of thermal expansion	(10^-6/K)	11.500
Temperature (°C)		20.000
Weight of shaft (kg)		36.042
Mass moment of inertia (kg*m²)		0.418
Momentum of mass GD2 (Nm²)		16.401

(Notice: Weight stands for the shaft only without considering the gears)

Label		Shaft 2
Drawing		
Initial position (mm)		25.000
Length (mm)		696.000
Speed (1/min)		800.00
Sense of rotation: clockwise		
Material		18CrNiMo7-6
Young's modulus (N/mm²)		206000.000
Poisson's ratio nu		0.300
Specific weight (kg/m³)		7830.000
Coefficient of thermal expansion	(10^-6/K)	11.500
Temperature (°C)		20.000
Weight of shaft (kg)		42.802
Mass moment of inertia (kg*m²)		0.054
Momentum of mass GD2 (Nm²)		2.099

(Notice: Weight stands for the shaft only without considering the gears)

Position in space (°)	0.000

Regard gears as masses and stiffness	
Consider deformations due to shearing	
Shear correction coefficient	1.100
Contact angle of rolling bearings is considered	
Reference temperature (°C)	20.000

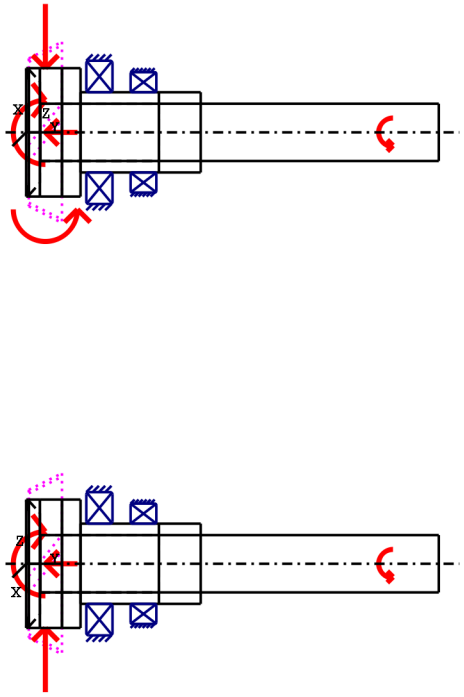


Figure: Load applications

SHAFT DEFINITION (Shaft 1)

Outer contour

Cylinder (Cylinder) y= 0.00...95.00 (mm)
d=224.10 (mm), l=95.00 (mm), Rz= 8.0

Chamfer right (Chamfer right)
l=20.00 (mm), alpha=45.00 (°)

Cylinder (Cylinder) y= 95.00...305.00 (mm)
d=140.00 (mm), l=210.00 (mm), Rz= 8.0

Radius left (Radius left)
r=5.00 (mm), Rz= 8.0

Inner contour

Cone inside (Conical bore) y= 0.00...24.00 (mm)
d1=220.00 (mm), d2=176.32 (mm), l=24.00 (mm)

Cylinder inside (Cylindrical bore) y= 24.00...232.00 (mm)
d=100.00 (mm), l=208.00 (mm)

Forces

Bevel gear (Bevel gear / hypoid gear) y= 33.59 (mm)

Operating pitch diameter	(mm)	287.0170	
Helix angle	(°)	30.0000	left
Half angle of cone	(°)	45.0000	Tip to the left
Working pressure angle at normal section	(°)	20.0000	
Position of contact point	(°)	0.0000	
Face width	(mm)	82.0000	
Power	(kW)	502.6548	driving (Output)
Torque	(Nm)	-6000.0000	
Axial force	(N)	-4643.6764	
Shearing force X	(N)	-29493.5314	
Shearing force Z	(N)	41809.3702	
Bending moment X	(Nm)	0.0000	
Bending moment Z	(Nm)	-666.4070	

Bearing

Taper roller bearing (single row) SKF 30228J2 (Kuzelikove_leve) y= 128.00 (mm)
Set fixed bearing right
d = 140.000 (mm), D = 250.000 (mm), B = 45.750 (mm), r = 4.000 (mm)
C = 418.000 (kN), C0 = 570.000 (kN), Cu = 58.500 (kN)
The bearing pressure angle will be considered in the calculation
Position (center of pressure) (mm) 103.8750

Taper roller bearing (single row) SKF 32028 X (Kuzelikove_prave) y= 205.00 (mm)
Set fixed bearing left
d = 140.000 (mm), D = 210.000 (mm), B = 45.000 (mm), r = 2.500 (mm)
C = 330.000 (kN), C0 = 565.000 (kN), Cu = 58.500 (kN)
The bearing pressure angle will be considered in the calculation
Position (center of pressure) (mm) 228.5000

SHAFT DEFINITION (Shaft 2)

Outer contour

Cylinder (Cylinder) y= 0.00...696.00 (mm)
d=100.00 (mm), l=696.00 (mm), Rz= 8.0

Inner contour

Forces

Coupling (Coupling / Motor) y= 616.00 (mm)

Eff. Diameter	(mm)	0.0000
Radial force coefficient	(-)	0.0000

Direction of radial force	(°)	0.0000	
Axial force coefficient	(-)	0.0000	
Length of load application	(mm)	160.0000	
Power	(kW)	502.6548	driven (Input)
Torque	(Nm)	6000.0000	
Mass	(kg)	0.0000	

Bearing

CONNECTIONS

Joint, general: Shaft 'Shaft 2' <-> Shaft 'Shaft 1' y= 160.00 (mm)

Degrees of freedom

X: fixed, Y: fixed, Z: fixed

Rx: fixed, Ry: fixed, Rz: fixed

Shaft 'Shaft 1': Bevel gear 'Bevel gear / hypoid gear' (y= 14.2993 (mm)) is taken into account as component of the shaft.

EI (y= 4.5986 (mm)): 1815809.6264 (Nm˳), EI (y= 24.0000 (mm)): 15730430.0599 (Nm˳), m (yS= 15.2207 (mm)): 2.7131 (kg)

Jp: 0.0420 (kg*m˳), Jxx: 0.0211 (kg*m˳), Jzz: 0.0211 (kg*m˳)

Shaft 'Shaft 1': Bevel gear 'Bevel gear / hypoid gear' (y= 43.2907 (mm)) is taken into account as component of the shaft.

EI (y= 24.0000 (mm)): 24492579.3823 (Nm˳), EI (y= 62.5814 (mm)): 24492579.3823 (Nm˳), m (yS= 45.1277 (mm)): 9.6547 (kg)

Jp: 0.1717 (kg*m˳), Jxx: 0.0870 (kg*m˳), Jzz: 0.0870 (kg*m˳)

---

maximum deflection		28.55	µm (Shaft 2, 721.00 (mm))

Center of mass

Shaft 1		189.5	mm
Shaft 2		348.0	mm

Deformation due to torsion

Shaft 1	[phi.t]	0.01	°
Shaft 2	[phi.t]	0.21	°

Probability of failure	[n]	10.00	%
Axial clearance	[uA]	10.00	µm

Rolling bearings, classical calculation (contact angle considered)

Shaft 'Shaft 1' Rolling bearing 'Kuzelikove_leve'

Position (Y-coordinate)	[y]	128.00	mm
Equivalent load	[P]	83.24	kN
Equivalent load	[P0]	83.24	kN
Life modification factor for reliability	[a1]	1.000	

Service life	[Lnh]	4517.59	h
Operating viscosity	[nu]	48.88	mm²/s
Reference viscosity	[nu1]	0.00	mm²/s
static safety factor	[S0]	6.85	
Bearing reaction force	[Fx]	51.474	kN
Bearing reaction force	[Fy]	-29.729	kN
Bearing reaction force	[Fz]	-65.416	kN
Bearing reaction force	[Fr]	83.240	kN (-51.8°)
Bearing reaction moment	[Mx]	1578.17	Nm
Bearing reaction moment	[My]	0.00	Nm
Bearing reaction moment	[Mz]	1241.82	Nm
Bearing reaction moment	[Mr]	2008.16	Nm (38.2°)
Oil level	[H]	111.250	mm
Torque of friction	[Mloss]	19.454	Nm
Power loss	[Ploss]	1629.740	W
Displacement of bearing	[ux]	0.001	mm
Displacement of bearing	[uy]	-0.012	mm
Displacement of bearing	[uz]	-0.001	mm
Displacement of bearing	[ur]	0.002	mm (-47.31°)
Misalignment of bearing	[rx]	-0.050	mrad (-0.17')
Misalignment of bearing	[ry]	0.103	mrad (0.35')
Misalignment of bearing	[rz]	-0.046	mrad (-0.16')
Misalignment of bearing	[rr]	0.068	mrad (0.23')

Shaft 'Shaft 1' Rolling bearing 'Kuzelikove_prave'

Position (Y-coordinate)	[y]	205.00	mm
Equivalent load	[P]	57.85	kN
Equivalent load	[P0]	40.52	kN
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	6909.54	h
Operating viscosity	[nu]	48.88	mm²/s
Reference viscosity	[nu1]	0.00	mm²/s
static safety factor	[S0]	13.94	
Bearing reaction force	[Fx]	-21.981	kN
Bearing reaction force	[Fy]	34.372	kN
Bearing reaction force	[Fz]	24.502	kN
Bearing reaction force	[Fr]	32.916	kN (131.9°)
Bearing reaction moment	[Mx]	575.79	Nm
Bearing reaction moment	[My]	0.00	Nm
Bearing reaction moment	[Mz]	516.55	Nm
Bearing reaction moment	[Mr]	773.54	Nm (41.9°)
Oil level	[H]	96.250	mm
Torque of friction	[Mloss]	19.186	Nm
Power loss	[Ploss]	1607.342	W
Displacement of bearing	[ux]	-0.000	mm
Displacement of bearing	[uy]	-0.010	mm
Displacement of bearing	[uz]	0.000	mm
Displacement of bearing	[ur]	0.000	mm (131.43°)
Misalignment of bearing	[rx]	-0.011	mrad (-0.04')
Misalignment of bearing	[ry]	0.190	mrad (0.65')
Misalignment of bearing	[rz]	-0.009	mrad (-0.03')
Misalignment of bearing	[rr]	0.014	mrad (0.05')

Bearing 'Joint, general'

Position (Y-coordinate)	[y]	160.00	mm

Bearing reaction force	[Fx]	0.000	kN
Bearing reaction force	[Fy]	0.000	kN
Bearing reaction force	[Fz]	0.420	kN
Bearing reaction force	[Fr]	0.420	kN (90°)
Bearing reaction moment	[Mx]	89.42	Nm
Bearing reaction moment	[My]	-6000.00	Nm
Bearing reaction moment	[Mz]	0.00	Nm
Bearing reaction moment	[Mr]	89.42	Nm (0°)
Displacement of bearing	[ux]	0.000	mm
Displacement of bearing	[uy]	0.000	mm
Displacement of bearing	[uz]	-0.000	mm
Displacement of bearing	[ur]	0.000	mm
Misalignment of bearing	[rx]	-0.000	mrad (0')
Misalignment of bearing	[ry]	0.000	mrad (0')
Misalignment of bearing	[rz]	0.000	mrad (0')
Misalignment of bearing	[rr]	0.000	mrad (0')

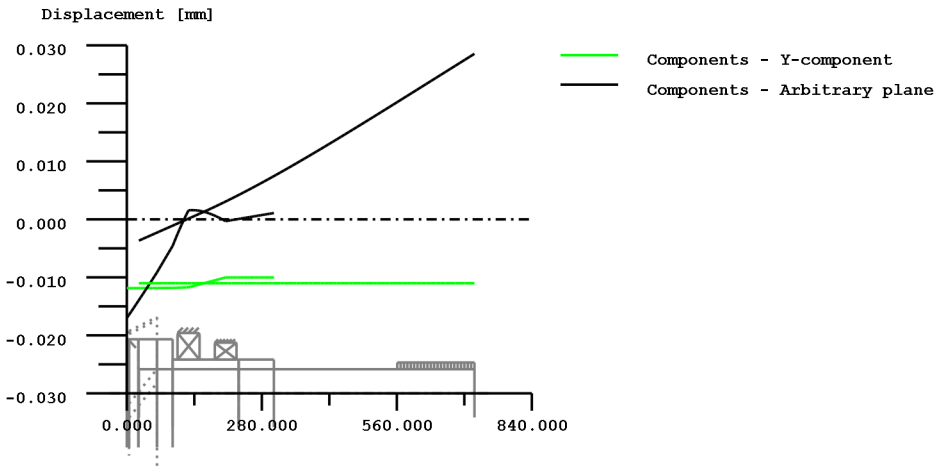
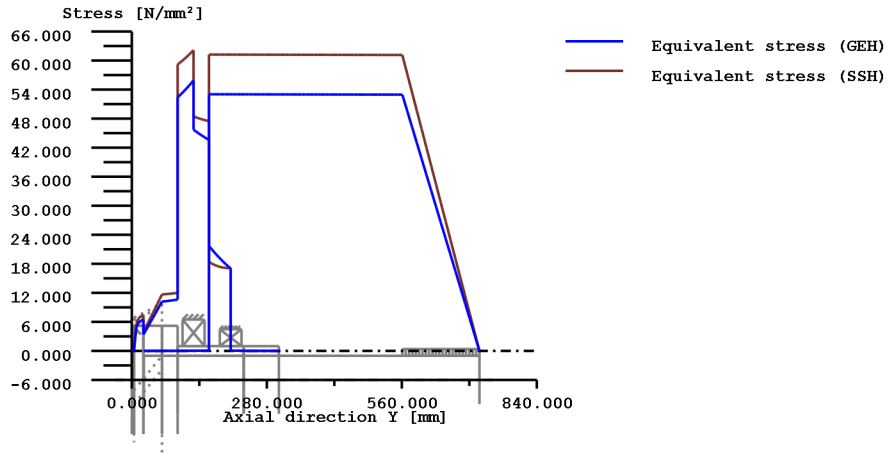


Figure: Displacement (bending etc.) (Arbitrary plane -58.28266122 °)



GEH(von Mises): sigV = ((sigB+sigZ,D)^2 + 3*(tauT+tauS)^2)^1/2SSH(Tresca): sigV = ((sigB-sigZ,D)^2 + 4*(tauT+tauS)^2)^1/2
Figure: Equivalent stress

Eigenfrequencies/Critical speeds

1. Eigenfrequency:	0.00 Hz, Critical speed:	0.00 1/min	Rigid body rotation Y 'Shaft 2'
2. Eigenfrequency:	214.13 Hz, Critical speed:	12847.99 1/min	Bending YZ 'Shaft 2'
3. Eigenfrequency:	1204.77 Hz, Critical speed:	72286.11 1/min	Bending XY 'Shaft 2'
4. Eigenfrequency:	1422.86 Hz, Critical speed:	85371.72 1/min	Torsion 'Shaft 2'

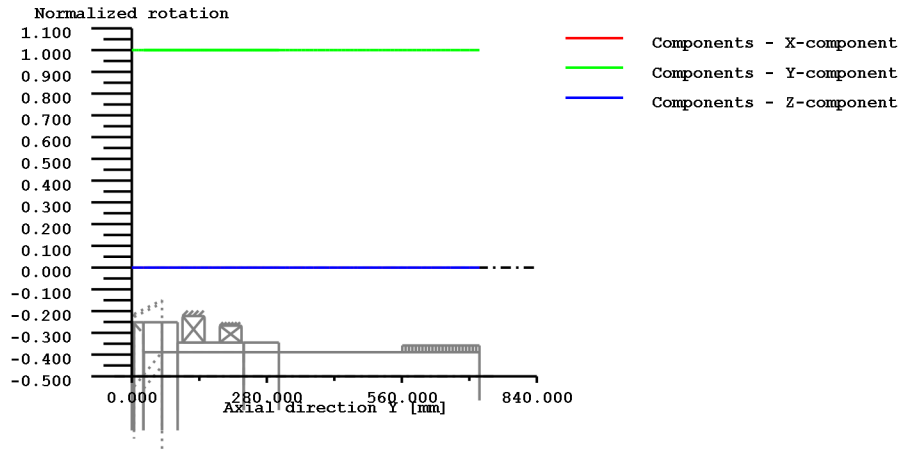


Figure: Eigenfrequencies (Normalized displacement)

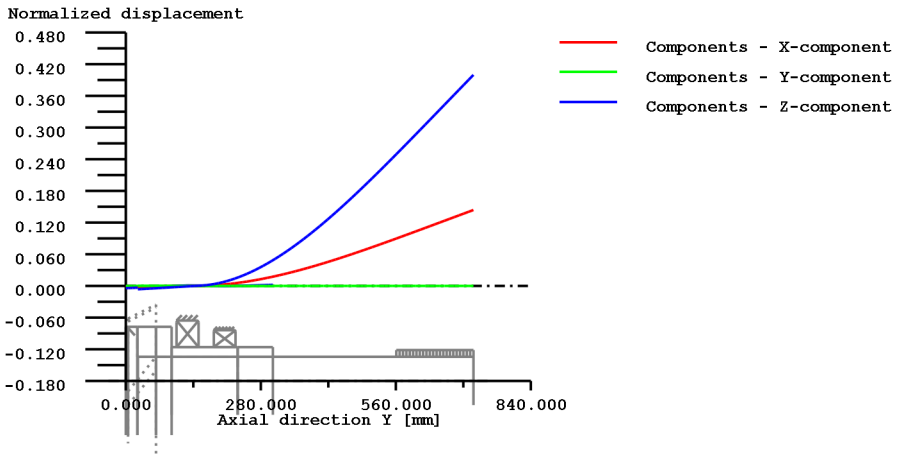


Figure: Eigenfrequencies (Normalized rotation)

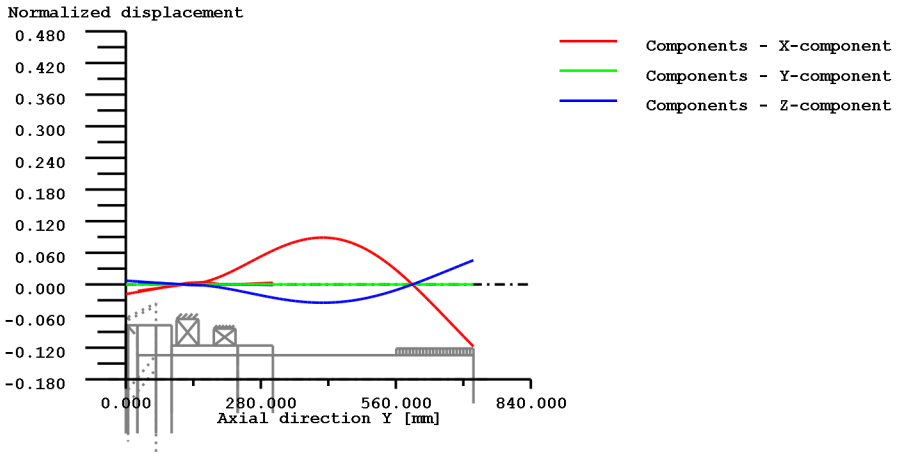


Figure: Eigenfrequencies (Normalized rotation)

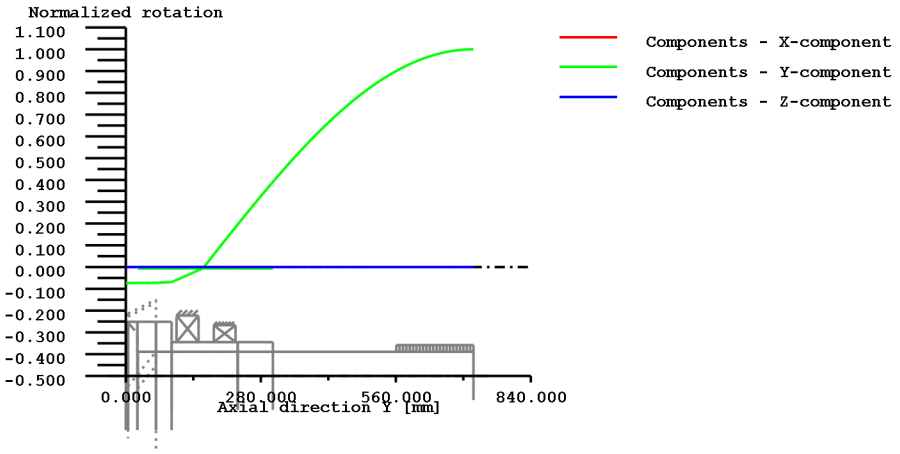


Figure: Eigenfrequencies (Normalized displacement)

Strength calculation as specified in

DIN 743:2012

Summary

Label	Shaft 1
Drawing	

Material	18CrNiMo7-6
Material type	Case-carburized steel
Material treatment	case-hardened
Surface treatment	No

Calculation of endurance limit and the static strength
Calculation for load case 2 (sig.av/sig.mv = const)

Cross section	Position (Y-Coord) (mm)	
A-A	95.00	Shoulder
B-B	232.00	Smooth shaft

Results:

Cross section	Kfb	Kfsig	K2d	SD	SS	SA
A-A	2.07	0.88	0.80	6.31	11.27	24.36
B-B	1.00	0.88	0.80	10000.00	10000.00	10000.00
Nominal safety:				1.20	1.20	1.20

Abbreviations:
Kfb: Notch factor bending
Kfsig: Surface factor
K2d: Size coefficient bending
SD: Safety endurance limit
SS: Safety against yield point
SA: Safety against incipient crack

The requirements of the safety proof of the shaft are:

satisfied [x] not satisfied [ ]

Design engineer:..... Date:..... Signature:.....

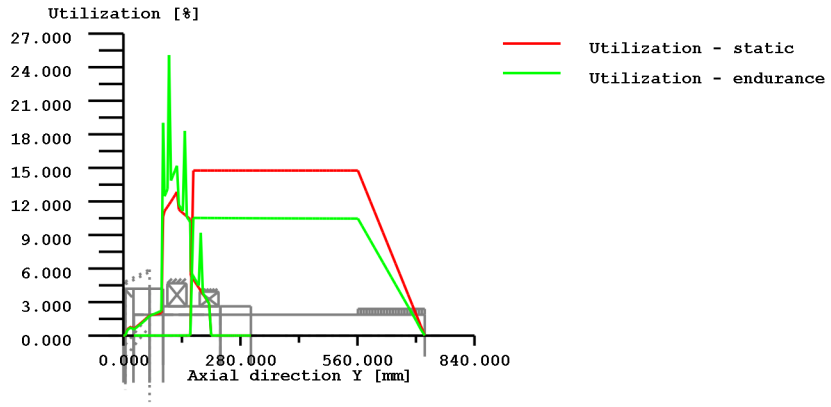


Figure: Strength

Calculation details:

General statements

Label	Shaft 1		
Drawing			
Length (mm)		[l]	305.00
Speed (1/min)		[n]	800.00

Material	18CrNiMo7-6
Material type	Case-carburized steel
Material treatment	case-hardened
Surface treatment	No

	Tension/Compression	Bending	Torsion	Shearing
Load factor static calculation	1.700	1.700	1.700	1.700
Load factor endurance limit	1.000	1.000	1.000	1.000

Reference diameter material (mm)	[dB]	16.00
sigB according DIN 743 (at dB) (N/mm²)	[sigB]	1200.00
sigS according DIN 743 (at dB) (N/mm²)	[sigS]	850.00
[sigzdW] (bei dB) (N/mm²)		480.00
[sigbW] (bei dB) (N/mm²)		600.00
[tautW] (bei dB) (N/mm²)		360.00
Thickness of raw material (mm)	[dWerkst]	230.00

Material data calculated according DIN743/3 with K1(d)
Material strength calculated from size of raw material
Geometric size coefficient K1d calculated from raw material diameter

[sigBeff] (N/mm²)	838.83

[sigSeff] (N/mm²)	594.17
[sigbF] (N/mm²)	653.59
[tautF] (N/mm²)	377.35
[sigBRand] (N/mm²)	2300.00
[sigzdW] (N/mm²)	335.53
[sigbW] (N/mm²)	419.41
[tautW] (N/mm²)	251.65

Endurance limit for single stage use

Calculation for load case 2 (sig.av/sig.mv = const)

Cross section 'A-A' Shoulder

Comment					
Position (Y-Coordinate) (mm)			[y]		95.00
External diameter (mm)			[da]		140.000
Inner diameter (mm)			[di]		100.000
Notch effect	Shoulder				
[D, r, t] (mm)		224.100	5.000	0.000	
Mean roughness (µm)			[Rz]		8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	2321.8	0.0	3000.0	0.0
Amplitude	2321.8	3557.8	3000.0	50916.8
Maximum value	7894.2	6048.2	10200.0	86558.6
Cross section, moment of resistance: (mm²)				
[A, Wb, Wt, A]	7539.8	199266.7	398533.5	7539.8

Stresses: (N/mm²)					
[sigzdm, sigbm, taum, tauqm] (N/mm²)		0.308	0.000	7.528	0.000
[sigzda, sigba, taua, tauqa] (N/mm²)		0.308	17.854	7.528	13.263
[sigzdmax,sigbmax,taumax,tauqmax] (N/mm²)		1.047	30.352	25.594	22.547
Technological size influence	[K1(sigB)]	0.699			
	[K1(sigS)]	0.699			

		Tension/Compression	Bending	Torsion
Stress concentration factor	[alfa]	2.665	2.349	1.712
References stress slope	[G']	0.460	0.460	0.230
Notch sensitivity factor n	[n]	1.135	1.135	1.096
Notch effect coefficient	[beta]	2.347	2.069	1.563
Geometrical size influence	[K2(d)]	1.000	0.805	0.805
Influence coefficient surface roughness				
	[KF]	0.876	0.876	0.929
Influence coefficient surface strengthening				
	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	2.489	2.713	2.019

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm²)	[sigmV]		13.042	
Equivalent mean stress (N/mm²)	[taumV]		7.530	
Fatigue limit of part (N/mm²)	[sigWK]	134.831	154.615	124.651

Influence coeff. mean stress sensitivity.				
	[PsisigK]	0.087	0.102	0.080
Permissible amplitude (N/mm²)	[sigADK]	15.076	143.942	115.387
Margin of safety endurance limit	[S]		6.309	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		525.7	

Present margin of safety				
for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.000	1.000
Increase coefficient	[gammaF]	1.100	1.100	1.000
Yield stress of part (N/mm²)	[sigFK]	653.586	653.586	343.043
Margin of safety yield stress	[S]		11.269	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		939.1	

Present margin of safety		
for proof of avoiding incipient crack on hard surface layers:		
Safety against incipient crack	[S]	24.357
Required safety	[Smin]	1.200
Result (%)	[S/Smin]	2029.8

Cross section 'B-B' Smooth shaft

Comment		
Position (Y-Coordinate) (mm)	[y]	232.00
External diameter (mm)	[da]	140.000
Inner diameter (mm)	[di]	0.000
Notch effect Smooth shaft		
Mean roughness (µm)	[Rz]	8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-0.0	0.0	0.0	0.0
Amplitude	0.0	3.1	0.0	87.3
Maximum value	-0.0	5.4	0.0	148.4
Cross section, moment of resistance: (mm²)				
[A, Wb, Wt, A]	15393.8	269391.6	538783.1	15393.8

Stresses: (N/mm²)				
[sigzdm, sigbm, taum, tauqm] (N/mm²)	-0.000	0.000	0.000	0.000
[sigzda, sigba, taua, tauqa] (N/mm²)	0.000	0.012	0.000	0.008
[sigzdmax,sigbmax,taumax,tauqmax] (N/mm²)	-0.000	0.020	0.000	0.013

Technological size influence	[K1(sigB)]	0.699		
	[K1(sigS)]	0.699		

		Tension/Compression	Bending	Torsion
Notch effect coefficient	[beta]	1.000	1.000	1.000
Geometrical size influence	[K2(d)]	1.000	0.805	0.805
Influence coefficient surface roughness				
	[KF]	0.876	0.876	0.929
Influence coefficient surface strengthening				
	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	1.141	1.384	1.319

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm²)	[sigmV]		0.000	
Equivalent mean stress (N/mm²)	[taumV]		0.000	
Fatigue limit of part (N/mm²)	[sigWK]	294.023	303.041	190.726
Influence coeff. mean stress sensitivity.				
	[PsisigK]	0.213	0.220	0.128
Permissible amplitude (N/mm²)	[sigADK]	294.023	303.041	190.726
Margin of safety endurance limit	[S]		10000.000	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		10000.0	

Present margin of safety				
for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.100	1.100
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm²)	[sigFK]	594.169	653.586	377.348
Margin of safety yield stress	[S]		10000.000	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		10000.0	

Present margin of safety		
for proof of avoiding incipient crack on hard surface layers:		
Safety against incipient crack	[S]	9999.999
Required safety	[Smin]	1.200
Result (%)	[S/Smin]	833333.3

Remarks:
- The shearing force is not considered in the analysis specified in DIN 743.
- Cross section with interference fit:
  The notching factor for the light fit case is no longer defined in DIN 743.
  The values are imported from the FKM-Guideline..

End of Report lines: 512

File

Name : Hridel_I_2_stavy_pro_C
Changed by: karlova am: 02.05.2014 um: 11:50:03

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label		Shaft 1
Drawing		OL 232 969
Initial position (mm)		0.000
Length (mm)		935.000
Speed (1/min)		800.00
Sense of rotation: clockwise		
Material		18CrNiMo7-6
Young's modulus (N/mm²)		206000.000
Poisson's ratio nu		0.300
Specific weight (kg/m³)		7830.000
Coefficient of thermal expansion	(10^-6/K)	11.500
Temperature (°C)		20.000
Weight of shaft (kg)		120.809
Mass moment of inertia (kg*m²)		0.551
Momentum of mass GD2 (Nm²)		21.623
(Notice: Weight stands for the shaft only without considering the gears)		
Position in space (°)		0.000
Regard gears as masses and stiffness		
Consider deformations due to shearing		
Shear correction coefficient		1.100
Contact angle of rolling bearings is considered		
Reference temperature (°C)		20.000

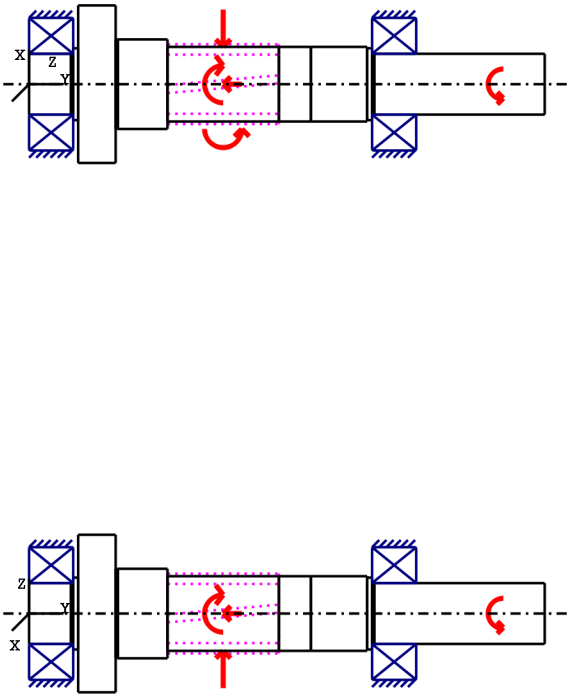


Figure: Load applications

SHAFT DEFINITION (Shaft 1)

Outer contour

Cylinder (Cylinder) y= 0.00...76.00 (mm)
d=110.00 (mm), l=76.00 (mm), Rz= 4.8

Chamfer left (Chamfer left)
l=2.00 (mm), alpha=45.00 (°)

Cylinder (Cylinder) y= 76.00...80.00 (mm)
d=109.20 (mm), l=4.00 (mm), Rz= 8.0

Radius left (Radius left)
r=1.00 (mm), Rz= 8.0

Radius right (Radius right)
r=1.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 80.00...89.00 (mm)
d=130.00 (mm), l=9.00 (mm), Rz= 4.8

Chamfer left (Chamfer left)
l=1.00 (mm), alpha=45.00 (°)

Radius right (Radius right)
r=2.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 89.00...157.00 (mm)

d=285.00 (mm), l=68.00 (mm), Rz= 4.8

Chamfer left (Chamfer left)
l=2.00 (mm), alpha=45.00 (°)

Cylinder (Cylinder) y= 157.00...161.00 (mm)
d=161.20 (mm), l=4.00 (mm), Rz= 8.0

Radius left (Radius left)
r=1.00 (mm), Rz= 8.0

Radius right (Radius right)
r=1.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 161.00...251.00 (mm)
d=162.00 (mm), l=90.00 (mm), Rz= 4.8

Chamfer left (Chamfer left)
l=1.00 (mm), alpha=45.00 (°)

Cylinder (Cylinder) y= 251.00...511.00 (mm)
d=135.00 (mm), l=260.00 (mm), Rz= 4.8

Chamfer right (Chamfer right)
l=1.00 (mm), alpha=45.00 (°)

Cylinder (Cylinder) y= 511.00...613.00 (mm)
d=135.00 (mm), l=102.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 613.00...622.00 (mm)
d=130.00 (mm), l=9.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 622.00...626.00 (mm)
d=109.20 (mm), l=4.00 (mm), Rz= 8.0

Radius left (Radius left)
r=1.00 (mm), Rz= 8.0

Radius right (Radius right)
r=1.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 626.00...935.00 (mm)
d=110.00 (mm), l=309.00 (mm), Rz= 4.8

Chamfer right (Chamfer right)
l=2.00 (mm), alpha=45.00 (°)

Inner contour

Forces

Cylindrical gear (Kolo_1) y= 352.00 (mm)

Operating pitch diameter	(mm)	144.3617	
Helix angle	(°)	14.2019	left
Working pressure angle at normal section	(°)	22.0888	

Position of contact point	(°)	0.0000
Length of load application	(mm)	202.0000
Axial force (Load spectrum)	(N)	-21036.69/-14725.68
Shearing force X (Load spectrum)	(N)	-34798.01/-24358.61
Shearing force Z (Load spectrum)	(N)	83124.54/58187.18
Bending moment X (Load spectrum)	(N)	0.00/0.00
Bending moment Z (Load spectrum)	(N)	-1518.45/-1062.91

load spectrum,driving (Output):

Element	Frequency (%)	Speed (1/min)	Power (kW)	Torque (Nm)
1	20.0000	800.0	-502.7	-6000.0
2	80.0000	800.0	-351.9	-4200.0

Coupling (Coupling / Motor) y= 860.00 (mm)

Eff. Diameter	(mm)	0.0000
Radial force coefficient	(-)	0.0000
Direction of radial force	(°)	0.0000
Axial force coefficient	(-)	0.0000
Length of load application	(mm)	150.0000
Mass	(kg)	0.0000

load spectrum,driven (Input):

Element	Frequency (%)	Speed (1/min)	Power (kW)	Torque (Nm)
1	20.0000	800.0	502.7	6000.0
2	80.0000	800.0	351.9	4200.0

Bearing

Spherical roller bearings SKF *22322E (SKF*22322E_levé) y= 40.00 (mm)

Set fixed bearing left

d = 110.000 (mm), D = 240.000 (mm), B = 80.000 (mm), r = 3.000 (mm)

C = 950.000 (kN), C0 = 1120.000 (kN), Cu = 100.000 (kN)

Bearing clearance DIN 620:1988 C0 (97.50 µm)

Spherical roller bearings SKF *22322E (SKF_22322E_prave) y= 662.00 (mm)

Set fixed bearing right

d = 110.000 (mm), D = 240.000 (mm), B = 80.000 (mm), r = 3.000 (mm)

C = 950.000 (kN), C0 = 1120.000 (kN), Cu = 100.000 (kN)

Bearing clearance DIN 620:1988 C0 (97.50 µm)

Shaft 'Shaft 1': Cylindrical gear 'Kolo_1' (y= 352.0000 (mm)) is taken into account as component of the shaft.

EI (y= 251.0000 (mm)): 3358707.5696 (Nm^2), EI (y= 453.0000 (mm)): 3358707.5696 (Nm^2), m (yS= 352.0000 (mm)): 3.2488 (kg)

Jp: 0.0159 (kg*m^2), Jxx: 0.0190 (kg*m^2), Jzz: 0.0190 (kg*m^2)

---

maximum deflection 154.12 µm (Shaft 1, 377.25 (mm))

Center of mass

Shaft 1 362.7 mm

Deformation due to torsion

Shaft 1 [phi.t] 0.10 °

Probability of failure	[n]	10.00	%
Axial clearance	[uA]	10.00	µm

Rolling bearings, classical calculation (contact angle considered)

Shaft 'Shaft 1' Rolling bearing 'SKF*22322E_levé'

Position (Y-coordinate)	[y]	40.00	mm
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	106939.32	h
Operating viscosity	[nu]	48.88	mm¸/s
Reference viscosity	[nu1]	0.00	mm¸/s
static safety factor	[S0]	12.81	

	Bearing reaction force			Bearing reaction moment		
	Fx (kN)	Fy (kN)	Fz (kN)	Mx (Nm)	My (Nm)	Mz (Nm)
1	19.784	21.037	-40.843	0.000	0.000	0.000
2	13.849	14.726	-28.414	0.000	0.000	0.000

	Displacement of bearing			Misalignment of bearing		
	ux (mm)	uy (mm)	uz (mm)	ux (mrad)	uy (mrad)	uz (mrad)
1	-0.0205	-0.0100	0.0442	0.396	-0.000	0.160
2	-0.0206	-0.0100	0.0442	0.277	-0.000	0.110

Shaft 'Shaft 1' Rolling bearing 'SKF_22322E_prave'

Position (Y-coordinate)	[y]	662.00	mm
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	> 1000000	h
Operating viscosity	[nu]	48.88	mm¸/s
Reference viscosity	[nu1]	0.00	mm¸/s
static safety factor	[S0]	25.62	

	Bearing reaction force			Bearing reaction moment		
	Fx (kN)	Fy (kN)	Fz (kN)	Mx (Nm)	My (Nm)	Mz (Nm)
1	15.014	0.000	-41.065	0.000	0.000	0.000
2	10.510	0.000	-28.556	0.000	0.000	0.000

	Displacement of bearing			Misalignment of bearing		
	ux (mm)	uy (mm)	uz (mm)	ux (mrad)	uy (mrad)	uz (mrad)
1	-0.0160	-0.0117	0.0460	-0.474	0.787	-0.197
2	-0.0161	-0.0112	0.0460	-0.330	0.551	-0.140

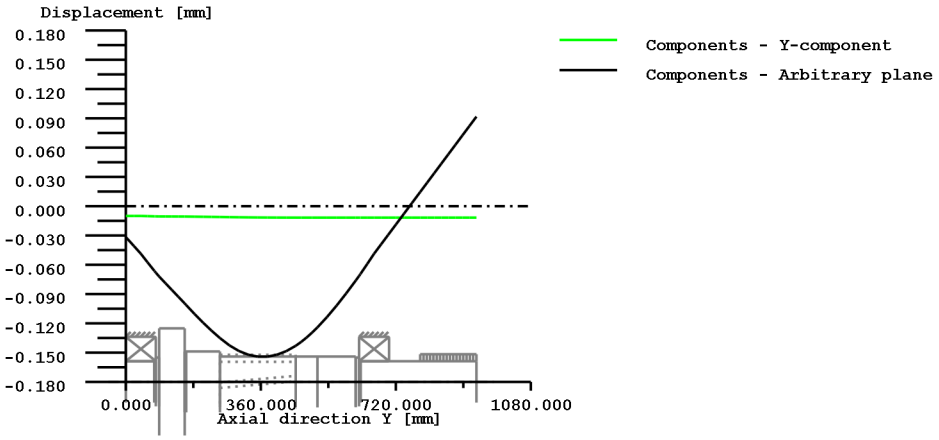
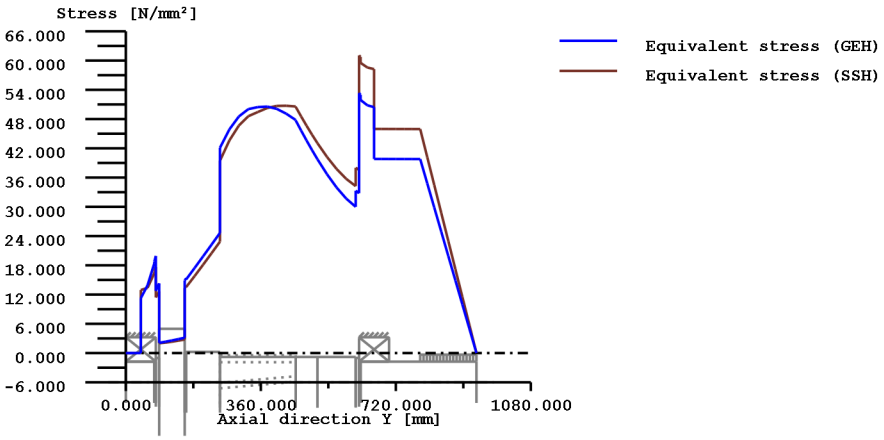


Figure: Displacement (bending etc.) (Arbitrary plane -67.81695976 °)



GEH(von Mises): sigV = ((sigB+sigZ,D)^2 + 3*(tauT+tauS)^2)^1/2SSH(Tresca): sigV = ((sigB-sigZ,D)^2 + 4*(tauT+tauS)^2)^1/2
Figure: Equivalent stress

Strength calculation as specified in

DIN 743:2012

with finite life fatigue strength according to FKM standard and FVA draft

Summary

Label	Shaft 1
Drawing	OL 232 969

Material	18CrNiMo7-6
Material type	Case-carburized steel
Material treatment	case-hardened
Surface treatment	No

Calculation of service strength and static strength
Woehler line (S-N curve) according Miner elementary
Calculation for load case 2 (sig.av/sig.mv = const)

Cross section	Position (Y-Coord) (mm)	
A-A	80.00	Shoulder

Results:

Cross section	Kfb	Kfsig	K2d	SD	SS	SA
A-A	2.61	0.88	0.82	7.95	36.23	33.71
Nominal safety:				1.20	1.20	1.20

Abbreviations:
Kfb: Notch factor bending
Kfsig: Surface factor
K2d: Size coefficient bending
SD: Safety endurance limit
SS: Safety against yield point
SA: Safety against incipient crack

The requirements of the safety proof of the shaft are:

satisfied [x] not satisfied [ ]

Design engineer:..... Date:..... Signature:.....

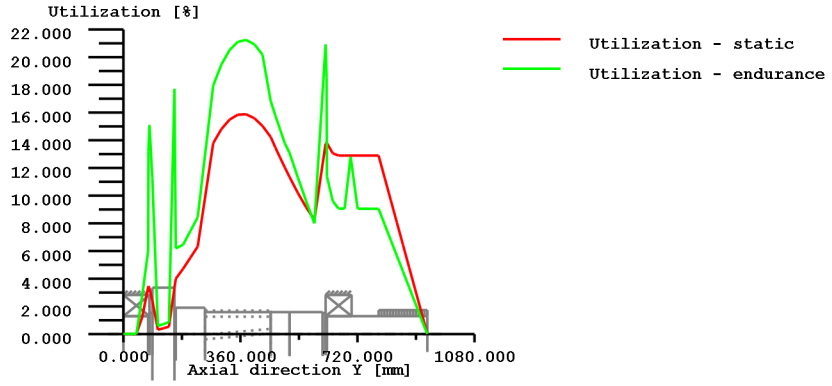


Figure: Strength

Calculation details:

General statements

Label	Shaft 1		
Drawing	OL 232 969		
Length (mm)		[l]	935.00
Speed (1/min)		[n]	800.00

Material	18CrNiMo7-6
Material type	Case-carburized steel
Material treatment	case-hardened
Surface treatment	No

	Tension/Compression	Bending	Torsion	Shearing
Load factor static calculation	1.700	1.700	1.700	1.700
Load factor endurance limit	1.000	1.000	1.000	1.000

Reference diameter material (mm)	[dB]	16.00
sigB according DIN 743 (at dB) (N/mm²)	[sigB]	1200.00
sigS according DIN 743 (at dB) (N/mm²)	[sigS]	850.00
[sigzdW] (bei dB) (N/mm²)		480.00
[sigbW] (bei dB) (N/mm²)		600.00
[tautW] (bei dB) (N/mm²)		360.00
Thickness of raw material (mm)	[dWerkst]	290.00

Material data calculated according DIN743/3 with K1(d)
Material strength calculated from size of raw material
Geometric size coefficient K1d calculated from raw material diameter

[sigBeff] (N/mm²)	807.42

[sigSeff] (N/mm²)	571.92
[sigbF] (N/mm²)	629.11
[tautF] (N/mm²)	363.22
[sigBRand] (N/mm²)	2300.00
[sigzdW] (N/mm²)	322.97
[sigbW] (N/mm²)	403.71
[tautW] (N/mm²)	242.23

Service strength for a load spectrum
Woehler line (S-N curve) according Miner elementary

Required life time	[h]	2400.00
Number of load cycles (Mio)	[NL]	115.200

Data of Woehler line (S-N curve) analog to FKM standard:

[ksigma, ktau]	15	25
[kDsigma, kDtau]	0	0
[NDsigma, NDtau]	1e+006	1e+006
[NDsigmaII, NDtauII]	0	0
[DM]	0.3	

Calculation for load case 2 (sig.av/sig.mv = const)

Cross section 'A-A' Shoulder

Comment				
Position (Y-Coordinate) (mm)	[y]	80.00		
External diameter (mm)	[da]	109.200		
Inner diameter (mm)	[di]	0.000		
Notch effect	Shoulder			
[D, r, t] (mm)	130.000	1.000	0.000	
Mean roughness (µm)	[Rz]	8.000		

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-10518.3	0.0	-0.0	0.0
Amplitude	10518.3	1817.4	0.0	45438.8
Maximum value	-35762.4	3089.6	0.0	77246.0
Cross section, moment of resistance: (mm²)				
[A, Wb, Wt, A]	9365.6	127840.3	255680.6	9365.6

Load spectrum, load base values (Mean-value + Amplitude):

Element	Frequency (%)	Tens./Press. (N)	Bending (Nm)	Torsion (Nm)	Shearing (N)
1	20.00	-21036.687	1817.388	-0.000	45438.796
2	80.00	-14725.681	1266.475	-0.000	31665.969

Stresses: (N/mm²)

[sigzdm, sigbm, taum, tauqm] (N/mm²)	-1.123	0.000	-0.000	0.000
[sigzda, sigba, taua, tauqa] (N/mm²)	1.123	14.216	0.000	6.469
[sigzdmax,sigbmax,taumax,tauqmax] (N/mm²)	-3.818	24.167	0.000	10.997

Technological size influence	[K1(sigB)]	0.673
	[K1(sigS)]	0.673

	Tension/Compression	Bending	Torsion

Stress concentration factor		[alfa]	3.816	3.426	2.199
References stress slope		[G']	2.454	2.454	1.150
Notch sensitivity factor	n	[n]	1.313	1.313	1.214
Notch effect coefficient		[beta]	2.907	2.610	1.811
Geometrical size influence		[K2(d)]	1.000	0.821	0.821
Influence coefficient surface roughness		[KF]	0.880	0.880	0.931
Influence coefficient surface strengthening		[KV]	1.000	1.000	1.000
Total influence coefficient		[K]	3.044	3.315	2.280

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm²)	[sigmV]		1.123	
Equivalent mean stress (N/mm²)	[taumV]		0.648	
Fatigue limit of part (N/mm²)	[sigWK]	106.089	121.772	106.226
Influence coeff. mean stress sensitivity.	[PsisigK]	0.070	0.082	0.070
Permissible amplitude (N/mm²)	[sigADK]	114.113	122.562	106.226
Permissible amplitude (N/mm²)	[sigANK]	114.113	122.562	106.226
Load spectrum factor	[fKoll]	1.000	1.000	1.000
Margin of safety endurance limit	[S]		7.947	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		662.3	

Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.100	1.100
Increase coefficient	[gammaF]	1.150	1.150	1.000
Yield stress of part (N/mm²)	[sigFK]	657.709	723.480	363.218
Margin of safety yield stress	[S]		36.234	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		2809.4	

Present margin of safety for proof of avoiding incipient crack on hard surface layers:		
Safety against incipient crack	[S]	33.713
Required safety	[Smin]	1.200
Result (%)	[S/Smin]	2809.4

Remarks:

- The shearing force is not considered in the analysis specified in DIN 743.
- Cross section with interference fit:
  The notching factor for the light fit case is no longer defined in DIN 743.
  The values are imported from the FKM-Guideline..

End of Report lines: 418

File

Name : Hridel_l_2_stavy_pro_C
Changed by: karlova am: 02.05.2014 um: 11:01:44

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label		Shaft 1
Drawing		OL 232 969
Initial position (mm)		0.000
Length (mm)		935.000
Speed (1/min)		800.00
Sense of rotation: clockwise		
Material		18CrNiMo7-6
Young's modulus (N/mm²)		206000.000
Poisson's ratio nu		0.300
Specific weight (kg/m³)		7830.000
Coefficient of thermal expansion	(10^-6/K)	11.500
Temperature (°C)		20.000
Weight of shaft (kg)		120.809
Mass moment of inertia (kg*m²)		0.551
Momentum of mass GD2 (Nm²)		21.623
(Notice: Weight stands for the shaft only without considering the gears)		
Position in space (°)		0.000
Regard gears as masses and stiffness		
Consider deformations due to shearing		
Shear correction coefficient		1.100
Contact angle of rolling bearings is considered		
Reference temperature (°C)		20.000

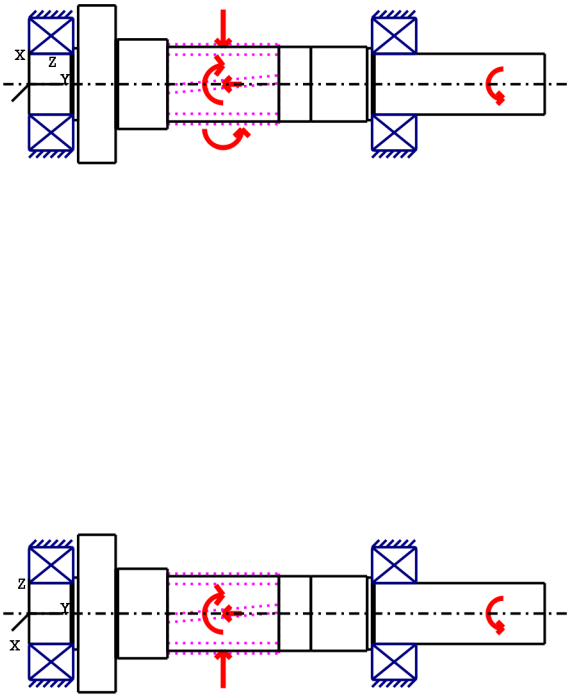


Figure: Load applications

SHAFT DEFINITION (Shaft 1)

Outer contour

Cylinder (Cylinder) y= 0.00...76.00 (mm)
d=110.00 (mm), l=76.00 (mm), Rz= 4.8

Chamfer left (Chamfer left)
l=2.00 (mm), alpha=45.00 (°)

Cylinder (Cylinder) y= 76.00...80.00 (mm)
d=109.20 (mm), l=4.00 (mm), Rz= 8.0

Radius left (Radius left)
r=1.00 (mm), Rz= 8.0

Radius right (Radius right)
r=1.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 80.00...89.00 (mm)
d=130.00 (mm), l=9.00 (mm), Rz= 4.8

Chamfer left (Chamfer left)
l=1.00 (mm), alpha=45.00 (°)

Radius right (Radius right)
r=2.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 89.00...157.00 (mm)

d=285.00 (mm), l=68.00 (mm), Rz= 4.8

Chamfer left (Chamfer left)
l=2.00 (mm), alpha=45.00 (°)

Cylinder (Cylinder) y= 157.00...161.00 (mm)
d=161.20 (mm), l=4.00 (mm), Rz= 8.0

Radius left (Radius left)
r=1.00 (mm), Rz= 8.0

Radius right (Radius right)
r=1.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 161.00...251.00 (mm)
d=162.00 (mm), l=90.00 (mm), Rz= 4.8

Chamfer left (Chamfer left)
l=1.00 (mm), alpha=45.00 (°)

Cylinder (Cylinder) y= 251.00...511.00 (mm)
d=135.00 (mm), l=260.00 (mm), Rz= 4.8

Chamfer right (Chamfer right)
l=1.00 (mm), alpha=45.00 (°)

Cylinder (Cylinder) y= 511.00...613.00 (mm)
d=135.00 (mm), l=102.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 613.00...622.00 (mm)
d=130.00 (mm), l=9.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 622.00...626.00 (mm)
d=109.20 (mm), l=4.00 (mm), Rz= 8.0

Radius left (Radius left)
r=1.00 (mm), Rz= 8.0

Radius right (Radius right)
r=1.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 626.00...935.00 (mm)
d=110.00 (mm), l=309.00 (mm), Rz= 4.8

Chamfer right (Chamfer right)
l=2.00 (mm), alpha=45.00 (°)

Inner contour

Forces

Cylindrical gear (Kolo_1) y= 352.00 (mm)

Operating pitch diameter	(mm)	144.3617	
Helix angle	(°)	14.2019	left
Working pressure angle at normal section	(°)	22.0888	

Position of contact point	(°)	0.0000	
Length of load application	(mm)	202.0000	
Power	(kW)	502.6548	driving (Output)
Torque	(Nm)	-6000.0000	
Axial force	(N)	-21036.6866	
Shearing force X	(N)	-34798.0129	
Shearing force Z	(N)	83124.5394	
Bending moment X	(Nm)	0.0000	
Bending moment Z	(Nm)	-1518.4459	

Coupling (Coupling / Motor) y= 860.00 (mm)

Eff. Diameter	(mm)	0.0000	
Radial force coefficient	(-)	0.0000	
Direction of radial force	(°)	0.0000	
Axial force coefficient	(-)	0.0000	
Length of load application	(mm)	150.0000	
Power	(kW)	502.6548	driven (Input)
Torque	(Nm)	6000.0000	
Mass	(kg)	0.0000	

Bearing

Spherical roller bearings SKF *22322E (SKF*22322E_levé) y= 40.00 (mm)
Set fixed bearing left
d = 110.000 (mm), D = 240.000 (mm), B = 80.000 (mm), r = 3.000 (mm)
C = 950.000 (kN), C0 = 1120.000 (kN), Cu = 100.000 (kN)
Bearing clearance DIN 620:1988 C0 (97.50 µm)

Spherical roller bearings SKF *22322E (SKF_22322E_prave) y= 662.00 (mm)
Set fixed bearing right
d = 110.000 (mm), D = 240.000 (mm), B = 80.000 (mm), r = 3.000 (mm)
C = 950.000 (kN), C0 = 1120.000 (kN), Cu = 100.000 (kN)
Bearing clearance DIN 620:1988 C0 (97.50 µm)

Shaft 'Shaft 1': Cylindrical gear 'Kolo_1' (y= 352.0000 (mm)) is taken into account as component of the shaft.
EI (y= 251.0000 (mm)): 3358707.5696 (Nm²), EI (y= 453.0000 (mm)): 3358707.5696 (Nm²), m (yS= 352.0000 (mm)): 3.2488 (kg)
Jp: 0.0159 (kg*m²), Jxx: 0.0190 (kg*m²), Jzz: 0.0190 (kg*m²)

---

maximum deflection 154.12 µm (Shaft 1, 377.25 (mm))

Center of mass
Shaft 1 362.7 mm

Deformation due to torsion
Shaft 1 [phi.t] 0.10 °

Probability of failure	[n]	10.00	%
Axial clearance	[uA]	10.00	µm

Rolling bearings, classical calculation (contact angle considered)

Shaft 'Shaft 1' Rolling bearing 'SKF*22322E_levé'

Position (Y-coordinate)	[y]	40.00	mm
Equivalent load	[P]	93.52	kN
Equivalent load	[P0]	87.46	kN
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	47302.36	h
Operating viscosity	[nu]	48.88	mm¿/s
Reference viscosity	[nu1]	0.00	mm¿/s
static safety factor	[S0]	12.81	
Bearing reaction force	[Fx]	19.784	kN
Bearing reaction force	[Fy]	21.037	kN
Bearing reaction force	[Fz]	-40.843	kN
Bearing reaction force	[Fr]	45.382	kN (-64.15°)
Oil level	[H]	103.750	mm
Torque of friction	[Mloss]	15.185	Nm
Power loss	[Ploss]	1272.109	W
Displacement of bearing	[ux]	-0.021	mm
Displacement of bearing	[uy]	-0.010	mm
Displacement of bearing	[uz]	0.044	mm
Displacement of bearing	[ur]	0.049	mm (114.93°)
Misalignment of bearing	[rx]	0.396	mrad (1.36')
Misalignment of bearing	[ry]	-0.000	mrad (0')
Misalignment of bearing	[rz]	0.160	mrad (0.55')
Misalignment of bearing	[rr]	0.427	mrad (1.47')

Shaft 'Shaft 1' Rolling bearing 'SKF_22322E_prave'

Position (Y-coordinate)	[y]	662.00	mm
Equivalent load	[P]	43.72	kN
Equivalent load	[P0]	43.72	kN
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	596281.38	h
Operating viscosity	[nu]	48.88	mm¿/s
Reference viscosity	[nu1]	0.00	mm¿/s
static safety factor	[S0]	25.62	
Bearing reaction force	[Fx]	15.014	kN
Bearing reaction force	[Fy]	0.000	kN
Bearing reaction force	[Fz]	-41.065	kN
Bearing reaction force	[Fr]	43.724	kN (-69.92°)
Oil level	[H]	103.750	mm
Torque of friction	[Mloss]	10.188	Nm
Power loss	[Ploss]	853.469	W
Displacement of bearing	[ux]	-0.016	mm
Displacement of bearing	[uy]	-0.012	mm
Displacement of bearing	[uz]	0.046	mm
Displacement of bearing	[ur]	0.049	mm (109.21°)
Misalignment of bearing	[rx]	-0.474	mrad (-1.63')
Misalignment of bearing	[ry]	0.787	mrad (2.7')
Misalignment of bearing	[rz]	-0.197	mrad (-0.68')
Misalignment of bearing	[rr]	0.513	mrad (1.76')

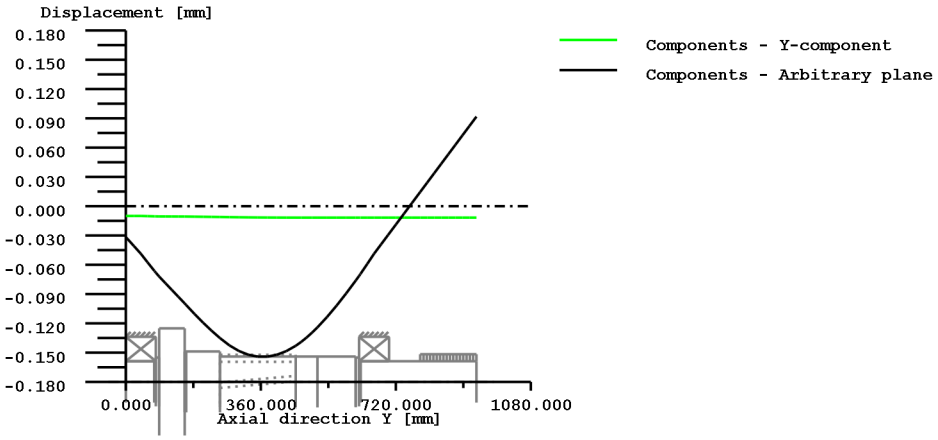
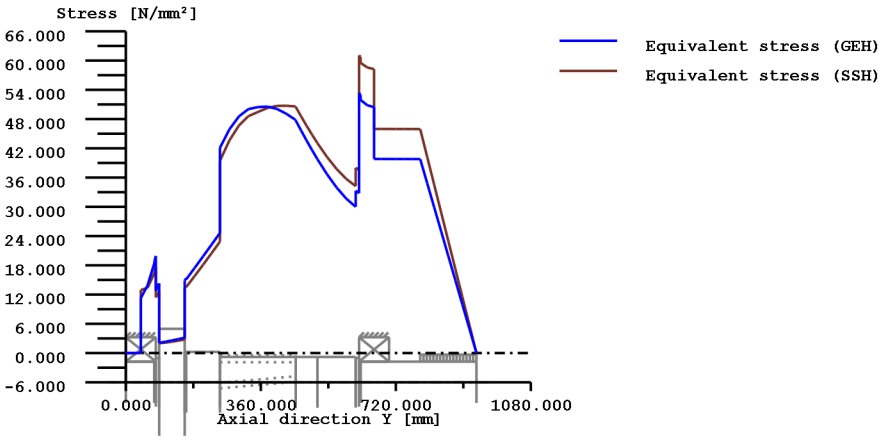


Figure: Displacement (bending etc.) (Arbitrary plane -67.81695976 °)



GEH(von Mises): sigV = ((sigB+sigZ,D)^2 + 3*(tauT+tauS)^2)^1/2SSH(Tresca): sigV = ((sigB-sigZ,D)^2 + 4*(tauT+tauS)^2)^1/2
Figure: Equivalent stress

Eigenfrequencies/Critical speeds

1. Eigenfrequency:	0.00 Hz, Critical speed:	0.01 1/min	Rigid body rotation Y 'Shaft 1'
2. Eigenfrequency:	527.87 Hz, Critical speed:	31671.96 1/min	Bending XY 'Shaft 1', Bending YZ 'Shaft 1'
3. Eigenfrequency:	905.66 Hz, Critical speed:	54339.78 1/min	Bending XY 'Shaft 1', Bending YZ 'Shaft 1'
4. Eigenfrequency:	1604.65 Hz, Critical speed:	96279.28 1/min	Torsion 'Shaft 1'

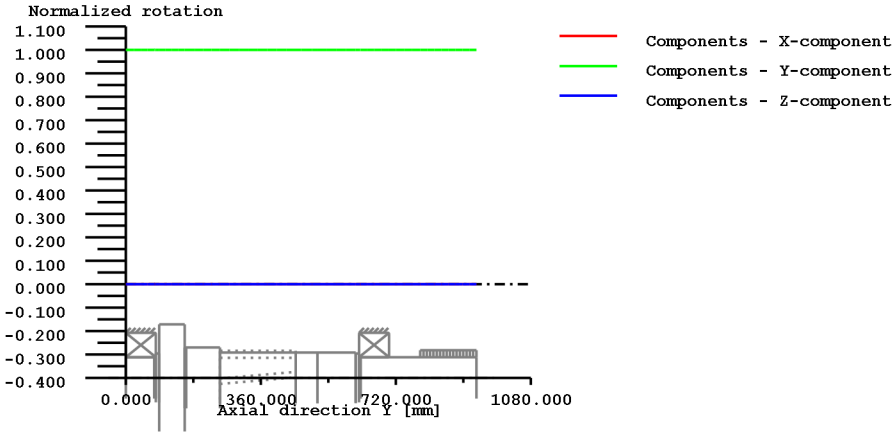


Figure: Eigenfrequencies (Normalized displacement)

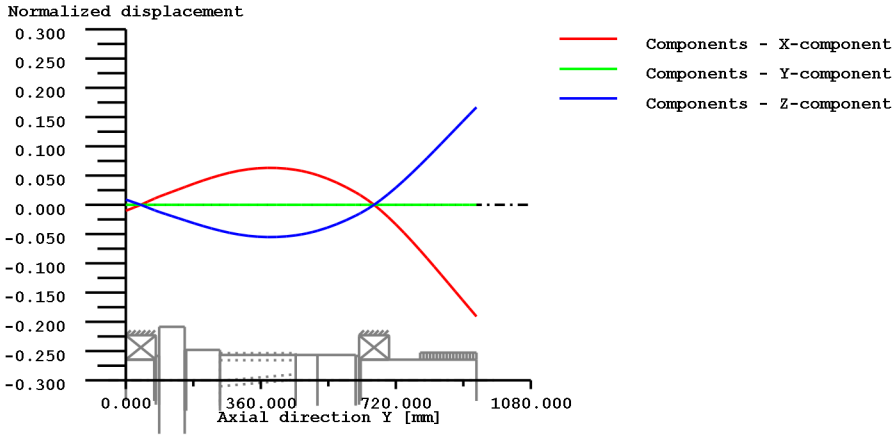


Figure: Eigenfrequencies (Normalized rotation)

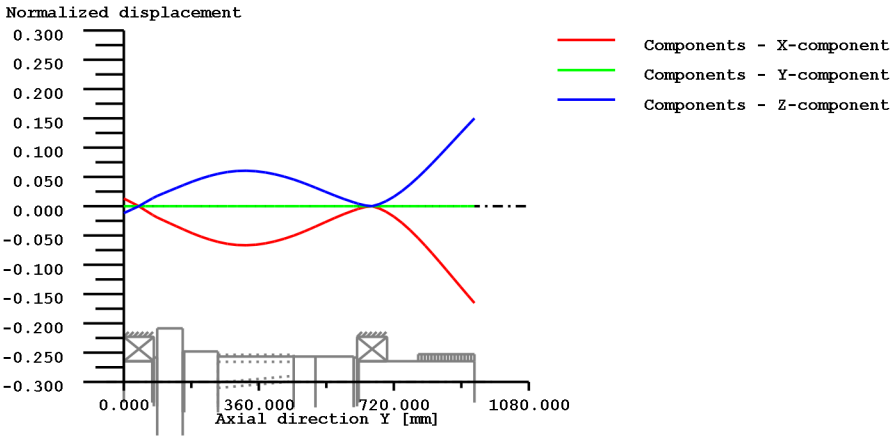


Figure: Eigenfrequencies (Normalized rotation)

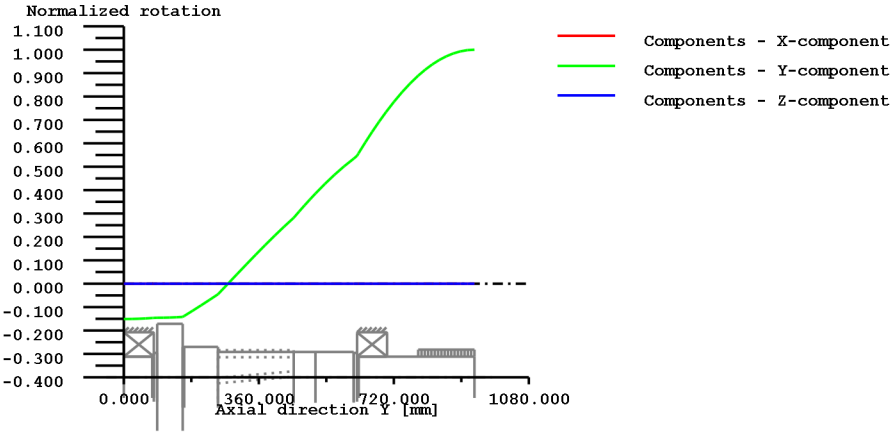


Figure: Eigenfrequencies (Normalized displacement)

Strength calculation as specified in

DIN 743:2012

Summary

Label	Shaft 1
Drawing	OL 232 969

Material	18CrNiMo7-6
Material type	Case-carburized steel
Material treatment	case-hardened
Surface treatment	No

Calculation of endurance limit and the static strength
Calculation for load case 2 (sig.av/sig.mv = const)

Cross section	Position (Y-Coord) (mm)	
A-A	80.00	Shoulder

Results:

Cross section	Kfb	Kfsig	K2d	SD	SS	SA
A-A	2.61	0.88	0.82	7.95	36.23	33.71
Nominal safety:				1.20	1.20	1.20

Abbreviations:
Kfb: Notch factor bending
Kfsig: Surface factor
K2d: Size coefficient bending
SD: Safety endurance limit
SS: Safety against yield point
SA: Safety against incipient crack

The requirements of the safety proof of the shaft are:

satisfied [x] not satisfied [ ]

Design engineer:..... Date:..... Signature:.....

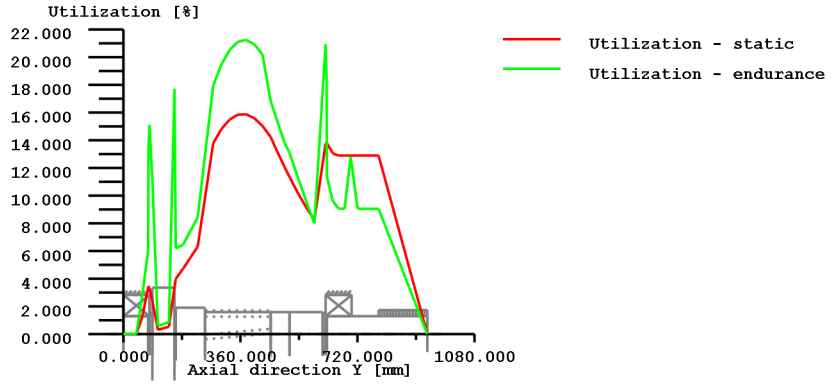


Figure: Strength

Calculation details:

General statements

Label	Shaft 1		
Drawing	OL 232 969		
Length (mm)		[l]	935.00
Speed (1/min)		[n]	800.00

Material	18CrNiMo7-6
Material type	Case-carburized steel
Material treatment	case-hardened
Surface treatment	No

	Tension/Compression	Bending	Torsion	Shearing
Load factor static calculation	1.700	1.700	1.700	1.700
Load factor endurance limit	1.000	1.000	1.000	1.000

Reference diameter material (mm)	[dB]	16.00
sigB according DIN 743 (at dB) (N/mm²)	[sigB]	1200.00
sigS according DIN 743 (at dB) (N/mm²)	[sigS]	850.00
[sigzdW] (bei dB) (N/mm²)		480.00
[sigbW] (bei dB) (N/mm²)		600.00
[tautW] (bei dB) (N/mm²)		360.00
Thickness of raw material (mm)	[dWerkst]	290.00

Material data calculated according DIN743/3 with K1(d)
Material strength calculated from size of raw material
Geometric size coefficient K1d calculated from raw material diameter

[sigBeff] (N/mm²)	807.42

[sigSeff] (N/mm²)	571.92
[sigbF] (N/mm²)	629.11
[tautF] (N/mm²)	363.22
[sigBRand] (N/mm²)	2300.00
[sigzdW] (N/mm²)	322.97
[sigbW] (N/mm²)	403.71
[tautW] (N/mm²)	242.23

Endurance limit for single stage use

Calculation for load case 2 (sig.av/sig.mv = const)

Cross section 'A-A' Shoulder

Comment					
Position (Y-Coordinate) (mm)		[y]		80.00	
External diameter (mm)		[da]		109.200	
Inner diameter (mm)		[di]		0.000	
Notch effect	Shoulder				
[D, r, t] (mm)	130.000	1.000	0.000		
Mean roughness (µm)		[Rz]		8.000	

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-10518.3	0.0	0.0	0.0
Amplitude	10518.3	1817.4	0.0	45433.7
Maximum value	-35762.4	3089.6	0.0	77237.3
Cross section, moment of resistance: (mm²)				
[A, Wb, Wt, A]	9365.6	127840.3	255680.6	9365.6

Stresses: (N/mm²)				
[sigzdm, sigbm, taum, tauqm] (N/mm²)	-1.123	0.000	0.000	0.000
[sigzda, sigba, taua, tauqa] (N/mm²)	1.123	14.216	0.000	6.468
[sigzdmax,sigbmax,taumax,tauqmax] (N/mm²)	-3.818	24.167	0.000	10.996

Technological size influence	[K1(sigB)]	0.673	
	[K1(sigS)]	0.673	

		Tension/Compression	Bending	Torsion
Stress concentration factor	[alfa]	3.816	3.426	2.199
References stress slope	[G']	2.454	2.454	1.150
Notch sensitivity factor n	[n]	1.313	1.313	1.214
Notch effect coefficient	[beta]	2.907	2.610	1.811
Geometrical size influence	[K2(d)]	1.000	0.821	0.821
Influence coefficient surface roughness				
	[KF]	0.880	0.880	0.931
Influence coefficient surface strengthening				
	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	3.044	3.315	2.280

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm²)	[sigmV]		1.123	
Equivalent mean stress (N/mm²)	[taumV]		0.648	
Fatigue limit of part (N/mm²)	[sigWK]	106.089	121.772	106.226

Influence coeff. mean stress sensitivity.				
	[PsisigK]	0.070	0.082	0.070
Permissible amplitude (N/mm²)	[sigADK]	114.113	122.562	106.226
Margin of safety endurance limit	[S]		7.947	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		662.3	
Present margin of safety				
for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.100	1.100
Increase coefficient	[gammaF]	1.150	1.150	1.000
Yield stress of part (N/mm²)	[sigFK]	657.709	723.480	363.218
Margin of safety yield stress	[S]		36.234	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		2809.4	
Present margin of safety				
for proof of avoiding incipient crack on hard surface layers:				
Safety against incipient crack	[S]		33.713	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		2809.4	

Remarks:

- The shearing force is not considered in the analysis specified in DIN 743.
- Cross section with interference fit:
  The notching factor for the light fit case is no longer defined in DIN 743.
  The values are imported from the FKM-Guideline..

End of Report lines: 418

File

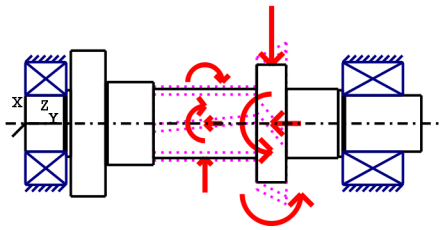
Name : Hridel_l_2_stavy
Changed by: karlova am: 02.05.2014 um: 11:48:04

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label		Shaft 1
Drawing		OL 232 969
Initial position (mm)		0.000
Length (mm)		776.000
Speed (1/min)		800.00
Sense of rotation: clockwise		
Material		18CrNiMo7-6
Young's modulus (N/mm²)		206000.000
Poisson's ratio nu		0.300
Specific weight (kg/m³)		7830.000
Coefficient of thermal expansion	(10^-6/K)	11.500
Temperature (°C)		20.000
Weight of shaft (kg)		121.345
Mass moment of inertia (kg*m²)		0.841
Momentum of mass GD2 (Nm²)		33.015
(Notice: Weight stands for the shaft only without considering the gears)		
Position in space (°)		0.000
Regard gears as masses and stiffness		
Consider deformations due to shearing		
Shear correction coefficient		1.100
Contact angle of rolling bearings is considered		
Reference temperature (°C)		20.000



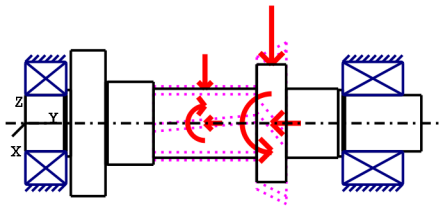


Figure: Load applications

SHAFT DEFINITION (Shaft 1)

Outer contour

Cylinder (Cylinder) y= 0.00...76.00 (mm)
d=110.00 (mm), l=76.00 (mm), Rz= 4.8

Chamfer left (Chamfer left)
l=2.00 (mm), alpha=45.00 (°)

Cylinder (Cylinder) y= 76.00...80.00 (mm)
d=109.20 (mm), l=4.00 (mm), Rz= 8.0

Radius left (Radius left)
r=1.00 (mm), Rz= 8.0

Radius right (Radius right)
r=1.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 80.00...89.00 (mm)
d=130.00 (mm), l=9.00 (mm), Rz= 4.8

Chamfer left (Chamfer left)
l=1.00 (mm), alpha=45.00 (°)

Radius right (Radius right)
r=2.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 89.00...157.00 (mm)

d=285.00 (mm), l=68.00 (mm), Rz= 4.8

Chamfer left (Chamfer left)
l=2.00 (mm), alpha=45.00 (°)

Cylinder (Cylinder) y= 157.00...161.00 (mm)
d=161.20 (mm), l=4.00 (mm), Rz= 8.0

Radius left (Radius left)
r=1.00 (mm), Rz= 8.0

Radius right (Radius right)
r=1.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 161.00...251.00 (mm)
d=162.00 (mm), l=90.00 (mm), Rz= 4.8

Chamfer left (Chamfer left)
l=1.00 (mm), alpha=45.00 (°)

Cylinder (Cylinder) y= 251.00...453.00 (mm)
d=135.00 (mm), l=202.00 (mm), Rz= 4.8

Chamfer right (Chamfer right)
l=1.00 (mm), alpha=45.00 (°)

Cylinder (Cylinder) y= 453.00...511.00 (mm)
d=230.00 (mm), l=58.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 511.00...613.00 (mm)
d=135.00 (mm), l=102.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 613.00...622.00 (mm)
d=130.00 (mm), l=9.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 622.00...626.00 (mm)
d=109.20 (mm), l=4.00 (mm), Rz= 8.0

Radius left (Radius left)
r=1.00 (mm), Rz= 8.0

Radius right (Radius right)
r=1.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 626.00...776.00 (mm)
d=110.00 (mm), l=150.00 (mm), Rz= 4.8

Chamfer right (Chamfer right)
l=2.00 (mm), alpha=45.00 (°)

Inner contour

Forces

Cylindrical gear (Kolo_1) y= 352.00 (mm)

Operating pitch diameter	(mm)	144.3617	
Helix angle	(°)	14.2019	left
Working pressure angle at normal section	(°)	22.0888	
Position of contact point	(°)	180.0000	
Length of load application	(mm)	202.0000	
Axial force (Load spectrum)	(N)	-21036.69/-14725.68	
Shearing force X (Load spectrum)	(N)	34798.01/24358.61	
Shearing force Z (Load spectrum)	(N)	-83124.54/-58187.18	
Bending moment X (Load spectrum)	(N)	0.00/0.00	
Bending moment Z (Load spectrum)	(N)	1518.45/1062.91	

load spectrum,driving (Output):

Element	Frequency (%)	Speed (1/min)	Power (kW)	Torque (Nm)
1	20.0000	800.0	-502.7	-6000.0
2	80.0000	800.0	-351.9	-4200.0

Hypoid gear (Kolo_K2) y= 482.50 (mm)

Operating pitch diameter	(mm)	287.0000	
Helix angle	(°)	30.0000	right
Half angle of cone	(°)	45.0000	Tip to the left
Working pressure angle at normal section	(°)	20.0000	
Position of contact point	(°)	0.0000	
Face width	(mm)	82.0000	
Axial force (Load spectrum)	(N)	-3070.81/-2149.57	
Shearing force X (Load spectrum)	(N)	-31068.42/-21747.90	
Shearing force Z (Load spectrum)	(N)	-41811.85/-29268.29	
Bending moment X (Load spectrum)	(N)	0.00/0.00	
Bending moment Z (Load spectrum)	(N)	-440.66/-308.46	

load spectrum,driven (Input):

Element	Frequency (%)	Speed (1/min)	Power (kW)	Torque (Nm)
1	20.0000	800.0	502.7	6000.0
2	80.0000	800.0	351.9	4200.0

Bearing

Spherical roller bearings SKF *22322E (SKF*22320EJA_levé) y= 40.00 (mm)

Free bearing

d = 110.000 (mm), D = 240.000 (mm), B = 80.000 (mm), r = 3.000 (mm)

C = 950.000 (kN), C0 = 1120.000 (kN), Cu = 100.000 (kN)

Bearing clearance DIN 620:1988 C0 (97.50 µm)

Taper roller bearing (paired) (O,TDO) Koyo 46T30322JR/93 (SKF_31322 XJ2 prave) y= 681.00 (mm)

Fixed bearing

d = 110.000 (mm), D = 240.000 (mm), B = 118.000 (mm), r = 3.000 (mm)

C = 824.000 (kN), C0 = 1180.000 (kN), Cu = 0.000 (kN)

Shaft 'Shaft 1': Cylindrical gear 'Kolo_1' (y= 352.0000 (mm)) is taken into account as component of the shaft.

EI (y= 251.0000 (mm)): 3358707.5696 (Nm˳), EI (y= 453.0000 (mm)): 3358707.5696 (Nm˳), m (yS= 352.0000 (mm)): 3.2488 (kg)

Jp: 0.0159 (kg*m˳), Jxx: 0.0190 (kg*m˳), Jzz: 0.0190 (kg*m˳)

Shaft 'Shaft 1': Bevel gear 'Kolo_K2' (y= 482.2543 (mm)) is taken into account as component of the shaft.
EI (y= 453.5086 (mm)): 28297525.7083 (Nm²), EI (y= 511.0000 (mm)): 28297525.7083 (Nm²), m (yS= 487.6150 (mm)): 10.5197 (kg)
Jp: 0.1823 (kg*m²), Jxx: 0.0938 (kg*m²), Jzz: 0.0938 (kg*m²)

Shaft 'Shaft 1': Bevel gear 'Kolo_K2' (y= 511.2457 (mm)) is taken into account as component of the shaft.
EI (y= 511.0000 (mm)): 3358707.5696 (Nm²), EI (y= 511.4914 (mm)): 3358707.5696 (Nm²), m (yS= 511.2457 (mm)): 0.2472 (kg)
Jp: 0.0036 (kg*m²), Jxx: 0.0018 (kg*m²), Jzz: 0.0018 (kg*m²)

---

maximum deflection		159.44	µm (Shaft 1, 352.00 (mm))

Center of mass

Shaft 1		326.9	mm

Deformation due to torsion

Shaft 1	[phi.t]	0.01	°

Probability of failure	[n]	10.00	%
Axial clearance	[uA]	10.00	µm

Rolling bearings, classical calculation (contact angle considered)

Shaft 'Shaft 1' Rolling bearing 'SKF*22320EJA_levé'

Position (Y-coordinate)	[y]	40.00	mm
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	544115.34	h
Operating viscosity	[nu]	48.88	mm²/s
Reference viscosity	[nu1]	0.00	mm²/s
static safety factor	[S0]	19.59	

	Bearing reaction force			Bearing reaction moment		
	Fx (kN)	Fy (kN)	Fz (kN)	Mx (Nm)	My (Nm)	Mz (Nm)
1	-9.921	0.000	56.319	0.000	0.000	0.000
2	-6.945	0.000	39.635	0.000	0.000	0.000

	Displacement of bearing			Misalignment of bearing		
	ux (mm)	uy (mm)	uz (mm)	ux (mrad)	uy (mrad)	uz (mrad)
1	0.0089	-0.0124	-0.0479	-0.465	-0.000	-0.033
2	0.0088	-0.0117	-0.0479	-0.304	-0.000	-0.019

Shaft 'Shaft 1' Rolling bearing 'SKF_31322 XJ2 prave'

Position (Y-coordinate)	[y]	681.00	mm
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	30896.52	h
Operating viscosity	[nu]	48.88	mm²/s
Reference viscosity	[nu1]	0.00	mm²/s
static safety factor	[S0]	10.15	

	Bearing reaction force			Bearing reaction moment		
	Fx (kN)	Fy (kN)	Fz (kN)	Mx (Nm)	My (Nm)	Mz (Nm)

1	6.191	24.107	69.947	0.000	0.000	0.000
2	4.334	16.875	49.150	0.000	0.000	0.000

	Displacement of bearing			Misalignment of bearing		
	ux (mm)	uy (mm)	uz (mm)	ux (mrad)	uy (mrad)	uz (mrad)
1	-0.0000	-0.0100	-0.0000	0.735	0.183	0.018
2	-0.0000	-0.0100	-0.0000	0.538	0.128	0.017

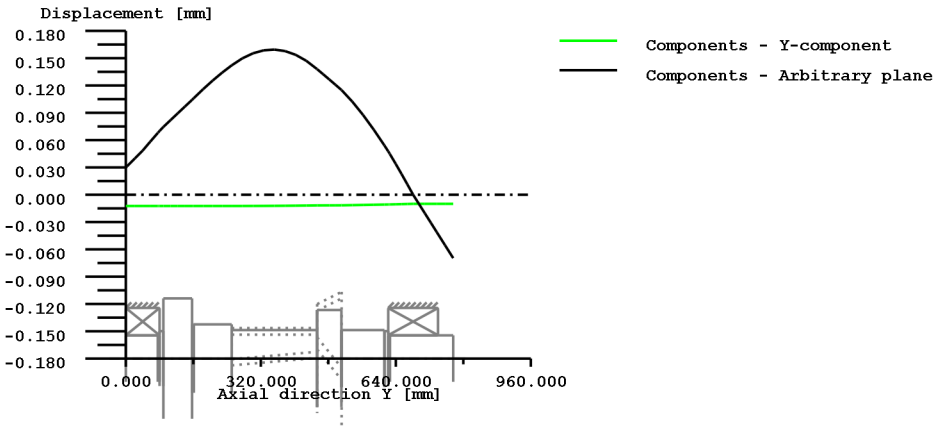
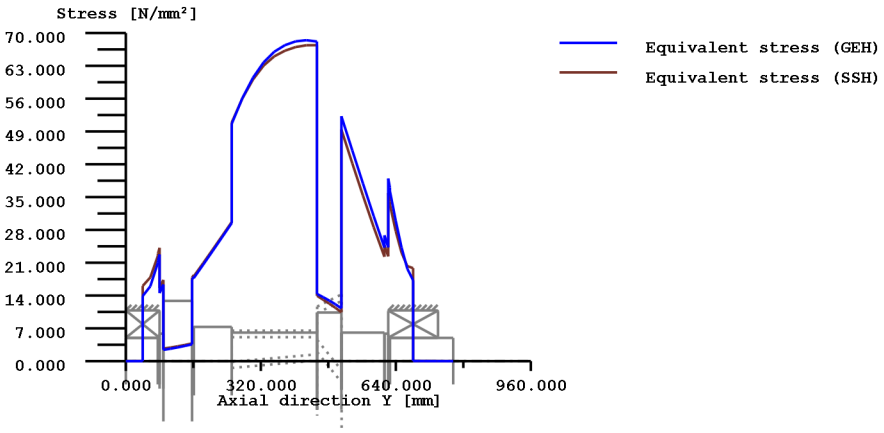


Figure: Displacement (bending etc.) (Arbitrary plane -85.21592805 °)



GEH(von Mises): sigV = ((sigB+sigZ,D)^2 + 3*(tauT+tauS)^2)^1/2SSH(Tresca): sigV = ((sigB-sigZ,D)^2 + 4*(tauT+tauS)^2)^1/2
Figure: Equivalent stress

Strength calculation as specified in

DIN 743:2012

with finite life fatigue strength according to FKM standard and FVA draft

Summary

Label	Shaft 1
Drawing	OL 232 969

Material	18CrNiMo7-6
Material type	Case-carburized steel
Material treatment	case-hardened
Surface treatment	No

Calculation of service strength and static strength
Woehler line (S-N curve) according Miner elementary
Calculation for load case 2 (sig.av/sig.mv = const)

Cross section	Position (Y-Coord) (mm)	
A-A	80.00	Shoulder

Results:

Cross section	Kfb	Kfsig	K2d	SD	SS	SA
A-A	2.61	0.88	0.82	6.81	23.81	22.09
Nominal safety:				1.20	1.20	1.20

Abbreviations:
Kfb: Notch factor bending
Kfsig: Surface factor
K2d: Size coefficient bending
SD: Safety endurance limit
SS: Safety against yield point
SA: Safety against incipient crack

The requirements of the safety proof of the shaft are:

satisfied [x] not satisfied [ ]

Design engineer:..... Date:..... Signature:.....

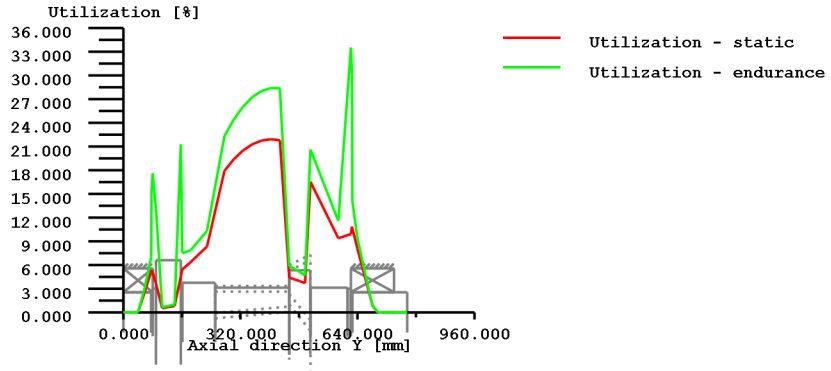


Figure: Strength

Calculation details:

General statements

Label	Shaft 1		
Drawing	OL 232 969		
Length (mm)		[l]	776.00
Speed (1/min)		[n]	800.00

Material	18CrNiMo7-6
Material type	Case-carburized steel
Material treatment	case-hardened
Surface treatment	No

	Tension/Compression	Bending	Torsion	Shearing
Load factor static calculation	1.700	1.700	1.700	1.700
Load factor endurance limit	1.000	1.000	1.000	1.000

Reference diameter material (mm)	[dB]	16.00
sigB according DIN 743 (at dB) (N/mm²)	[sigB]	1200.00
sigS according DIN 743 (at dB) (N/mm²)	[sigS]	850.00
[sigzdW] (bei dB) (N/mm²)		480.00
[sigbW] (bei dB) (N/mm²)		600.00
[tautW] (bei dB) (N/mm²)		360.00
Thickness of raw material (mm)	[dWerkst]	290.00

Material data calculated according DIN743/3 with K1(d)
Material strength calculated from size of raw material
Geometric size coefficient K1d calculated from raw material diameter

[sigBeff] (N/mm²)	807.42

[sigSeff] (N/mm²)	571.92
[sigbF] (N/mm²)	629.11
[tautF] (N/mm²)	363.22
[sigBRand] (N/mm²)	2300.00
[sigzdW] (N/mm²)	322.97
[sigbW] (N/mm²)	403.71
[tautW] (N/mm²)	242.23

Service strength for a load spectrum

Woehler line (S-N curve) according	Miner elementary		
Required life time	[h]	2400.00	
Number of load cycles (Mio)	[NL]	115.200	
Data of Woehler line (S-N curve) analog to FKM standard:			
[ksigma, ktau]	15	25	
[kDsigma, kDtau]	0	0	
[NDsigma, NDtau]	1e+006	1e+006	
[NDsigmaII, NDtauII]	0	0	
[DM]	0.3		

Calculation for load case 2 (sig.av/sig.mv = const)

Cross section 'A-A' Shoulder

Comment				
Position (Y-Coordinate) (mm)	[y]	80.00		
External diameter (mm)	[da]	109.200		
Inner diameter (mm)	[di]	0.000		
Notch effect	Shoulder			
[D, r, t] (mm)	130.000	1.000	0.000	
Mean roughness (µm)	[Rz]	8.000		

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	0.0	0.0	-0.0	0.0
Amplitude	0.0	2285.1	0.0	57129.6
Maximum value	0.0	3884.7	0.0	97120.3
Cross section, moment of resistance: (mm²)				
[A, Wb, Wt, A]	9365.6	127840.3	255680.6	9365.6

Load spectrum, load base values (Mean-value + Amplitude):

Element	Frequency (%)	Tens./Press. (N)	Bending (Nm)	Torsion (Nm)	Shearing (N)
1	20.00	0.000	2285.145	-0.000	57129.560
2	80.00	0.000	1607.261	-0.000	40182.462

Stresses: (N/mm²)				
[sigzdm, sigbm, taum, tauqm] (N/mm²)	0.000	0.000	-0.000	0.000
[sigzda, sigba, taua, tauqa] (N/mm²)	0.000	17.875	0.000	8.133
[sigzdmax,sigbmax,taumax,tauqmax] (N/mm²)	0.000	30.387	0.000	13.827

Technological size influence	[K1(sigB)]	0.673
	[K1(sigS)]	0.673

	Tension/Compression	Bending	Torsion

Stress concentration factor		[alfa]	3.816	3.426	2.199
References stress slope		[G']	2.454	2.454	1.150
Notch sensitivity factor	n	[n]	1.313	1.313	1.214
Notch effect coefficient		[beta]	2.907	2.610	1.811
Geometrical size influence		[K2(d)]	1.000	0.821	0.821
Influence coefficient surface roughness		[KF]	0.880	0.880	0.931
Influence coefficient surface strengthening		[KV]	1.000	1.000	1.000
Total influence coefficient		[K]	3.044	3.315	2.280

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm²)	[sigmV]		0.000	
Equivalent mean stress (N/mm²)	[taumV]		0.000	
Fatigue limit of part (N/mm²)	[sigWK]	106.089	121.772	106.226
Influence coeff. mean stress sensitivity.	[PsisigK]	0.070	0.082	0.070
Permissible amplitude (N/mm²)	[sigADK]	106.089	121.772	106.226
Permissible amplitude (N/mm²)	[sigANK]	106.089	121.772	106.226
Load spectrum factor	[fKoll]	1.000	1.000	1.000
Margin of safety endurance limit	[S]		6.812	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		567.7	

Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.100	1.100
Increase coefficient	[gammaF]	1.150	1.150	1.000
Yield stress of part (N/mm²)	[sigFK]	657.709	723.480	363.218
Margin of safety yield stress	[S]		23.808	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1841.1	

Present margin of safety for proof of avoiding incipient crack on hard surface layers:		
Safety against incipient crack	[S]	22.093
Required safety	[Smin]	1.200
Result (%)	[S/Smin]	1841.1

Remarks:

- The shearing force is not considered in the analysis specified in DIN 743.
- Cross section with interference fit:
  The notching factor for the light fit case is no longer defined in DIN 743.
  The values are imported from the FKM-Guideline..

End of Report lines: 437

File

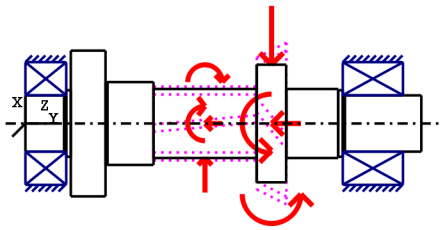
Name : Hridel_l_2_stavy
Changed by: karlova am: 02.05.2014 um: 10:55:00

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label		Shaft 1
Drawing		OL 232 969
Initial position (mm)		0.000
Length (mm)		776.000
Speed (1/min)		800.00
Sense of rotation: clockwise		
Material		18CrNiMo7-6
Young's modulus (N/mm²)		206000.000
Poisson's ratio nu		0.300
Specific weight (kg/m³)		7830.000
Coefficient of thermal expansion	(10^-6/K)	11.500
Temperature (°C)		20.000
Weight of shaft (kg)		121.345
Mass moment of inertia (kg*m²)		0.841
Momentum of mass GD2 (Nm²)		33.015
(Notice: Weight stands for the shaft only without considering the gears)		
Position in space (°)		0.000
Regard gears as masses and stiffness		
Consider deformations due to shearing		
Shear correction coefficient		1.100
Contact angle of rolling bearings is considered		
Reference temperature (°C)		20.000



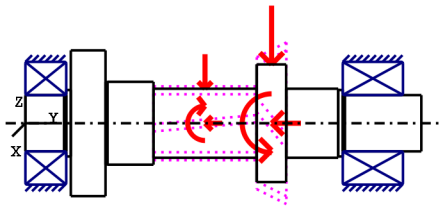


Figure: Load applications

SHAFT DEFINITION (Shaft 1)

Outer contour

Cylinder (Cylinder) y= 0.00...76.00 (mm)
d=110.00 (mm), l=76.00 (mm), Rz= 4.8

Chamfer left (Chamfer left)
l=2.00 (mm), alpha=45.00 (°)

Cylinder (Cylinder) y= 76.00...80.00 (mm)
d=109.20 (mm), l=4.00 (mm), Rz= 8.0

Radius left (Radius left)
r=1.00 (mm), Rz= 8.0

Radius right (Radius right)
r=1.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 80.00...89.00 (mm)
d=130.00 (mm), l=9.00 (mm), Rz= 4.8

Chamfer left (Chamfer left)
l=1.00 (mm), alpha=45.00 (°)

Radius right (Radius right)
r=2.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 89.00...157.00 (mm)

d=285.00 (mm), l=68.00 (mm), Rz= 4.8

Chamfer left (Chamfer left)
l=2.00 (mm), alpha=45.00 (°)

Cylinder (Cylinder) y= 157.00...161.00 (mm)
d=161.20 (mm), l=4.00 (mm), Rz= 8.0

Radius left (Radius left)
r=1.00 (mm), Rz= 8.0

Radius right (Radius right)
r=1.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 161.00...251.00 (mm)
d=162.00 (mm), l=90.00 (mm), Rz= 4.8

Chamfer left (Chamfer left)
l=1.00 (mm), alpha=45.00 (°)

Cylinder (Cylinder) y= 251.00...453.00 (mm)
d=135.00 (mm), l=202.00 (mm), Rz= 4.8

Chamfer right (Chamfer right)
l=1.00 (mm), alpha=45.00 (°)

Cylinder (Cylinder) y= 453.00...511.00 (mm)
d=230.00 (mm), l=58.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 511.00...613.00 (mm)
d=135.00 (mm), l=102.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 613.00...622.00 (mm)
d=130.00 (mm), l=9.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 622.00...626.00 (mm)
d=109.20 (mm), l=4.00 (mm), Rz= 8.0

Radius left (Radius left)
r=1.00 (mm), Rz= 8.0

Radius right (Radius right)
r=1.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 626.00...776.00 (mm)
d=110.00 (mm), l=150.00 (mm), Rz= 4.8

Chamfer right (Chamfer right)
l=2.00 (mm), alpha=45.00 (°)

Inner contour

Forces

Cylindrical gear (Kolo_1) y= 352.00 (mm)

Operating pitch diameter	(mm)	144.3617	
Helix angle	(°)	14.2019	left
Working pressure angle at normal section	(°)	22.0888	
Position of contact point	(°)	180.0000	
Length of load application	(mm)	202.0000	
Power	(kW)	502.6548	driving (Output)
Torque	(Nm)	-6000.0000	
Axial force	(N)	-21036.6866	
Shearing force X	(N)	34798.0129	
Shearing force Z	(N)	-83124.5394	
Bending moment X	(Nm)	0.0000	
Bending moment Z	(Nm)	1518.4459	

Hypoid gear (Kolo_K2) y= 482.50 (mm)

Operating pitch diameter	(mm)	287.0000	
Helix angle	(°)	30.0000	right
Half angle of cone	(°)	45.0000	Tip to the left
Working pressure angle at normal section	(°)	20.0000	
Position of contact point	(°)	0.0000	
Face width	(mm)	82.0000	
Power	(kW)	502.6548	driven (Input)
Torque	(Nm)	6000.0000	
Axial force	(N)	-3070.8072	
Shearing force X	(N)	-31068.4226	
Shearing force Z	(N)	-41811.8467	
Bending moment X	(Nm)	0.0000	
Bending moment Z	(Nm)	-440.6608	

Bearing

Spherical roller bearings SKF *22322E (SKF*22320EJA_levé) y= 40.00 (mm)

Free bearing

d = 110.000 (mm), D = 240.000 (mm), B = 80.000 (mm), r = 3.000 (mm)

C = 950.000 (kN), C0 = 1120.000 (kN), Cu = 100.000 (kN)

Bearing clearance DIN 620:1988 C0 (97.50 µm)

Taper roller bearing (paired) (O,TDO) Koyo 46T30322JR/93 (SKF_31322 XJ2 prave) y= 681.00 (mm)

Fixed bearing

d = 110.000 (mm), D = 240.000 (mm), B = 118.000 (mm), r = 3.000 (mm)

C = 824.000 (kN), C0 = 1180.000 (kN), Cu = 0.000 (kN)

Shaft 'Shaft 1': Cylindrical gear 'Kolo_1' (y= 352.0000 (mm)) is taken into account as component of the shaft.

EI (y= 251.0000 (mm)): 3358707.5696 (Nm^2), EI (y= 453.0000 (mm)): 3358707.5696 (Nm^2), m (yS= 352.0000 (mm)): 3.2488 (kg)

Jp: 0.0159 (kg*m^2), Jxx: 0.0190 (kg*m^2), Jzz: 0.0190 (kg*m^2)

Shaft 'Shaft 1': Bevel gear 'Kolo_K2' (y= 482.2543 (mm)) is taken into account as component of the shaft.

EI (y= 453.5086 (mm)): 28297525.7083 (Nm^2), EI (y= 511.0000 (mm)): 28297525.7083 (Nm^2), m (yS= 487.6150 (mm)): 10.5197 (kg)

Jp: 0.1823 (kg*m^2), Jxx: 0.0938 (kg*m^2), Jzz: 0.0938 (kg*m^2)

Shaft 'Shaft 1': Bevel gear 'Kolo_K2' (y= 511.2457 (mm)) is taken into account as component of the shaft.
EI (y= 511.0000 (mm)): 3358707.5696 (Nm^2), EI (y= 511.4914 (mm)): 3358707.5696 (Nm^2), m (yS= 511.2457 (mm)): 0.2472 (kg)
Jp: 0.0036 (kg*m^2), Jxx: 0.0018 (kg*m^2), Jzz: 0.0018 (kg*m^2)

---

maximum deflection		159.44	µm (Shaft 1, 352.00 (mm))

Center of mass

Shaft 1		326.9	mm

Deformation due to torsion

Shaft 1	[phi.t]	0.01	°

Probability of failure	[n]	10.00	%
Axial clearance	[uA]	10.00	µm

Rolling bearings, classical calculation (contact angle considered)

Shaft 'Shaft 1' Rolling bearing 'SKF*22320EJA_levé'

Position (Y-coordinate)	[y]	40.00	mm
Equivalent load	[P]	57.19	kN
Equivalent load	[P0]	57.19	kN
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	243709.67	h
Operating viscosity	[nu]	48.88	mm^2/s
Reference viscosity	[nu1]	0.00	mm^2/s
static safety factor	[S0]	19.59	
Bearing reaction force	[Fx]	-9.921	kN
Bearing reaction force	[Fy]	0.000	kN
Bearing reaction force	[Fz]	56.319	kN
Bearing reaction force	[Fr]	57.186	kN (99.99°)
Oil level	[H]	103.750	mm
Torque of friction	[Mloss]	11.614	Nm
Power loss	[Ploss]	973.004	W
Displacement of bearing	[ux]	0.009	mm
Displacement of bearing	[uy]	-0.012	mm
Displacement of bearing	[uz]	-0.048	mm
Displacement of bearing	[ur]	0.049	mm (-79.47°)
Misalignment of bearing	[rx]	-0.465	mrad (-1.6')
Misalignment of bearing	[ry]	-0.000	mrad (0')
Misalignment of bearing	[rz]	-0.033	mrad (-0.11')
Misalignment of bearing	[rr]	0.466	mrad (1.6')

Shaft 'Shaft 1' Rolling bearing 'SKF_31322 XJ2 prave'

Position (Y-coordinate)	[y]	681.00	mm
Equivalent load	[P]	117.47	kN
Equivalent load	[P0]	116.27	kN
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	13763.95	h
Operating viscosity	[nu]	48.88	mm^2/s
Reference viscosity	[nu1]	0.00	mm^2/s
static safety factor	[S0]	10.15	
Bearing reaction force	[Fx]	6.191	kN

Bearing reaction force	[Fy]	24.107	kN
Bearing reaction force	[Fz]	69.947	kN
Bearing reaction force	[Fr]	70.221	kN (84.94°)
Oil level	[H]	103.750	mm
Torque of friction	[Mloss]	23.811	Nm
Power loss	[Ploss]	1994.805	W
Displacement of bearing	[ux]	-0.000	mm
Displacement of bearing	[uy]	-0.010	mm
Displacement of bearing	[uz]	-0.000	mm
Displacement of bearing	[ur]	0.000	mm
Misalignment of bearing	[rx]	0.735	mrad (2.53')
Misalignment of bearing	[ry]	0.183	mrad (0.63')
Misalignment of bearing	[rz]	0.018	mrad (0.06')
Misalignment of bearing	[rr]	0.735	mrad (2.53')

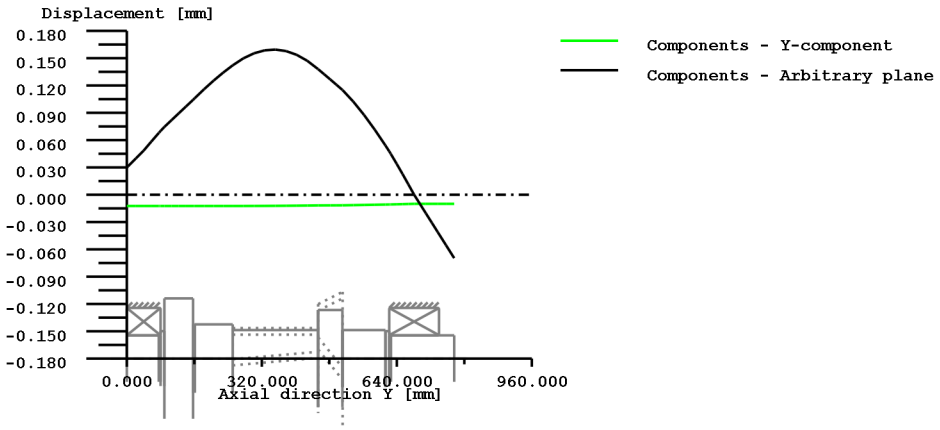
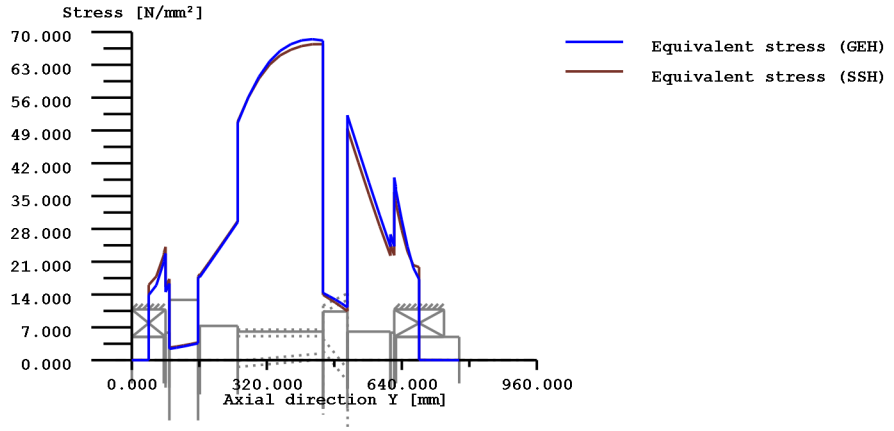


Figure: Displacement (bending etc.) (Arbitrary plane -85.21592805 °)



GEH(von Mises): sigV = ((sigB+sigZ,D)^2 + 3*(tauT+tauS)^2)^1/2SSH(Tresca): sigV = ((sigB-sigZ,D)^2 + 4*(tauT+tauS)^2)^1/2
Figure: Equivalent stress

Eigenfrequencies/Critical speeds

1. Eigenfrequency:	0.00 Hz, Critical speed:	0.03 1/min	Rigid body rotation Y 'Shaft 1'
2. Eigenfrequency:	579.37 Hz, Critical speed:	34762.39 1/min	Bending YZ 'Shaft 1', Bending XY 'Shaft 1'
3. Eigenfrequency:	1291.11 Hz, Critical speed:	77466.59 1/min	Torsion 'Shaft 1'
4. Eigenfrequency:	1458.67 Hz, Critical speed:	87520.42 1/min	Axial 'Shaft 1'

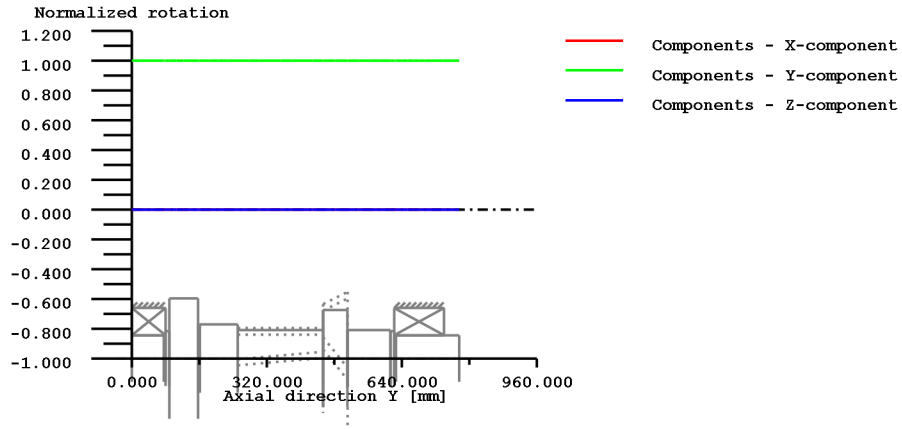


Figure: Eigenfrequencies (Normalized displacement)

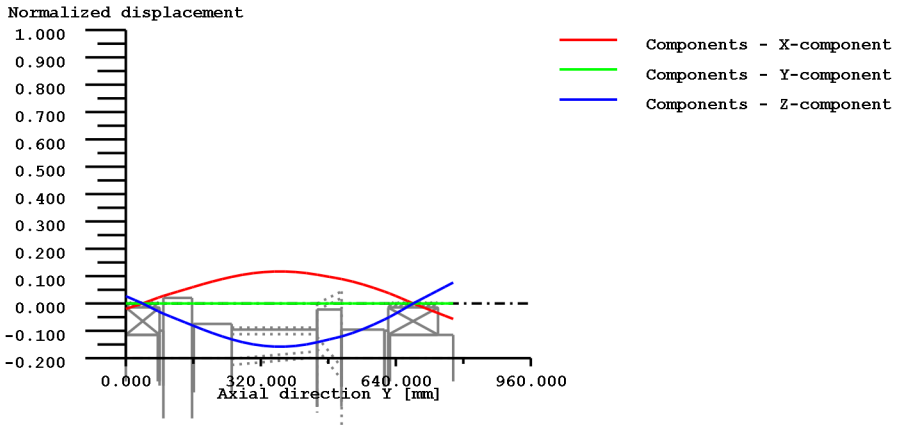


Figure: Eigenfrequencies (Normalized rotation)

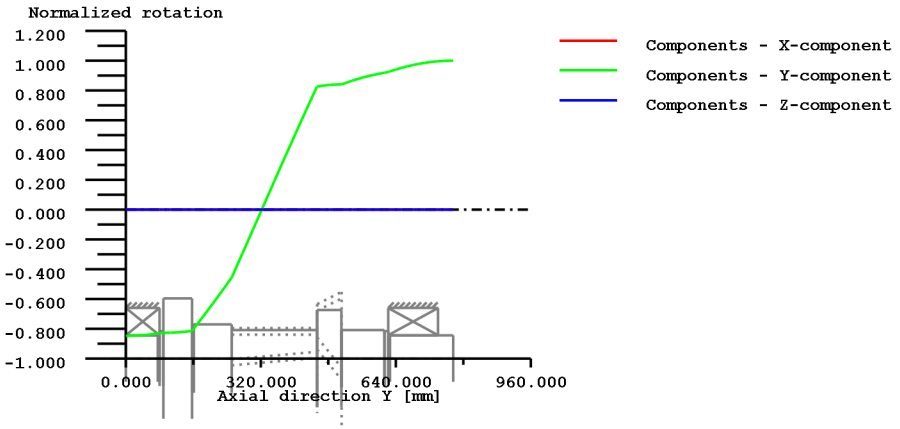


Figure: Eigenfrequencies (Normalized displacement)

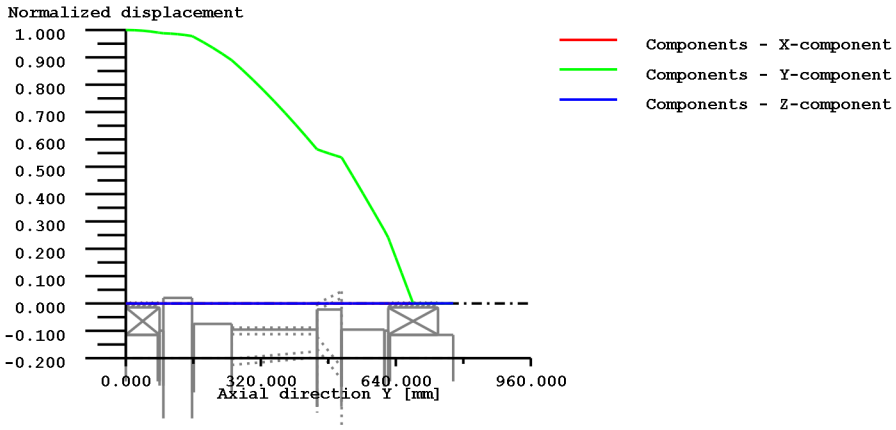


Figure: Eigenfrequencies (Normalized rotation)

Strength calculation as specified in

DIN 743:2012

Summary

Label	Shaft 1
Drawing	OL 232 969

Material	18CrNiMo7-6
Material type	Case-carburized steel
Material treatment	case-hardened
Surface treatment	No

Calculation of endurance limit and the static strength
Calculation for load case 2 (sig.av/sig.mv = const)

Cross section	Position (Y-Coord) (mm)	
A-A	80.00	Shoulder

Results:

Cross section	Kfb	Kfsig	K2d	SD	SS	SA
A-A	2.61	0.88	0.82	6.81	23.81	22.09
Nominal safety:				1.20	1.20	1.20

Abbreviations:
Kfb: Notch factor bending
Kfsig: Surface factor
K2d: Size coefficient bending
SD: Safety endurance limit
SS: Safety against yield point
SA: Safety against incipient crack

The requirements of the safety proof of the shaft are:

satisfied [x] not satisfied [ ]

Design engineer:..... Date:..... Signature:.....

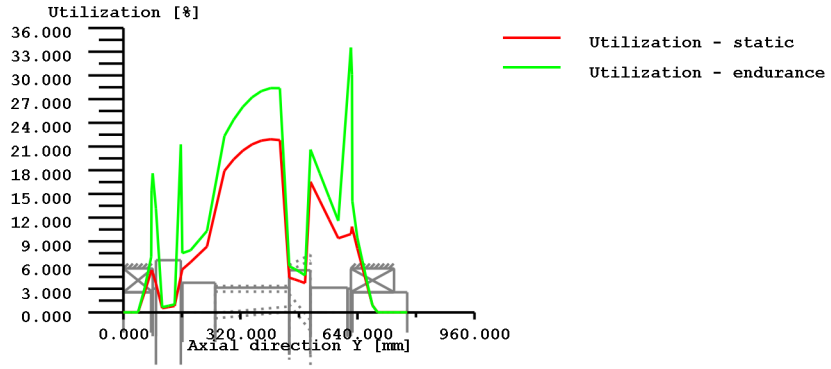


Figure: Strength

Calculation details:

General statements

Label	Shaft 1		
Drawing	OL 232 969		
Length (mm)		[l]	776.00
Speed (1/min)		[n]	800.00

Material	18CrNiMo7-6
Material type	Case-carburized steel
Material treatment	case-hardened
Surface treatment	No

	Tension/Compression	Bending	Torsion	Shearing
Load factor static calculation	1.700	1.700	1.700	1.700
Load factor endurance limit	1.000	1.000	1.000	1.000

Reference diameter material (mm)	[dB]	16.00
sigB according DIN 743 (at dB) (N/mm²)	[sigB]	1200.00
sigS according DIN 743 (at dB) (N/mm²)	[sigS]	850.00
[sigzdW] (bei dB) (N/mm²)		480.00
[sigbW] (bei dB) (N/mm²)		600.00
[tautW] (bei dB) (N/mm²)		360.00
Thickness of raw material (mm)	[dWerkst]	290.00

Material data calculated according DIN743/3 with K1(d)
Material strength calculated from size of raw material
Geometric size coefficient K1d calculated from raw material diameter

[sigBeff] (N/mm²)	807.42

[sigSeff] (N/mm²)	571.92
[sigbF] (N/mm²)	629.11
[tautF] (N/mm²)	363.22
[sigBRand] (N/mm²)	2300.00
[sigzdW] (N/mm²)	322.97
[sigbW] (N/mm²)	403.71
[tautW] (N/mm²)	242.23

Endurance limit for single stage use

Calculation for load case 2 (sig.av/sig.mv = const)

Cross section 'A-A' Shoulder

Comment					
Position (Y-Coordinate) (mm)			[y]		80.00
External diameter (mm)			[da]		109.200
Inner diameter (mm)			[di]		0.000
Notch effect	Shoulder				
[D, r, t] (mm)		130.000	1.000	0.000	
Mean roughness (µm)			[Rz]		8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-0.0	0.0	0.0	0.0
Amplitude	0.0	2285.1	0.0	57129.6
Maximum value	-0.0	3884.7	0.0	97120.3
Cross section, moment of resistance: (mm²)				
[A, Wb, Wt, A]	9365.6	127840.3	255680.6	9365.6

Stresses: (N/mm²)				
[sigzdm, sigbm, taum, tauqm] (N/mm²)	-0.000	0.000	0.000	0.000
[sigzda, sigba, taua, tauqa] (N/mm²)	0.000	17.875	0.000	8.133
[sigzdmax,sigbmax,taumax,tauqmax] (N/mm²)	-0.000	30.387	0.000	13.827

Technological size influence	[K1(sigB)]	0.673	
	[K1(sigS)]	0.673	

		Tension/Compression	Bending	Torsion
Stress concentration factor	[alfa]	3.816	3.426	2.199
References stress slope	[G']	2.454	2.454	1.150
Notch sensitivity factor n	[n]	1.313	1.313	1.214
Notch effect coefficient	[beta]	2.907	2.610	1.811
Geometrical size influence	[K2(d)]	1.000	0.821	0.821
Influence coefficient surface roughness				
	[KF]	0.880	0.880	0.931
Influence coefficient surface strengthening				
	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	3.044	3.315	2.280

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm²)	[sigmV]		0.000	
Equivalent mean stress (N/mm²)	[taumV]		0.000	
Fatigue limit of part (N/mm²)	[sigWK]	106.089	121.772	106.226

Influence coeff. mean stress sensitivity.				
	[PsisigK]	0.070	0.082	0.070
Permissible amplitude (N/mm²)	[sigADK]	106.089	121.772	106.226
Margin of safety endurance limit	[S]		6.812	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		567.7	
Present margin of safety				
for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.100	1.100
Increase coefficient	[gammaF]	1.150	1.150	1.000
Yield stress of part (N/mm²)	[sigFK]	657.709	723.480	363.218
Margin of safety yield stress	[S]		23.809	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1841.1	
Present margin of safety				
for proof of avoiding incipient crack on hard surface layers:				
Safety against incipient crack	[S]		22.093	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1841.1	

Remarks:

- The shearing force is not considered in the analysis specified in DIN 743.
- Cross section with interference fit:
  The notching factor for the light fit case is no longer defined in DIN 743.
  The values are imported from the FKM-Guideline..

End of Report lines: 437

Important hint: At least one warning has occurred during the calculation:
1-> The speed is 0! ('SKF 61836')

2-> The required service life of bearing 'Rolling bearing 'Spoj. SKF 61836 levé' is not achieved!
The static margin of safety is low (in range 0.5 - 2.0).

Please check whether these values are acceptable or not.

3-> The speed is 0! ('SKF 61836')

4-> The required service life of bearing 'Rolling bearing 'Spoj. SKF 61836 pravé' is not achieved!
The static margin of safety is low (in range 0.5 - 2.0).

Please check whether these values are acceptable or not.

5-> The speed is 0! ('SKF 61832')

6-> Rolling bearing 'Spoj. SKF 61832 levé:
The minimal load of the bearing is not achieved!
(P = 0.3 kN, Pmind = 0.5 kN, Condition: P/C > 1.000 %)

7-> The required service life of bearing 'Rolling bearing 'Spoj. SKF 61832 levé' is not achieved!

8-> The speed is 0! ('SKF 61832')

9-> Rolling bearing 'Spoj. SKF 61832 pravé:
The minimal load of the bearing is not achieved!
(P = 0.0 kN, Pmind = 0.5 kN, Condition: P/C > 1.000 %)

10-> The required service life of bearing 'Rolling bearing 'Spoj. SKF 61832 pravé' is not achieved!

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label	Shaft
Drawing	OL 232 959
Initial position (mm)	0.000
Length (mm)	760.000
Speed (1/min)	212.50
Sense of rotation: counter clockwise	
Material	18CrNiMo7-6
Young's modulus (N/mm²)	206000.000
Poisson's ratio nu	0.300
Specific weight (kg/m³)	7830.000

Coefficient of thermal expansion	(10^-6/K)	11.500
Temperature (°C)		20.000
Weight of shaft (kg)		134.349
Mass moment of inertia (kg*m²)		0.488
Momentum of mass GD2 (Nm²)		19.158

Label	Shaft 2 (Zástupce kola 2)
Drawing	Ozubené kolo 2 (OL 232 960)
Initial position (mm)	284.500
Length (mm)	155.000
Speed (1/min)	212.50

Sense of rotation: counter clockwise

Material		18CrNiMo7-6
Young's modulus (N/mm²)		206000.000
Poisson's ratio nu		0.300
Specific weight (kg/m³)		7830.000
Coefficient of thermal expansion	(10^-6/K)	11.500
Temperature (°C)		20.000
Weight of shaft (kg)		131.248
Mass moment of inertia (kg*m²)		4.438
Momentum of mass GD2 (Nm²)		174.145

Label	Shaft 3 (zástupce kola 4)
Drawing	ozubené kolo 4 (OL232 961)
Initial position (mm)	531.500
Length (mm)	109.500
Speed (1/min)	212.50

Sense of rotation: counter clockwise

Material		18CrNiMo7-6
Young's modulus (N/mm²)		206000.000
Poisson's ratio nu		0.300
Specific weight (kg/m³)		7830.000
Coefficient of thermal expansion	(10^-6/K)	11.500
Temperature (°C)		20.000
Weight of shaft (kg)		34.825
Mass moment of inertia (kg*m²)		0.547
Momentum of mass GD2 (Nm²)		21.445

Position in space (°)	0.000

Consider deformations due to shearing

Shear correction coefficient	1.100

Contact angle of rolling bearings is considered

Reference temperature (°C)	20.000

Figure: Load applications

SHAFT DEFINITION (Shaft)

Outer contour

Cylinder (Cylinder) y= 0.00...109.00 (mm)
d=160.00 (mm), l=109.00 (mm), Rz= 8.0

Chamfer left (Chamfer left)
l=2.00 (mm), alpha=45.00 (°)

Cylinder (Cylinder) y= 109.00...403.50 (mm)
d=180.00 (mm), l=294.50 (mm), Rz= 8.0

Square groove (Square groove) y= 370.28...374.43 (mm)
b=4.15 (mm), t=2.50 (mm), r=0.50 (mm), Rz= 8.0

Chamfer right (Chamfer right)
l=22.00 (mm), alpha=25.00 (°)

Cylinder (Cylinder) y= 403.50...418.50 (mm)
d=158.00 (mm), l=15.00 (mm), Rz= 8.0

Radius left (Radius left)
r=1.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 418.50...570.00 (mm)
d=168.00 (mm), l=151.50 (mm), Rz= 8.0

Cylinder (Cylinder) y= 570.00...760.00 (mm)

d=160.00 (mm), l=190.00 (mm), Rz= 8.0

Chamfer right (Chamfer right)
l=2.00 (mm), alpha=45.00 (°)

Inner contour

Forces

Cylindrical gear (Cylindrical gear 5 (OL232 959)) y= 202.50 (mm)

Operating pitch diameter	(mm)	199.4521	
Helix angle	(°)	14.0000	right
Working pressure angle at normal section	(°)	25.0000	
Position of contact point	(°)	180.0000	
Length of load application	(mm)	160.0000	
Axial force (Load spectrum)	(N)	-56473.52/-39531.46	
Shearing force X (Load spectrum)	(N)	108853.45/76197.41	
Shearing force Z (Load spectrum)	(N)	226502.90/158552.03	
Bending moment X (Load spectrum)	(N)	0.00/0.00	
Bending moment Z (Load spectrum)	(N)	5631.88/3942.32	

load spectrum,driving (Output):

Element	Frequency (%)	Speed (1/min)	Power (kW)	Torque (Nm)
1	20.0000	-212.5	-502.7	22588.2
2	80.0000	-212.5	-351.9	15811.8

Bearing

Spherical roller bearings SKF *24132CC/W33 (SKF*24132CC levé) y= 54.50 (mm)
Set fixed bearing left
d = 160.000 (mm), D = 270.000 (mm), B = 109.000 (mm), r = 2.100 (mm)
C = 1180.000 (kN), C0 = 1760.000 (kN), Cu = 163.000 (kN)
Bearing clearance DIN 620:1988 C0 (140.00 µm)

Spherical roller bearings SKF *24132CC/W33 (SKF*24132CC pravé) y= 703.50 (mm)
Set fixed bearing right
d = 160.000 (mm), D = 270.000 (mm), B = 109.000 (mm), r = 2.100 (mm)
C = 1180.000 (kN), C0 = 1760.000 (kN), Cu = 163.000 (kN)
Bearing clearance DIN 620:1988 C0 (140.00 µm)

SHAFT DEFINITION (Shaft 2 (Zástupce kola 2))

Outer contour

Cylinder (Cylinder) y= 0.00...120.00 (mm)
d=460.00 (mm), l=120.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 120.00...155.00 (mm)
d=440.00 (mm), l=35.00 (mm), Rz= 8.0

Inner contour

Cone inside (Conical bore) y= 0.00...2.00 (mm)
d1=229.00 (mm), d2=225.00 (mm), l=2.00 (mm)

Cylinder inside (Cylindrical bore) y= 2.00...27.85 (mm)
d=225.00 (mm), l=25.85 (mm)

Cylinder inside (Cylindrical bore) y= 27.85...33.00 (mm)
d=236.00 (mm), l=5.15 (mm)

Cylinder inside (Cylindrical bore) y= 33.00...112.00 (mm)
d=225.00 (mm), l=79.00 (mm)

Cone inside (Conical bore) y= 112.00...114.00 (mm)
d1=225.00 (mm), d2=229.00 (mm), l=2.00 (mm)

Cylinder inside (Cylindrical bore) y= 114.00...121.00 (mm)
d=360.00 (mm), l=7.00 (mm)

Cylinder inside (Cylindrical bore) y= 121.00...155.00 (mm)
d=348.00 (mm), l=34.00 (mm)

Forces

Cylindrical gear (Cylindrical gear 2 (OL232 960)) y= 60.00 (mm)

Operating pitch diameter	(mm)	466.1728	
Helix angle	(°)	13.0000	right
Working pressure angle at normal section	(°)	20.0000	
Position of contact point	(°)	0.0000	
Length of load application	(mm)	120.0000	
Axial force (Load spectrum)	(N)	22373.27/15661.29	
Shearing force X (Load spectrum)	(N)	-36199.89/-25339.92	
Shearing force Z (Load spectrum)	(N)	96909.27/67836.49	
Bending moment X (Load spectrum)	(N)	-0.00/-0.00	
Bending moment Z (Load spectrum)	(N)	5214.90/3650.43	

load spectrum,driven (Input):

Element	Frequency (%)	Speed (1/min)	Power (kW)	Torque (Nm)
1	20.0000	-212.5	502.7	-22588.2
2	80.0000	-212.5	351.9	-15811.8

Bearing

SHAFT DEFINITION (Shaft 3 (zástupce kola 4))

Outer contour

Cylinder (Cylinder) y= 0.00...33.00 (mm)
d=300.00 (mm), l=33.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 33.00...39.50 (mm)
d=275.00 (mm), l=6.50 (mm), Rz= 8.0

Cylinder (Cylinder) y= 39.50...109.50 (mm)
d=298.54 (mm), l=70.00 (mm), Rz= 8.0

Inner contour

Cylinder inside (Cylindrical bore) y= 0.00...37.50 (mm)
d=185.00 (mm), l=37.50 (mm)

Cone inside (Conical bore) y= 37.50...39.50 (mm)
d1=185.00 (mm), d2=189.00 (mm), l=2.00 (mm)

Cylinder inside (Cylindrical bore) y= 39.50...59.50 (mm)
d=200.00 (mm), l=20.00 (mm)

Cone inside (Conical bore) y= 59.50...60.50 (mm)
d1=192.00 (mm), d2=190.00 (mm), l=1.00 (mm)

Cylinder inside (Cylindrical bore) y= 60.50...88.50 (mm)
d=190.00 (mm), l=28.00 (mm)

Cone inside (Conical bore) y= 88.50...89.50 (mm)
d1=190.00 (mm), d2=192.00 (mm), l=1.00 (mm)

Cylinder inside (Cylindrical bore) y= 89.50...108.50 (mm)
d=200.00 (mm), l=19.00 (mm)

Cone inside (Conical bore) y= 108.50...109.50 (mm)
d1=200.00 (mm), d2=202.00 (mm), l=1.00 (mm)

Forces

Bearing

CONNECTIONS

Deep groove ball bearing (single row) SKF 61836 (Spoj. SKF 61836 levé) y= 301.00 (mm)
Shaft 'Shaft' <-> Shaft 'Shaft 2 (Zástupce kola 2)'
Set fixed bearing right
d = 180.000 (mm), D = 225.000 (mm), B = 22.000 (mm), r = 1.100 (mm)
C = 62.400 (kN), C0 = 81.500 (kN), Cu = 2.450 (kN)
Bearing clearance DIN 620:1988 C0 (40.50 µm)

Deep groove ball bearing (single row) SKF 61836 (Spoj. SKF 61836 pravé) y= 359.00 (mm)
Shaft 'Shaft' <-> Shaft 'Shaft 2 (Zástupce kola 2)'
Set fixed bearing left
d = 180.000 (mm), D = 225.000 (mm), B = 22.000 (mm), r = 1.100 (mm)
C = 62.400 (kN), C0 = 81.500 (kN), Cu = 2.450 (kN)
Bearing clearance DIN 620:1988 C0 (40.50 µm)

Deep groove ball bearing (single row) SKF 61832 (Spoj. SKF 61832 levé) y= 581.00 (mm)
Shaft 'Shaft' <-> Shaft 'Shaft 3 (zástupce kola 4)'

Set fixed bearing right
d = 160.000 (mm), D = 200.000 (mm), B = 20.000 (mm), r = 1.100 (mm)
C = 49.400 (kN), C0 = 64.000 (kN), Cu = 2.000 (kN)
Bearing clearance DIN 620:1988 C0 (35.50 µm)

Deep groove ball bearing (single row) SKF 61832 (Spoj. SKF 61832 pravé) y= 631.00 (mm)
Shaft 'Shaft' <-> Shaft 'Shaft 3 (zástupce kola 4)'
Set fixed bearing left
d = 160.000 (mm), D = 200.000 (mm), B = 20.000 (mm), r = 1.100 (mm)
C = 49.400 (kN), C0 = 64.000 (kN), Cu = 2.000 (kN)
Bearing clearance DIN 620:1988 C0 (35.50 µm)

Joint, general (Shaft - kolo 2): Shaft 'Shaft' <-> Shaft 'Shaft 2 (Zástupce kola 2)' y= 423.00 (mm)
Degrees of freedom
X: free, Y: free, Z: free
Rx: free, Ry: fixed, Rz: free

Joint, general (Shaft - kolo 4): Shaft 'Shaft' <-> Shaft 'Shaft 3 (zástupce kola 4)' y= 547.00 (mm)
Degrees of freedom
X: free, Y: free, Z: free
Rx: free, Ry: fixed, Rz: free

---

maximum deflection		264.15	µm (Shaft 2 (Zástupce kola 2),	439.50 (mm))

Center of mass

Shaft		370.7	mm
Shaft 2 (Zástupce kola 2)		80.7	mm
Shaft 3 (zástupce kola 4)		63.6	mm

Deformation due to torsion

Shaft	[phi.t]	-0.04	°
Shaft 2 (Zástupce kola 2)	[phi.t]	0.00	°
Shaft 3 (zástupce kola 4)	[phi.t]	0.00	°

Probability of failure	[n]	10.00	%
Axial clearance	[uA]	10.00	µm

Rolling bearings, classical calculation (contact angle considered)

Shaft 'Shaft' Rolling bearing 'SKF*24132CC levé'

Position (Y-coordinate)	[y]	54.50	mm
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	17249.40	h
Operating viscosity	[nu]	48.88	mm¸/s
Reference viscosity	[nu1]	0.00	mm¸/s
static safety factor	[S0]	5.96	

	Bearing reaction force			Bearing reaction moment		
	Fx (kN)	Fy (kN)	Fz (kN)	Mx (Nm)	My (Nm)	Mz (Nm)
1	-80.719	34.100	-227.022	0.000	0.000	0.000
2	-56.503	23.870	-158.485	0.000	0.000	0.000

Displacement of bearing **Misalignment of bearing**

	ux (mm)	uy (mm)	uz (mm)	ux (mrad)	uy (mrad)	uz (mrad)
1	0.0240	-0.0100	0.0658	0.763	-0.000	-0.030
2	0.0241	-0.0100	0.0657	0.534	0.000	-0.008

Shaft 'Shaft' Rolling bearing 'SKF*24132CC pravé'

Position (Y-coordinate)	[y]	703.50	mm
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	829215.97	h
Operating viscosity	[nu]	48.88	mm¸/s
Reference viscosity	[nu1]	0.00	mm¸/s
static safety factor	[S0]	18.77	

	Bearing reaction force			Bearing reaction moment		
	Fx (kN)	Fy (kN)	Fz (kN)	Mx (Nm)	My (Nm)	Mz (Nm)
1	8.065	0.000	-93.443	0.000	0.000	0.000
2	5.646	0.000	-64.956	0.000	0.000	0.000

	Displacement of bearing			Misalignment of bearing		
	ux (mm)	uy (mm)	uz (mm)	ux (mrad)	uy (mrad)	uz (mrad)
1	-0.0051	-0.0104	0.0698	-0.648	-0.642	0.038
2	-0.0052	-0.0103	0.0698	-0.450	-0.450	0.040

Rolling bearing 'Spoj. SKF 61836 levé'

Position (Y-coordinate)	[y]	301.00	mm
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	0.00	h
Operating viscosity	[nu]	48.88	mm¸/s
Reference viscosity	[nu1]	0.00	mm¸/s
static safety factor	[S0]	0.97	

	Bearing reaction force			Bearing reaction moment		
	Fx (kN)	Fy (kN)	Fz (kN)	Mx (Nm)	My (Nm)	Mz (Nm)
1	80.862	0.000	24.082	0.000	0.000	0.000
2	56.604	0.000	16.814	0.000	0.000	0.000

	Displacement of bearing			Misalignment of bearing		
	ux (mm)	uy (mm)	uz (mm)	ux (mrad)	uy (mrad)	uz (mrad)
1	-0.0193	-0.0103	-0.0062	0.028	0.376	-0.705
2	-0.0193	-0.0102	-0.0062	-0.002	0.264	-0.683

Rolling bearing 'Spoj. SKF 61836 pravé'

Position (Y-coordinate)	[y]	359.00	mm
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	0.00	h
Operating viscosity	[nu]	48.88	mm¸/s
Reference viscosity	[nu1]	0.00	mm¸/s
static safety factor	[S0]	0.59	

	Bearing reaction force			Bearing reaction moment		
	Fx (kN)	Fy (kN)	Fz (kN)	Mx (Nm)	My (Nm)	Mz (Nm)
1	-117.062	22.373	71.540	0.000	0.000	0.000
2	-81.943	15.661	49.735	0.000	0.000	0.000

Displacement of bearing	Misalignment of bearing

	ux (mm)	uy (mm)	uz (mm)	ux (mrad)	uy (mrad)	uz (mrad)
1	0.0173	-0.0100	-0.0105	-0.153	0.215	-0.703
2	0.0174	-0.0100	-0.0104	-0.128	0.150	-0.682

Rolling bearing 'Spoj. SKF 61832 levé'

Position (Y-coordinate)	[y]	581.00	mm
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	0.00	h
Operating viscosity	[nu]	48.88	mm¸/s
Reference viscosity	[nu1]	0.00	mm¸/s
static safety factor	[S0]	> 100	

	Bearing reaction force			Bearing reaction moment		
	Fx (kN)	Fy (kN)	Fz (kN)	Mx (Nm)	My (Nm)	Mz (Nm)
1	-0.000	0.000	-0.312	0.000	0.000	0.000
2	-0.000	0.000	-0.312	0.000	0.000	0.000

	Displacement of bearing			Misalignment of bearing		
	ux (mm)	uy (mm)	uz (mm)	ux (mrad)	uy (mrad)	uz (mrad)
1	0.0000	-0.0000	0.0177	0.102	0.000	0.006
2	0.0000	-0.0000	0.0177	0.071	0.000	0.003

Rolling bearing 'Spoj. SKF 61832 pravé'

Position (Y-coordinate)	[y]	631.00	mm
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	0.00	h
Operating viscosity	[nu]	48.88	mm¸/s
Reference viscosity	[nu1]	0.00	mm¸/s
static safety factor	[S0]	> 100	

	Bearing reaction force			Bearing reaction moment		
	Fx (kN)	Fy (kN)	Fz (kN)	Mx (Nm)	My (Nm)	Mz (Nm)
1	0.000	0.000	-0.030	0.000	0.000	0.000
2	0.000	0.000	-0.030	0.000	0.000	0.000

	Displacement of bearing			Misalignment of bearing		
	ux (mm)	uy (mm)	uz (mm)	ux (mrad)	uy (mrad)	uz (mrad)
1	0.0002	0.0000	0.0177	0.033	0.000	-0.000
2	0.0002	0.0000	0.0177	0.023	0.000	-0.001

Bearing 'Joint, general (Shaft - kolo 2)'

Position (Y-coordinate)	[y]	423.00	mm

	Bearing reaction force			Bearing reaction moment		
	Fx (kN)	Fy (kN)	Fz (kN)	Mx (Nm)	My (Nm)	Mz (Nm)
1	0.000	0.000	0.000	0.000	-22588.234	0.000
2	0.000	0.000	0.000	0.000	-15811.764	0.000

	Displacement of bearing			Misalignment of bearing		
	ux (mm)	uy (mm)	uz (mm)	ux (mrad)	uy (mrad)	uz (mrad)
1	0.0632	-0.0100	-0.0301	-0.360	0.000	-0.721
2	0.0616	-0.0100	-0.0255	-0.273	0.000	-0.694

Bearing 'Joint, general (Shaft - kolo 4)'

Position (Y-coordinate) [y] 547.00 mm

	Bearing reaction force			Bearing reaction moment		
	Fx (kN)	Fy (kN)	Fz (kN)	Mx (Nm)	My (Nm)	Mz (Nm)
1	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000

	Displacement of bearing			Misalignment of bearing		
	ux (mm)	uy (mm)	uz (mm)	ux (mrad)	uy (mrad)	uz (mrad)
1	0.0001	-0.0000	0.0154	0.161	0.000	0.011
2	0.0001	-0.0000	0.0161	0.112	0.000	0.007

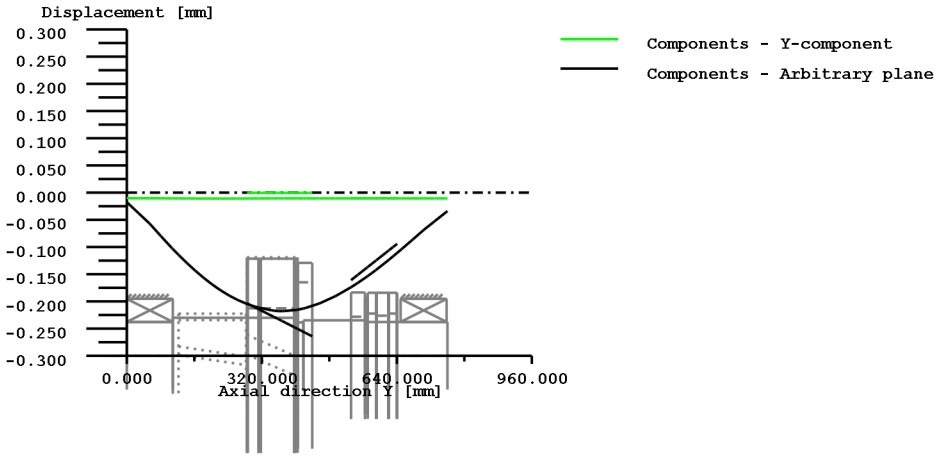
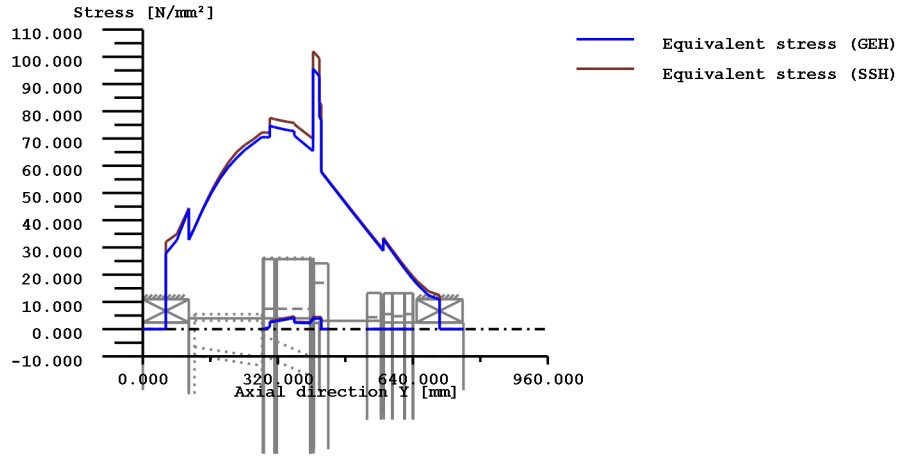


Figure: Displacement (bending etc.) (Arbitrary plane -75.00424171 °)



GEH(von Mises): sigV = ((sigB+sigZ,D)^2 + 3*(tauT+tauS)^2)^1/2SSH(Tresca): sigV = ((sigB-sigZ,D)^2 + 4*(tauT+tauS)^2)^1/2
Figure: Equivalent stress

End of Report lines: 468

Important hint: At least one warning has occurred during the calculation:

1-> The required service life of bearing 'Shaft 'Shaft', Rolling bearing 'SKF*24132CC levé" is not achieved!

2-> The speed is 0! ('SKF 61836')

3-> The static margin of safety of bearing 'Rolling bearing 'Spoj. SKF 61836 levé' is low (in range 0.5 - 2.0).

Please check whether these values are acceptable or not.

4-> The speed is 0! ('SKF 61836')

5-> The static margin of safety of bearing 'Rolling bearing 'Spoj. SKF 61836 pravé' is low (in range 0.5 - 2.0).

Please check whether these values are acceptable or not.

6-> The speed is 0! ('SKF 61832')

7-> Rolling bearing 'Spoj. SKF 61832 levé:
The minimal load of the bearing is not achieved!
(P = 0.3 kN, Pmind = 0.5 kN, Condition: P/C > 1.000 %)

8-> The speed is 0! ('SKF 61832')

9-> Rolling bearing 'Spoj. SKF 61832 pravé:
The minimal load of the bearing is not achieved!
(P = 0.0 kN, Pmind = 0.5 kN, Condition: P/C > 1.000 %)

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label		Shaft
Drawing		OL 232 959
Initial position (mm)		0.000
Length (mm)		760.000
Speed (1/min)		212.50
Sense of rotation: counter clockwise		
Material		18CrNiMo7-6
Young's modulus (N/mm²)		206000.000
Poisson's ratio nu		0.300
Specific weight (kg/m³)		7830.000
Coefficient of thermal expansion	(10^-6/K)	11.500
Temperature (°C)		20.000
Weight of shaft (kg)		134.349
Mass moment of inertia (kg*m²)		0.488

Momentum of mass GD2 (Nm²)		19.158
Label		Shaft 2 (Zástupce kola 2)
Drawing		Ozubené kolo 2 (OL 232 960)
Initial position (mm)		284.500
Length (mm)		155.000
Speed (1/min)		212.50
Sense of rotation: counter clockwise		
Material		18CrNiMo7-6
Young's modulus (N/mm²)		206000.000
Poisson's ratio nu		0.300
Specific weight (kg/m³)		7830.000
Coefficient of thermal expansion	(10^-6/K)	11.500
Temperature (°C)		20.000
Weight of shaft (kg)		131.248
Mass moment of inertia (kg*m²)		4.438
Momentum of mass GD2 (Nm²)		174.145
Label		Shaft 3 (zástupce kola 4)
Drawing		ozubené kolo 4 (OL232 961)
Initial position (mm)		531.500
Length (mm)		109.500
Speed (1/min)		212.50
Sense of rotation: counter clockwise		
Material		18CrNiMo7-6
Young's modulus (N/mm²)		206000.000
Poisson's ratio nu		0.300
Specific weight (kg/m³)		7830.000
Coefficient of thermal expansion	(10^-6/K)	11.500
Temperature (°C)		20.000
Weight of shaft (kg)		34.825
Mass moment of inertia (kg*m²)		0.547
Momentum of mass GD2 (Nm²)		21.445
Position in space (°)		0.000
Consider deformations due to shearing		
Shear correction coefficient		1.100
Contact angle of rolling bearings is considered		
Reference temperature (°C)		20.000

Figure: Load applications

SHAFT DEFINITION (Shaft)

Outer contour

Cylinder (Cylinder) y= 0.00...109.00 (mm)
d=160.00 (mm), l=109.00 (mm), Rz= 8.0

Chamfer left (Chamfer left)
l=2.00 (mm), alpha=45.00 (°)

Cylinder (Cylinder) y= 109.00...403.50 (mm)
d=180.00 (mm), l=294.50 (mm), Rz= 8.0

Square groove (Square groove) y= 370.28...374.43 (mm)
b=4.15 (mm), t=2.50 (mm), r=0.50 (mm), Rz= 8.0

Chamfer right (Chamfer right)
l=22.00 (mm), alpha=25.00 (°)

Cylinder (Cylinder) y= 403.50...418.50 (mm)
d=158.00 (mm), l=15.00 (mm), Rz= 8.0

Radius left (Radius left)
r=1.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 418.50...570.00 (mm)
d=168.00 (mm), l=151.50 (mm), Rz= 8.0

Cylinder (Cylinder) y= 570.00...760.00 (mm)

d=160.00 (mm), l=190.00 (mm), Rz= 8.0

Chamfer right (Chamfer right)
l=2.00 (mm), alpha=45.00 (°)

Inner contour

Forces

Cylindrical gear (Cylindrical gear 5 (OL232 959))			y= 202.50 (mm)
Operating pitch diameter	(mm)	199.4521	
Helix angle	(°)	14.0000	right
Working pressure angle at normal section	(°)	25.0000	
Position of contact point	(°)	180.0000	
Length of load application	(mm)	160.0000	
Power	(kW)	502.6548	driving (Output)
Torque	(Nm)	22588.2342	
Axial force	(N)	-56473.5151	
Shearing force X	(N)	108853.4485	
Shearing force Z	(N)	226502.8978	
Bending moment X	(Nm)	0.0000	
Bending moment Z	(Nm)	5631.8793	

Bearing

Spherical roller bearings SKF *24132CC/W33 (SKF*24132CC levé) y= 54.50 (mm)
Set fixed bearing left
d = 160.000 (mm), D = 270.000 (mm), B = 109.000 (mm), r = 2.100 (mm)
C = 1180.000 (kN), C0 = 1760.000 (kN), Cu = 163.000 (kN)
Bearing clearance DIN 620:1988 C0 (140.00 µm)

Spherical roller bearings SKF *24132CC/W33 (SKF*24132CC pravé) y= 703.50 (mm)
Set fixed bearing right
d = 160.000 (mm), D = 270.000 (mm), B = 109.000 (mm), r = 2.100 (mm)
C = 1180.000 (kN), C0 = 1760.000 (kN), Cu = 163.000 (kN)
Bearing clearance DIN 620:1988 C0 (140.00 µm)

SHAFT DEFINITION (Shaft 2 (Zástupce kola 2))

Outer contour

Cylinder (Cylinder) y= 0.00...120.00 (mm)
d=460.00 (mm), l=120.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 120.00...155.00 (mm)
d=440.00 (mm), l=35.00 (mm), Rz= 8.0

Inner contour

Cone inside (Conical bore) y= 0.00...2.00 (mm)
d1=229.00 (mm), d2=225.00 (mm), l=2.00 (mm)

Cylinder inside (Cylindrical bore) y= 2.00...27.85 (mm)
d=225.00 (mm), l=25.85 (mm)

Cylinder inside (Cylindrical bore) y= 27.85...33.00 (mm)
d=236.00 (mm), l=5.15 (mm)

Cylinder inside (Cylindrical bore) y= 33.00...112.00 (mm)
d=225.00 (mm), l=79.00 (mm)

Cone inside (Conical bore) y= 112.00...114.00 (mm)
d1=225.00 (mm), d2=229.00 (mm), l=2.00 (mm)

Cylinder inside (Cylindrical bore) y= 114.00...121.00 (mm)
d=360.00 (mm), l=7.00 (mm)

Cylinder inside (Cylindrical bore) y= 121.00...155.00 (mm)
d=348.00 (mm), l=34.00 (mm)

Forces

Cylindrical gear (Cylindrical gear 2 (OL232 960))			y= 60.00 (mm)
Operating pitch diameter	(mm)	466.1728	
Helix angle	(°)	13.0000	right
Working pressure angle at normal section	(°)	20.0000	
Position of contact point	(°)	0.0000	
Length of load application	(mm)	120.0000	
Power	(kW)	502.6548	driven (Input)
Torque	(Nm)	-22588.2342	
Axial force	(N)	22373.2673	
Shearing force X	(N)	-36199.8896	
Shearing force Z	(N)	96909.2674	
Bending moment X	(Nm)	-0.0000	
Bending moment Z	(Nm)	5214.9048	

Bearing

SHAFT DEFINITION (Shaft 3 (zástupce kola 4))

Outer contour

Cylinder (Cylinder) y= 0.00...33.00 (mm)
d=300.00 (mm), l=33.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 33.00...39.50 (mm)
d=275.00 (mm), l=6.50 (mm), Rz= 8.0

Cylinder (Cylinder) y= 39.50...109.50 (mm)
d=298.54 (mm), l=70.00 (mm), Rz= 8.0

Inner contour

Cylinder inside (Cylindrical bore) y= 0.00...37.50 (mm)
d=185.00 (mm), l=37.50 (mm)

Cone inside (Conical bore) y= 37.50...39.50 (mm)
d1=185.00 (mm), d2=189.00 (mm), l=2.00 (mm)

Cylinder inside (Cylindrical bore) y= 39.50...59.50 (mm)
d=200.00 (mm), l=20.00 (mm)

Cone inside (Conical bore) y= 59.50...60.50 (mm)
d1=192.00 (mm), d2=190.00 (mm), l=1.00 (mm)

Cylinder inside (Cylindrical bore) y= 60.50...88.50 (mm)
d=190.00 (mm), l=28.00 (mm)

Cone inside (Conical bore) y= 88.50...89.50 (mm)
d1=190.00 (mm), d2=192.00 (mm), l=1.00 (mm)

Cylinder inside (Cylindrical bore) y= 89.50...108.50 (mm)
d=200.00 (mm), l=19.00 (mm)

Cone inside (Conical bore) y= 108.50...109.50 (mm)
d1=200.00 (mm), d2=202.00 (mm), l=1.00 (mm)

Forces

Bearing

CONNECTIONS

Deep groove ball bearing (single row) SKF 61836 (Spoj. SKF 61836 levé) y= 301.00 (mm)
Shaft 'Shaft' <-> Shaft 'Shaft 2 (Zástupce kola 2)'
Set fixed bearing right
d = 180.000 (mm), D = 225.000 (mm), B = 22.000 (mm), r = 1.100 (mm)
C = 62.400 (kN), C0 = 81.500 (kN), Cu = 2.450 (kN)
Bearing clearance DIN 620:1988 C0 (40.50 µm)

Deep groove ball bearing (single row) SKF 61836 (Spoj. SKF 61836 pravé) y= 359.00 (mm)
Shaft 'Shaft' <-> Shaft 'Shaft 2 (Zástupce kola 2)'
Set fixed bearing left
d = 180.000 (mm), D = 225.000 (mm), B = 22.000 (mm), r = 1.100 (mm)
C = 62.400 (kN), C0 = 81.500 (kN), Cu = 2.450 (kN)
Bearing clearance DIN 620:1988 C0 (40.50 µm)

Deep groove ball bearing (single row) SKF 61832 (Spoj. SKF 61832 levé) y= 581.00 (mm)
Shaft 'Shaft' <-> Shaft 'Shaft 3 (zástupce kola 4)'
Set fixed bearing right
d = 160.000 (mm), D = 200.000 (mm), B = 20.000 (mm), r = 1.100 (mm)
C = 49.400 (kN), C0 = 64.000 (kN), Cu = 2.000 (kN)
Bearing clearance DIN 620:1988 C0 (35.50 µm)

Deep groove ball bearing (single row) SKF 61832 (Spoj. SKF 61832 pravé) y= 631.00 (mm)

Shaft 'Shaft' <-> Shaft 'Shaft 3 (zástupce kola 4)'
Set fixed bearing left
d = 160.000 (mm), D = 200.000 (mm), B = 20.000 (mm), r = 1.100 (mm)
C = 49.400 (kN), C0 = 64.000 (kN), Cu = 2.000 (kN)
Bearing clearance DIN 620:1988 C0 (35.50 µm)

Joint, general (Shaft - kolo 2): Shaft 'Shaft' <-> Shaft 'Shaft 2 (Zástupce kola 2)' y= 423.00 (mm)
Degrees of freedom
X: free, Y: free, Z: free
Rx: free, Ry: fixed, Rz: free

Joint, general (Shaft - kolo 4): Shaft 'Shaft' <-> Shaft 'Shaft 3 (zástupce kola 4)' y= 547.00 (mm)
Degrees of freedom
X: free, Y: free, Z: free
Rx: free, Ry: fixed, Rz: free

---

maximum deflection		264.15	µm (Shaft 2 (Zástupce kola 2),	439.50 (mm))

Center of mass

Shaft		370.7	mm
Shaft 2 (Zástupce kola 2)		80.7	mm
Shaft 3 (zástupce kola 4)		63.6	mm

Deformation due to torsion

Shaft	[phi.t]	-0.04	°
Shaft 2 (Zástupce kola 2)	[phi.t]	0.00	°
Shaft 3 (zástupce kola 4)	[phi.t]	0.00	°

Probability of failure	[n]	10.00	%
Axial clearance	[uA]	10.00	µm

Rolling bearings, classical calculation (contact angle considered)

Shaft 'Shaft' Rolling bearing 'SKF*24132CC levé'

Position (Y-coordinate)	[y]	54.50	mm
Equivalent load	[P]	298.92	kN
Equivalent load	[P0]	295.51	kN
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	7625.46	h
Operating viscosity	[nu]	48.88	mm¸/s
Reference viscosity	[nu1]	0.00	mm¸/s
static safety factor	[S0]	5.96	
Bearing reaction force	[Fx]	-80.719	kN
Bearing reaction force	[Fy]	34.100	kN
Bearing reaction force	[Fz]	-227.022	kN
Bearing reaction force	[Fr]	240.946	kN (-109.57°)
Oil level	[H]	121.250	mm
Torque of friction	[Mloss]	41.076	Nm
Power loss	[Ploss]	914.070	W
Displacement of bearing	[ux]	0.024	mm
Displacement of bearing	[uy]	-0.010	mm
Displacement of bearing	[uz]	0.066	mm
Displacement of bearing	[ur]	0.070	mm (69.93°)

Misalignment of bearing	[rx]	0.763	mrad (2.62')
Misalignment of bearing	[ry]	-0.000	mrad (0')
Misalignment of bearing	[rz]	-0.030	mrad (-0.1')
Misalignment of bearing	[rr]	0.764	mrad (2.63')

Shaft 'Shaft' Rolling bearing 'SKF*24132CC pravé'

Position (Y-coordinate)	[y]	703.50	mm
Equivalent load	[P]	93.79	kN
Equivalent load	[P0]	93.79	kN
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	363274.29	h
Operating viscosity	[nu]	48.88	mm¸/s
Reference viscosity	[nu1]	0.00	mm¸/s
static safety factor	[S0]	18.77	
Bearing reaction force	[Fx]	8.065	kN
Bearing reaction force	[Fy]	0.000	kN
Bearing reaction force	[Fz]	-93.443	kN
Bearing reaction force	[Fr]	93.790	kN (-85.07°)
Oil level	[H]	121.250	mm
Torque of friction	[Mloss]	15.146	Nm
Power loss	[Ploss]	337.045	W
Displacement of bearing	[ux]	-0.005	mm
Displacement of bearing	[uy]	-0.010	mm
Displacement of bearing	[uz]	0.070	mm
Displacement of bearing	[ur]	0.070	mm (94.19°)
Misalignment of bearing	[rx]	-0.648	mrad (-2.23')
Misalignment of bearing	[ry]	-0.642	mrad (-2.21')
Misalignment of bearing	[rz]	0.038	mrad (0.13')
Misalignment of bearing	[rr]	0.649	mrad (2.23')

Rolling bearing 'Spoj. SKF 61836 levé'

Position (Y-coordinate)	[y]	301.00	mm
Equivalent load	[P]	84.37	kN
Equivalent load	[P0]	84.37	kN
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	> 1000000	h
Operating viscosity	[nu]	48.88	mm¸/s
Reference viscosity	[nu1]	0.00	mm¸/s
static safety factor	[S0]	0.97	
Bearing reaction force	[Fx]	80.862	kN
Bearing reaction force	[Fy]	0.000	kN
Bearing reaction force	[Fz]	24.082	kN
Bearing reaction force	[Fr]	84.372	kN (16.58°)
Displacement of bearing	[ux]	-0.019	mm
Displacement of bearing	[uy]	-0.010	mm
Displacement of bearing	[uz]	-0.006	mm
Displacement of bearing	[ur]	0.020	mm (-162.17°)
Misalignment of bearing	[rx]	0.028	mrad (0.1')
Misalignment of bearing	[ry]	0.376	mrad (1.29')
Misalignment of bearing	[rz]	-0.705	mrad (-2.42')
Misalignment of bearing	[rr]	0.705	mrad (2.43')

Rolling bearing 'Spoj. SKF 61836 pravé'

Position (Y-coordinate)	[y]	359.00	mm

Equivalent load	[P]	137.19	kN
Equivalent load	[P0]	137.19	kN
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	> 1000000	h
Operating viscosity	[nu]	48.88	mm¿/s
Reference viscosity	[nu1]	0.00	mm¿/s
static safety factor	[S0]	0.59	
Bearing reaction force	[Fx]	-117.062	kN
Bearing reaction force	[Fy]	22.373	kN
Bearing reaction force	[Fz]	71.540	kN
Bearing reaction force	[Fr]	137.191	kN (148.57°)
Displacement of bearing	[ux]	0.017	mm
Displacement of bearing	[uy]	-0.010	mm
Displacement of bearing	[uz]	-0.010	mm
Displacement of bearing	[ur]	0.020	mm (-31.22°)
Misalignment of bearing	[rx]	-0.153	mrad (-0.52')
Misalignment of bearing	[ry]	0.215	mrad (0.74')
Misalignment of bearing	[rz]	-0.703	mrad (-2.42')
Misalignment of bearing	[rr]	0.719	mrad (2.47')

Rolling bearing 'Spoj. SKF 61832 levé'

Position (Y-coordinate)	[y]	581.00	mm
Equivalent load	[P]	0.31	kN
Equivalent load	[P0]	0.31	kN
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	> 1000000	h
Operating viscosity	[nu]	48.88	mm¿/s
Reference viscosity	[nu1]	0.00	mm¿/s
static safety factor	[S0]	> 100	
Bearing reaction force	[Fx]	-0.000	kN
Bearing reaction force	[Fy]	0.000	kN
Bearing reaction force	[Fz]	-0.312	kN
Bearing reaction force	[Fr]	0.312	kN (-90°)
Displacement of bearing	[ux]	0.000	mm
Displacement of bearing	[uy]	-0.000	mm
Displacement of bearing	[uz]	0.018	mm
Displacement of bearing	[ur]	0.018	mm (89.91°)
Misalignment of bearing	[rx]	0.102	mrad (0.35')
Misalignment of bearing	[ry]	0.000	mrad (0')
Misalignment of bearing	[rz]	0.006	mrad (0.02')
Misalignment of bearing	[rr]	0.102	mrad (0.35')

Rolling bearing 'Spoj. SKF 61832 pravé'

Position (Y-coordinate)	[y]	631.00	mm
Equivalent load	[P]	0.03	kN
Equivalent load	[P0]	0.03	kN
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	> 1000000	h
Operating viscosity	[nu]	48.88	mm¿/s
Reference viscosity	[nu1]	0.00	mm¿/s
static safety factor	[S0]	> 100	
Bearing reaction force	[Fx]	0.000	kN
Bearing reaction force	[Fy]	0.000	kN
Bearing reaction force	[Fz]	-0.030	kN
Bearing reaction force	[Fr]	0.030	kN (-90°)

Displacement of bearing	[ux]	0.000	mm
Displacement of bearing	[uy]	0.000	mm
Displacement of bearing	[uz]	0.018	mm
Displacement of bearing	[ur]	0.018	mm (89.4°)
Misalignment of bearing	[rx]	0.033	mrad (0.11')
Misalignment of bearing	[ry]	0.000	mrad (0')
Misalignment of bearing	[rz]	-0.000	mrad (0')
Misalignment of bearing	[rr]	0.033	mrad (0.11')

Bearing 'Joint, general (Shaft - kolo 2)'

Position (Y-coordinate)	[y]	423.00	mm
Bearing reaction force	[Fx]	0.000	kN
Bearing reaction force	[Fy]	0.000	kN
Bearing reaction force	[Fz]	0.000	kN
Bearing reaction force	[Fr]	0.000	kN
Bearing reaction moment	[Mx]	0.00	Nm
Bearing reaction moment	[My]	-22588.23	Nm
Bearing reaction moment	[Mz]	0.00	Nm
Bearing reaction moment	[Mr]	0.00	Nm (0°)
Displacement of bearing	[ux]	0.063	mm
Displacement of bearing	[uy]	-0.010	mm
Displacement of bearing	[uz]	-0.030	mm
Displacement of bearing	[ur]	0.070	mm (-25.48°)
Misalignment of bearing	[rx]	-0.360	mrad (-1.24')
Misalignment of bearing	[ry]	0.000	mrad (0')
Misalignment of bearing	[rz]	-0.721	mrad (-2.48')
Misalignment of bearing	[rr]	0.806	mrad (2.77')

Bearing 'Joint, general (Shaft - kolo 4)'

Position (Y-coordinate)	[y]	547.00	mm
Bearing reaction force	[Fx]	0.000	kN
Bearing reaction force	[Fy]	0.000	kN
Bearing reaction force	[Fz]	0.000	kN
Bearing reaction force	[Fr]	0.000	kN
Displacement of bearing	[ux]	0.000	mm
Displacement of bearing	[uy]	-0.000	mm
Displacement of bearing	[uz]	0.015	mm
Displacement of bearing	[ur]	0.015	mm (89.53°)
Misalignment of bearing	[rx]	0.161	mrad (0.55')
Misalignment of bearing	[ry]	0.000	mrad (0')
Misalignment of bearing	[rz]	0.011	mrad (0.04')
Misalignment of bearing	[rr]	0.161	mrad (0.55')

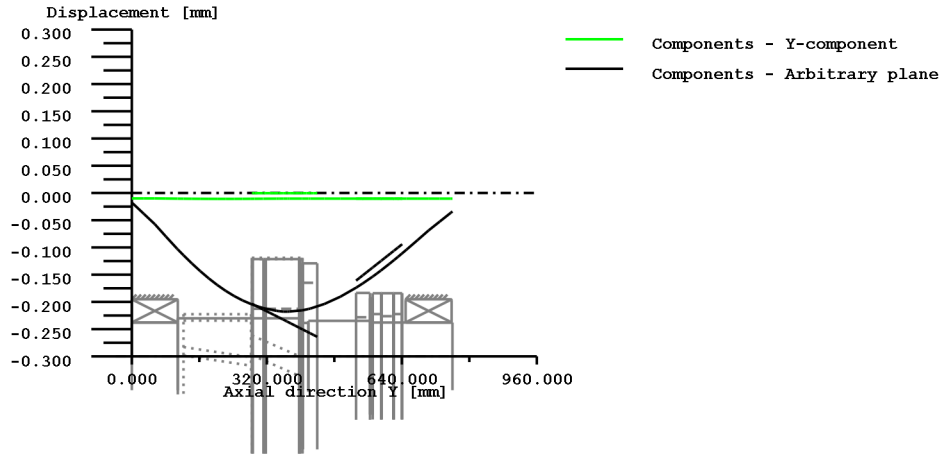
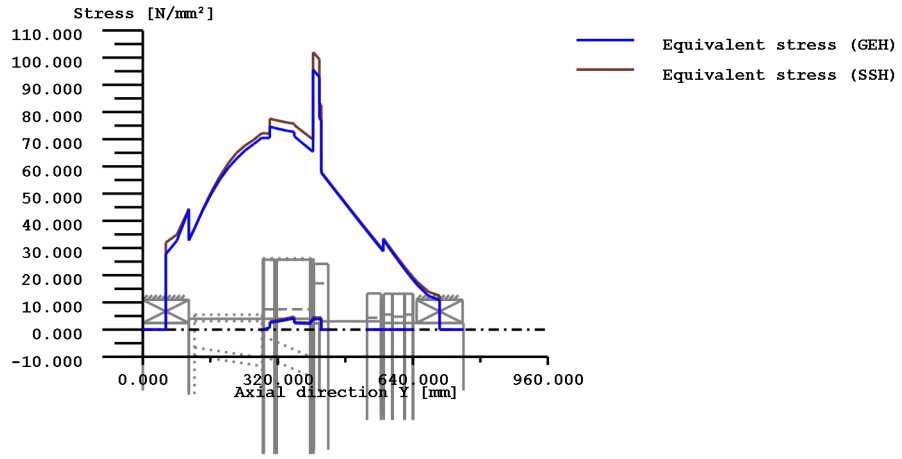


Figure: Displacement (bending etc.) (Arbitrary plane -75.00424171 °)



GEH(von Mises): sigV = ((sigB+sigZ,D)^2 + 3*(tauT+tauS)^2)^1/2SSH(Tresca): sigV = ((sigB-sigZ,D)^2 + 4*(tauT+tauS)^2)^1/2
Figure: Equivalent stress

Eigenfrequencies/Critical speeds

1. Eigenfrequency:	0.00 Hz, Critical speed:	0.00 1/min	Rigid body rotation Y 'Shaft'
2. Eigenfrequency:	0.01 Hz, Critical speed:	0.61 1/min	Rigid body translation Y 'Shaft 3 (zástupce kola 4)'
3. Eigenfrequency:	409.71 Hz, Critical speed:	24582.57 1/min	Bending YZ 'Shaft', Bending XY 'Shaft'
4. Eigenfrequency:	852.31 Hz, Critical speed:	51138.56 1/min	Bending XY 'Shaft'

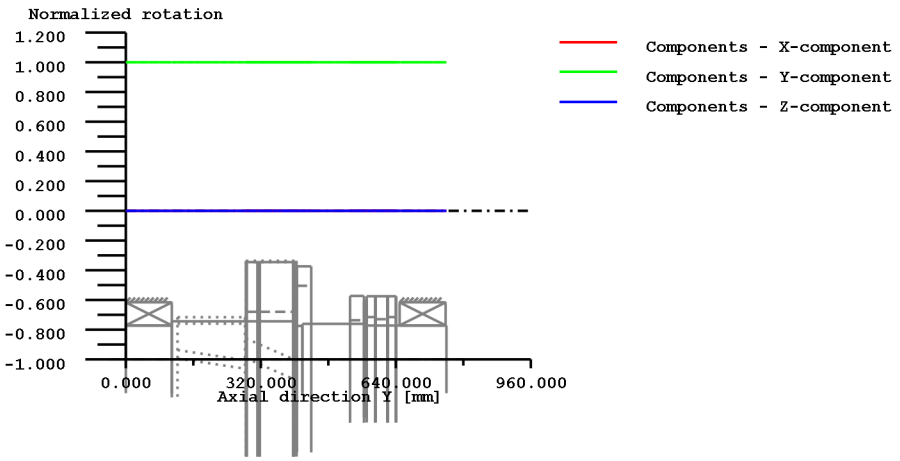


Figure: Eigenfrequencies (Normalized displacement)

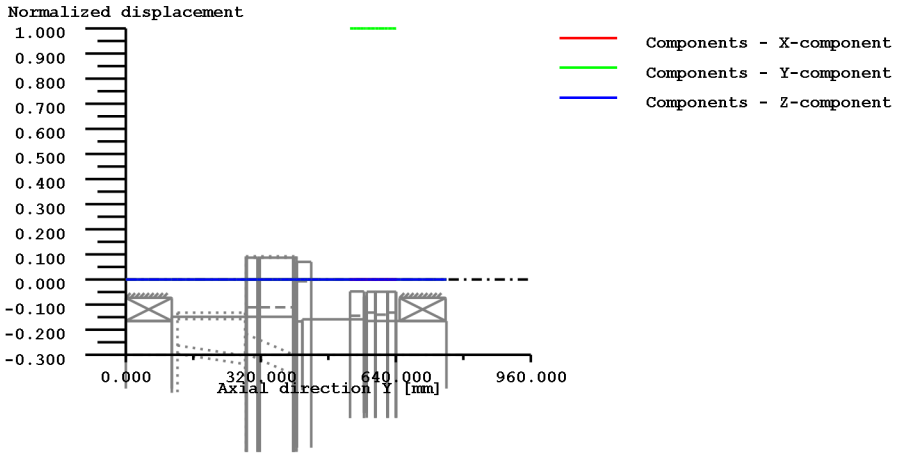


Figure: Eigenfrequencies (Normalized rotation)

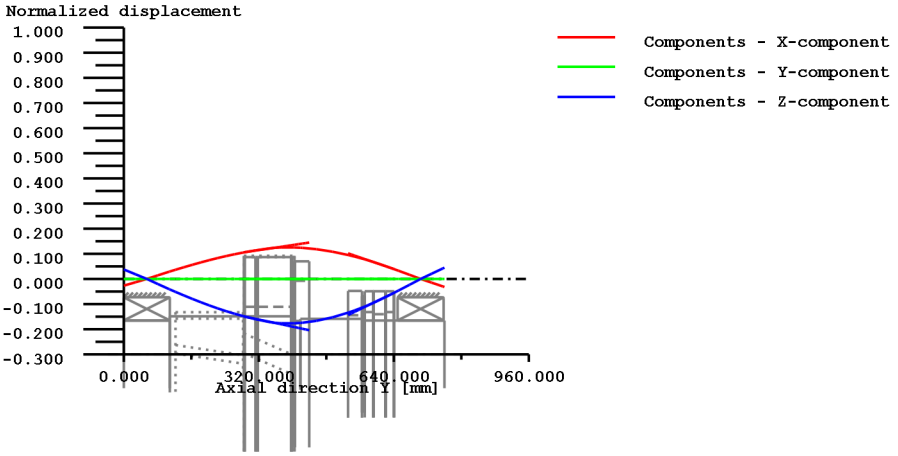


Figure: Eigenfrequencies (Normalized rotation)

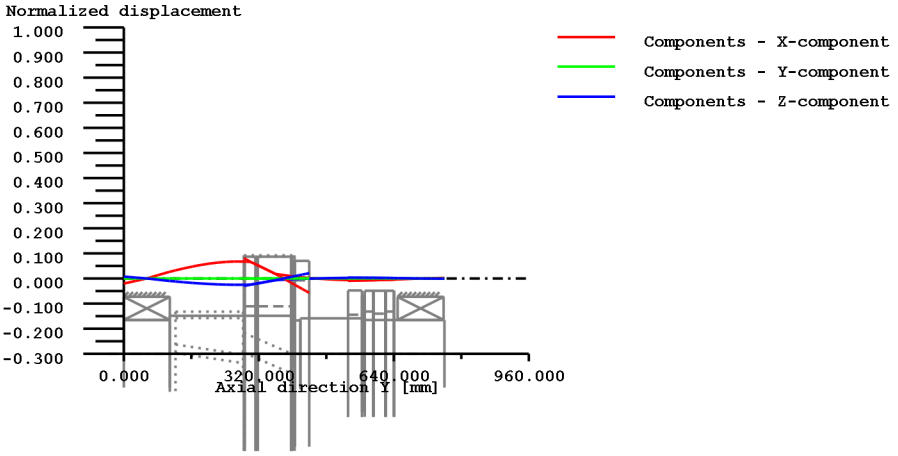


Figure: Eigenfrequencies (Normalized rotation)

End of Report lines: 512

File

Name : Hřídel_III_2_stavy
Changed by: karlova am: 02.05.2014 um: 11:52:09

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label		Shaft III
Drawing		OL 232 965
Initial position (mm)		0.000
Length (mm)		758.000
Speed (1/min)		59.65
Sense of rotation: clockwise		
Material		18CrNiMo7-6
Young's modulus (N/mm²)		206000.000
Poisson's ratio nu		0.300
Specific weight (kg/m³)		7830.000
Coefficient of thermal expansion	(10^-6/K)	11.500
Temperature (°C)		20.000
Weight of shaft (kg)		301.890
Mass moment of inertia (kg*m²)		2.526
Momentum of mass GD2 (Nm²)		99.107
Position in space (°)		0.000
Consider deformations due to shearing		
Shear correction coefficient		1.100
Rolling bearing stiffness is calculated from inner bearing geometry		
Reference temperature (°C)		20.000

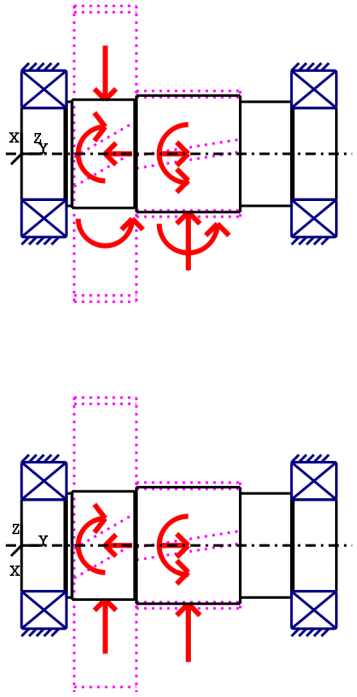


Figure: Load applications

SHAFT DEFINITION (Shaft III)

Outer contour

Cylinder (Cylinder) y= 0.00...104.00 (mm)
d=220.00 (mm), l=104.00 (mm), Rz= 8.0

Chamfer left (Chamfer left)
l=2.00 (mm), alpha=45.00 (°)

Radius right (Radius right)
r=0.40 (mm), Rz= 8.0

Cylinder (Cylinder) y= 104.00...108.00 (mm)
d=219.20 (mm), l=4.00 (mm), Rz= 8.0

Radius left (Radius left)
r=1.00 (mm), Rz= 8.0

Radius right (Radius right)
r=1.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 108.00...121.50 (mm)
d=250.00 (mm), l=13.50 (mm), Rz= 8.0

Chamfer left (Chamfer left)
l=2.00 (mm), alpha=45.00 (°)

Radius right (Radius right)

r=2.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 121.50...272.50 (mm)
d=260.00 (mm), l=151.00 (mm), Rz= 8.0

Chamfer left (Chamfer left)
l=2.00 (mm), alpha=45.00 (°)

Radius right (Radius right)
r=2.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 272.50...276.50 (mm)
d=259.20 (mm), l=4.00 (mm), Rz= 8.0

Radius left (Radius left)
r=1.00 (mm), Rz= 8.0

Radius right (Radius right)
r=1.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 276.50...526.50 (mm)
d=280.00 (mm), l=250.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 526.50...650.00 (mm)
d=250.00 (mm), l=123.50 (mm), Rz= 8.0

Chamfer right (Chamfer right)
l=2.00 (mm), alpha=45.00 (°)

Radius left (Radius left)
r=5.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 650.00...654.00 (mm)
d=219.20 (mm), l=4.00 (mm), Rz= 8.0

Radius left (Radius left)
r=1.00 (mm), Rz= 8.0

Radius right (Radius right)
r=1.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 654.00...758.00 (mm)
d=220.00 (mm), l=104.00 (mm), Rz= 8.0

Chamfer right (Chamfer right)
l=2.00 (mm), alpha=45.00 (°)

Radius left (Radius left)
r=0.40 (mm), Rz= 8.0

Inner contour

Forces

Cylindrical gear (Kolo_7 (OL 323 962)) y= 201.50 (mm)

Operating pitch diameter	(mm)	710.5479	
Helix angle	(°)	14.1069	left
Working pressure angle at normal section(°)		25.8978	
Position of contact point	(°)	0.0000	
Length of load application	(mm)	150.0000	
Axial force (Load spectrum)	(N)	-56921.96/-39845.37	
Shearing force X (Load spectrum)(N)		-113391.04/-79373.73	
Shearing force Z (Load spectrum)(N)		226499.57/158549.70	
Bending moment X (Load spectrum)(N)		0.00/0.00	
Bending moment Z (Load spectrum)(N)		-20222.89/-14156.02	

load spectrum,driving (Output):

Element	Frequency (%)	Speed (1/min)	Power (kW)	Torque (Nm)
1	20.0000	59.6	-502.7	-80469.4
2	80.0000	59.6	-351.9	-56328.6

Cylindrical gear (Pastorek_6 (OL 232 963)) y= 401.50 (mm)

Operating pitch diameter	(mm)	302.2220	
Helix angle	(°)	15.1650	left
Working pressure angle at normal section(°)		21.8883	
Position of contact point	(°)	180.0000	
Length of load application	(mm)	250.0000	
Axial force (Load spectrum)	(N)	144332.82/101032.97	
Shearing force X (Load spectrum)(N)		221663.87/155164.71	
Shearing force Z (Load spectrum)(N)		532518.49/372762.94	
Bending moment X (Load spectrum)(N)		-0.00/-0.00	
Bending moment Z (Load spectrum)(N)		-21810.28/-15267.19	

load spectrum,driven (Input):

Element	Frequency (%)	Speed (1/min)	Power (kW)	Torque (Nm)
1	20.0000	59.6	502.7	80469.4
2	80.0000	59.6	351.9	56328.6

Bearing

Spherical roller bearings SKF *22244CC/W33 (SKF*22244CC/W33_levé) y= 54.00 (mm)

Set fixed bearing left
d = 220.000 (mm), D = 400.000 (mm), B = 108.000 (mm), r = 4.000 (mm)
C = 1760.000 (kN), C0 = 2360.000 (kN), Cu = 196.000 (kN)
Ctheo = 1759.368 (kN), C0theo = 2360.135 (kN)
Calculation with approximate bearings internal geometry (*)
Z = 11, Dpw = 319.176 (mm), Dw = 57.366 (mm), Lwe = 52.465 (mm)
di = 266.770 (mm), do = 381.660 (mm), ri = 190.836 (mm), ro = 190.836 (mm), Pd = 0.180 (mm)

Tolerance field	Mean value
Tolerance	DIN 620:1988 PN
Tolerance shaft	k6, 220.018 mm (min = 220.004 mm , max = 220.033 mm)
Tolerance hub	H7, 400.029 mm (min = 400.000 mm , max = 400.057 mm)

Change of diametral clearance due to: n = 0 (1/min)

Interference fit	-27.57 µm
Temperature	0.00 µm
Shaft and housing roughness	0.00 µm
Total bearing clearance change	-22.30 µm, n = 59.65 (1/min)
Bearing clearance	DIN 620:1988 C0 (180.00 µm)
Operating bearing clearance	180.00 µm + (-22.30 µm) = 157.70 µm

Spherical roller bearings SKF *22244CC/W33 (SKF*22244CC/W33_pravé) y= 704.00 (mm)

Set fixed bearing right
d = 220.000 (mm), D = 400.000 (mm), B = 108.000 (mm), r = 4.000 (mm)
C = 1760.000 (kN), C0 = 2360.000 (kN), Cu = 196.000 (kN)
Ctheo = 1759.368 (kN), C0theo = 2360.135 (kN)
Calculation with approximate bearings internal geometry (*)
Z = 11, Dpw = 319.176 (mm), Dw = 57.366 (mm), Lwe = 52.465 (mm)
di = 266.770 (mm), do = 381.660 (mm), ri = 190.836 (mm), ro = 190.836 (mm), Pd = 0.180 (mm)

Tolerance field	Mean value
Tolerance	DIN 620:1988 PN
Tolerance shaft	k6, 220.018 mm (min = 220.004 mm , max = 220.033 mm)
Tolerance hub	H7, 400.029 mm (min = 400.000 mm , max = 400.057 mm)
Change of diametral clearance due to: n = 0 (1/min)	
Interference fit	-27.57 µm
Temperature	0.00 µm
Shaft and housing roughness	0.00 µm
Total bearing clearance change	-22.30 µm, n = 59.65 (1/min)
Bearing clearance	DIN 620:1988 C0 (180.00 µm)
Operating bearing clearance	180.00 µm + (-22.30 µm) = 157.70 µm

---

maximum deflection		299.95	µm (Shaft III,	339.00 (mm))

Center of mass

Shaft III		377.9	mm

Deformation due to torsion

Shaft III	[phi.t]	0.02	°

Probability of failure	[n]	10.00	%
Axial clearance	[uA]	10.00	µm

Rolling bearing stiffness calculated from internal geometry

Shaft 'Shaft III' Rolling bearing 'SKF*22244CC/W33_levé'

Position (Y-coordinate)	[y]	54.00	mm
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	72419.43	h
Operating viscosity	[nu]	48.88	mm¸/s
Reference viscosity	[nu1]	0.00	mm¸/s
static safety factor	[S0]	5.56	

	Bearing reaction force			Bearing reaction moment		
	Fx (kN)	Fy (kN)	Fz (kN)	Mx (Nm)	My (Nm)	Mz (Nm)
1	49.167	-0.000	-421.442	-0.000	0.000	0.000
2	34.417	-0.000	-294.564	-0.000	0.000	0.000

	Displacement of bearing			Misalignment of bearing		
	ux (mm)	uy (mm)	uz (mm)	ux (mrad)	uy (mrad)	uz (mrad)
1	-0.0273	0.4208	0.2322	0.263	-0.000	-0.259
2	-0.0223	0.3535	0.2046	0.168	-0.000	-0.209

Shaft 'Shaft III' Rolling bearing 'SKF*22244CC/W33_pravé'

Position (Y-coordinate)	[y]	704.00	mm

Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	24337.94	h
Operating viscosity	[nu]	48.88	mm²/s
Reference viscosity	[nu1]	0.00	mm²/s
static safety factor	[S0]	4.01	

	Bearing reaction force			Bearing reaction moment		
	Fx (kN)	Fy (kN)	Fz (kN)	Mx (Nm)	My (Nm)	Mz (Nm)
1	-157.440	-87.411	-334.615	0.000	-0.000	0.000
2	-110.208	-61.188	-233.788	0.000	-0.000	0.000

	Displacement of bearing			Misalignment of bearing		
	ux (mm)	uy (mm)	uz (mm)	ux (mrad)	uy (mrad)	uz (mrad)
1	0.0829	0.4192	0.1761	-0.419	0.380	-0.068
2	0.0730	0.3524	0.1548	-0.310	0.266	-0.075

(*) Note concerning roller bearings with approximated bearing geometry:
The inner geometry of these bearings is not charted in the data base.
The geometry is calculated backwards from C and C0 (values in the manufacturer catalog) according to ISO281.
Therefore the calculated geometry can differ from the real geometry.
Differences in the bearing stiffness results can be considerable in some cases.

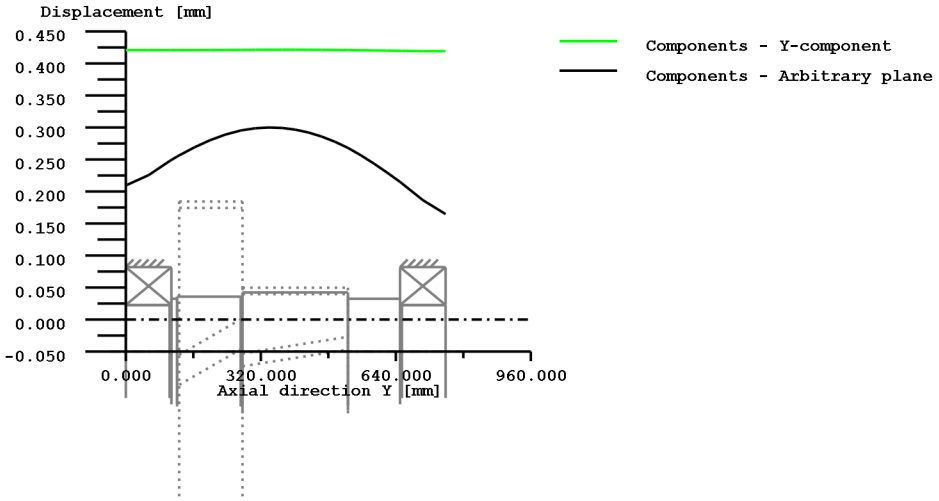
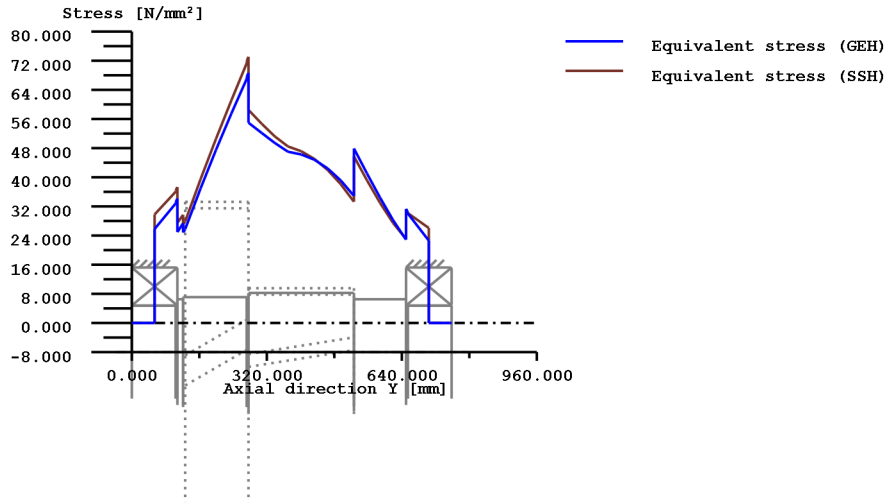


Figure: Displacement (bending etc.) (Arbitrary plane 81.40590411 °)



GEH(von Mises): sigV = ((sigB+sigZ,D)^2 + 3*(tauT+tauS)^2)^1/2SSH(Tresca): sigV = ((sigB-sigZ,D)^2 + 4*(tauT+tauS)^2)^1/2
Figure: Equivalent stress

Strength calculation as specified in

DIN 743:2012

with finite life fatigue strength according to FKM standard and FVA draft

Summary

Label	Shaft III
Drawing	OL 232 965

Material	18CrNiMo7-6
Material type	Case-carburized steel
Material treatment	case-hardened
Surface treatment	No

Calculation of service strength and static strength
Woehler line (S-N curve) according Miner elementary
Calculation for load case 2 (sig.av/sig.mv = const)

Cross section	Position (Y-Coord) (mm)	
A-A	121.50	Shoulder
B-B	276.50	Shoulder
C-C	526.50	Shoulder
D-D	650.00	Shoulder

Results:

Cross section	Kfb	Kfsig	K2d	SD	SS	SA
A-A	2.18	0.88	0.80	7.54	21.79	27.06
B-B	3.11	0.88	0.80	1.91	6.38	6.46
C-C	2.16	0.88	0.80	3.25	9.93	13.36
D-D	3.25	0.88	0.80	4.70	25.36	18.95
Nominal safety:				1.20	1.20	1.20

Abbreviations:
Kfb: Notch factor bending
Kfsig: Surface factor
K2d: Size coefficient bending
SD: Safety endurance limit
SS: Safety against yield point
SA: Safety against incipient crack

The requirements of the safety proof of the shaft are:

satisfied [x] not satisfied [ ]

Design engineer:..... Date:..... Signature:.....

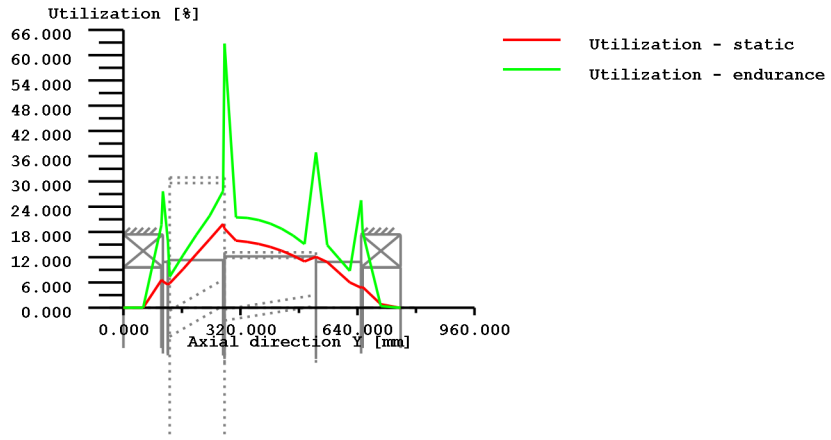


Figure: Strength

Calculation details:

General statements

Label	Shaft III		
Drawing	OL 232 965		
Length (mm)		[l]	758.00
Speed (1/min)		[n]	59.65

Material	18CrNiMo7-6
Material type	Case-carburized steel
Material treatment	case-hardened
Surface treatment	No

	Tension/Compression	Bending	Torsion	Shearing
Load factor static calculation	1.700	1.700	1.700	1.700
Load factor endurance limit	1.000	1.000	1.000	1.000

Reference diameter material (mm)	[dB]	16.00
sigB according DIN 743 (at dB) (N/mm²)	[sigB]	1200.00
sigS according DIN 743 (at dB) (N/mm²)	[sigS]	850.00
[sigzdW] (bei dB) (N/mm²)		480.00
[sigbW] (bei dB) (N/mm²)		600.00
[tautW] (bei dB) (N/mm²)		360.00
Thickness of raw material (mm)	[dWerkst]	290.00

Material data calculated according DIN743/3 with K1(d)
Material strength calculated from size of raw material
Geometric size coefficient K1d calculated from raw material diameter

[sigBeff] (N/mm²)	807.42

[sigSeff] (N/mm²)	571.92
[sigbF] (N/mm²)	629.11
[tautF] (N/mm²)	363.22
[sigBRand] (N/mm²)	2300.00
[sigzdW] (N/mm²)	322.97
[sigbW] (N/mm²)	403.71
[tautW] (N/mm²)	242.23

Service strength for a load spectrum

Woehler line (S-N curve) according	Miner elementary		
Required life time	[h]		2400.00
Number of load cycles (Mio)	[NL]		8.590
Data of Woehler line (S-N curve) analog to FKM standard:			
[ksigma, ktau]	15	25	
[kDsigma, kDtau]	0	0	
[NDsigma, NDtau]	1e+006	1e+006	
[NDsigmaII, NDtauII]	0	0	
[DM]	0.3		

Calculation for load case 2 (sig.av/sig.mv = const)

Cross section 'A-A' Shoulder

Comment				
Position (Y-Coordinate) (mm)	[y]			121.50
External diameter (mm)	[da]			250.000
Inner diameter (mm)	[di]			0.000
Notch effect	Shoulder			
[D, r, t] (mm)	260.000	2.000	0.000	
Mean roughness (µm)	[Rz]			8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	0.0	0.0	-0.0	0.0
Amplitude	0.0	28661.7	0.0	424674.2
Maximum value	0.0	48725.0	0.0	721946.1
Cross section, moment of resistance: (mm²)				
[A, Wb, Wt, A]	49087.4	1533980.8	3067961.6	49087.4

Load spectrum, load base values (Mean-value + Amplitude):

Element	Frequency (%)	Tens./Press. (N)	Bending (Nm)	Torsion (Nm)	Shearing (N)
1	20.00	0.000	28661.750	-0.000	424674.200
2	80.00	0.000	20039.789	-0.000	296941.441

Stresses: (N/mm²)				
[sigzdm, sigbm, taum, tauqm] (N/mm²)	0.000	0.000	-0.000	0.000
[sigzda, sigba, taua, tauqa] (N/mm²)	0.000	18.685	0.000	11.535
[sigzdmax,sigbmax,taumax,tauqmax] (N/mm²)	0.000	31.764	0.000	19.610

Technological size influence	[K1(sigB)]	0.673
	[K1(sigS)]	0.673

	Tension/Compression	Bending	Torsion

Stress concentration factor	[alfa]	2.808	2.676	1.740
References stress slope	[G']	1.288	1.288	0.575
Notch sensitivity factor n	[n]	1.226	1.226	1.151
Notch effect coefficient	[beta]	2.290	2.182	1.511
Geometrical size influence	[K2(d)]	1.000	0.800	0.800
Influence coefficient surface roughness	[KF]	0.880	0.880	0.931
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	2.427	2.864	1.963

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm²)	[sigmV]		0.000	
Equivalent mean stress (N/mm²)	[taumV]		0.000	
Fatigue limit of part (N/mm²)	[sigWK]	133.090	140.958	123.381
Influence coeff. mean stress sensitivity.	[PsisigK]	0.090	0.096	0.083
Permissible amplitude (N/mm²)	[sigADK]	133.089	140.958	123.381
Permissible amplitude (N/mm²)	[sigANK]	133.089	140.958	123.381
Load spectrum factor	[fKoll]	1.000	1.000	1.000
Margin of safety endurance limit	[S]		7.544	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		628.7	

Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.100	1.100
Increase coefficient	[gammaF]	1.100	1.100	1.000
Yield stress of part (N/mm²)	[sigFK]	629.113	692.024	363.218
Margin of safety yield stress	[S]		21.787	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1815.5	

Present margin of safety for proof of avoiding incipient crack on hard surface layers:		
Safety against incipient crack	[S]	27.061
Required safety	[Smin]	1.200
Result (%)	[S/Smin]	2255.1

Cross section 'B-B' Shoulder

Comment				
Position (Y-Coordinate) (mm)	[y]		276.50	
External diameter (mm)	[da]		259.200	
Inner diameter (mm)	[di]		0.000	
Notch effect Shoulder				
[D, r, t] (mm)	280.000	1.000	0.000	
Mean roughness (µm)	[Rz]		8.000	

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	28461.0	0.0	40234.7	0.0
Amplitude	28461.0	79125.6	40234.7	206267.6
Maximum value	96767.3	134513.6	136798.0	350654.9
Cross section, moment of resistance: (mm²)				
[A, Wb, Wt, A]	52766.7	1709640.8	3419281.7	52766.7

Load spectrum, load base values (Mean-value + Amplitude):

Element	Frequency	Tens./Press.	Bending	Torsion	Shearing
	(%)	(N)	(Nm)	(Nm)	(N)
1	20.00	56921.960	79125.620	80469.401	206267.601
2	80.00	39845.372	55328.450	56328.581	144269.439

Stresses: (N/mm²)

[sigzdm, sigbm, taum, tauqm] (N/mm²)	0.539	0.000	11.767	0.000
[sigzda, sigba, taua, tauqa] (N/mm²)	0.539	46.282	11.767	5.212
[sigzdmax,sigbmax,taumax,tauqmax] (N/mm²)	1.834	78.679	40.008	8.861

Technological size influence	[K1(sigB)]	0.673
	[K1(sigS)]	0.673

		Tension/Compression	Bending	Torsion
Stress concentration factor	[alfa]	4.390	4.083	2.437
References stress slope	[G']	2.454	2.454	1.150
Notch sensitivity factor n	[n]	1.313	1.313	1.214
Notch effect coefficient	[beta]	3.344	3.110	2.007
Geometrical size influence	[K2(d)]	1.000	0.800	0.800
Influence coefficient surface roughness	[KF]	0.880	0.880	0.931
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	3.481	4.025	2.584

Present margin of safety for endurance limit:

Equivalent mean stress (N/mm²)	[sigmV]		20.388	
Equivalent mean stress (N/mm²)	[taumV]		11.771	
Fatigue limit of part (N/mm²)	[sigWK]	92.778	100.301	93.755
Influence coeff. mean stress sensitivity.	[PsisigK]	0.061	0.066	0.062
Permissible amplitude (N/mm²)	[sigADK]	16.951	97.458	88.310
Permissible amplitude (N/mm²)	[sigANK]	16.951	97.458	88.310
Load spectrum factor	[fKoll]	1.000	1.000	1.000
Margin of safety endurance limit	[S]		1.909	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		159.1	

Present margin of safety
for proof against exceed of yield point:

Static notch sensitivity factor	[K2F]	1.000	1.100	1.100
Increase coefficient	[gammaF]	1.150	1.150	1.000
Yield stress of part (N/mm²)	[sigFK]	657.709	723.480	363.218
Margin of safety yield stress	[S]		6.379	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		531.6	

Present margin of safety
for proof of avoiding incipient crack on hard surface layers:

Safety against incipient crack	[S]	6.461
Required safety	[Smin]	1.200
Result (%)	[S/Smin]	538.4

Cross section 'C-C' Shoulder

Comment				
Position (Y-Coordinate) (mm)		[y]		526.50
External diameter (mm)		[da]		250.000
Inner diameter (mm)		[di]		0.000
Notch effect	Shoulder			
[D, r, t] (mm)	280.000	5.000	0.000	
Mean roughness (µm)		[Rz]		8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-43705.4	0.0	-0.0	0.0
Amplitude	43705.4	65904.0	0.0	370577.0
Maximum value	-148598.5	112036.8	0.0	629980.8
Cross section, moment of resistance: (mm²)				
[A, Wb, Wt, A]	49087.4	1533980.8	3067961.6	49087.4

Load spectrum, load base values (Mean-value + Amplitude):

Element	Frequency (%)	Tens./Press. (N)	Bending (Nm)	Torsion (Nm)	Shearing (N)
1	20.00	-87410.859	65903.991	-0.000	370576.970
2	80.00	-61187.601	46084.571	-0.000	259235.251

Stresses: (N/mm²)					
[sigzdm, sigbm, taum, tauqm] (N/mm²)		-0.890	0.000	-0.000	0.000
[sigzda, sigba, taua, tauqa] (N/mm²)		0.890	42.963	0.000	10.066
[sigzdmax,sigbmax,taumax,tauqmax] (N/mm²)		-3.027	73.037	0.000	17.112
Technological size influence	[K1(sigB)]	0.673			
	[K1(sigS)]	0.673			

		Tension/Compression	Bending	Torsion
Stress concentration factor	[alfa]	2.671	2.468	1.698
References stress slope	[G']	0.512	0.512	0.230
Notch sensitivity factor n	[n]	1.143	1.143	1.096
Notch effect coefficient	[beta]	2.338	2.160	1.549
Geometrical size influence	[K2(d)]	1.000	0.800	0.800
Influence coefficient surface roughness	[KF]	0.880	0.880	0.931
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	2.474	2.836	2.011

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm²)	[sigmV]		0.890	
Equivalent mean stress (N/mm²)	[taumV]		0.514	
Fatigue limit of part (N/mm²)	[sigWK]	130.522	142.335	120.442
Influence coeff. mean stress sensitivity.	[PsisigK]	0.088	0.097	0.081
Permissible amplitude (N/mm²)	[sigADK]	143.106	142.621	120.442
Permissible amplitude (N/mm²)	[sigANK]	143.106	142.621	120.442
Load spectrum factor	[fKoll]	1.000	1.000	1.000

Margin of safety endurance limit	[S]	3.252
Required safety	[Smin]	1.200
Result (%)	[S/Smin]	271.0

Present margin of safety
for proof against exceed of yield point:

Static notch sensitivity factor	[K2F]	1.000	1.100	1.100
Increase coefficient	[gammaF]	1.100	1.100	1.000
Yield stress of part (N/mm²)	[sigFK]	629.113	692.024	363.218
Margin of safety yield stress	[S]		9.928	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		827.3	

Present margin of safety
for proof of avoiding incipient crack on hard surface layers:

Safety against incipient crack	[S]	13.361
Required safety	[Smin]	1.200
Result (%)	[S/Smin]	1113.4

Cross section 'D-D' Shoulder

Comment				
Position (Y-Coordinate) (mm)	[y]	650.00		
External diameter (mm)	[da]	219.200		
Inner diameter (mm)	[di]	0.000		
Notch effect	Shoulder			
[D, r, t] (mm)	250.000	1.000	0.000	
Mean roughness (µm)	[Rz]	8.000		

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-43705.4	0.0	-0.0	0.0
Amplitude	43705.4	19984.8	0.0	370083.4
Maximum value	-148598.5	33974.1	0.0	629141.8
Cross section, moment of resistance: (mm²)				
[A, Wb, Wt, A]	37737.3	1034002.4	2068004.8	37737.3

Load spectrum, load base values (Mean-value + Amplitude):

Element	Frequency (%)	Tens./Press. (N)	Bending (Nm)	Torsion (Nm)	Shearing (N)
1	20.00	-87410.859	19984.789	-0.000	370083.425
2	80.00	-61187.601	13972.341	-0.000	258741.809

Stresses: (N/mm²)				
[sigzdm, sigbm, taum, tauqm] (N/mm²)	-1.158	0.000	-0.000	0.000
[sigzda, sigba, taua, tauqa] (N/mm²)	1.158	19.328	0.000	13.076
[sigzdmax,sigbmax,taumax,tauqmax] (N/mm²)	-3.938	32.857	0.000	22.229

Technological size influence	[K1(sigB)]	0.673
	[K1(sigS)]	0.673

	Tension/Compression	Bending	Torsion
Stress concentration factor [alfa]	4.707	4.258	2.579
References stress slope [G']	2.430	2.430	1.150

Notch sensitivity factor	n	[n]	1.311	1.311	1.214
Notch effect coefficient		[beta]	3.590	3.248	2.125
Geometrical size influence		[K2(d)]	1.000	0.800	0.800
Influence coefficient surface roughness		[KF]	0.880	0.880	0.931
Influence coefficient surface strengthening		[KV]	1.000	1.000	1.000
Total influence coefficient		[K]	3.727	4.197	2.730

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm²)	[sigmV]		1.158	
Equivalent mean stress (N/mm²)	[taumV]		0.669	
Fatigue limit of part (N/mm²)	[sigWK]	86.655	96.192	88.724
Influence coeff. mean stress sensitivity.	[PsisigK]	0.057	0.063	0.058
Permissible amplitude (N/mm²)	[sigADK]	91.864	96.559	88.724
Permissible amplitude (N/mm²)	[sigANK]	91.864	96.559	88.724
Load spectrum factor	[fKoll]	1.000	1.000	1.000
Margin of safety endurance limit	[S]		4.700	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		391.7	

Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.100	1.100
Increase coefficient	[gammaF]	1.150	1.150	1.000
Yield stress of part (N/mm²)	[sigFK]	657.709	723.480	363.218
Margin of safety yield stress	[S]		25.363	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1579.1	

Present margin of safety for proof of avoiding incipient crack on hard surface layers:		
Safety against incipient crack	[S]	18.949
Required safety	[Smin]	1.200
Result (%)	[S/Smin]	1579.1

Remarks:

- The shearing force is not considered in the analysis specified in DIN 743.
- Cross section with interference fit:
  The notching factor for the light fit case is no longer defined in DIN 743.
  The values are imported from the FKM-Guideline..

End of Report lines: 681

File

Name : Hřídel_III_2_stavy
Changed by: karlova am: 02.05.2014 um: 11:14:07

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label		Shaft III
Drawing		OL 232 965
Initial position (mm)		0.000
Length (mm)		758.000
Speed (1/min)		59.65
Sense of rotation: clockwise		
Material		18CrNiMo7-6
Young's modulus (N/mm²)		206000.000
Poisson's ratio nu		0.300
Specific weight (kg/m³)		7830.000
Coefficient of thermal expansion	(10^-6/K)	11.500
Temperature (°C)		20.000
Weight of shaft (kg)		301.890
Mass moment of inertia (kg*m²)		2.526
Momentum of mass GD2 (Nm²)		99.107
Position in space (°)		0.000
Consider deformations due to shearing		
Shear correction coefficient		1.100
Rolling bearing stiffness is calculated from inner bearing geometry		
Reference temperature (°C)		20.000

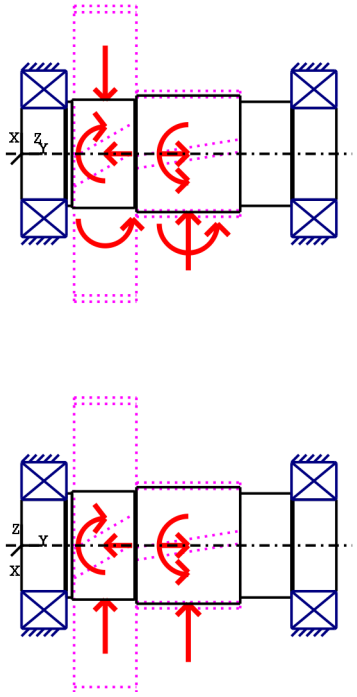


Figure: Load applications

SHAFT DEFINITION (Shaft III)

Outer contour

Cylinder (Cylinder) y= 0.00...104.00 (mm)
d=220.00 (mm), l=104.00 (mm), Rz= 8.0

Chamfer left (Chamfer left)
l=2.00 (mm), alpha=45.00 (°)

Radius right (Radius right)
r=0.40 (mm), Rz= 8.0

Cylinder (Cylinder) y= 104.00...108.00 (mm)
d=219.20 (mm), l=4.00 (mm), Rz= 8.0

Radius left (Radius left)
r=1.00 (mm), Rz= 8.0

Radius right (Radius right)
r=1.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 108.00...121.50 (mm)
d=250.00 (mm), l=13.50 (mm), Rz= 8.0

Chamfer left (Chamfer left)
l=2.00 (mm), alpha=45.00 (°)

Radius right (Radius right)

r=2.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 121.50...272.50 (mm)
d=260.00 (mm), l=151.00 (mm), Rz= 8.0

Chamfer left (Chamfer left)
l=2.00 (mm), alpha=45.00 (°)

Radius right (Radius right)
r=2.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 272.50...276.50 (mm)
d=259.20 (mm), l=4.00 (mm), Rz= 8.0

Radius left (Radius left)
r=1.00 (mm), Rz= 8.0

Radius right (Radius right)
r=1.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 276.50...526.50 (mm)
d=280.00 (mm), l=250.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 526.50...650.00 (mm)
d=250.00 (mm), l=123.50 (mm), Rz= 8.0

Chamfer right (Chamfer right)
l=2.00 (mm), alpha=45.00 (°)

Radius left (Radius left)
r=5.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 650.00...654.00 (mm)
d=219.20 (mm), l=4.00 (mm), Rz= 8.0

Radius left (Radius left)
r=1.00 (mm), Rz= 8.0

Radius right (Radius right)
r=1.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 654.00...758.00 (mm)
d=220.00 (mm), l=104.00 (mm), Rz= 8.0

Chamfer right (Chamfer right)
l=2.00 (mm), alpha=45.00 (°)

Radius left (Radius left)
r=0.40 (mm), Rz= 8.0

Inner contour

Forces

Cylindrical gear (Kolo_7 (OL 323 962)) y= 201.50 (mm)

Operating pitch diameter	(mm)	710.5479	
Helix angle	(°)	14.1069	left
Working pressure angle at normal section	(°)	25.8978	
Position of contact point	(°)	0.0000	
Length of load application	(mm)	150.0000	
Power	(kW)	502.6548	driving (Output)
Torque	(Nm)	-80469.4009	
Axial force	(N)	-56921.9591	
Shearing force X	(N)	-113391.0362	
Shearing force Z	(N)	226499.5669	
Bending moment X	(Nm)	0.0000	
Bending moment Z	(Nm)	-20222.8905	

Cylindrical gear (Pastorek_6 (OL 232 963)) y= 401.50 (mm)

Operating pitch diameter	(mm)	302.2220	
Helix angle	(°)	15.1650	left
Working pressure angle at normal section	(°)	21.8883	
Position of contact point	(°)	180.0000	
Length of load application	(mm)	250.0000	
Power	(kW)	502.6548	driven (Input)
Torque	(Nm)	80469.4009	
Axial force	(N)	144332.8187	
Shearing force X	(N)	221663.8710	
Shearing force Z	(N)	532518.4859	
Bending moment X	(Nm)	-0.0000	
Bending moment Z	(Nm)	-21810.2766	

Bearing

Spherical roller bearings SKF *22244CC/W33 (SKF*22244CC/W33_levé) y= 54.00 (mm)

Set fixed bearing left
d = 220.000 (mm), D = 400.000 (mm), B = 108.000 (mm), r = 4.000 (mm)
C = 1760.000 (kN), C0 = 2360.000 (kN), Cu = 196.000 (kN)
Ctheo = 1759.368 (kN), C0theo = 2360.135 (kN)
Calculation with approximate bearings internal geometry (*)
Z = 11, Dpw = 319.176 (mm), Dw = 57.366 (mm), Lwe = 52.465 (mm)
di = 266.770 (mm), do = 381.660 (mm), ri = 190.836 (mm), ro = 190.836 (mm), Pd = 0.180 (mm)

Tolerance field	Mean value
Tolerance	DIN 620:1988 PN
Tolerance shaft	k6, 220.018 mm (min = 220.004 mm , max = 220.033 mm)
Tolerance hub	H7, 400.029 mm (min = 400.000 mm , max = 400.057 mm)

Change of diametral clearance due to: n = 0 (1/min)

Interference fit	-27.57 µm
Temperature	0.00 µm
Shaft and housing roughness	0.00 µm
Total bearing clearance change	-22.30 µm, n = 59.65 (1/min)
Bearing clearance	DIN 620:1988 C0 (180.00 µm)
Operating bearing clearance	180.00 µm + (-22.30 µm) = 157.70 µm

Spherical roller bearings SKF *22244CC/W33 (SKF*22244CC/W33_pravé) y= 704.00 (mm)

Set fixed bearing right
d = 220.000 (mm), D = 400.000 (mm), B = 108.000 (mm), r = 4.000 (mm)
C = 1760.000 (kN), C0 = 2360.000 (kN), Cu = 196.000 (kN)
Ctheo = 1759.368 (kN), C0theo = 2360.135 (kN)
Calculation with approximate bearings internal geometry (*)
Z = 11, Dpw = 319.176 (mm), Dw = 57.366 (mm), Lwe = 52.465 (mm)

di = 266.770 (mm), do = 381.660 (mm), ri = 190.836 (mm), ro = 190.836 (mm), Pd = 0.180 (mm)

Tolerance field	Mean value
Tolerance	DIN 620:1988 PN
Tolerance shaft	k6, 220.018 mm (min = 220.004 mm , max = 220.033 mm)
Tolerance hub	H7, 400.029 mm (min = 400.000 mm , max = 400.057 mm)
Change of diametral clearance due to: n = 0 (1/min)	
Interference fit	-27.57 µm
Temperature	0.00 µm
Shaft and housing roughness	0.00 µm
Total bearing clearance change	-22.30 µm, n = 59.65 (1/min)
Bearing clearance	DIN 620:1988 C0 (180.00 µm)
Operating bearing clearance	180.00 µm + (-22.30 µm) = 157.70 µm

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maximum deflection	299.95	µm (Shaft III,	339.00 (mm))

Center of mass

Shaft III	377.9	mm

Deformation due to torsion

Shaft III	[phi.t]	0.02	°

Probability of failure	[n]	10.00	%
Axial clearance	[uA]	10.00	µm

Rolling bearing stiffness calculated from internal geometry

Shaft 'Shaft III' Rolling bearing 'SKF*22244CC/W33_levé'

Position (Y-coordinate)	[y]	54.00	mm
Equivalent load	[P]	424.30	kN
Equivalent load	[P0]	424.30	kN
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	32040.72	h
Operating viscosity	[nu]	48.88	mm¸/s
Reference viscosity	[nu1]	0.00	mm¸/s
static safety factor	[S0]	5.56	
Bearing reaction force	[Fx]	49.167	kN
Bearing reaction force	[Fy]	-0.000	kN
Bearing reaction force	[Fz]	-421.442	kN
Bearing reaction force	[Fr]	424.300	kN (-83.35°)
Bearing reaction moment	[Mx]	-0.00	Nm
Bearing reaction moment	[My]	0.00	Nm
Bearing reaction moment	[Mz]	0.00	Nm
Bearing reaction moment	[Mr]	0.00	Nm (135°)
Oil level	[H]	177.500	mm
Torque of friction	[Mloss]	25.570	Nm
Power loss	[Ploss]	159.724	W
Displacement of bearing	[ux]	-0.027	mm
Displacement of bearing	[uy]	0.421	mm
Displacement of bearing	[uz]	0.232	mm
Displacement of bearing	[ur]	0.234	mm (96.7°)
Misalignment of bearing	[rx]	0.263	mrad (0.9')
Misalignment of bearing	[ry]	-0.000	mrad (0')
Misalignment of bearing	[rz]	-0.259	mrad (-0.89')

Misalignment of bearing	[rr]	0.369	mrad (1.27')

Shaft 'Shaft III' Rolling bearing 'SKF*22244CC/W33_pravé'

Position (Y-coordinate)	[y]	704.00	mm
Equivalent load	[P]	588.33	kN
Equivalent load	[P0]	588.33	kN
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	10778.11	h
Operating viscosity	[nu]	48.88	mm²/s
Reference viscosity	[nu1]	0.00	mm²/s
static safety factor	[S0]	4.01	
Bearing reaction force	[Fx]	-157.440	kN
Bearing reaction force	[Fy]	-87.411	kN
Bearing reaction force	[Fz]	-334.615	kN
Bearing reaction force	[Fr]	369.803	kN (-115.2°)
Bearing reaction moment	[Mx]	0.00	Nm
Bearing reaction moment	[My]	-0.00	Nm
Bearing reaction moment	[Mz]	0.00	Nm
Bearing reaction moment	[Mr]	0.00	Nm (8.3°)
Oil level	[H]	177.500	mm
Torque of friction	[Mloss]	29.502	Nm
Power loss	[Ploss]	184.284	W
Displacement of bearing	[ux]	0.083	mm
Displacement of bearing	[uy]	0.419	mm
Displacement of bearing	[uz]	0.176	mm
Displacement of bearing	[ur]	0.195	mm (64.78°)
Misalignment of bearing	[rx]	-0.419	mrad (-1.44')
Misalignment of bearing	[ry]	0.380	mrad (1.31')
Misalignment of bearing	[rz]	-0.068	mrad (-0.23')
Misalignment of bearing	[rr]	0.425	mrad (1.46')

(*) Note concerning roller bearings with approximated bearing geometry:
The inner geometry of these bearings is not charted in the data base.
The geometry is calculated backwards from C and C0 (values in the manufacturer catalog) according to ISO281.
Therefore the calculated geometry can differ from the real geometry.
Differences in the bearing stiffness results can be considerable in some cases.

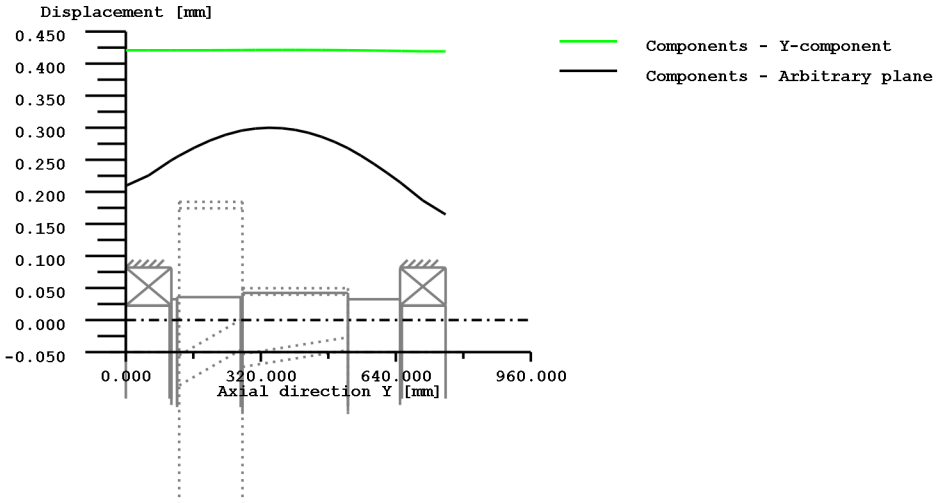
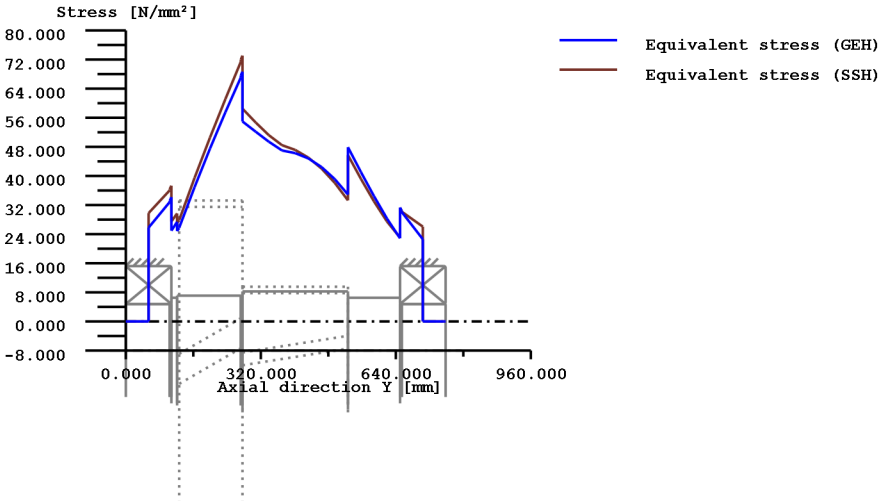


Figure: Displacement (bending etc.) (Arbitrary plane 81.40590411 °)



GEH(von Mises): sigV = ((sigB+sigZ,D)^2 + 3*(tauT+tauS)^2)^1/2SSH(Tresca): sigV = ((sigB-sigZ,D)^2 + 4*(tauT+tauS)^2)^1/2
Figure: Equivalent stress

Eigenfrequencies/Critical speeds

1. Eigenfrequency:	0.03 Hz, Critical speed:	1.99 1/min	Rigid body rotation Y 'Shaft III'
2. Eigenfrequency:	111.79 Hz, Critical speed:	6707.13 1/min	Axial 'Shaft III'
3. Eigenfrequency:	514.75 Hz, Critical speed:	30884.89 1/min	Bending XY 'Shaft III'
4. Eigenfrequency:	651.13 Hz, Critical speed:	39067.58 1/min	Bending YZ 'Shaft III'

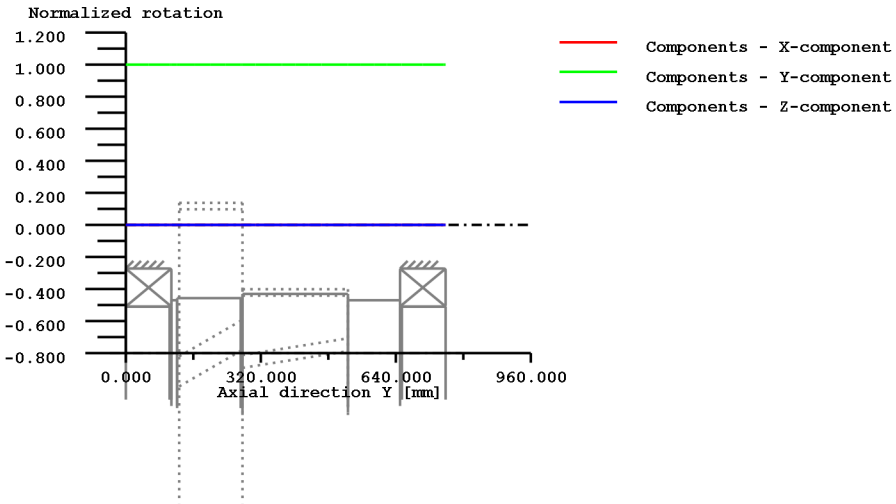


Figure: Eigenfrequencies (Normalized displacement)

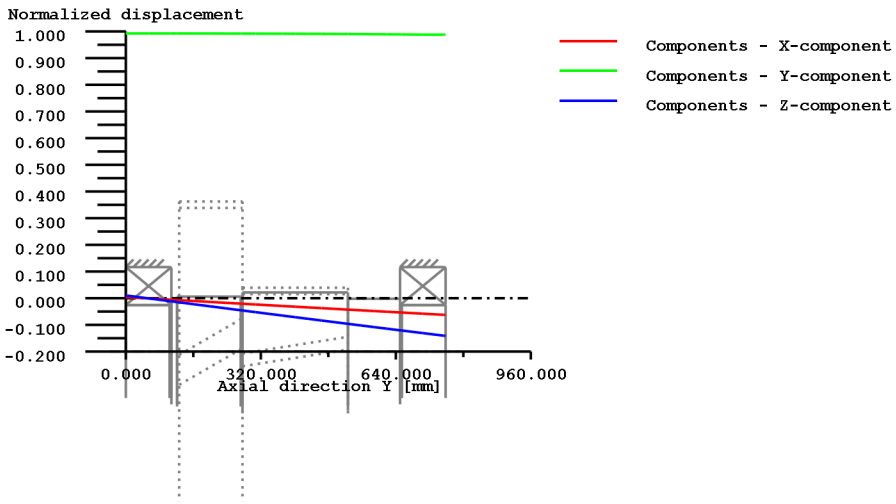


Figure: Eigenfrequencies (Normalized rotation)

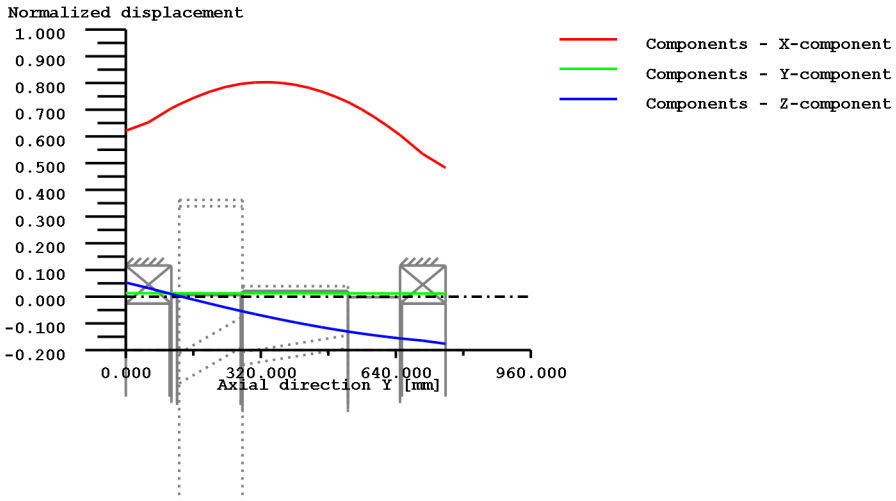


Figure: Eigenfrequencies (Normalized rotation)

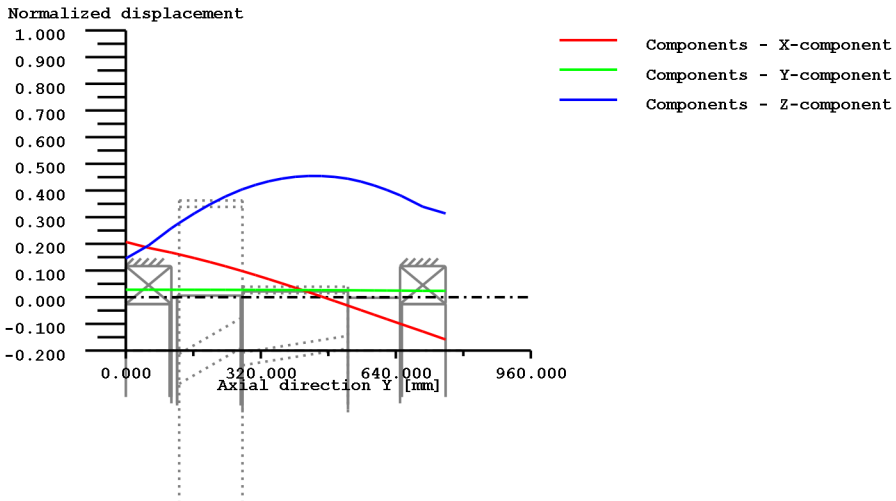


Figure: Eigenfrequencies (Normalized rotation)

Strength calculation as specified in

DIN 743:2012

Summary

Label	Shaft III
Drawing	OL 232 965

Material	18CrNiMo7-6
Material type	Case-carburized steel
Material treatment	case-hardened
Surface treatment	No

Calculation of endurance limit and the static strength
Calculation for load case 2 (sig.av/sig.mv = const)

Cross section	Position (Y-Coord) (mm)	
A-A	121.50	Shoulder
B-B	276.50	Shoulder
C-C	526.50	Shoulder
D-D	650.00	Shoulder

Results:

Cross section	Kfb	Kfsig	K2d	SD	SS	SA
A-A	2.18	0.88	0.80	7.54	21.79	27.06
B-B	3.11	0.88	0.80	1.91	6.39	6.47
C-C	2.16	0.88	0.80	3.25	9.93	13.36
D-D	3.25	0.88	0.80	4.70	25.36	18.95
Nominal safety:				1.20	1.20	1.20

Abbreviations:
Kfb: Notch factor bending
Kfsig: Surface factor
K2d: Size coefficient bending
SD: Safety endurance limit
SS: Safety against yield point
SA: Safety against incipient crack

The requirements of the safety proof of the shaft are:

satisfied [x] not satisfied [ ]

Design engineer:..... Date:..... Signature:.....

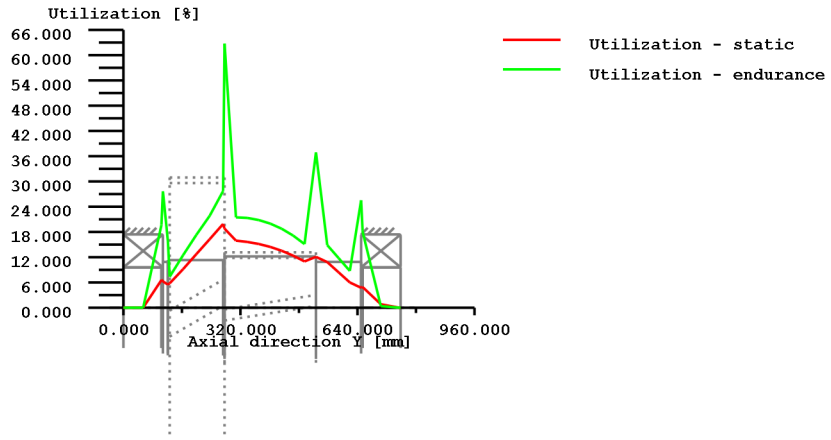


Figure: Strength

Calculation details:

General statements

Label	Shaft III		
Drawing	OL 232 965		
Length (mm)		[l]	758.00
Speed (1/min)		[n]	59.65

Material	18CrNiMo7-6
Material type	Case-carburized steel
Material treatment	case-hardened
Surface treatment	No

	Tension/Compression	Bending	Torsion	Shearing
Load factor static calculation	1.700	1.700	1.700	1.700
Load factor endurance limit	1.000	1.000	1.000	1.000

Reference diameter material (mm)	[dB]	16.00
sigB according DIN 743 (at dB) (N/mm²)	[sigB]	1200.00
sigS according DIN 743 (at dB) (N/mm²)	[sigS]	850.00
[sigzdW] (bei dB) (N/mm²)		480.00
[sigbW] (bei dB) (N/mm²)		600.00
[tautW] (bei dB) (N/mm²)		360.00
Thickness of raw material (mm)	[dWerkst]	290.00

Material data calculated according DIN743/3 with K1(d)
Material strength calculated from size of raw material
Geometric size coefficient K1d calculated from raw material diameter

[sigBeff] (N/mm²)	807.42

[sigSeff] (N/mm²)	571.92
[sigbF] (N/mm²)	629.11
[tautF] (N/mm²)	363.22
[sigBRand] (N/mm²)	2300.00
[sigzdW] (N/mm²)	322.97
[sigbW] (N/mm²)	403.71
[tautW] (N/mm²)	242.23

Endurance limit for single stage use

Calculation for load case 2 (sig.av/sig.mv = const)

Cross section 'A-A' Shoulder

Comment					
Position (Y-Coordinate) (mm)			[y]		121.50
External diameter (mm)			[da]		250.000
Inner diameter (mm)			[di]		0.000
Notch effect	Shoulder				
[D, r, t] (mm)		260.000	2.000	0.000	
Mean roughness (µm)			[Rz]		8.000

	Tension/Compression		Bending		Torsion		Shearing
Stress: (N) (Nm)							
Mean value	0.0		0.0		0.0		0.0
Amplitude	0.0		28661.7		0.0		424638.8
Maximum value	0.0		48724.9		0.0		721886.0
Cross section, moment of resistance: (mm²)							
[A, Wb, Wt, A]	49087.4		1533980.8		3067961.6		49087.4

Stresses: (N/mm²)					
[sigzdm, sigbm, taum, tauqm] (N/mm²)	0.000		0.000	0.000	0.000
[sigzda, sigba, taua, tauqa] (N/mm²)	0.000		18.685	0.000	11.534
[sigzdmax,sigbmax,taumax,tauqmax] (N/mm²)	0.000		31.764	0.000	19.608

Technological size influence	[K1(sigB)]	0.673	
	[K1(sigS)]	0.673	

		Tension/Compression	Bending	Torsion
Stress concentration factor	[alfa]	2.808	2.676	1.740
References stress slope	[G']	1.288	1.288	0.575
Notch sensitivity factor n	[n]	1.226	1.226	1.151
Notch effect coefficient	[beta]	2.290	2.182	1.511
Geometrical size influence	[K2(d)]	1.000	0.800	0.800
Influence coefficient surface roughness				
	[KF]	0.880	0.880	0.931
Influence coefficient surface strengthening				
	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	2.427	2.864	1.963

Present margin of safety for endurance limit:

Equivalent mean stress (N/mm²)	[sigmV]		0.000	
Equivalent mean stress (N/mm²)	[taumV]		0.000	
Fatigue limit of part (N/mm²)	[sigWK]	133.090	140.958	123.381

Influence coeff. mean stress sensitivity.				
	[PsisigK]	0.090	0.096	0.083
Permissible amplitude (N/mm²)	[sigADK]	133.089	140.958	123.381
Margin of safety endurance limit	[S]		7.544	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		628.7	

Present margin of safety				
for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.100	1.100
Increase coefficient	[gammaF]	1.100	1.100	1.000
Yield stress of part (N/mm²)	[sigFK]	629.113	692.024	363.218
Margin of safety yield stress	[S]		21.787	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1815.6	

Present margin of safety		
for proof of avoiding incipient crack on hard surface layers:		
Safety against incipient crack	[S]	27.061
Required safety	[Smin]	1.200
Result (%)	[S/Smin]	2255.1

Cross section 'B-B' Shoulder

Comment				
Position (Y-Coordinate) (mm)		[y]		276.50
External diameter (mm)		[da]		259.200
Inner diameter (mm)		[di]		0.000
Notch effect	Shoulder			
[D, r, t] (mm)	280.000	1.000	0.000	
Mean roughness (µm)		[Rz]		8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	28461.0	0.0	40234.7	0.0
Amplitude	28461.0	78942.6	40234.7	206189.7
Maximum value	96767.3	134202.4	136798.0	350522.5
Cross section, moment of resistance: (mm²)				
[A, Wb, Wt, A]	52766.7	1709640.8	3419281.7	52766.7

Stresses: (N/mm²)				
[sigzdm, sigbm, taum, tauqm] (N/mm²)	0.539	0.000	11.767	0.000
[sigzda, sigba, taua, tauqa] (N/mm²)	0.539	46.175	11.767	5.210
[sigzdmax,sigbmax,taumax,tauqmax] (N/mm²)	1.834	78.497	40.008	8.857

Technological size influence	[K1(sigB)]	0.673	
	[K1(sigS)]	0.673	

	Tension/Compression	Bending	Torsion
Stress concentration factor	[alfa]	4.390	4.083	2.437
References stress slope	[G']	2.454	2.454	1.150
Notch sensitivity factor n	[n]	1.313	1.313	1.214
Notch effect coefficient	[beta]	3.344	3.110	2.007
Geometrical size influence	[K2(d)]	1.000	0.800	0.800
Influence coefficient surface roughness				

	[KF]	0.880	0.880	0.931
Influence coefficient surface strengthening				
	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	3.481	4.025	2.584

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm²)	[sigmV]		20.388	
Equivalent mean stress (N/mm²)	[taumV]		11.771	
Fatigue limit of part (N/mm²)	[sigWK]	92.778	100.301	93.755
Influence coeff. mean stress sensitivity.				
	[PsisigK]	0.061	0.066	0.062
Permissible amplitude (N/mm²)	[sigADK]	16.951	97.451	88.310
Margin of safety endurance limit	[S]		1.912	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		159.4	

Present margin of safety				
for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.100	1.100
Increase coefficient	[gammaF]	1.150	1.150	1.000
Yield stress of part (N/mm²)	[sigFK]	657.709	723.480	363.218
Margin of safety yield stress	[S]		6.386	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		532.2	

Present margin of safety		
for proof of avoiding incipient crack on hard surface layers:		
Safety against incipient crack	[S]	6.474
Required safety	[Smin]	1.200
Result (%)	[S/Smin]	539.5

Cross section 'C-C' Shoulder

Comment				
Position (Y-Coordinate) (mm)		[y]	526.50	
External diameter (mm)		[da]	250.000	
Inner diameter (mm)		[di]	0.000	
Notch effect	Shoulder			
[D, r, t] (mm)	280.000	5.000	0.000	
Mean roughness (µm)		[Rz]	8.000	

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-43705.4	0.0	0.0	0.0
Amplitude	43705.4	65904.0	0.0	370577.0
Maximum value	-148598.5	112036.8	0.0	629980.8
Cross section, moment of resistance: (mm²)				
[A, Wb, Wt, A]	49087.4	1533980.8	3067961.6	49087.4

Stresses: (N/mm²)				
[sigzdm, sigbm, taum, tauqm] (N/mm²)	-0.890	0.000	0.000	0.000
[sigzda, sigba, taua, tauqa] (N/mm²)	0.890	42.963	0.000	10.066
[sigzdmax,sigbmax,taumax,tauqmax] (N/mm²)	-3.027	73.037	0.000	17.112

Technological size influence	[K1(sigB)]	0.673
	[K1(sigS)]	0.673

		Tension/Compression	Bending	Torsion
Stress concentration factor	[alfa]	2.671	2.468	1.698
References stress slope	[G']	0.512	0.512	0.230
Notch sensitivity factor n	[n]	1.143	1.143	1.096
Notch effect coefficient	[beta]	2.338	2.160	1.549
Geometrical size influence	[K2(d)]	1.000	0.800	0.800
Influence coefficient surface roughness	[KF]	0.880	0.880	0.931
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	2.474	2.836	2.011

Present margin of safety for endurance limit:

Equivalent mean stress (N/mm²)	[sigmV]		0.890	
Equivalent mean stress (N/mm²)	[taumV]		0.514	
Fatigue limit of part (N/mm²)	[sigWK]	130.522	142.335	120.442
Influence coeff. mean stress sensitivity.	[PsisigK]	0.088	0.097	0.081
Permissible amplitude (N/mm²)	[sigADK]	143.106	142.621	120.442
Margin of safety endurance limit	[S]		3.252	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		271.0	

Present margin of safety
for proof against exceed of yield point:

Static notch sensitivity factor	[K2F]	1.000	1.100	1.100
Increase coefficient	[gammaF]	1.100	1.100	1.000
Yield stress of part (N/mm²)	[sigFK]	629.113	692.024	363.218
Margin of safety yield stress	[S]		9.928	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		827.3	

Present margin of safety
for proof of avoiding incipient crack on hard surface layers:

Safety against incipient crack	[S]		13.361
Required safety	[Smin]		1.200
Result (%)	[S/Smin]		1113.4

Cross section 'D-D' Shoulder

Comment					
Position (Y-Coordinate) (mm)			[y]		650.00
External diameter (mm)			[da]		219.200
Inner diameter (mm)			[di]		0.000
Notch effect	Shoulder				
[D, r, t] (mm)		250.000	1.000	0.000	
Mean roughness (µm)			[Rz]		8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-43705.4	0.0	0.0	0.0
Amplitude	43705.4	19984.5	0.0	370141.3
Maximum value	-148598.5	33973.7	0.0	629240.3
Cross section, moment of resistance: (mm²)				
[A, Wb, Wt, A]	37737.3	1034002.4	2068004.8	37737.3

Stresses: (N/mm²)					
[sigzdm, sigbm, taum, tauqm] (N/mm²)		-1.158	0.000	0.000	0.000
[sigzda, sigba, taua, tauqa] (N/mm²)		1.158	19.327	0.000	13.078
[sigzdmax,sigbmax,taumax,tauqmax] (N/mm²)		-3.938	32.856	0.000	22.232
Technological size influence	[K1(sigB)]	0.673			
	[K1(sigS)]	0.673			
		Tension/Compression	Bending	Torsion	
Stress concentration factor	[alfa]	4.707	4.258	2.579	
References stress slope	[G']	2.430	2.430	1.150	
Notch sensitivity factor n	[n]	1.311	1.311	1.214	
Notch effect coefficient	[beta]	3.590	3.248	2.125	
Geometrical size influence	[K2(d)]	1.000	0.800	0.800	
Influence coefficient surface roughness					
	[KF]	0.880	0.880	0.931	
Influence coefficient surface strengthening					
	[KV]	1.000	1.000	1.000	
Total influence coefficient	[K]	3.727	4.197	2.730	
Present margin of safety for endurance limit:					
Equivalent mean stress (N/mm²)	[sigmV]		1.158		
Equivalent mean stress (N/mm²)	[taumV]		0.669		
Fatigue limit of part (N/mm²)	[sigWK]	86.655	96.192	88.724	
Influence coeff. mean stress sensitivity.					
	[PsisigK]	0.057	0.063	0.058	
Permissible amplitude (N/mm²)	[sigADK]	91.864	96.559	88.724	
Margin of safety endurance limit	[S]		4.700		
Required safety	[Smin]		1.200		
Result (%)	[S/Smin]		391.7		
Present margin of safety					
for proof against exceed of yield point:					
Static notch sensitivity factor	[K2F]	1.000	1.100	1.100	
Increase coefficient	[gammaF]	1.150	1.150	1.000	
Yield stress of part (N/mm²)	[sigFK]	657.709	723.480	363.218	
Margin of safety yield stress	[S]		25.363		
Required safety	[Smin]		1.200		
Result (%)	[S/Smin]		1579.1		
Present margin of safety					
for proof of avoiding incipient crack on hard surface layers:					
Safety against incipient crack	[S]		18.949		
Required safety	[Smin]		1.200		
Result (%)	[S/Smin]		1579.1		

Remarks:

- The shearing force is not considered in the analysis specified in DIN 743.
- Cross section with interference fit:
  The notching factor for the light fit case is no longer defined in DIN 743.
  The values are imported from the FKM-Guideline..

End of Report lines: 662

File

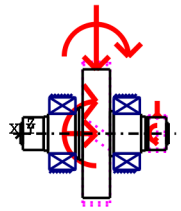
Name : Hridel_IV_2_stavy
Changed by: karlova am: 02.05.2014 um: 11:41:11

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label		Shaft 1
Drawing		
Initial position (mm)		0.000
Length (mm)		1270.000
Speed (1/min)		14.68
Sense of rotation: counter clockwise		
Material		42 CrMo 4 (2)
Young's modulus (N/mm²)		206000.000
Poisson's ratio nu		0.300
Specific weight (kg/m³)		7830.000
Coefficient of thermal expansion	(10^-6/K)	11.500
Temperature (°C)		20.000
Weight of shaft (kg)		2402.047
Mass moment of inertia (kg*m²)		420.073
Momentum of mass GD2 (Nm²)		16483.645
(Notice: Weight stands for the shaft only without considering the gears)		
Position in space (°)		0.000
Regard gears as masses and stiffness		
Consider deformations due to shearing		
Shear correction coefficient		1.100
Contact angle of rolling bearings is considered		
Reference temperature (°C)		20.000



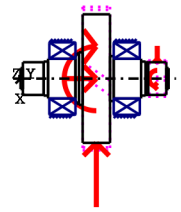


Figure: Load applications

SHAFT DEFINITION (Shaft 1)

Outer contour

Cylinder (Cylinder) y= 0.00...20.00 (mm)
d=180.00 (mm), l=20.00 (mm), Rz= 8.0

Chamfer left (Chamfer left)
l=1.00 (mm), alpha=45.00 (°)

Radius right (Radius right)
r=0.40 (mm), Rz= 8.0

Radius left (Radius left)
r=0.40 (mm), Rz= 8.0

Cylinder (Cylinder) y= 20.00...198.00 (mm)
d=280.00 (mm), l=178.00 (mm), Rz= 8.0

Radius right (Radius right)
r=47.50 (mm), Rz= 8.0

Cylinder (Cylinder) y= 198.00...236.00 (mm)
d=291.00 (mm), l=38.00 (mm), Rz= 8.0

Radius right (Radius right)
r=12.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 236.00...471.00 (mm)

d=340.00 (mm), l=235.00 (mm), Rz= 8.0

Relief groove right (Relief groove right)
r=1.00 (mm), t=1.00 (mm), l=2.00 (mm), Rz= 8.0
Own Input, Form B, FKM

Taper (Cone) y= 471.00...501.50 (mm)
dl=385.00 (mm), dr=450.00 (mm), l=30.50 (mm), Rz= 8.0

Cylinder (Cylinder) y= 501.50...532.50 (mm)
d=450.00 (mm), l=31.00 (mm), Rz= 8.0

Chamfer right (2)
l=2.00 (mm), alpha=45.00 (°)

Cylinder (Cylinder) y= 532.50...767.50 (mm)
d=1100.00 (mm), l=235.00 (mm), Rz= 8.0

Radius left (Radius left)
r=0.40 (mm), Rz= 8.0

Chamfer right (Chamfer right)
l=2.00 (mm), alpha=45.00 (°)

Cylinder (Cylinder) y= 767.50...799.00 (mm)
d=385.00 (mm), l=31.50 (mm), Rz= 8.0

Chamfer right (Chamfer right)
l=2.00 (mm), alpha=45.00 (°)

Radius left (Radius left)
r=10.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 799.00...1034.00 (mm)
d=340.00 (mm), l=235.00 (mm), Rz= 8.0

Radius left (Radius left)
r=0.40 (mm), Rz= 8.0

Cylinder (Cylinder) y= 1034.00...1072.00 (mm)
d=291.00 (mm), l=38.00 (mm), Rz= 8.0

Radius left (Radius left)
r=12.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 1072.00...1250.00 (mm)
d=280.00 (mm), l=178.00 (mm), Rz= 8.0

Radius left (Radius left)
r=47.50 (mm), Rz= 8.0

Cylinder (Cylinder) y= 1250.00...1270.00 (mm)
d=180.00 (mm), l=20.00 (mm), Rz= 8.0

Radius left (Radius left)
r=0.40 (mm), Rz= 8.0

Chamfer right (Chamfer right)
l=2.00 (mm), alpha=45.00 (°)

Inner contour

Forces

Cylindrical gear (Kolo_8) y= 650.00 (mm)

Operating pitch diameter	(mm)	1227.7778	
Helix angle	(°)	15.1950	right
Working pressure angle at normal section	(°)	21.8883	
Position of contact point	(°)	0.0000	
Length of load application	(mm)	235.0000	
Axial force (Load spectrum)	(N)	136267.12/95386.98	
Shearing force X (Load spectrum)	(N)	-208873.63/-146211.54	
Shearing force Z (Load spectrum)	(N)	501719.46/351203.62	
Bending moment X (Load spectrum)	(N)	-0.00/-0.00	
Bending moment Z (Load spectrum)	(N)	83652.87/58557.01	

load spectrum,driven (Input):

Element	Frequency (%)	Speed (1/min)	Power (kW)	Torque (Nm)
1	20.0000	-14.7	473.5	-308000.0
2	80.0000	-14.7	331.4	-215600.0

Cylindrical gear (Drazkovani_vlevo) y= 1172.50 (mm)

Operating pitch diameter	(mm)	310.0000	
Spur gear			
Working pressure angle at normal section	(°)	24.5802	
Position of contact point	(°)	0.0000	
Length of load application	(mm)	155.0000	
Axial force (Load spectrum)	(N)	-0.00/-0.00	
Shearing force X (Load spectrum)	(N)	-908933.18/-636253.22	
Shearing force Z (Load spectrum)	(N)	-1987096.77/-1390967.74	
Bending moment X (Load spectrum)	(N)	0.00/0.00	
Bending moment Z (Load spectrum)	(N)	-0.00/-0.00	

load spectrum,driving (Output):

Element	Frequency (%)	Speed (1/min)	Power (kW)	Torque (Nm)
1	20.0000	-14.7	-473.5	308000.0
2	80.0000	-14.7	-331.4	215600.0

Bearing

Spherical roller bearings SKF *23268CA/W33 (SKF_23260_leve) y= 359.00 (mm)
Set fixed bearing left
d = 340.000 (mm), D = 620.000 (mm), B = 224.000 (mm), r = 6.000 (mm)
C = 5100.000 (kN), C0 = 7800.000 (kN), Cu = 550.000 (kN)
Bearing clearance DIN 620:1988 C0 (255.00 µm)

Spherical roller bearings SKF *23268CA/W33 (SKF_23260_prave) y= 911.00 (mm)
Set fixed bearing right
d = 340.000 (mm), D = 620.000 (mm), B = 224.000 (mm), r = 6.000 (mm)
C = 5100.000 (kN), C0 = 7800.000 (kN), Cu = 550.000 (kN)
Bearing clearance DIN 620:1988 C0 (255.00 µm)

Shaft 'Shaft 1': Cylindrical gear 'Kolo_8' (y= 650.0000 (mm)) is taken into account as component of the shaft.
EI (y= 532.5000 (mm)): 14804981182.0139 (Nm²), EI (y= 767.5000 (mm)): 14804981182.0139 (Nm²), m (yS= 650.0000 (mm)): 429.8494 (kg)
Jp: 146.0112 (kg*m²), Jxx: 74.9838 (kg*m²), Jzz: 74.9838 (kg*m²)

Shaft 'Shaft 1': Cylindrical gear 'Drazkovani_vlevo' (y= 1172.5000 (mm)) is taken into account as component of the shaft.
EI (y= 1095.0000 (mm)): 62154023.0409 (Nm²), EI (y= 1250.0000 (mm)): 62154023.0409 (Nm²), m (yS= 1172.5000 (mm)): 16.8716 (kg)
Jp: 0.3680 (kg*m²), Jxx: 0.2178 (kg*m²), Jzz: 0.2178 (kg*m²)

---

maximum deflection		767.57	µm (Shaft 1, 1270.00 (mm))

Center of mass

Shaft 1		643.6	mm

Deformation due to torsion

Shaft 1	[phi.t]	0.08	°

Probability of failure	[n]	10.00	%
Axial clearance	[uA]	10.00	µm

Rolling bearings, classical calculation (contact angle considered)

Shaft 'Shaft 1' Rolling bearing 'SKF_23260_leve'

Position (Y-coordinate)	[y]	359.00	mm
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	271422.42	h
Operating viscosity	[nu]	48.88	mm²/s
Reference viscosity	[nu1]	0.00	mm²/s
static safety factor	[S0]	6.18	

	Bearing reaction force			Bearing reaction moment		
	Fx (kN)	Fy (kN)	Fz (kN)	Mx (Nm)	My (Nm)	Mz (Nm)
1	-483.375	0.000	-1165.255	0.000	0.000	0.000
2	-338.362	0.000	-811.682	0.000	0.000	0.000

	Displacement of bearing			Misalignment of bearing		
	ux (mm)	uy (mm)	uz (mm)	ux (mrad)	uy (mrad)	uz (mrad)
1	0.0498	0.0111	0.1174	-0.369	-0.000	0.206
2	0.0500	0.0107	0.1173	-0.382	-0.000	0.206

Shaft 'Shaft 1' Rolling bearing 'SKF_23260_prave'

Position (Y-coordinate)	[y]	911.00	mm
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	10058.18	h
Operating viscosity	[nu]	48.88	mm²/s
Reference viscosity	[nu1]	0.00	mm²/s
static safety factor	[S0]	2.32	

	Bearing reaction force			Bearing reaction moment		
	Fx (kN)	Fy (kN)	Fz (kN)	Mx (Nm)	My (Nm)	Mz (Nm)
1	1601.182	-136.267	2678.576	0.000	0.000	0.000
2	1120.827	-95.387	1879.390	0.000	0.000	0.000

	Displacement of bearing			Misalignment of bearing		
	ux (mm)	uy (mm)	uz (mm)	ux (mrad)	uy (mrad)	uz (mrad)
1	-0.0637	0.0100	-0.1105	-0.915	0.391	0.427
2	-0.0635	0.0100	-0.1105	-0.764	0.273	0.361

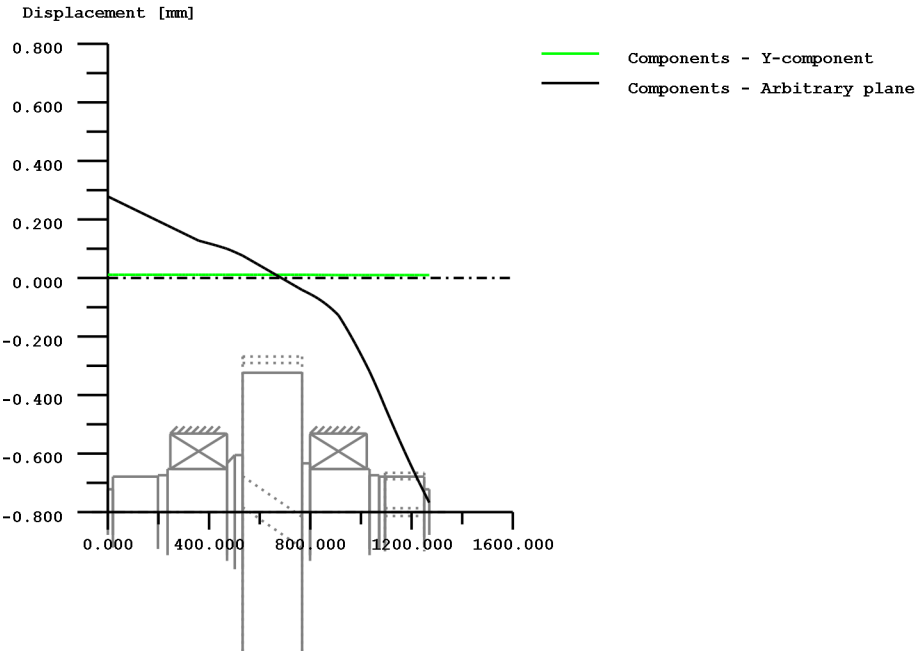
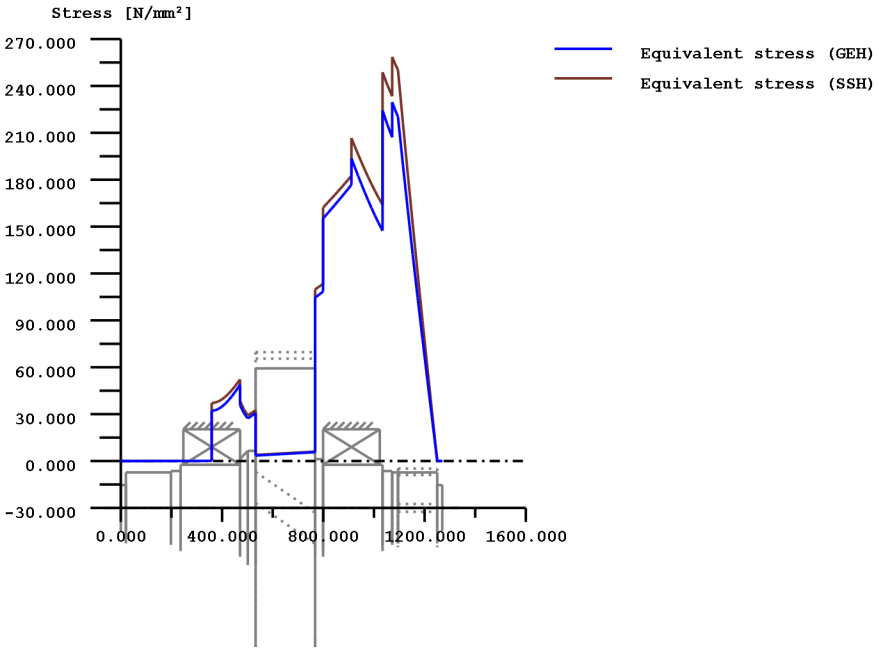


Figure: Displacement (bending etc.) (Arbitrary plane 64.32976452 °)



GEH(von Mises): sigV = ((sigB+sigZ,D)^2 + 3*(tauT+tauS)^2)^1/2SSH(Tresca): sigV = ((sigB-sigZ,D)^2 + 4*(tauT+tauS)^2)^1/2
Figure: Equivalent stress

Strength calculation as specified in

DIN 743:2012

with finite life fatigue strength according to FKM standard and FVA draft

Summary

Label	Shaft 1
Drawing	

Material	42 CrMo 4 (2)
Material type	Through hardened steel
Material treatment	flame/ind. hardened
Surface treatment	No

Calculation of service strength and static strength
Woehler line (S-N curve) according Miner elementary
Calculation for load case 2 (sig.av/sig.mv = const)

Cross section	Position (Y-Coord) (mm)	
A-A	1095.00	Smooth shaft

Results:

Cross section	Kfb	Kfsig	K2d	SD	SS	SA
A-A	1.00	0.89	0.80	2.38	2.26	9.98
Nominal safety:				1.20	1.20	1.20

Abbreviations:
Kfb: Notch factor bending
Kfsig: Surface factor
K2d: Size coefficient bending
SD: Safety endurance limit
SS: Safety against yield point
SA: Safety against incipient crack

The requirements of the safety proof of the shaft are:

satisfied [x] not satisfied [ ]

Design engineer:..... Date:..... Signature:.....

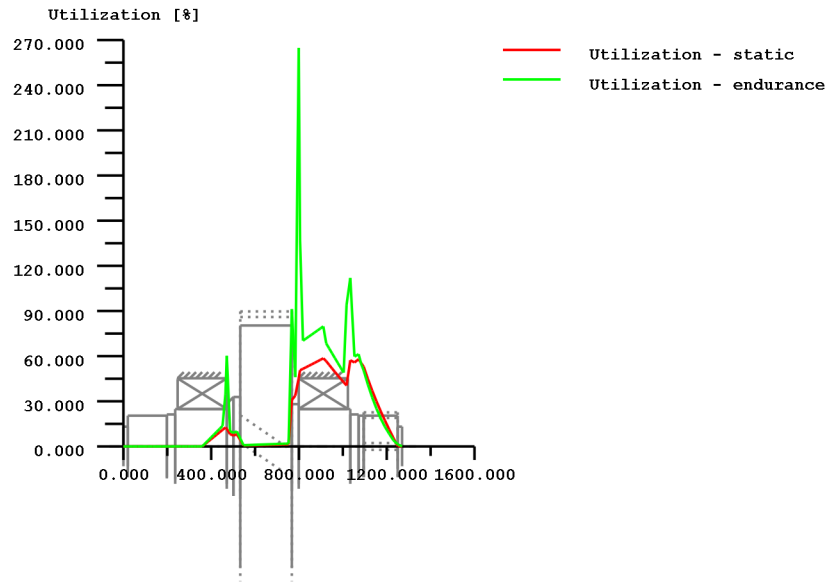


Figure: Strength

Calculation details:

General statements

Label	Shaft 1		
Drawing			
Length (mm)		[l]	1270.00
Speed (1/min)		[n]	14.68

Material	42 CrMo 4 (2)
Material type	Through hardened steel
Material treatment	flame/ind. hardened
Surface treatment	No

	Tension/Compression	Bending	Torsion	Shearing
Load factor static calculation	1.700	1.700	1.700	1.700
Load factor endurance limit	1.000	1.000	1.000	1.000

Reference diameter material (mm)	[dB]	16.00
sigB according DIN 743 (at dB) (N/mm²)	[sigB]	1100.00
sigS according DIN 743 (at dB) (N/mm²)	[sigS]	900.00
[sigzdW] (bei dB) (N/mm²)		440.00
[sigbW] (bei dB) (N/mm²)		550.00
[tautW] (bei dB) (N/mm²)		330.00
Thickness of raw material (mm)	[dWerkst]	1110.00

Material data calculated according DIN743/3 with K1(d)
Material strength calculated from size of raw material
Geometric size coefficient K1d calculated from raw material diameter

[sigBeff] (N/mm²)	737.00

[sigSeff] (N/mm²)	513.00
[sigbF] (N/mm²)	564.30
[tautF] (N/mm²)	325.80
[sigBRand] (N/mm²)	2050.00
[sigzdW] (N/mm²)	294.80
[sigbW] (N/mm²)	368.50
[tautW] (N/mm²)	221.10

Service strength for a load spectrum
Woehler line (S-N curve) according Miner elementary
Required life time [h] 2400.00
Number of load cycles (Mio) [NL] 2.114
Data of Woehler line (S-N curve) analog to FKM standard:

[ksigma, ktau]	15	25
[kDsigma, kDtau]	0	0
[NDsigma, NDtau]	1e+006	1e+006
[NDsigmaII, NDtauII]	0	0
[DM]	0.3	

Calculation for load case 2 (sig.av/sig.mv = const)

Cross section 'A-A' Smooth shaft

Comment
Position (Y-Coordinate) (mm) [y] 1095.00
External diameter (mm) [da] 280.000
Inner diameter (mm) [di] 0.000
Notch effect Smooth shaft
Mean roughness (µm) [Rz] 8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	0.0	0.0	154000.0	0.0
Amplitude	0.0	169415.3	154000.0	2185989.1
Maximum value	0.0	288006.0	523600.0	3716181.4
Cross section, moment of resistance: (mm²)				
[A, Wb, Wt, A]	61575.2	2155132.6	4310265.1	61575.2

Load spectrum, load base values (Mean-value + Amplitude):

Element	Frequency (%)	Tens./Press. (N)	Bending (Nm)	Torsion (Nm)	Shearing (N)
1	20.00	0.000	169415.299	308000.000	2185989.063
2	80.00	0.000	118611.453	215600.000	1530455.571

Stresses: (N/mm²)

[sigzdm, sigbm, taum, tauqm] (N/mm²)	0.000	0.000	35.729	0.000
[sigzda, sigba, taua, tauqa] (N/mm²)	0.000	78.610	35.729	47.335
[sigzdmax,sigbmax,taumax,tauqmax] (N/mm²)	0.000	133.637	121.477	80.469

Technological size influence [K1(sigB)] 0.670
[K1(sigS)] 0.570

	Tension/Compression	Bending	Torsion

Notch effect coefficient	[beta]	1.000	1.000	1.000
Geometrical size influence	[K2(d)]	1.000	0.800	0.800
Influence coefficient surface roughness	[KF]	0.887	0.887	0.935
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	1.127	1.377	1.319

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm²)	[sigmV]		61.884	
Equivalent mean stress (N/mm²)	[taumV]		35.729	
Fatigue limit of part (N/mm²)	[sigWK]	261.623	267.647	167.603
Influence coeff. mean stress sensitivity.	[PsisigK]	0.216	0.222	0.128
Permissible amplitude (N/mm²)	[sigADK]	0.008	227.851	148.546
Permissible amplitude (N/mm²)	[sigANK]	0.008	227.851	148.546
Load spectrum factor	[fKoll]	1.000	1.002	1.002
Margin of safety endurance limit	[S]		2.382	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		198.5	

Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.100	1.100
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm²)	[sigFK]	513.000	564.300	325.799
Margin of safety yield stress	[S]		2.264	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		188.7	

Present margin of safety for proof of avoiding incipient crack on hard surface layers:		
Safety against incipient crack	[S]	9.978
Required safety	[Smin]	1.200
Result (%)	[S/Smin]	831.5

Remarks:

- The shearing force is not considered in the analysis specified in DIN 743.
- Cross section with interference fit:
  The notching factor for the light fit case is no longer defined in DIN 743.
  The values are imported from the FKM-Guideline..

End of Report lines: 437

File

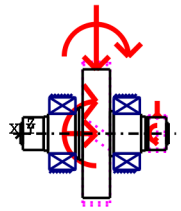
Name : Hridel_IV_2_stavy
Changed by: karlova am: 02.05.2014 um: 11:20:53

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label		Shaft 1
Drawing		
Initial position (mm)		0.000
Length (mm)		1270.000
Speed (1/min)		14.68
Sense of rotation: counter clockwise		
Material		42 CrMo 4 (2)
Young's modulus (N/mm²)		206000.000
Poisson's ratio nu		0.300
Specific weight (kg/m³)		7830.000
Coefficient of thermal expansion	(10^-6/K)	11.500
Temperature (°C)		20.000
Weight of shaft (kg)		2402.047
Mass moment of inertia (kg*m²)		420.073
Momentum of mass GD2 (Nm²)		16483.645
(Notice: Weight stands for the shaft only without considering the gears)		
Position in space (°)		0.000
Regard gears as masses and stiffness		
Consider deformations due to shearing		
Shear correction coefficient		1.100
Contact angle of rolling bearings is considered		
Reference temperature (°C)		20.000



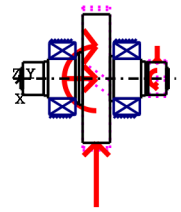


Figure: Load applications

SHAFT DEFINITION (Shaft 1)

Outer contour

Cylinder (Cylinder) y= 0.00...20.00 (mm)
d=180.00 (mm), l=20.00 (mm), Rz= 8.0

Chamfer left (Chamfer left)
l=1.00 (mm), alpha=45.00 (°)

Radius right (Radius right)
r=0.40 (mm), Rz= 8.0

Radius left (Radius left)
r=0.40 (mm), Rz= 8.0

Cylinder (Cylinder) y= 20.00...198.00 (mm)
d=280.00 (mm), l=178.00 (mm), Rz= 8.0

Radius right (Radius right)
r=47.50 (mm), Rz= 8.0

Cylinder (Cylinder) y= 198.00...236.00 (mm)
d=291.00 (mm), l=38.00 (mm), Rz= 8.0

Radius right (Radius right)
r=12.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 236.00...471.00 (mm)

d=340.00 (mm), l=235.00 (mm), Rz= 8.0

Relief groove right (Relief groove right)
r=1.00 (mm), t=1.00 (mm), l=2.00 (mm), Rz= 8.0
Own Input, Form B, FKM

Taper (Cone) y= 471.00...501.50 (mm)
dl=385.00 (mm), dr=450.00 (mm), l=30.50 (mm), Rz= 8.0

Cylinder (Cylinder) y= 501.50...532.50 (mm)
d=450.00 (mm), l=31.00 (mm), Rz= 8.0

Chamfer right (2)
l=2.00 (mm), alpha=45.00 (°)

Cylinder (Cylinder) y= 532.50...767.50 (mm)
d=1100.00 (mm), l=235.00 (mm), Rz= 8.0

Radius left (Radius left)
r=0.40 (mm), Rz= 8.0

Chamfer right (Chamfer right)
l=2.00 (mm), alpha=45.00 (°)

Cylinder (Cylinder) y= 767.50...799.00 (mm)
d=385.00 (mm), l=31.50 (mm), Rz= 8.0

Chamfer right (Chamfer right)
l=2.00 (mm), alpha=45.00 (°)

Radius left (Radius left)
r=10.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 799.00...1034.00 (mm)
d=340.00 (mm), l=235.00 (mm), Rz= 8.0

Radius left (Radius left)
r=0.40 (mm), Rz= 8.0

Cylinder (Cylinder) y= 1034.00...1072.00 (mm)
d=291.00 (mm), l=38.00 (mm), Rz= 8.0

Radius left (Radius left)
r=12.00 (mm), Rz= 8.0

Cylinder (Cylinder) y= 1072.00...1250.00 (mm)
d=280.00 (mm), l=178.00 (mm), Rz= 8.0

Radius left (Radius left)
r=47.50 (mm), Rz= 8.0

Cylinder (Cylinder) y= 1250.00...1270.00 (mm)
d=180.00 (mm), l=20.00 (mm), Rz= 8.0

Radius left (Radius left)
r=0.40 (mm), Rz= 8.0

Chamfer right (Chamfer right)
l=2.00 (mm), alpha=45.00 (°)

Inner contour

Forces

Cylindrical gear (Kolo_8)			y= 650.00 (mm)
Operating pitch diameter	(mm)	1227.7778	
Helix angle	(°)	15.1950	right
Working pressure angle at normal section	(°)	21.8883	
Position of contact point	(°)	0.0000	
Length of load application	(mm)	235.0000	
Power	(kW)	473.4841	driven (Input)
Torque	(Nm)	-308000.0000	
Axial force	(N)	136267.1212	
Shearing force X	(N)	-208873.6335	
Shearing force Z	(N)	501719.4570	
Bending moment X	(Nm)	-0.0000	
Bending moment Z	(Nm)	83652.8716	

Cylindrical gear (Drazkovani_vlevo)			y= 1172.50 (mm)
Operating pitch diameter	(mm)	310.0000	
Spur gear			
Working pressure angle at normal section	(°)	24.5802	
Position of contact point	(°)	0.0000	
Length of load application	(mm)	155.0000	
Power	(kW)	473.4841	driving (Output)
Torque	(Nm)	308000.0000	
Axial force	(N)	-0.0000	
Shearing force X	(N)	-908933.1769	
Shearing force Z	(N)	-1987096.7742	
Bending moment X	(Nm)	0.0000	
Bending moment Z	(Nm)	-0.0000	

Bearing

Spherical roller bearings SKF *23268CA/W33 (SKF_23260_leve) y= 359.00 (mm)
Set fixed bearing left
d = 340.000 (mm), D = 620.000 (mm), B = 224.000 (mm), r = 6.000 (mm)
C = 5100.000 (kN), C0 = 7800.000 (kN), Cu = 550.000 (kN)
Bearing clearance DIN 620:1988 C0 (255.00 µm)

Spherical roller bearings SKF *23268CA/W33 (SKF_23260_prave) y= 911.00 (mm)
Set fixed bearing right
d = 340.000 (mm), D = 620.000 (mm), B = 224.000 (mm), r = 6.000 (mm)
C = 5100.000 (kN), C0 = 7800.000 (kN), Cu = 550.000 (kN)
Bearing clearance DIN 620:1988 C0 (255.00 µm)

Shaft 'Shaft 1': Cylindrical gear 'Kolo_8' (y= 650.0000 (mm)) is taken into account as component of the shaft.
EI (y= 532.5000 (mm)): 14804981182.0139 (Nm˛), EI (y= 767.5000 (mm)): 14804981182.0139 (Nm˛), m (yS= 650.0000 (mm)): 429.8494 (kg)

Jp: 146.0112 (kg*m˳), Jxx: 74.9838 (kg*m˳), Jzz: 74.9838 (kg*m˳)

Shaft 'Shaft 1': Cylindrical gear 'Drazkovani_vlevo' (y= 1172.5000 (mm)) is taken into account as component of the shaft.
EI (y= 1095.0000 (mm)): 62154023.0409 (Nm˳), EI (y= 1250.0000 (mm)): 62154023.0409 (Nm˳), m (yS= 1172.5000 (mm)): 16.8716 (kg)
Jp: 0.3680 (kg*m˳), Jxx: 0.2178 (kg*m˳), Jzz: 0.2178 (kg*m˳)

---

maximum deflection		767.57	µm (Shaft 1, 1270.00 (mm))

Center of mass

Shaft 1		643.6	mm

Deformation due to torsion

Shaft 1	[phi.t]	0.08	°

Probability of failure	[n]	10.00	%
Axial clearance	[uA]	10.00	µm

Rolling bearings, classical calculation (contact angle considered)

Shaft 'Shaft 1' Rolling bearing 'SKF_23260_leve'

Position (Y-coordinate)	[y]	359.00	mm
Equivalent load	[P]	1261.54	kN
Equivalent load	[P0]	1261.54	kN
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	119497.42	h
Operating viscosity	[nu]	48.88	mm˳/s
Reference viscosity	[nu1]	0.00	mm˳/s
static safety factor	[S0]	6.18	
Bearing reaction force	[Fx]	-483.375	kN
Bearing reaction force	[Fy]	0.000	kN
Bearing reaction force	[Fz]	-1165.255	kN
Bearing reaction force	[Fr]	1261.535	kN (-112.53°)
Oil level	[H]	275.000	mm
Torque of friction	[Mloss]	53.883	Nm
Power loss	[Ploss]	82.834	W
Displacement of bearing	[ux]	0.050	mm
Displacement of bearing	[uy]	0.011	mm
Displacement of bearing	[uz]	0.117	mm
Displacement of bearing	[ur]	0.128	mm (67°)
Misalignment of bearing	[rx]	-0.369	mrad (-1.27')
Misalignment of bearing	[ry]	-0.000	mrad (0')
Misalignment of bearing	[rz]	0.206	mrad (0.71')
Misalignment of bearing	[rr]	0.422	mrad (1.45')

Shaft 'Shaft 1' Rolling bearing 'SKF_23260_prave'

Position (Y-coordinate)	[y]	911.00	mm
Equivalent load	[P]	3379.57	kN
Equivalent load	[P0]	3365.95	kN
Life modification factor for reliability	[a1]	1.000	
Service life	[Lnh]	4475.25	h

Operating viscosity	[nu]	48.88	mm²/s
Reference viscosity	[nu1]	0.00	mm²/s
static safety factor	[S0]	2.32	
Bearing reaction force	[Fx]	1601.182	kN
Bearing reaction force	[Fy]	-136.267	kN
Bearing reaction force	[Fz]	2678.576	kN
Bearing reaction force	[Fr]	3120.665	kN (59.13°)
Oil level	[H]	275.000	mm
Torque of friction	[Mloss]	141.142	Nm
Power loss	[Ploss]	216.976	W
Displacement of bearing	[ux]	-0.064	mm
Displacement of bearing	[uy]	0.010	mm
Displacement of bearing	[uz]	-0.110	mm
Displacement of bearing	[ur]	0.128	mm (-119.95°)
Misalignment of bearing	[rx]	-0.915	mrad (-3.15')
Misalignment of bearing	[ry]	0.391	mrad (1.34')
Misalignment of bearing	[rz]	0.427	mrad (1.47')
Misalignment of bearing	[rr]	1.010	mrad (3.47')

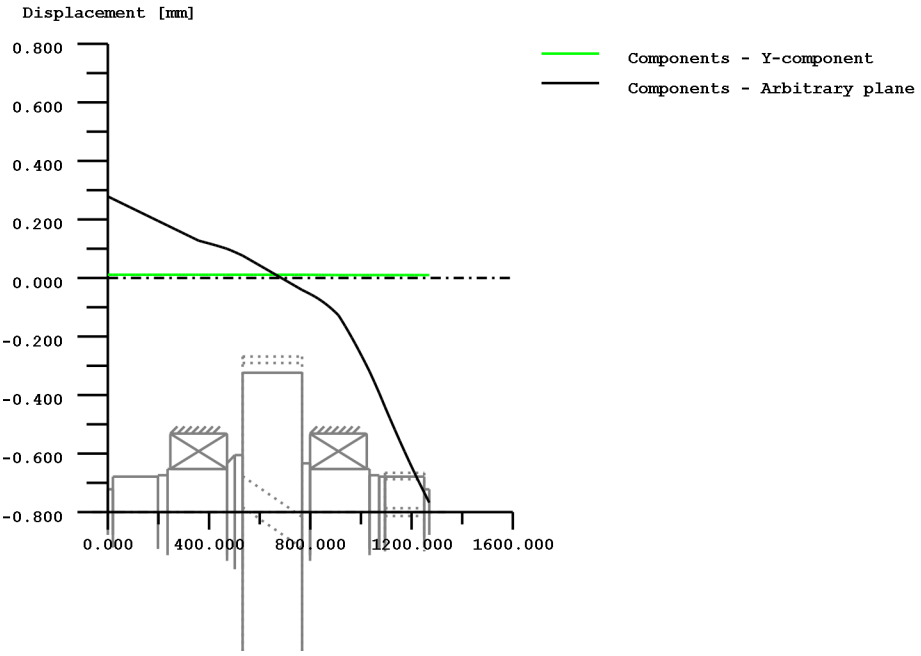
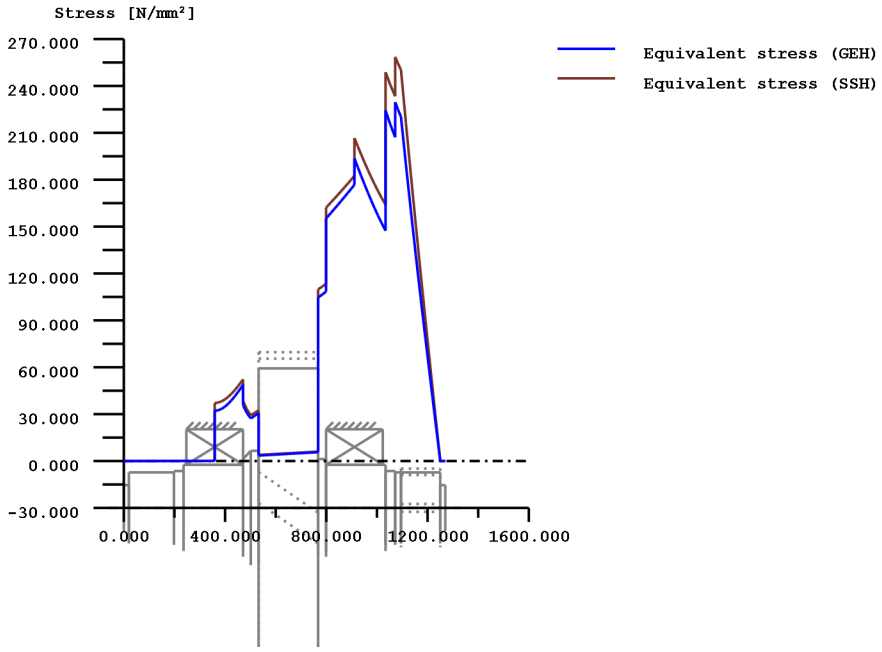


Figure: Displacement (bending etc.) (Arbitrary plane 64.32976452 °)



GEH(von Mises): sigV = ((sigB+sigZ,D)^2 + 3*(tauT+tauS)^2)^1/2SSH(Tresca): sigV = ((sigB-sigZ,D)^2 + 4*(tauT+tauS)^2)^1/2
Figure: Equivalent stress

Eigenfrequencies/Critical speeds

1. Eigenfrequency:	0.00 Hz,	Critical speed:	0.00 1/min	Rigid body rotation Y 'Shaft 1'
2. Eigenfrequency:	767.65 Hz,	Critical speed:	46059.16 1/min	Bending YZ 'Shaft 1'

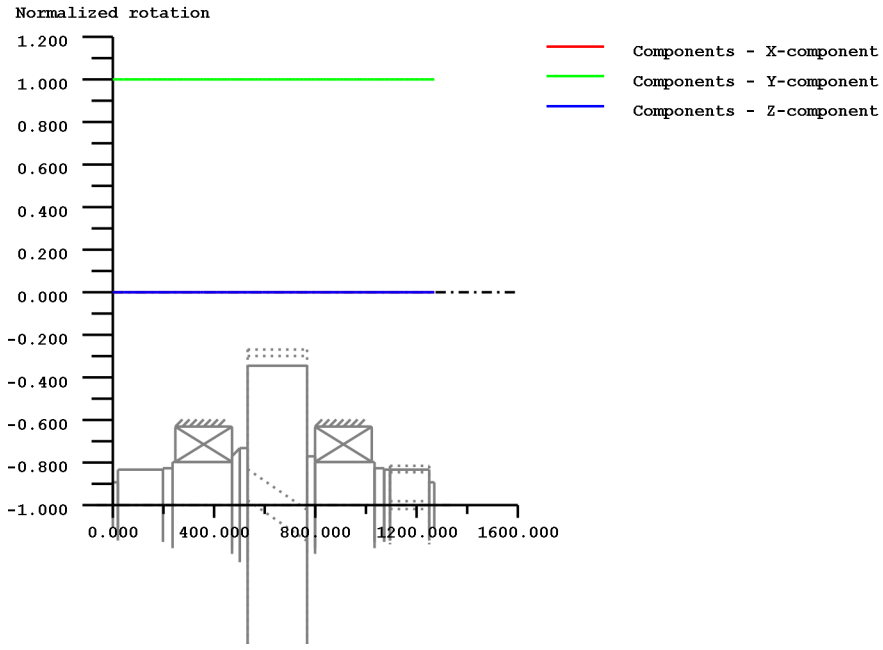


Figure: Eigenfrequencies (Normalized displacement)

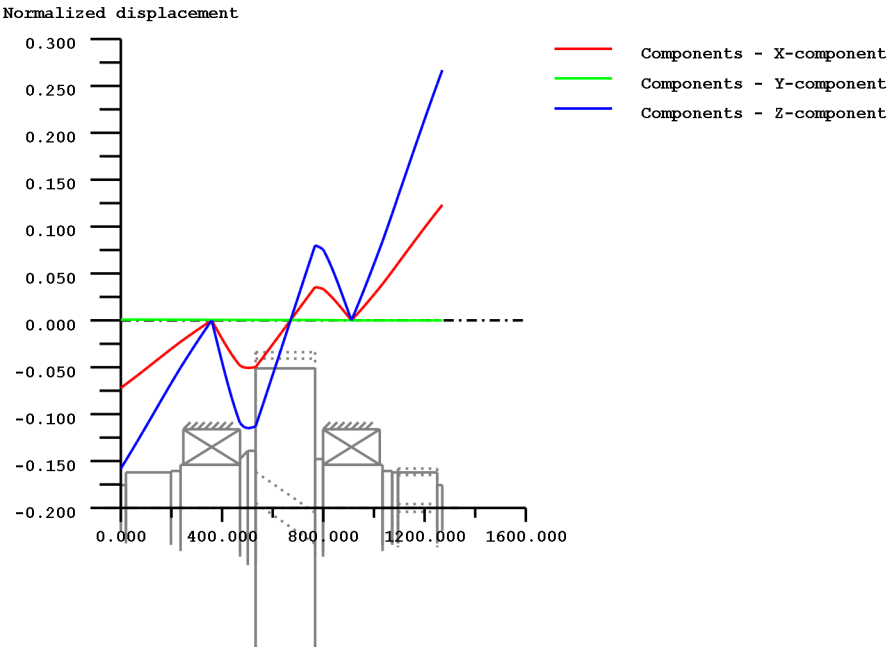


Figure: Eigenfrequencies (Normalized rotation)

Strength calculation as specified in

DIN 743:2012

Summary

Label	Shaft 1
Drawing	

Material	42 CrMo 4 (2)
Material type	Through hardened steel
Material treatment	flame/ind. hardened
Surface treatment	No

Calculation of endurance limit and the static strength
Calculation for load case 2 (sig.av/sig.mv = const)

Cross section	Position (Y-Coord) (mm)	
A-A	1095.00	Smooth shaft

Results:

Cross section	Kfb	Kfsig	K2d	SD	SS	SA
A-A	1.00	0.89	0.80	2.38	2.26	9.98
Nominal safety:				1.20	1.20	1.20

Abbreviations:
Kfb: Notch factor bending
Kfsig: Surface factor
K2d: Size coefficient bending
SD: Safety endurance limit
SS: Safety against yield point
SA: Safety against incipient crack

The requirements of the safety proof of the shaft are:

satisfied [x] not satisfied [ ]

Design engineer:..... Date:..... Signature:.....

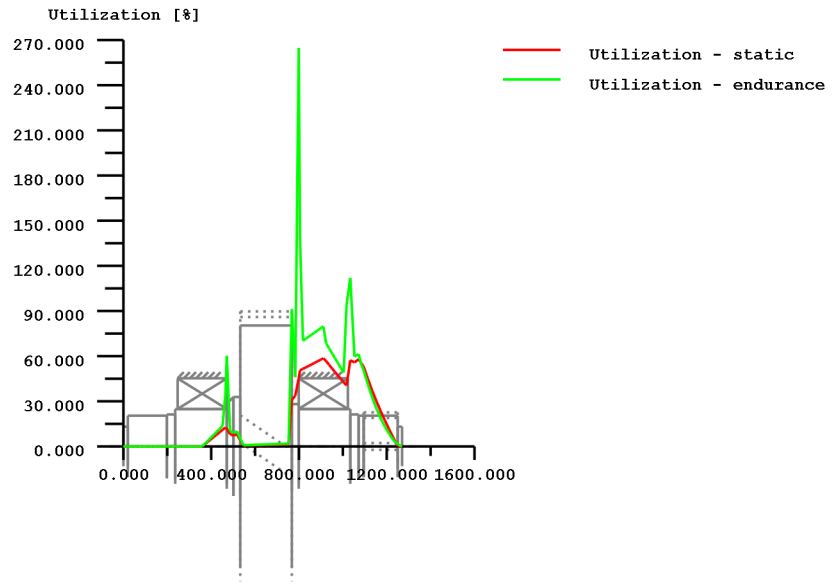


Figure: Strength

Calculation details:

General statements

Label	Shaft 1		
Drawing			
Length (mm)		[l]	1270.00
Speed (1/min)		[n]	14.68

Material	42 CrMo 4 (2)
Material type	Through hardened steel
Material treatment	flame/ind. hardened
Surface treatment	No

	Tension/Compression	Bending	Torsion	Shearing
Load factor static calculation	1.700	1.700	1.700	1.700
Load factor endurance limit	1.000	1.000	1.000	1.000

Reference diameter material (mm)	[dB]	16.00
sigB according DIN 743 (at dB) (N/mm²)	[sigB]	1100.00
sigS according DIN 743 (at dB) (N/mm²)	[sigS]	900.00
[sigzdW] (bei dB) (N/mm²)		440.00
[sigbW] (bei dB) (N/mm²)		550.00
[tautW] (bei dB) (N/mm²)		330.00
Thickness of raw material (mm)	[dWerkst]	1110.00

Material data calculated according DIN743/3 with K1(d)
Material strength calculated from size of raw material
Geometric size coefficient K1d calculated from raw material diameter

[sigBeff] (N/mm²)	737.00

[sigSeff] (N/mm²)	513.00
[sigbF] (N/mm²)	564.30
[tautF] (N/mm²)	325.80
[sigBRand] (N/mm²)	2050.00
[sigzdW] (N/mm²)	294.80
[sigbW] (N/mm²)	368.50
[tautW] (N/mm²)	221.10

Endurance limit for single stage use

Calculation for load case 2 (sig.av/sig.mv = const)

Cross section 'A-A' Smooth shaft

Comment			
Position (Y-Coordinate) (mm)		[y]	1095.00
External diameter (mm)		[da]	280.000
Inner diameter (mm)		[di]	0.000
Notch effect	Smooth shaft		
Mean roughness (µm)		[Rz]	8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-0.0	0.0	154000.0	0.0
Amplitude	0.0	169415.3	154000.0	2185989.1
Maximum value	-0.0	288006.0	523600.0	3716181.4
Cross section, moment of resistance: (mm²)				
[A, Wb, Wt, A]	61575.2	2155132.6	4310265.1	61575.2

Stresses: (N/mm²)				
[sigzdm, sigbm, taum, tauqm] (N/mm²)	-0.000	0.000	35.729	0.000
[sigzda, sigba, taua, tauqa] (N/mm²)	0.000	78.610	35.729	47.335
[sigzdmax,sigbmax,taumax,tauqmax] (N/mm²)	-0.000	133.637	121.477	80.469

Technological size influence	[K1(sigB)]	0.670	
	[K1(sigS)]	0.570	

		Tension/Compression	Bending	Torsion
Notch effect coefficient	[beta]	1.000	1.000	1.000
Geometrical size influence	[K2(d)]	1.000	0.800	0.800
Influence coefficient surface roughness	[KF]	0.887	0.887	0.935
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	1.127	1.377	1.319

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm²)	[sigmV]		61.884	
Equivalent mean stress (N/mm²)	[taumV]		35.729	
Fatigue limit of part (N/mm²)	[sigWK]	261.623	267.647	167.603
Influence coeff. mean stress sensitivity.	[PsisigK]	0.216	0.222	0.128
Permissible amplitude (N/mm²)	[sigADK]	0.008	227.851	148.546
Margin of safety endurance limit	[S]		2.378	

Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		198.1	

Present margin of safety				
for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.100	1.100
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm²)	[sigFK]	513.000	564.300	325.799
Margin of safety yield stress	[S]		2.264	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		188.7	

Present margin of safety		
for proof of avoiding incipient crack on hard surface layers:		
Safety against incipient crack	[S]	9.978
Required safety	[Smin]	1.200
Result (%)	[S/Smin]	831.5

Remarks:
- The shearing force is not considered in the analysis specified in DIN 743.
- Cross section with interference fit:
  The notching factor for the light fit case is no longer defined in DIN 743.
  The values are imported from the FKM-Guideline..

End of Report lines: 433

PŘÍLOHA č. 3

Výsledky výpočtů spojovacích prvků

KISSsoft Release 03/2013

KISSsoft evaluation

File

Name : Nalisování_kolo3

Changed by: Lenka am: 04.05.2014 um: 17:28:11

Important hint: At least one warning has occurred during the calculation:

1-> For the raw diameter (150 mm) of the material (18CrNiMo7-6)
the database has no values
for tensile stress and yield point !
Guessed values are assumed.
For the input of material data:
Call the KISSsoft database tool in the menu Extras

Cylindrical interference fit [M01a]

Calculation method: According DIN 7190:2001 (elastic range)
with additions (Centrifugal force, Micro sliding, Assembly, etc.)
for shrunken or pressed fits

Diameter shaft (mm)	[DiA]/[DiI]	145.00/	0.00		
Diameter hub (mm)	[DaA]/[DaI]	292.49/	145.00		
Length of Interference fit (mm)	[l]	72.00			
Diameter of joint (mm)	[DF]	145.00			
Tolerance Shaft		u6			
Upper allowance Shaft (µm)	[AoI]	215.0			
Lower allowance Shaft (µm)	[AuI]	190.0			
Tolerance measure Shaft (µm)	[TI]	25.0			
Tolerance hub		H7			
Upper allowance Hub (µm)	[AoA]	40.0			
Lower allowance Hub (µm)	[AuA]	0.0			
Tolerance measure Hub (µm)	[TA]	40.0			
Largest interference (µm)	[Po]	215.0			
Smallest interference (µm)	[Pu]	150.0			
Nominal torque (Nm)	[T]	7600.00			
Application factor	[KA]	1.25			
Service torque (Nm)	[Tb]	9500.00			
Axial force (N)	[FA]	9471.60			
Bending moment (Nm)	[Mb]	0.00			
Radial force (N)	[Fr]	15325.00			
Circumferential force (N)	[Fu]	131034.48			
Speed (1/min)	[n]	800.00			
Interference (µm)	[P]	182.5 (	150.0..	215.0)	
Embedding (µm)	[s]	7.68			
Effective interference at 20°C(68°F) (µm)	[Pw]	174.82 (	142.3..	207.3)	
Effective interference at working temp.. (µm)	[PwTh]	174.82 (	142.3..	207.3)	
Service temperature shaft (°C)	[ThB]	20			
Service temperature hub (°C)	[ThB]	20			
Pressure stress by					
- Interference (after mounting) (N/mm²)	[pM]	93.66 (	76.25..	111.08)	
- Interference (working) (N/mm²)	[p]	93.30 (	75.89..	110.71)	
- Bending moment (N/mm²)	[pb]	0.00			

- Radial force (N/mm²)	[pr]	1.47	
Coefficient of friction, axial	[mya]	0.100	
Coefficient of friction, circumferential	[myu]	0.100	
Safety against sliding	[Sr]	2.33 (	1.89.. 2.76)
Required safety against sliding	[SSr]	1.20	

Equivalent stress according to von Mises

Shaft

Material		18CrNiMo7-6	
Young's modulus (N/mm²)	[El]	206000.00	
Poisson's ratio (-)	[nyl]	0.30	
Density (kg/m³)	[rho]	7830.00	
Coefficient of thermal expansion (10^-6/K)	[alpha]	11.50	
Tensile strength (N/mm²)	[Rm]	600.00 (d= 0- 0mm)	
Yield point (N/mm²)	[Rp]	425.00 (d= 0- 0mm)	
Surface class of roughness	N6 Rz=4.8 (Grinding)		
Surface roughness (µm)	[Rz]	4.80	
External diameter (mm)	[DiA]	145.00	
Diameter increase (µm)	[deltaD]	-45.93 (	-37.35.. -54.51)
Diameter increase (o/oo)	[deltaD]	-0.32 (	-0.26.. -0.38)
Equivalent stress outsideø (N/mm²)	[sigVa]	93.27 (	75.86.. 110.68)
- Radial stress (N/mm²)	[sigRa]	-93.30 (	-75.89.. -110.71)
- Tangential stress (N/mm²)	[sigTa]	-93.25 (	-75.83.. -110.66)
- With outside load (N/mm²)	[sigVaMF]	94.74 (	77.33.. 112.15)
Inner diameter (mm)	[Dil]	0.00	
Equivalent stress insideø (N/mm²)	[sigVi]	93.18 (	75.77.. 110.59)
- Radial stress (N/mm²)	[sigRi]	-93.18 (	-75.77.. -110.59)
- Tangential stress (N/mm²)	[sigTi]	-93.18 (	-75.77.. -110.59)
Safety against fracture	[SiRm]	6.33 (	7.76.. 5.35)
Required safety against fracture	[SSi.Rm]	1.50	
Safety against yield point	[Si.Rp]	4.49 (	5.50.. 3.79)
Required safety against yield point	[SSi.Rp]	1.00	

Hub

Material		18CrNiMo7-6	
Young's modulus (N/mm²)	[EA]	206000.00	
Poisson's ratio (-)	[nyA]	0.30	
Density (kg/m³)	[rho]	7830.00	
Coefficient of thermal expansion (10^-6/K)	[alpha]	11.50	
Tensile strength (N/mm²)	[Rm]	900.00 (d= 40- 100mm)	
Yield point (N/mm²)	[Rp]	640.00 (d= 40- 100mm)	
Surface class of roughness	N6 Rz=4.8 (Grinding)		
Surface roughness (µm)	[Rz]	4.80	
External diameter (mm)	[DaA]	292.49	
Diameter increase (µm)	[deltaD]	86.96 (	70.85.. 103.07)

Diameter increase (o/oo)	[deltaD]	0.30 (	0.24.. 0.35)
Equivalent stress outsideø (N/mm²)	[sigVa]	61.24 (	49.90.. 72.59)
- Radial stress (N/mm²)	[sigRa]	-0.00 (	-0.00.. -0.00)
- Tangential stress (N/mm²)	[sigTa]	61.24 (	49.90.. 72.59)
Inner diameter (mm)	[DaI]	145.00	
Diameter increase (µm)	[deltaD]	128.89 (	104.97.. 152.81)
Diameter increase (o/oo)	[deltaD]	0.89 (	0.72.. 1.05)
Equivalent stress insideø (N/mm²)	[sigVi]	217.34 (	176.96.. 257.73)
- Radial stress (N/mm²)	[sigRi]	-93.30 (	-75.89.. -110.71)
- Tangential stress (N/mm²)	[sigTi]	155.12 (	126.36.. 183.88)
- With outside load (N/mm²)	[sigViMF]	220.75 (	180.36.. 261.14)
Safety against fracture	[Si.Rm]	4.08 (	4.99.. 3.45)
Required safety against fracture	[SSi.Rm]	1.50	
Safety against yield point	[Si.Re]	2.90 (	3.55.. 2.45)
Required safety against yield point	[SSi.Re]	1.00	

Mere elastic stress, no verification of elastic plastic interference fit according to DIN 7190.

Service / Mounting / Remounting

Transverse-interference-fit:

Mounting clearance (mm)	[PsTh]	0.145

Temperature difference for mounting:

Shaft temperature: (°C)	Hub temperature: [ThA] (°C)
20	236
-150	110

(calculated using coefficient of thermal expansion)

shaft according to DIN 7190 (10^-6/K)	[alpha]	8.50

Longitudinal pressure fit:

Assembly temperature shaft (°C)	[ThM]	20.00
Assembly temperature hub (°C)	[ThM]	20.00
Coefficient. of friction (Longitudinal)	[mye=mya*1.3]	0.13
Press on (force) (kN)	[Fpress]	399.36 (325.12.. 473.60)
Coefficient. of friction (Longitudinal)	[myll=mya*1.6]	0.16
Press out (force) (kN)	[Fpress]	491.52 (400.14.. 582.89)
Coefficient. of friction	[my]	0.16
Max. torque to avoid Micro sliding (Nm)	[Tlimit]	10940.72 (8898.81.. 12982.63)

Notice concerning the display: Number-1 (Number-2.. Number-3):

Number-1: Value calculated with the mean allowance

Number-2: Value of the smallest possible allowance

Number-3: Value of the largest possible allowance

Notice: All strains and stresses are calculated for the purely elastic case.

End of Report lines: 157

KISSsoft Release 03/2013

KISSsoft evaluation

File

Name : Nalisování_kolo6
Changed by: Lenka am: 04.05.2014 um: 19:00:17

Important hint: At least one warning has occurred during the calculation:
1-> For the raw diameter (240 mm) of the material (18CrNiMo7-6)
the database has no values
for tensile stress and yield point !
Guessed values are assumed.
For the input of material data:
Call the KISSsoft database tool in the menu Extras

2-> For the raw diameter (240 mm) of the material (18CrNiMo7-6)
the database has no values
for tensile stress and yield point !
Guessed values are assumed.
For the input of material data:
Call the KISSsoft database tool in the menu Extras

Cylindrical interference fit [M01a]

Calculation method: According DIN 7190:2001 (elastic range)
with additions (Centrifugal force, Micro sliding, Assembly, etc.)
for shrunken or pressed fits

Diameter shaft (mm)	[DiA]/[DiI]	238.00/	0.00		
Diameter hub (mm)	[DaA]/[DaI]	704.94/	238.00		
Length of Interference fit (mm)	[l]	148.00			
Diameter of joint (mm)	[DF]	238.00			
Tolerance Shaft		u6			
Upper allowance Shaft (µm)	[AoI]	313.0			
Lower allowance Shaft (µm)	[AuI]	284.0			
Tolerance measure Shaft (µm)	[TI]	29.0			
Tolerance hub		H7			
Upper allowance Hub (µm)	[AoA]	46.0			
Lower allowance Hub (µm)	[AuA]	0.0			
Tolerance measure Hub (µm)	[TA]	46.0			
Largest interference (µm)	[Po]	313.0			
Smallest interference (µm)	[Pu]	238.0			
Nominal torque (Nm)	[T]	77400.00			
Application factor	[KA]	1.25			
Service torque (Nm)	[Tb]	96750.00			
Axial force (N)	[FA]	56922.80			
Bending moment (Nm)	[Mb]	0.00			
Radial force (N)	[Fr]	109719.40			
Circumferential force (N)	[Fu]	813025.21			
Speed (1/min)	[n]	72.70			
Interference (µm)	[P]	275.5 (	238.0..	313.0)	
Embedding (µm)	[s]	7.68			
Effective interference at 20°C(68°F) (µm)	[Pw]	267.82 (	230.3..	305.3)	

Effective interference at working temp.. (µm)	[PwTh]	267.82 (230.3.. 305.3)	
Service temperature shaft (°C)	[ThB]	20	
Service temperature hub (°C)	[ThB]	20	
Pressure stress by			
- Interference (after mounting) (N/mm²)	[pM]	102.69 (88.31.. 117.07)	
- Interference (working) (N/mm²)	[p]	102.67 (88.29.. 117.05)	
- Bending moment (N/mm²)	[pb]	0.00	
- Radial force (N/mm²)	[pr]	3.11	
Coefficient of friction, axial	[mya]	0.100	
Coefficient of friction, circumferential	[myu]	0.100	
Safety against sliding	[Sr]	1.39 (1.20.. 1.59)	
Required safety against sliding	[SSr]	1.20	

Equivalent stress according to von Mises

Shaft

Material		18CrNiMo7-6	
Young's modulus (N/mm²)	[EI]	206000.00	
Poisson's ratio (-)	[nyI]	0.30	
Density (kg/m³)	[rho]	7830.00	
Coefficient of thermal expansion (10^-6/K)	[alpha]	11.50	
Tensile strength (N/mm²)	[Rm]	600.00 (d= 0- 0mm)	
Yield point (N/mm²)	[Rp]	425.00 (d= 0- 0mm)	
Surface class of roughness	N6 Rz=4.8 (Grinding)		
Surface roughness (µm)	[Rz]	4.80	
External diameter (mm)	[DiA]	238.00	
Diameter increase (µm)	[deltaD]	-83.03 (-71.41.. -94.66)	
Diameter increase (o/oo)	[deltaD]	-0.35 (-0.30.. -0.40)	
Equivalent stress outsideø (N/mm²)	[sigVa]	102.67 (88.29.. 117.05)	
- Radial stress (N/mm²)	[sigRa]	-102.67 (-88.29.. -117.05)	
- Tangential stress (N/mm²)	[sigTa]	-102.67 (-88.29.. -117.05)	
- With outside load (N/mm²)	[sigVaMF]	105.79 (91.41.. 120.17)	
Inner diameter (mm)	[DiI]	0.00	
Equivalent stress insideø (N/mm²)	[sigVi]	102.67 (88.29.. 117.05)	
- Radial stress (N/mm²)	[sigRi]	-102.67 (-88.29.. -117.05)	
- Tangential stress (N/mm²)	[sigTi]	-102.67 (-88.29.. -117.05)	
Safety against fracture	[SiRm]	5.67 (6.56.. 4.99)	
Required safety against fracture	[SSi.Rm]	1.50	
Safety against yield point	[Si.Rp]	4.02 (4.65.. 3.54)	
Required safety against yield point	[SSi.Rp]	1.00	

Hub

Material		18CrNiMo7-6	
Young's modulus (N/mm²)	[EA]	206000.00	
Poisson's ratio (-)	[nyA]	0.30	
Density (kg/m³)	[rho]	7830.00	
Coefficient of thermal expansion (10^-6/K)	[alpha]	11.50	

Tensile strength (N/mm²)	[Rm]	600.00 (d= 0- 0mm)
Yield point (N/mm²)	[Rp]	425.00 (d= 0- 0mm)
Surface class of roughness	N6 Rz=4.8 (Grinding)	
Surface roughness (µm)	[Rz]	4.80
External diameter (mm)	[DaA]	704.94
Diameter increase (µm)	[deltaD]	90.45 (77.79.. 103.12)
Diameter increase (o/oo)	[deltaD]	0.13 (0.11.. 0.15)
Equivalent stress outsideø (N/mm²)	[sigVa]	26.43 (22.73.. 30.13)
- Radial stress (N/mm²)	[sigRa]	0.00 (0.00.. 0.00)
- Tangential stress (N/mm²)	[sigTa]	26.43 (22.73.. 30.13)
Inner diameter (mm)	[DaI]	238.00
Diameter increase (µm)	[deltaD]	184.79 (158.91.. 210.66)
Diameter increase (o/oo)	[deltaD]	0.78 (0.67.. 0.89)
Equivalent stress insideø (N/mm²)	[sigVi]	201.19 (173.02.. 229.36)
- Radial stress (N/mm²)	[sigRi]	-102.67 (-88.29.. -117.05)
- Tangential stress (N/mm²)	[sigTi]	129.14 (111.06.. 147.22)
- With outside load (N/mm²)	[sigViMF]	207.29 (179.12.. 235.46)
Safety against fracture	[Si.Rm]	2.89 (3.35.. 2.55)
Required safety against fracture	[SSi.Rm]	1.50
Safety against yield point	[Si.Re]	2.05 (2.37.. 1.80)
Required safety against yield point	[SSi.Re]	1.00

Mere elastic stress, no verification of elastic plastic interference fit according to DIN 7190.

Service / Mounting / Remounting

Transverse-interference-fit:

Mounting clearance (mm)	[PsTh]	0.238

Temperature difference for mounting:

Shaft temperature: (°C)	Hub temperature: [ThA] (°C)
20	221
-150	96

(calculated using coefficient of thermal expansion)

shaft according to DIN 7190 (10^-6/K)	[alpha]	8.50

Longitudinal pressure fit:

Assembly temperature shaft (°C)	[ThM]	20.00
Assembly temperature hub (°C)	[ThM]	20.00
Coefficient. of friction (Longitudinal)	[mye=mya*1.3]	0.13
Press on (force) (kN)	[Fpress]	1477.32 (1270.47.. 1684.18)
Coefficient. of friction (Longitudinal)	[myll=mya*1.6]	0.16
Press out (force) (kN)	[Fpress]	1818.25 (1563.66.. 2072.84)

Notice:
Micro sliding can occur in Interference fit!
=> Risk of contact corrosion.

Coefficient. of friction	[my]	0.16
Max. torque to avoid Micro sliding (Nm)	[Tlimit]	57820.28 (49722.69.. 65917.87)

Notice concerning the display: Number-1 (Number-2.. Number-3):
Number-1: Value calculated with the mean allowance
Number-2: Value of the smallest possible allowance
Number-3: Value of the largest possible allowance

Notice: All strains and stresses are calculated for the purely elastic case.

End of Report lines: 160

KISSsoft Release 03/2013

KISSsoft evaluation

File

Name : Nalisování_kolo8
Changed by: Lenka am: 04.05.2014 um: 19:11:54

Important hint: At least one warning has occurred during the calculation:
1-> For the raw diameter (390 mm) of the material (18CrNiMo7-6)
the database has no values
for tensile stress and yield point !
Guessed values are assumed.
For the input of material data:
Call the KISSsoft database tool in the menu Extras

2-> For the raw diameter (420 mm) of the material (18CrNiMo7-6)
the database has no values
for tensile stress and yield point !
Guessed values are assumed.
For the input of material data:
Call the KISSsoft database tool in the menu Extras

Cylindrical interference fit [M01a]

Calculation method: According DIN 7190:2001 (elastic range)
with additions (Centrifugal force, Micro sliding, Assembly, etc.)
for shrunken or pressed fits

Diameter shaft (mm)	[DiA]/[DiI]	385.00/	0.00	
Diameter hub (mm)	[DaA]/[DaI]	1211.30/	385.00	
Length of Interference fit (mm)	[l]	235.00		
Diameter of joint (mm)	[DF]	385.00		
Tolerance Shaft		u6		
Upper allowance Shaft (µm)	[AoI]	471.0		
Lower allowance Shaft (µm)	[AuI]	435.0		
Tolerance measure Shaft (µm)	[TI]	36.0		
Tolerance hub		H7		
Upper allowance Hub (µm)	[AoA]	57.0		
Lower allowance Hub (µm)	[AuA]	0.0		
Tolerance measure Hub (µm)	[TA]	57.0		
Largest interference (µm)	[Po]	471.0		
Smallest interference (µm)	[Pu]	378.0		
Nominal torque (Nm)	[T]	308000.00		
Application factor	[KA]	1.00		
Service torque (Nm)	[Tb]	308000.00		
Axial force (N)	[FA]	539782.00		
Bending moment (Nm)	[Mb]	0.00		
Radial force (N)	[Fr]	144634.00		
Circumferential force (N)	[Fu]	1600000.00		
Speed (1/min)	[n]	17.90		
Interference (µm)	[P]	424.5 (	378.0..	471.0)
Embedding (µm)	[s]	7.68		
Effective interference at 20°C(68°F) (µm)	[Pw]	416.82 (	370.3..	463.3)

Effective interference at working temp.. (µm)	[PwTh]	416.82 (370.3.. 463.3)	
Service temperature shaft (°C)	[ThB]	20	
Service temperature hub (°C)	[ThB]	20	
Pressure stress by			
- Interference (after mounting) (N/mm²)	[pM]	100.25 (89.06.. 111.43)	
- Interference (working) (N/mm²)	[p]	100.24 (89.06.. 111.43)	
- Bending moment (N/mm²)	[pb]	0.00	
- Radial force (N/mm²)	[pr]	1.60	
Coefficient of friction, axial	[mya]	0.100	
Coefficient of friction, circumferential	[myu]	0.100	
Safety against sliding	[Sr]	1.69 (1.50.. 1.88)	
Required safety against sliding	[SSr]	1.20	

Equivalent stress according to von Mises

Shaft

Material		18CrNiMo7-6	
Young's modulus (N/mm²)	[EI]	206000.00	
Poisson's ratio (-)	[nyI]	0.30	
Density (kg/m³)	[rho]	7830.00	
Coefficient of thermal expansion (10^-6/K)	[alpha]	11.50	
Tensile strength (N/mm²)	[Rm]	600.00 (d= 0- 0mm)	
Yield point (N/mm²)	[Rp]	425.00 (d= 0- 0mm)	
Surface class of roughness	N6 Rz=4.8 (Grinding)		
Surface roughness (µm)	[Rz]	4.80	
External diameter (mm)	[DiA]	385.00	
Diameter increase (µm)	[deltaD]	-131.14 (-116.51.. -145.77)	
Diameter increase (o/oo)	[deltaD]	-0.34 (-0.30.. -0.38)	
Equivalent stress outsideø (N/mm²)	[sigVa]	100.24 (89.06.. 111.43)	
- Radial stress (N/mm²)	[sigRa]	-100.24 (-89.06.. -111.43)	
- Tangential stress (N/mm²)	[sigTa]	-100.24 (-89.06.. -111.43)	
- With outside load (N/mm²)	[sigVaMF]	101.84 (90.66.. 113.03)	
Inner diameter (mm)	[DiI]	0.00	
Equivalent stress insideø (N/mm²)	[sigVi]	100.24 (89.06.. 111.43)	
- Radial stress (N/mm²)	[sigRi]	-100.24 (-89.06.. -111.43)	
- Tangential stress (N/mm²)	[sigTi]	-100.24 (-89.06.. -111.43)	
Safety against fracture	[SiRm]	5.89 (6.62.. 5.31)	
Required safety against fracture	[SSi.Rm]	1.50	
Safety against yield point	[Si.Rp]	4.17 (4.69.. 3.76)	
Required safety against yield point	[SSi.Rp]	1.00	

Hub

Material		18CrNiMo7-6	
Young's modulus (N/mm²)	[EA]	206000.00	
Poisson's ratio (-)	[nyA]	0.30	
Density (kg/m³)	[rho]	7830.00	
Coefficient of thermal expansion (10^-6/K)	[alpha]	11.50	

Tensile strength (N/mm²)	[Rm]	600.00 (d= 0- 0mm)
Yield point (N/mm²)	[Rp]	425.00 (d= 0- 0mm)
Surface class of roughness	N6 Rz=4.8 (Grinding)	
Surface roughness (µm)	[Rz]	4.80
External diameter (mm)	[DaA]	1211.30
Diameter increase (µm)	[deltaD]	132.49 (117.71.. 147.27)
Diameter increase (o/oo)	[deltaD]	0.11 (0.10.. 0.12)
Equivalent stress outsideø (N/mm²)	[sigVa]	22.53 (20.02.. 25.05)
- Radial stress (N/mm²)	[sigRa]	-0.00 (0.00.. -0.00)
- Tangential stress (N/mm²)	[sigTa]	22.53 (20.02.. 25.05)
Inner diameter (mm)	[DaI]	385.00
Diameter increase (µm)	[deltaD]	285.68 (253.81.. 317.55)
Diameter increase (o/oo)	[deltaD]	0.74 (0.66.. 0.82)
Equivalent stress insideø (N/mm²)	[sigVi]	193.47 (171.89.. 215.06)
- Radial stress (N/mm²)	[sigRi]	-100.24 (-89.06.. -111.43)
- Tangential stress (N/mm²)	[sigTi]	122.78 (109.09.. 136.48)
- With outside load (N/mm²)	[sigViMF]	196.56 (174.98.. 218.14)
Safety against fracture	[Si.Rm]	3.05 (3.43.. 2.75)
Required safety against fracture	[SSi.Rm]	1.50
Safety against yield point	[Si.Re]	2.16 (2.43.. 1.95)
Required safety against yield point	[SSi.Re]	1.00

Mere elastic stress, no verification of elastic plastic interference fit according to DIN 7190.

Service / Mounting / Remounting

Transverse-interference-fit:

Mounting clearance (mm)	[PsTh]	0.385

Temperature difference for mounting:

Shaft temperature: (°C)	Hub temperature: [ThA] (°C)
20	213
-150	88

(calculated using coefficient of thermal expansion)

shaft according to DIN 7190 (10^-6/K)	[alpha]	8.50

Longitudinal pressure fit:

Assembly temperature shaft (°C)	[ThM]	20.00
Assembly temperature hub (°C)	[ThM]	20.00
Coefficient. of friction (Longitudinal)	[mye=mya*1.3]	0.13
Press on (force) (kN)	[Fpress]	3704.21 (3290.97.. 4117.45)
Coefficient. of friction (Longitudinal)	[myll=mya*1.6]	0.16
Press out (force) (kN)	[Fpress]	4559.03 (4050.43.. 5067.63)

Notice:
Micro sliding can occur in Interference fit!
=> Risk of contact corrosion.

Coefficient. of friction	[my]	0.16
Max. torque to avoid Micro sliding (Nm)	[Tlimit]	240648.18 (213800.72.. 267495.64)

Notice concerning the display: Number-1 (Number-2.. Number-3):
Number-1: Value calculated with the mean allowance
Number-2: Value of the smallest possible allowance
Number-3: Value of the largest possible allowance

Notice: All strains and stresses are calculated for the purely elastic case.

End of Report lines: 160

KISSsoft Release 03/2013

KISSsoft evaluation

File

Name : Ozubeni_spojka
Changed by: Lenka am: 04.05.2014 um: 16:08:37

CALCULATION OF A CYLINDRICAL SPUR GEAR PAIR

Drawing or article number:
Gear 1: 0.000.0
Gear 2: 0.000.0

Strength calculation with load spectrum
Required service life (h): 2400.00

Load spectrum

Nominal Power [P] 460.9345 kW
Application factor [KA] 1.00

Load spectrum : Own Input
Number of element in the Load spectrum: 2
Reference gear: 1

i	[%]	[kW]	[1/min]	[Nm]	KV	KHb	Kgam	YM1	YM2	Oil°
1	20.00000	460.9345	786.0000	5600.0000	1.0591	1.0555	1.0000	1.0000	1.0000	70
2	80.00000	322.6541	786.0000	3920.0000	1.0682	1.0786	1.0000	1.0000	1.0000	70

Woehler line (S-N curve) at the fatigue stress according: according to standard

Notice:
Calculation-method according to:
- ISO 6336, part 6
During the calculation al the load-coefficients (ISO6336: KV, KHb, KFb; AGMA2001: Knu, Km, ..)
for each load spectrum element are calculated separately.

Notice:
Calculation with methods ISO6336 and AGMA 2001 results in a reduction
of resistance in the domain of fatigue resistance
(from circa 10^7 to 10^10 cycles with a reduction of circa 15 %).
The lifetime calculation takes this into account
(also with the S-N curve (Woehler Curve) of the Miner type).

Safety root: 0.94 0.81
Safety flank: 0.89 0.89

Safety scuffing (Integral) 2.38
Safety scuffing (Flash) 2.57
(Safety against scuffing/micropitting/EHT is indicated for the weakest element of the load spectrum.)

ONLY AS INFORMATION: CALCULATION WITH REFERENCE POWER

Calculation method ISO 6336:2006 Method B

		GEAR 1	GEAR 2
Power (kW)	[P]	460.934	
Speed (1/min)	[n]	786.0	786.0
Torque (Nm)	[T]	5600.0	5600.0
Application factor	[KA]	1.00	
Required service life	[H]	2400.00	
Gear driving (+) / driven (-)		+	-

1. TOOTH GEOMETRY AND MATERIAL

(geometry calculation according to DIN 3960:1987)

		GEAR 1	GEAR 2
Center distance (mm)	[a]	168.000	
Centre distance tolerance	ISO 286:2010 Measure js7		
Normal module (mm)	[mn]	4.0000	
Pressure angle at normal section (°)	[alfn]	20.0000	
Helix angle at reference circle (°)	[beta]	0.0000	
Number of teeth	[z]	42	42
Facewidth (mm)	[b]	131.00	49.00
Hand of gear		Spur gear	
Accuracy grade	[Q-ISO 1328:1995]	8	6
Inner diameter (mm)	[di]	0.00	0.00
Inner diameter of gear rim (mm)	[dbi]	0.00	0.00

Material

Gear 1: 18CrNiMo7-6, Case-carburized steel, case-hardened
ISO 6336-5 Figure 9/10 (MQ), core strength >=25HRC Jominy J=12mm<HRC28

Gear 2: 18CrNiMo7-6, Case-carburized steel, case-hardened
ISO 6336-5 Figure 9/10 (MQ), core strength >=25HRC Jominy J=12mm<HRC28

		GEAR 1	GEAR 2
Surface hardness		HRC 61	HRC 61
Material quality according to ISO 6336:2006 Normal (Life factors ZNT and YNT >=0.85)			
Fatigue strength. tooth root stress (N/mm²)	[sigFlim]	430.00	430.00
Fatigue strength for Hertzian pressure (N/mm²)	[sigHlim]	1500.00	1500.00
Tensile strength (N/mm²)	[Rm]	1200.00	1200.00
Yield point (N/mm²)	[Rp]	850.00	850.00
Young's modulus (N/mm²)	[E]	206000	206000
Poisson's ratio	[ny]	0.300	0.300
Mean roughness, Ra, tooth flank (µm)	[RAH]	0.60	0.60
Mean roughness height, Rz, flank (µm)	[RZH]	4.80	4.80
Mean roughness height, Rz, root (µm)	[RZF]	20.00	20.00

Tool or reference profile of gear 1 :

Reference profile	1.25 / 0.38 / 1.0 ISO 53.2:1997 Profil A	
Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.380

Addendum coefficient	[haP*]	1.000
Tip radius factor	[rhoaP*]	0.000
Tip form height coefficient	[hFaP*]	0.000
Protuberance height factor	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Ramp angle	[alfKP]	0.000

not topping

Tool or reference profile of gear 2 :

Reference profile	1.25 / 0.38 / 1.0 ISO 53.2:1997 Profil A	
Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.380
Addendum coefficient	[haP*]	1.000
Tip radius factor	[rhoaP*]	0.000
Tip form height coefficient	[hFaP*]	0.000
Protuberance height factor	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Ramp angle	[alfKP]	0.000

not topping

Summary of reference profile gears:

Dedendum reference profile (in module)	[hfP*]	1.250	1.250
Root radius reference profile (in module)	[rofP*]	0.380	0.380
Addendum reference profile (in module)	[haP*]	1.000	1.000
Protuberance height coefficient (in module)	[hprP*]	0.000	0.000
Protuberance angle (°)	[alfprP]	0.000	0.000
Tip form height coefficient (in module)	[hFaP*]	0.000	0.000
Ramp angle (°)	[alfKP]	0.000	0.000

Type of profile modification:

none (only running-in)

Tip relief (µm)	[Ca]	2.0	2.0

Lubrication type	oil bath lubrication	
Type of oil	Oil: ISO-VG 220	
Lubricant base	Mineral-oil base	
Kinem. viscosity oil at 40 °C (mm²/s)	[nu40]	220.00
Kinem. viscosity oil at 100 °C (mm²/s)	[nu100]	17.50
FZG test A/8.3/90 (ISO 14635-1:2006)	[FZGtestA]	12
Specific density at 15 °C (kg/dm³)	[roOil]	0.895
Oil temperature (°C)	[TS]	70.000

		------- GEAR 1 --------	GEAR 2 --
Overall transmission ratio	[itot]	-1.000	
Gear ratio	[u]	1.000	
Transverse module (mm)	[mt]	4.000	
Pressure angle at pitch circle (°)	[alft]	20.000	
Working transverse pressure angle (°)	[alfwt]	20.000	
	[alfwt.e/i]	20.019 /	19.981
Working pressure angle at normal section (°)	[alfwn]	20.000	
Helix angle at operating pitch circle (°)	[betaw]	0.000	
Base helix angle (°)	[betab]	0.000	
Reference centre distance (mm)	[ad]	168.000	
Sum of profile shift coefficients	[Summexi]	0.0000	
Profile shift coefficient	[x]	0.0000	0.0000
Tooth thickness (Arc) (module) (module)	[sn*]	1.5708	1.5708

Tip alteration (mm)	[k*mn]	0.000	0.000
Reference diameter (mm)	[d]	168.000	168.000
Base diameter (mm)	[db]	157.868	157.868
Tip diameter (mm)	[da]	176.000	176.000
(mm)	[da.e/i]	176.000 / 175.990	176.000 / 175.990
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / -0.010	0.000 / -0.010
Tip form diameter (mm)	[dFa]	176.000	176.000
(mm)	[dFa.e/i]	176.000 / 175.990	176.000 / 175.990
Active tip diameter (mm)	[dNa.e/i]	176.000 / 175.990	176.000 / 175.990
Operating pitch diameter (mm)	[dw]	168.000	168.000
(mm)	[dw.e/i]	168.020 / 167.980	168.020 / 167.980
Root diameter (mm)	[df]	158.000	158.000
Generating Profile shift coefficient	[xE.e/i]	-0.0326/ -0.0498	-0.0326/ -0.0498
Manufactured root diameter with xE (mm)	[df.e/i]	157.739 / 157.602	157.739 / 157.602
Theoretical tip clearance (mm)	[c]	1.000	1.000
Effective tip clearance (mm)	[c.e/i]	1.224 / 1.111	1.224 / 1.111
Active root diameter (mm)	[dNf]	162.172	162.172
(mm)	[dNf.e/i]	162.204 / 162.146	162.204 / 162.146
Root form diameter (mm)	[dFf]	161.503	161.503
(mm)	[dFf.e/i]	161.344 / 161.261	161.344 / 161.261
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	0.472 / 0.401	0.472 / 0.401
Addendum (mm)	[ha=mn*(haP*+x)]	4.000	4.000
(mm)	[ha.e/i]	4.000 / 3.995	4.000 / 3.995
Dedendum (mm)	[hf=mn*(hfP*-x)]	5.000	5.000
(mm)	[hf.e/i]	5.131 / 5.199	5.131 / 5.199
Roll angle at dFa (°)	[xsi_dFa.e/i]	28.238 / 28.230	28.238 / 28.230
Roll angle to dNa (°)	[xsi_dNa.e/i]	28.238 / 28.230	28.238 / 28.230
Roll angle to dNf (°)	[xsi_dNf.e/i]	13.521 / 13.427	13.521 / 13.427
Roll angle at dFf (°)	[xsi_dFf.e/i]	12.088 / 11.942	12.088 / 11.942
Tooth height (mm)	[H]	9.000	9.000
Virtual gear no. of teeth	[zn]	42.000	42.000
Normal tooth thickness at tip cyl. (mm)	[san]	3.056	3.056
(mm)	[san.e/i]	2.962 / 2.905	2.962 / 2.905
Normal spacewidth at root cylinder (mm)	[efn]	3.558	3.558
(mm)	[efn.e/i]	0.000 / 0.000	0.000 / 0.000
Max. sliding velocity at tip (m/s)	[vga]	1.675	1.675
Specific sliding at the tip	[zetaa]	0.523	0.523
Specific sliding at the root	[zetaf]	-1.096	-1.096
Sliding factor on tip	[Kga]	0.242	0.242
Sliding factor on root	[Kgf]	-0.242	-0.242
Pitch on reference circle (mm)	[pt]	12.566	
Base pitch (mm)	[pbt]	11.809	
Transverse pitch on contact-path (mm)	[pet]	11.809	
Length of path of contact (mm)	[ga, e/i]	20.345 (20.404 / 20.264)	
Length T1-A, T2-A (mm)	[T1A, T2A]	18.557(18.499/ 18.627)	38.902(38.902/ 38.891)
Length T1-B (mm)	[T1B, T2B]	27.094(27.094/ 27.083)	30.366(30.307/ 30.435)
Length T1-C (mm)	[T1C, T2C]	28.730(28.700/ 28.759)	28.730(28.700/ 28.759)
Length T1-D (mm)	[T1D, T2D]	30.366(30.307/ 30.435)	27.094(27.094/ 27.083)
Length T1-E (mm)	[T1E, T2E]	38.902(38.902/ 38.891)	18.557(18.499/ 18.627)
Length T1-T2 (mm)	[T1T2]	57.459 (57.401 / 57.518)	
Diameter of single contact point B (mm)	[d-B]	166.909(166.909/ 166.902)	169.147(169.105/ 169.197)
Diameter of single contact point D (mm)	[d-D]	169.147(169.105/ 169.197)	166.909(166.909/ 166.902)
Addendum contact ratio	[eps]	0.861(0.864/ 0.858)	0.861(0.864/ 0.858)
Minimal length of contact line (mm)	[Lmin]	49.000	

Transverse contact ratio	[eps_a]	1.723
Transverse contact ratio with allowances	[eps_a.e/m/i]	1.728 / 1.722 / 1.716

Overlap ratio	[eps_b]	0.000
Total contact ratio	[eps_g]	1.723
Total contact ratio with allowances	[eps_g.e/m/i]	1.728 / 1.722 / 1.716

2. FACTORS OF GENERAL INFLUENCE

		------- GEAR 1 -------- GEAR 2 --
Nominal circum. force at pitch circle (N)	[Ft]	66666.7
Axial force (N)	[Fa]	0.0
Radial force (N)	[Fr]	24264.7
Normal force (N)	[Fnorm]	70945.2
Tangent.load at p.c.d.per mm (N/mm) (N/mm)	[w]	1360.54
Only as information: Forces at operating pitch circle:		
Nominal circumferential force (N)	[Ftw]	66666.7
Axial force (N)	[Faw]	0.0
Radial force (N)	[Frw]	24264.7
Circumferential speed pitch d.. (m/sec)	[v]	6.91
Running-in value (µm)	[yp]	1.4
Running-in value (µm)	[yf]	1.7
Correction coefficient	[CM]	0.800
Gear body coefficient	[CR]	1.000
Reference profile coefficient	[CBS]	0.975
Material coefficient	[E/Est]	1.000
Singular tooth stiffness (N/mm/µm)	[c']	13.667
Meshing stiffness (N/mm/µm)	[cgalf]	21.077
Meshing stiffness (N/mm/µm)	[cgbet]	17.915
Reduced mass (kg/mm)	[mRed]	0.04798
Resonance speed (min-1)	[nE1]	4765
Resonance ratio (-)	[N]	0.165
Subcritical range		
Running-in value (µm)	[ya]	1.4
Bearing distance l of pinion shaft (mm)	[l]	262.000
Distance s of pinion shaft (mm)	[s]	26.200
Outside diameter of pinion shaft (mm)	[dsh]	131.000
Load according to figure 13, ISO 6336-1:2006 0:a), 1:b), 2:c), 3:d), 4:e)	[-]	4
Coefficient K' according to Figure 13, ISO 6336-1:2006	[K']	-1.00
Without support effect		
Tooth trace deviation (active) (µm)	[Fby]	8.93
from deformation of shaft (µm)	[fsh*B1]	0.96
Tooth without tooth trace modification		
Position of Contact pattern: favorable		
from production tolerances (µm)	[fma*B2]	23.26
Tooth trace deviation, theoretical (µm)	[Fbx]	10.50
Running-in value (µm)	[yb]	1.58
Dynamic factor	[KV]	1.059
Face load factor - flank	[KHb]	1.055
- Tooth root	[KFb]	1.045
- Scuffing	[KBb]	1.055
Transverse load factor - flank	[KHa]	1.000
- Tooth root	[KFa]	1.000

- Scuffing	[KBa]	1.000	
Helical load factor scuffing	[Kbg]	1.000	
Number of load cycles (in mio.)	[NL]	113.184	113.184

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: B
(Calculate tooth shape coefficient YF with addendum mod. x)

		------- GEAR 1	-------- GEAR 2 --
Tooth form factor	[YF]	1.26	1.26
Stress correction factor	[YS]	2.05	2.05
Working angle (°)	[alfFen]	19.04	19.04
Bending lever arm (mm)	[hF]	3.81	3.81
Tooth thickness at root (mm)	[sFn]	8.56	8.56
Tooth root radius (mm)	[roF]	2.10	2.10

(hF* = 0.952/ 0.952 sFn* = 2.140/ 2.140 roF* = 0.526/ 0.526 dsFn = 159.62/ 159.62 alfsFn = 30.00/ 30.00)

Contact ratio factor	[Yeps]	1.000	
Helical load factor	[Ybet]	1.000	
Deep tooth factor	[YDT]	1.000	
Gear rim factor	[YB]	1.000	1.000
Effective facewidth (mm)	[beff]	57.00	49.00
Nominal stress at tooth root (N/mm²)	[sigF0]	752.50	875.36
Tooth root stress (N/mm²)	[sigF]	833.01	969.01

Permissible bending stress at root of Test-gear			
Support factor	[YdrelT]	0.995	0.995
Surface factor	[YRrelT]	0.957	0.957
Size coefficient (Tooth root)	[YX]	1.000	1.000
Finite life factor	[YNT]	0.930	0.930
[YdrelT*YRrelT*YX*YNT]		0.886	0.886
Alternating bending coefficient	[YM]	1.000	1.000
Stress correction factor	[Yst]	2.00	
Yst*sigFlim (N/mm²)	[sigFE]	860.00	860.00
Permissible tooth root stress (N/mm²)	[sigFP=sigFG/SFmin]	543.97	543.97
Limit strength tooth root (N/mm²)	[sigFG]	761.56	761.56
Required safety	[SFmin]	1.40	1.40
Safety for Tooth root stress	[SF=sigFG/sigF]	0.91	0.79
Transmittable power (kW)	[kWRating]	301.00	258.75

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		------- GEAR 1	-------- GEAR 2 --
Zone factor	[ZH]	2.495	
Elasticity coefficient (N^.5/mm)	[ZE]	189.812	
Contact ratio factor	[Zeps]	0.871	
Helix angle factor	[Zbet]	1.000	
Effective facewidth (mm)	[beff]	49.00	
Nominal flank pressure (N/mm²)	[sigH0]	1660.21	
Surface pressure at operating pitch circle (N/mm²)	[sigHw]	1755.35	
Single tooth contact factor	[ZB,ZD]	1.00	1.00

Flank pressure (N/mm²)	[sigH]	1758.21	1758.21
Lubrication coefficient at NL	[ZL]	1.020	1.020
Speed coefficient at NL	[ZV]	0.990	0.990
Roughness coefficient at NL	[ZR]	0.972	0.972
Material pairing coefficient at NL	[ZW]	1.000	1.000
Finite life factor	[ZNT]	0.975	0.975
	[ZL*ZV*ZR*ZNT]	0.958	0.958
Small amount of pitting permissible (0=no, 1=yes)		0	0
Size coefficient (flank)	[ZX]	1.000	1.000
Permissible surface pressure (N/mm²)	[sigHP=sigHG/SHmin]	1436.63	1436.63
Limit strength pitting (N/mm²)	[sigHG]	1436.63	1436.63
Safety for surface pressure at operating pitch circle			
	[SHw]	0.82	0.82
Required safety	[SHmin]	1.00	1.00
Transmittable power (kW)	[kWRating]	307.75	307.75

4b. MICROPITTING ACCORDING TO ISO TR 15144-1:2010

Calculation did not run. (Lubricant: Load stage micropitting test is unknown.)

5. STRENGTH AGAINST SCUFFING

Calculation method according to
ISO TR 13989:2000

Lubrication coefficient (for lubrication type)	[XS]	1.000	
Multiple meshing factor	[Xmp]	1.000	
Relative structure coefficient (Scuffing)	[XWrelT]	1.000	
Thermal contact factor (N/mm/s^.5/K)	[BM]	13.780	13.780
Relevant tip relief (µm)	[Ca]	2.00	2.00
Optimal tip relief (µm)	[Ceff]	99.55	
Ca taken as optimal in the calculation (0=no, 1=yes)		0	0
Effective facewidth (mm)	[beff]	49.000	
Applicable circumferential force/facewidth (N/mm)			
	[wBt]	1520.956	
(Kbg = 1.000, wBt*Kbg = 1520.956)			
Pressure angle factor (eps1: 0.861, eps2: 0.861)	[Xalfbet]	0.978	
Flash temperature-criteria			
Lubricant factor	[XL]	0.830	
Tooth mass temperature (°C)	[theMi]	91.99	
theM = theoil + XS*0.47*Xmp*theflm	[theflm]	46.78	
Scuffing temperature (°C)	[theS]	348.80	
Coordinate gamma (point of highest temp.)	[Gamma]	-0.354	
[Gamma.A]=-0.354 [Gamma.E]=0.354			
Highest contact temp. (°C)	[theB]	178.34	
Flash factor (°K*N^-.75*s^.5*m^-.5*mm)	[XM]	50.058	
Approach factor	[XJ]	1.244	
Load sharing factor	[XGam]	0.333	
Dynamic viscosity (mPa*s)	[etaM]	41.90 (70.0 °C)	
Coefficient of friction	[mym]	0.072	

Integral temperature-criteria		
Lubricant factor	[XL]	1.000
Tooth mass temperature (°C)	[theM-C]	95.92
theM-C = theoil + XS*0.70*theflaint	[theflaint]	37.03
Integral scuffing temperature (°C)	[theSint]	360.78
Flash factor (°K*N^-.75*s^.5*m^-.5*mm)	[XM]	50.058
Running-in factor (well run in)	[XE]	1.000
Contact ratio factor	[Xeps]	0.247
Dynamic viscosity (mPa*s)	[etaOil]	41.90 (70.0 °C)
Averaged coefficient of friction	[mym]	0.069
Geometry factor	[XBE]	0.268
Meshing factor	[XQ]	1.000
Tip relief factor	[XCa]	1.080
Integral tooth flank temperature (°C)	[theint]	151.46

6. MEASUREMENTS FOR TOOTH THICKNESS

		------- GEAR 1 --------	GEAR 2 --
Tooth thickness deviation		DIN 3967 cd25	DIN 3967 cd25
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.095 / -0.145	-0.095 / -0.145
Number of teeth spanned	[k]	5.000	5.000
Base tangent length (no backlash) (mm)	[Wk]	55.491	55.491
Actual base tangent length ('span') (mm)	[Wk.e/i]	55.402 / 55.355	55.402 / 55.355
Diameter of contact point (mm)	[dMWk.m]	167.300	167.300
Theoretical diameter of ball/pin (mm)	[DM]	6.782	6.782
Eff. Diameter of ball/pin (mm)	[DMeff]	7.000	7.000
Theor. dim. centre to ball (mm)	[MrK]	89.006	89.006
Actual dimension centre to ball (mm)	[MrK.e/i]	88.889 / 88.828	88.889 / 88.828
Diameter of contact point (mm)	[dMMr.m]	168.177	168.177
Diametral measurement over two balls without clearance (mm)	[MdK]	178.012	178.012
Actual dimension over balls (mm)	[MdK.e/i]	177.778 / 177.655	177.778 / 177.655
Diametral measurement over rolls without clearance (mm)	[MdR]	178.012	178.012
Actual dimension over rolls (mm)	[MdR.e/i]	177.778 / 177.655	177.778 / 177.655
Chordal tooth thickness (no backlash) (mm)	['sn]	6.282	6.282
Actual chordal tooth thickness (mm)	['sn.e/i]	6.187 / 6.137	6.187 / 6.137
Reference chordal height from da.m (mm)	[ha]	4.056	4.056
Tooth thickness (Arc) (mm)	[sn]	6.283	6.283
(mm)	[sn.e/i]	6.188 / 6.138	6.188 / 6.138
Backlash free center distance (mm)	[aControl.e/i]	167.737 /167.598	
Backlash free center distance, allowances (mm)	[jta]	-0.263 / -0.402	
dNf.i with aControl (mm)	[dNf0.i]	161.646	161.646
Reserve (dNf0.i-dFf.e)/2 (mm)	[cF0.i]	0.151	0.151
Centre distance allowances (mm)	[Aa.e/i]	0.020 / -0.020	
Circumferential backlash from Aa (mm)	[jtw_Aa.e/i]	0.015 / -0.015	
Radial clearance (mm)	[jrw]	0.422 / 0.243	
Circumferential backlash (transverse section) (mm)	[jtw]	0.305 / 0.175	
Torsional angle for fixed gear 1 (°)		0.2077 / 0.1197	
Normal backlash (mm)	[jnw]	0.286 / 0.165	

7. GEAR ACCURACY

		------- GEAR 1	-------- GEAR 2 --
According to ISO 1328:1995:			
Accuracy grade	[Q-ISO1328]	8	6
Single pitch deviation (µm)	[fpt]	20.00	10.00
Base circle pitch deviation (µm)	[fpb]	18.80	9.40
Cumulative circular pitch deviation over k/8 pitches (µm)	[Fpk/8]	39.00	20.00
Profile form deviation (µm)	[ffa]	23.00	12.00
Profile slope deviation (µm)	[fHa]	19.00	9.50
Total profile deviation (µm)	[Fa]	30.00	15.00
Helix form deviation (µm)	[ffb]	25.00	10.00
Helix slope deviation (µm)	[fHb]	25.00	10.00
Total helix deviation (µm)	[Fb]	35.00	15.00
Total cumulative pitch deviation (µm)	[Fp]	72.00	36.00
Concentricity deviation (µm)	[Fr]	58.00	29.00
Total radial composite deviation (µm)	[Fi"]	86.00	43.00
Radial tooth-to-tooth composite deviation (µm)	[fi"]	29.00	15.00
Total tangential composite deviation (µm)	[Fi']	113.00	57.00
Tangential tooth-to-tooth composite deviation (µm)	[fi']	41.00	21.00

Axis alignment tolerances (recommendation acc. ISO TR 10064:1992, Quality		6)
Maximum value for deviation error of axis (µm)	[fSigbet]	40.10 (Fb= 15.00)
Maximum value for inclination error of axes (µm)	[fSigdel]	80.20

8. ADDITIONAL DATA

Torsional stiffness (MNm/rad)	[cr]	6.4		6.4
Mean coeff. of friction (acc. Niemann)	[mum]		0.064	
Wear sliding coef. by Niemann	[zetw]		0.901	
Power loss from gear load (kW)	[PVZ]		3.357	
(Meshing efficiency (%)	[etaz]		99.272)	
Weight - calculated with da (kg)	[Mass]	24.954		9.334
Total weight (kg)	[Mass]		34.289	
Moment of inertia (System referenced to wheel 1):				
calculation without consideration of the exact tooth shape				
single gears ((da+df)/2...di) (kg*m²)	[TraeghMom]	0.07801		0.02918
System ((da+df)/2...di) (kg*m²)	[TraeghMom]		0.10719	

9. DETERMINATION OF TOOTHFORM

Data for the tooth form calculation :

Calculation of Gear 1

Tooth form, Gear 1, Step 1: automatic (final treatment)
haP*= 1.041, hfP*= 1.250, rofP*= 0.380

Calculation of Gear 2

Tooth form, Gear 2, Step 1: automatic (final treatment)
haP*= 1.041, hfP*= 1.250, rofP*= 0.380

REMARKS:

- Specifications with [.e/i] imply: Maximum [e] and Minimal value [i] with consideration of all tolerances
  Specifications with [.m] imply: Mean value within tolerance
- For the backlash tolerance, the center distance tolerances and the tooth thickness deviation are taken into account. Shown is the maximal and the minimal backlash corresponding the largest resp. the smallest allowances
  The calculation is done for the Operating pitch circle..
- Details of calculation method:
  cg according to method B
  KV according to method B
  KHb, KFb according method C
  fma following equation (64), fsh following (57/58), Fbx following (52/53/57)
  KHa, KFa according to method B

End of Report lines: 528

KISSsoft Release 03/2013

KISSsoft evaluation

File

Name : Drazkovani_vystup
Changed by: Lenka am: 04.05.2014 um: 14:19:06

Straight-sided spline [M02b]

Calculation method: G.Niemann, Maschinenelemente I, 4th Edition, 2005.

Label	Own Input	
Inner diameter (mm)	[d1]	270.00
External diameter (mm)	[d2]	279.00
Medium diameter (mm)	[dm]	274.50
Number of keys	[nK]	54.00
Width (mm)	[b]	170.00
Height of key (mm)	[h]	4.50
Supporting length (mm)	[ltr]	170.00
Length factor	[k1]	1.04
Participation factor (equivalent)	[kphibeq]	1.30
Participation factor (maximum load)	[kphibmax]	1.10
Nominal torque (Nm)	[Tnenn]	380000.00
Application factor	[KA]	1.00
Service torque (Nm)	[Teq]	380000.00
Maximum torque (Nm)	[Tmax]	380000.00
Number of load peaks	[NL]	1000
Torque curve: No alternating torque		
Load direction changing coefficient	[fw]	1.00
Manufacturing tolerances according to Niemann		H7

Shaft

Material		C45 (1)
Type		Through hardened steel
Treatment		unalloyed, through hardened
Tensile strength (N/mm²)	[Rm]	590.00 (d=250-500mm)
Yield point (N/mm²)	[Rp]	325.00 (d=250-500mm)
Pressure stress (equiv. load) (N/mm²)	[peq]	90.19
Pressure stress (maxim. load) (N/mm²)	[pmax]	90.19
Support factor	[fs]	1.20
Load peak coefficient	[fL]	1.50
Hardness influence coefficient	[fH]	1.00
Permissible pressure (N/mm²)	[pzuleq]	390.00
Permissible pressure (N/mm²)	[pzulmax]	585.00
fw * pzul / peq		4.32
fL * pzul / pmax		6.49
Required safety		1.00
Minimal safety		4.32

Hub

Material		C45 (1)
Type		Through hardened steel
Treatment		unalloyed, through hardened
Tensile strength (N/mm²)	[Rm]	590.00 (d=250-500mm)
Yield point (N/mm²)	[Rp]	325.00 (d=250-500mm)
Small external diameter (mm)	[D1]	300.00
Bi+B75g external diameter (mm)	[D2]	300.00
Width of hub-part with D2 (mm)	[c]	170.00
Equivalent diameter hub (mm)	[D]	300.00
Distance a0 (mm)	[a0]	85.00
Pressure stress (equiv. load) (N/mm²)	[peq]	90.19
Pressure stress (maxim. load) (N/mm²)	[pmax]	90.19
Support factor	[fs]	1.50
Load peak coefficient	[fL]	1.50
Hardness influence coefficient	[fH]	1.00
Permissible pressure (N/mm²)	[pzuleq]	487.50
Permissible pressure (N/mm²)	[pzulmax]	731.25
fw * pzul / peq		5.41
fL * pzul / pmax		8.11
Required safety		1.00
Minimal safety		5.41

Remarks:
Pressure load: p(eq,max) = kphib(eq,max)*k1*T*2000/(dm*ltr*h*z)
Coefficient for load direction changes according to DIN 6892:1998/ fig. 6
pzuleq = fs*fH*fw*(Rm,Rp)
pzulmax = fs*fH*fL*(Rm,Rp)
(Rm:for brittle material; Rp:for ductile material)

End of Report lines: 90

KISSsoft evaluation

File

Name : Pero
Changed by: Lenka am: 04.05.2014 um: 12:40:24

Important hint: At least one warning has occurred during the calculation:
1-> For the raw diameter (140 mm) of the material (18CrNiMo7-6)
the database has no values
for tensile stress and yield point !
Guessed values are assumed.
For the input of material data:
Call the KISSsoft database tool in the menu Extras

Keys [M02a]

Calculation method: DIN 6892-B:2012

Label		DIN 6885.1:1968 Default
Key width (mm)	[b]	36.00
Key height (mm)	[h]	20.00
Chamfer (mean value) (mm)	[r]	1.10
Shaft diameter (mm)	[d]	135.00
Nominal torque (Nm)	[T]	6000.00
Application factor	[KA]	1.50
equivalent torque (Nm)	[Teq]	9000.00
Maximum torque (Nm)	[Tmax]	9000.00
Minimal frictional torque for interference fit (Nm)	[TRmin]	0.00
Torque curve: Alternating torque, slow increase		
Maximum backwards torque (Nm)	[TmaxR]	8800.00
Number of load peaks	[NL]	2
Number of change of load direction	[NW]	4
Load direction changing coefficient	[fw]	1.00
Number of keys	[i]	1
Load factor	[phi]	1.00
equivalent circumferential stress (N)	[Feq]	133333.33
Maximal circumferential force (N)	[Fmax]	133333.33
Contact coefficient for equivalent surface pressure	[Kneq]	1.00
Contact coefficient for maximal surface pressure	[Knmax]	1.00
Help coefficient	[Kle]	1.065
Load distribution coefficient	[Kl]	1.065
Friction factor	[KReq]	1.000
Friction factor	[KR]	1.000

Shaft

Material 18CrNiMo7-6

Type		Case-carburized steel
Treatment		case-hardened
Tensile strength (N/mm²)	[Rm]	600.00 (d= 0- 0mm)
Yield point (N/mm²)	[Re]	425.00 (d= 0- 0mm)
Groove depth shaft (minimal value) (mm)	[t1]	12.00
Chamfer on shaft (mm)	[s1]	0.01
Supporting key length (mm)	[ltr]	94.00
Supporting key height (mm)	[t1tr]	8.44
Pressure stress (N/mm²)	[peq]	178.88
Pressure stress (N/mm²)	[pmax]	178.88
Support factor	[fs]	1.30
Hardness influence coefficient	[fH]	1.15
Permissible surface pressure (N/mm²)	[pzul]	635.38
Load peak frequency coefficient	[fL]	1.50
Load direction changing coefficient	[fw]	1.00
fw * pzul / peq		3.55
fL * pzul / pmax		5.33
Safety		3.55

Hub

Material		18CrNiMo7-6
Type		Case-carburized steel
Treatment		case-hardened
Tensile strength (N/mm²)	[Rm]	900.00 (d=40-100mm)
Yield point (N/mm²)	[Re]	640.00 (d=40-100mm)
Groove depth hub (minimal value) (mm)	[t2]	8.40
Chamfer on hub (mm)	[s2]	0.10
Supporting key length (mm)	[ltr]	94.00
Supporting key height (mm)	[t2tr]	9.27
Small outside diameter of hub (mm)	[D1]	180.00
Big outside diameter of hub (mm)	[D2]	230.00
Width of hub-part with D2 (mm)	[c]	40.00
Equivalent diameter hub (mm)	[D]	194.46
Distance a0 (Figure 2, DIN 6892) (mm)	[a0]	100.00
Pressure stress (N/mm²)	[peq]	162.88
Pressure stress (N/mm²)	[pmax]	162.88
Support factor	[fs]	1.50
Hardness influence coefficient	[fH]	1.15
Permissible surface pressure (N/mm²)	[pzul]	1104.00
Load peak frequency coefficient	[fL]	1.50
Load direction changing coefficient	[fw]	1.00
fw * pzul / peq		6.78
fL * pzul / pmax		10.17
Safety		6.78

Key

Material		C45 (1)
Type		Through hardened steel
Treatment		unalloyed, through hardened
Tensile strength (N/mm²)	[Rm]	650.00 (d=16-40mm)
Yield point (N/mm²)	[Re]	430.00 (d=16-40mm)

Pressure stress (N/mm²)	[peq]	178.88 /	162.88
Pressure stress (N/mm²)	[pmax]	178.88 /	162.88
Support factor	[fs]	1.10	
Hardness influence coefficient	[fH]	1.00	
Permissible surface pressure (N/mm²)	[pzul]	473.00	
Load peak frequency coefficient	[fL]	1.50	
Load direction changing coefficient	[fw]	1.00	
fw * pzul / peq		2.64	
fL * pzul / pmax		3.97	
Safety		2.64	
Cross section area (mm²)	[b*ltr]	3384.00	
Shear stress (N/mm²)	[tau]	39.40	

Remarks:

Safety = Minimum (fw*pzul/peq, fL*pzul/pmax)
Condition according to DIN 6892 Safety >= 1.0
Chamfer on key: Mean value as in examples in DIN 6892
Groove depth: Minimum value as in examples in DIN 6892

End of Report lines: 128

PŘÍLOHA č. 4

Zpráva z pevnostní analýzy - výběr

Zpráva pevnostní analýzy

Autodesk®

Analyzovaný soubor:	Skrin_nova_MKP_22_3.iam
Verze aplikace Autodesk Inventor:	2013 (Build 170138000, 138)
Datum vyhotovení:	23.3.2014, 17:41
Autor simulace:	Lenka
Souhrn:	

⊟ Informace o projektu (iVlastnosti)

⊟ Souhrn

Autor	Lenka

⊟ Projekt

Číslo součásti	Skrin_nova_MKP_22_3
Kreslil	Lenka
Náklady	0,00 Kč
Datum vytvoření	18.3.2014

⊟ Stav

Stav návrhu	Rozpracováno

⊟ Fyzické

Hmotnost	8681,49 kg
Plocha	36714600 mm^2
Objem	1105330000 mm^3
Těžiště	x=80,5928 mm y=-1207,2 mm z=5,29097 mm

Poznámka: Fyzikální hodnoty se mohou lišit od fyzikálních hodnot použitých v analýze MKP uvedené dále.

⊟ Simulace:1

Obecné cíle a nastavení:

Cíl návrhu	Jediný bod
Typ simulace	Modální analýza
Datum poslední úpravy	22.3.2014, 22:10
Počet režimů	8

Rozsah frekvencí	Není definováno
Vypočítat předem načtené režimy	Ne
Zvýšená přesnost	Ne

Nastavení sítě:

Prům. velikost prvku (zlomek průměru modelu)	0,05
Min. velikost prvku (zlomek prům. velikosti)	0,2
Součinitel zemních těles	1,5
Max. úhel pootočení	60 deg
Vytvořit zakřivené prvky sítě	Ne
Použít pro síť sestavy měření založená na součástech	Ano

⊟ Materiály

Název	Ocel, měkká, svařovaná	
Obecné	Měrná hmotnost	7,86 g/cm^3
	Mez kluzu v tahu	207 MPa
	Mez pevnosti v tahu	345 MPa
Napětí	Youngův modul	220 GPa
	Poissonova konstanta	0,275 ul
	Modul pružnosti	86,2745 GPa
Tepelné napětí	Koeficient roztažnosti	0,000012 ul/c
	Tepelná vodivost	56 W/(m K)
	Měrné teplo	460 J/(kg c)
Názvy součástí	Spodek_skrine_nový.ipt Viko_skrine_nove.ipt	

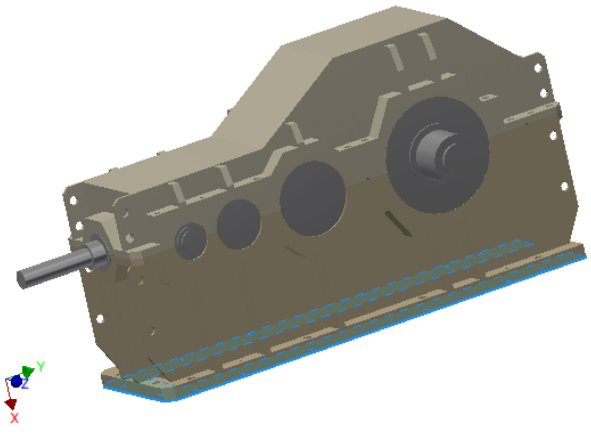
Název	Ocel, legovaná	
Obecné	Měrná hmotnost	7,85 g/cm^3
	Mez kluzu v tahu	250 MPa
	Mez pevnosti v tahu	400 MPa
Napětí	Youngův modul	205 GPa
	Poissonova konstanta	0,3 ul
	Modul pružnosti	78,8462 GPa
Tepelné napětí	Koeficient roztažnosti	0,000012 ul/c
	Tepelná vodivost	44,5 W/(m K)
	Měrné teplo	475 J/(kg c)
Názvy součástí	Hridel_vystup_novy_proMKP.ipt Hridel_III_novy_proMKP.ipt Hridel_II_novy_proMKP.ipt Hridel_I_novy_proMKP.ipt Hridel_0_novy_proMKP.ipt	

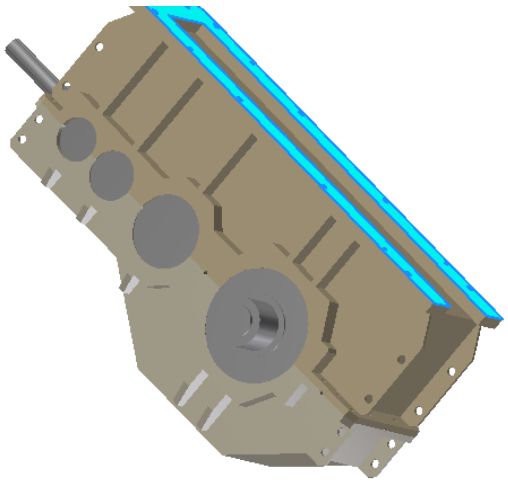
⊟ Provozní podmínky

⊟ Pevná vazba:1

Typ vazby	Pevná vazba

⊟ Vybrané plochy





⊟

Dotyky (Vázaný)

Název	Názvy součástí
Vázaný:1	Spodek_skrine_nový:1 Viko_skrine_nove:1
Vázaný:2	Spodek_skrine_nový:1 Viko_skrine_nove:1
Vázaný:3	Spodek_skrine_nový:1 Viko_skrine_nove:1
Vázaný:4	Spodek_skrine_nový:1 Viko_skrine_nove:1
Vázaný:5	Spodek_skrine_nový:1 Viko_skrine_nove:1
Vázaný:6	Spodek_skrine_nový:1 Viko_skrine_nove:1
Vázaný:7	Spodek_skrine_nový:1 Viko_skrine_nove:1
Vázaný:8	Spodek_skrine_nový:1 Viko_skrine_nove:1
Vázaný:9	Spodek_skrine_nový:1 Viko_skrine_nove:1
Vázaný:10	Spodek_skrine_nový:1 Hridel_vystup_novy_proMKP:1
Vázaný:11	Spodek_skrine_nový:1 Hridel_vystup_novy_proMKP:1
Vázaný:12	Spodek_skrine_nový:1 Hridel_III_novy_proMKP:1
Vázaný:13	Spodek_skrine_nový:1 Hridel_III_novy_proMKP:1
Vázaný:14	Spodek_skrine_nový:1 Hridel_II_novy_proMKP:1
Vázaný:15	Spodek_skrine_nový:1 Hridel_II_novy_proMKP:1
Vázaný:16	Spodek_skrine_nový:1 Hridel_I_novy_proMKP:1
Vázaný:17	Spodek_skrine_nový:1 Hridel_I_novy_proMKP:1
Vázaný:18	Spodek_skrine_nový:1 Hridel_I_novy_proMKP:1
Vázaný:19	Spodek_skrine_nový:1 Hridel_0_novy_proMKP:1
Vázaný:20	Spodek_skrine_nový:1 Hridel_0_novy_proMKP:1
Vázaný:21	Spodek_skrine_nový:1 Hridel_0_novy_proMKP:1
Vázaný:22	Spodek_skrine_nový:1 Hridel_0_novy_proMKP:1
Vázaný:23	Viko_skrine_nove:1 Hridel_vystup_novy_proMKP:1
Vázaný:24	Viko_skrine_nove:1 Hridel_vystup_novy_proMKP:1
Vázaný:25	Viko_skrine_nove:1 Hridel_III_novy_proMKP:1
Vázaný:26	Viko_skrine_nove:1 Hridel_III_novy_proMKP:1
Vázaný:27	Viko_skrine_nove:1 Hridel_II_novy_proMKP:1
Vázaný:28	Viko_skrine_nove:1 Hridel_II_novy_proMKP:1
Vázaný:29	Viko_skrine_nove:1 Hridel_I_novy_proMKP:1
Vázaný:30	Viko_skrine_nove:1 Hridel_I_novy_proMKP:1
Vázaný:31	Viko_skrine_nove:1 Hridel_I_novy_proMKP:1
Vázaný:32	Viko_skrine_nove:1 Hridel_0_novy_proMKP:1
Vázaný:33	Viko_skrine_nove:1 Hridel_0_novy_proMKP:1
Vázaný:34	Viko_skrine_nove:1 Hridel_0_novy_proMKP:1
Vázaný:35	Viko_skrine_nove:1 Hridel_0_novy_proMKP:1
Vázaný:36	Hridel_vystup_novy_proMKP:1 Hridel_III_novy_proMKP:1
Vázaný:37	Hridel_III_novy_proMKP:1 Hridel_II_novy_proMKP:1
Vázaný:38	Hridel_II_novy_proMKP:1 Hridel_I_novy_proMKP:1
Vázaný:39	Spodek_skrine_nový:1 Hridel_I_novy_proMKP:1
Vázaný:40	Viko_skrine_nove:1 Hridel_I_novy_proMKP:1

⊟ Výsledky

⊟ Frekvenční hodnoty

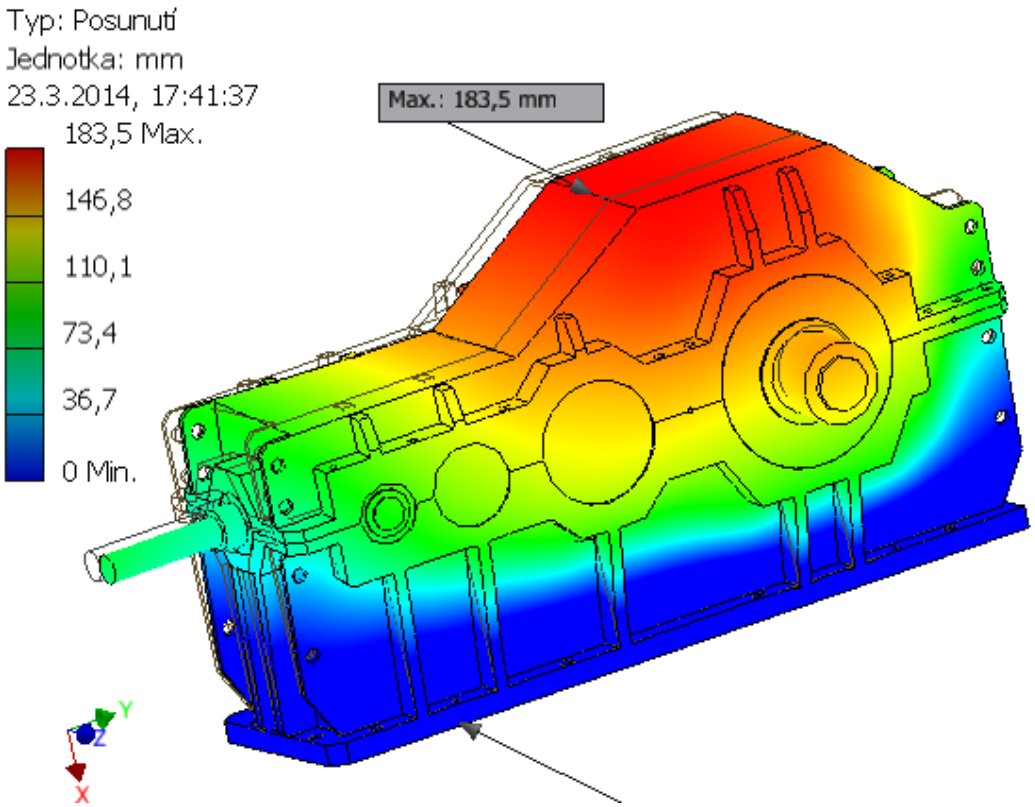
F1	107,53 Hz	F3	228,10 Hz	F5	318,77 Hz	F7	405,67 Hz
F2	192,13 Hz	F4	313,22 Hz	F6	383,72 Hz	F8	427,56 Hz

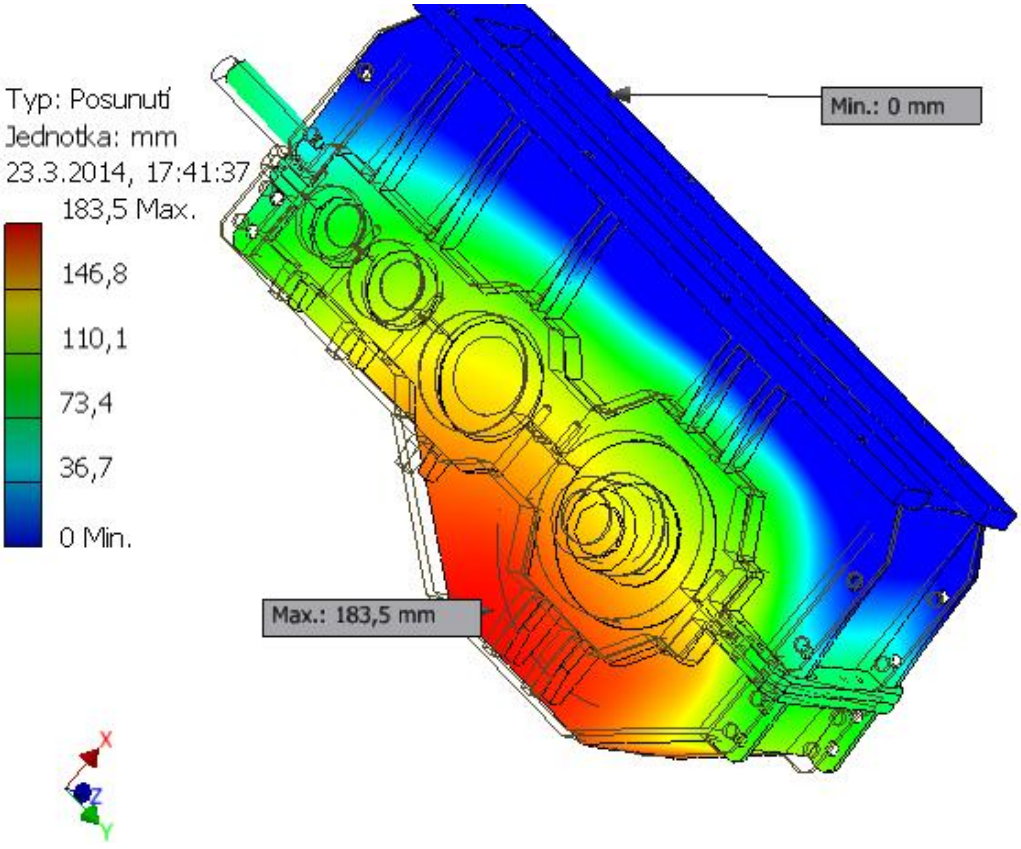
Souhrn výsledků

Název	**Hodnota výsledku**
Objem	1105330000 mm^3
Hmotnost	8681,49 kg

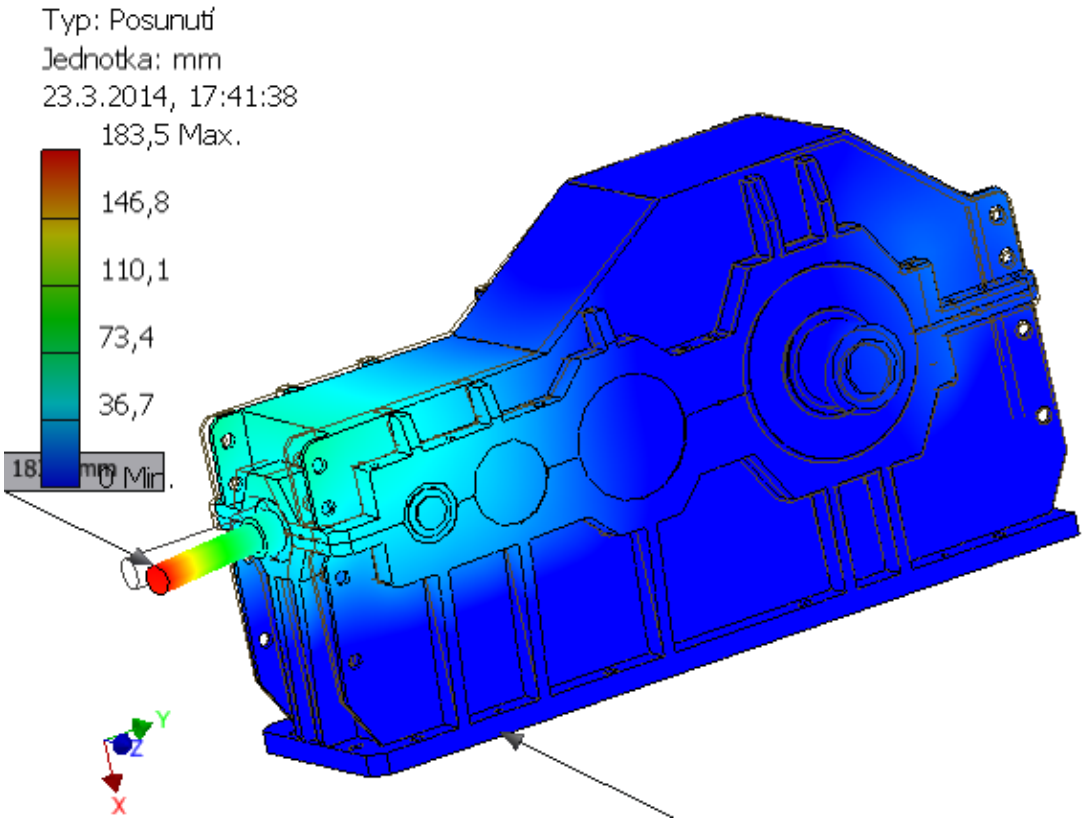
⊟ Obrázky

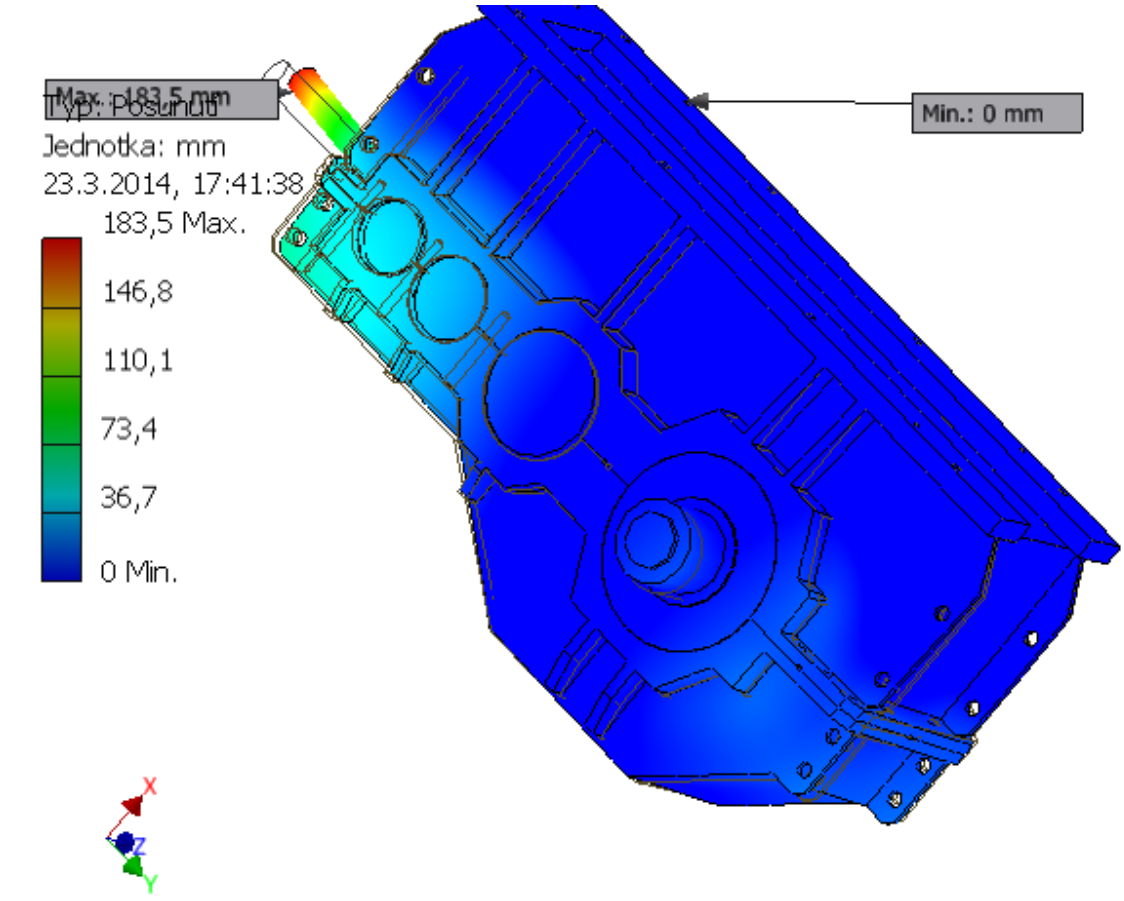
⊟ F1 107,53 Hz Posunutí



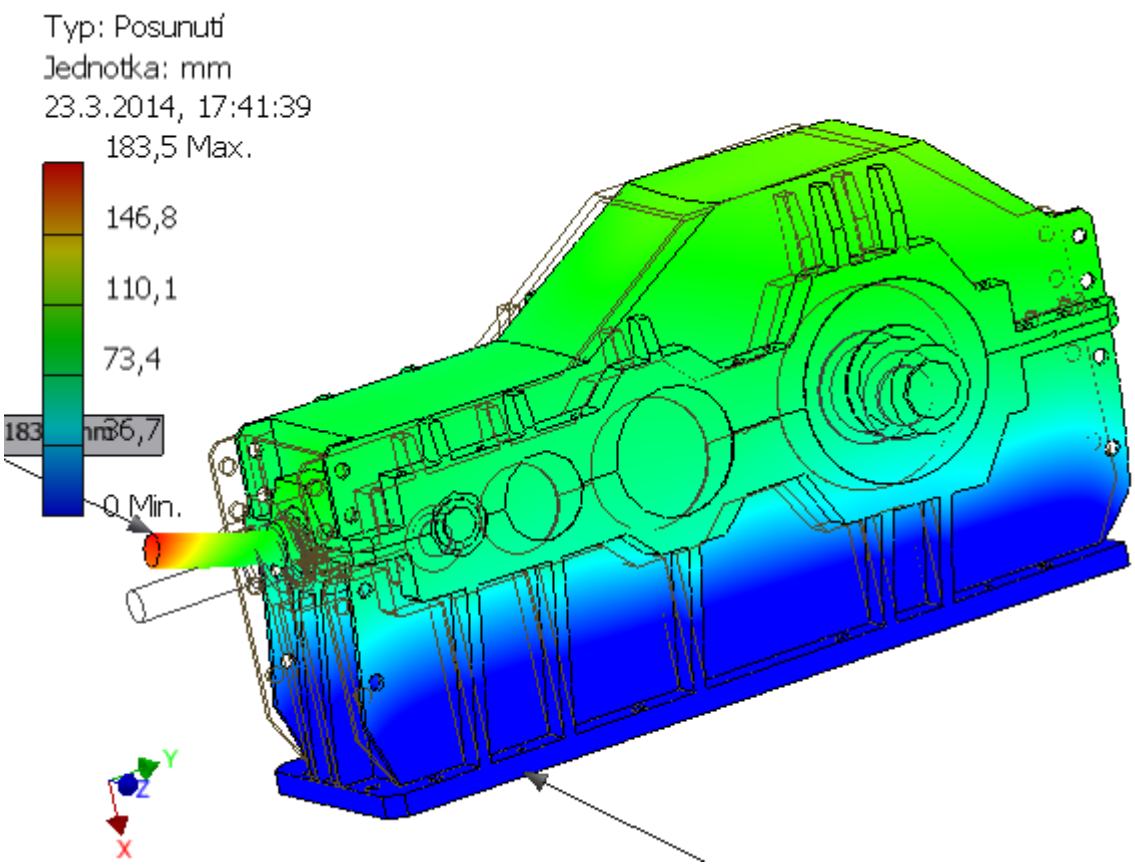


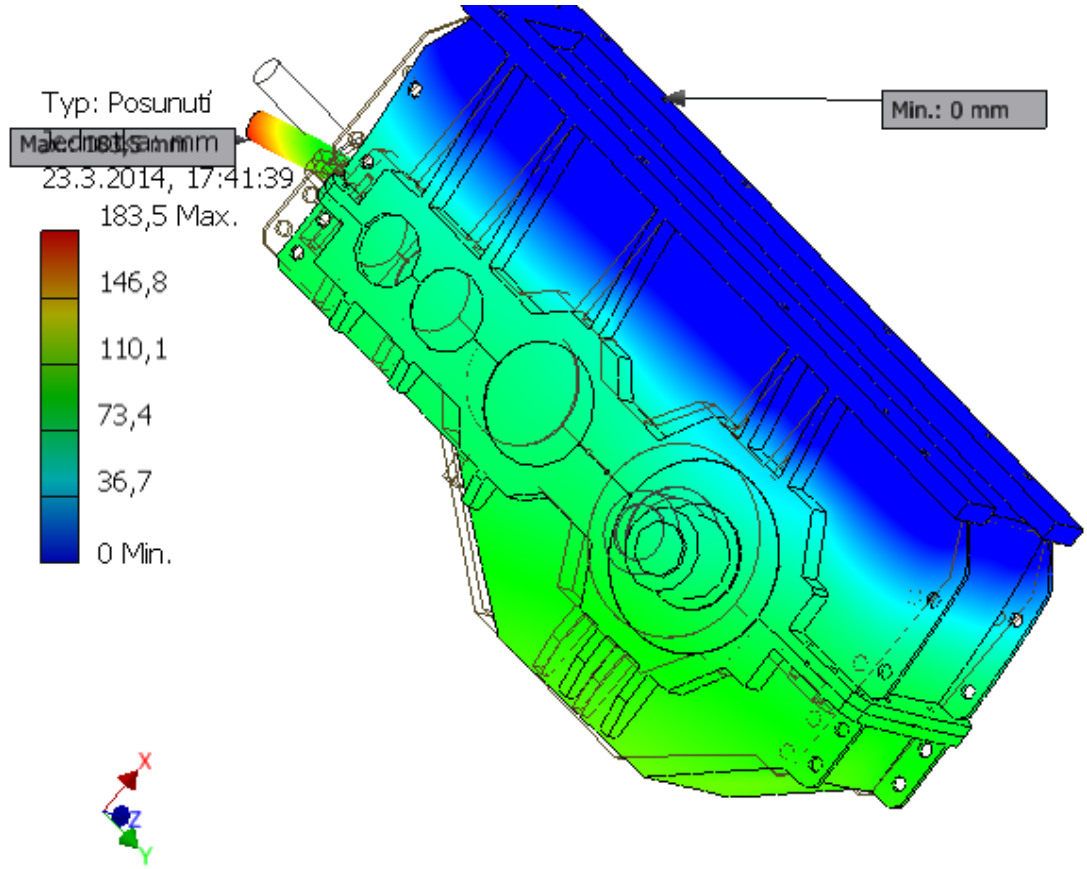
⊟ F2 192,13 Hz Posunutí



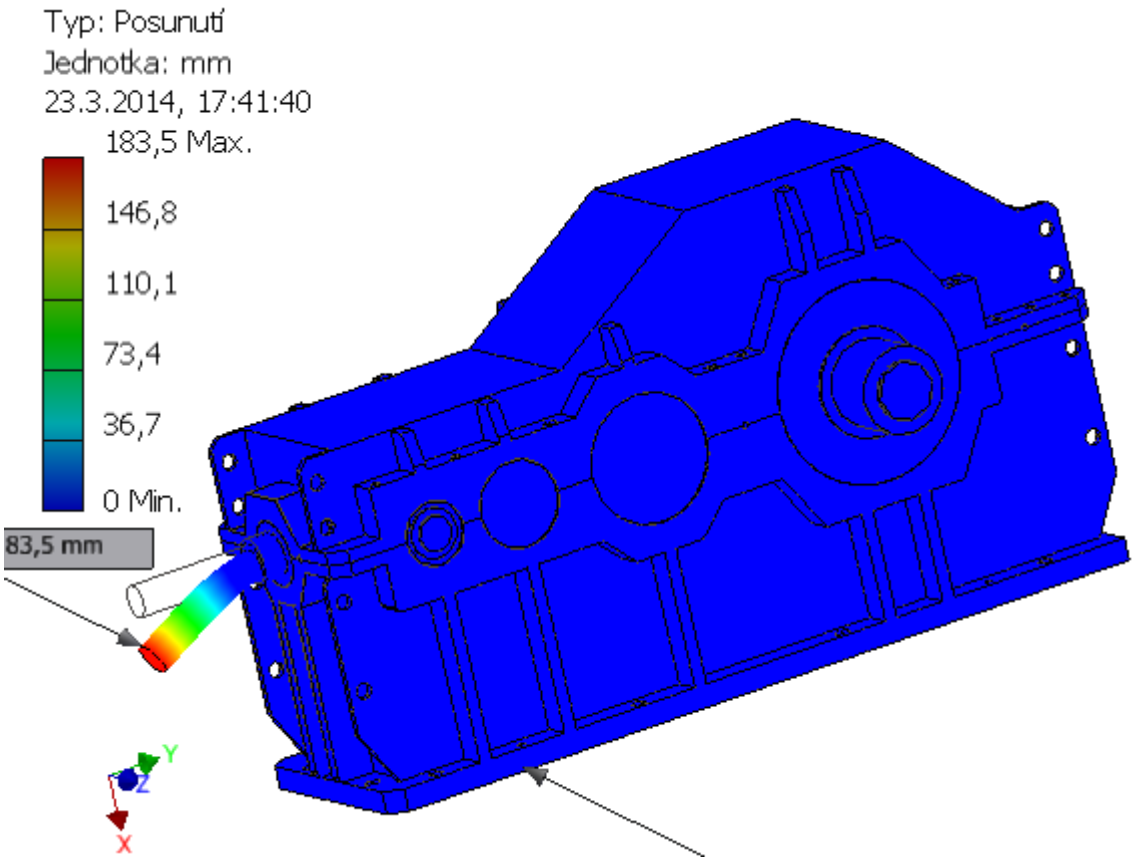


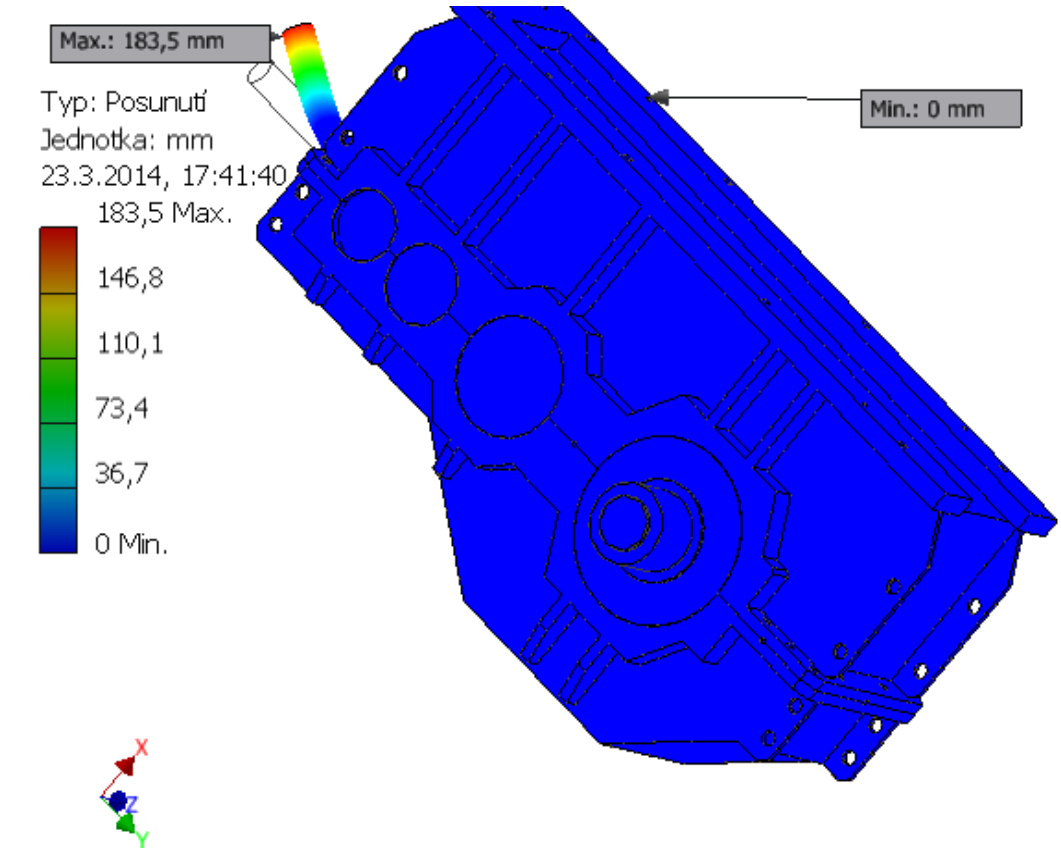
⊟ F3 228,10 Hz Posunutí



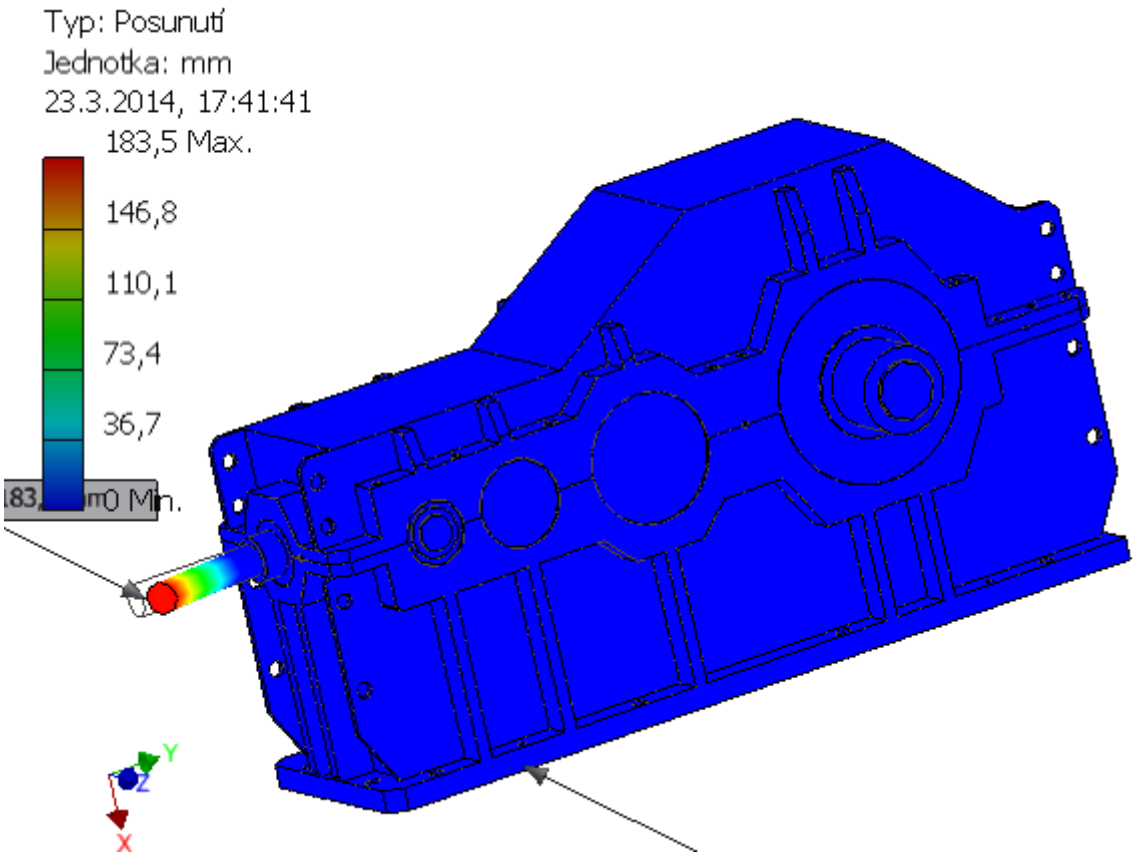


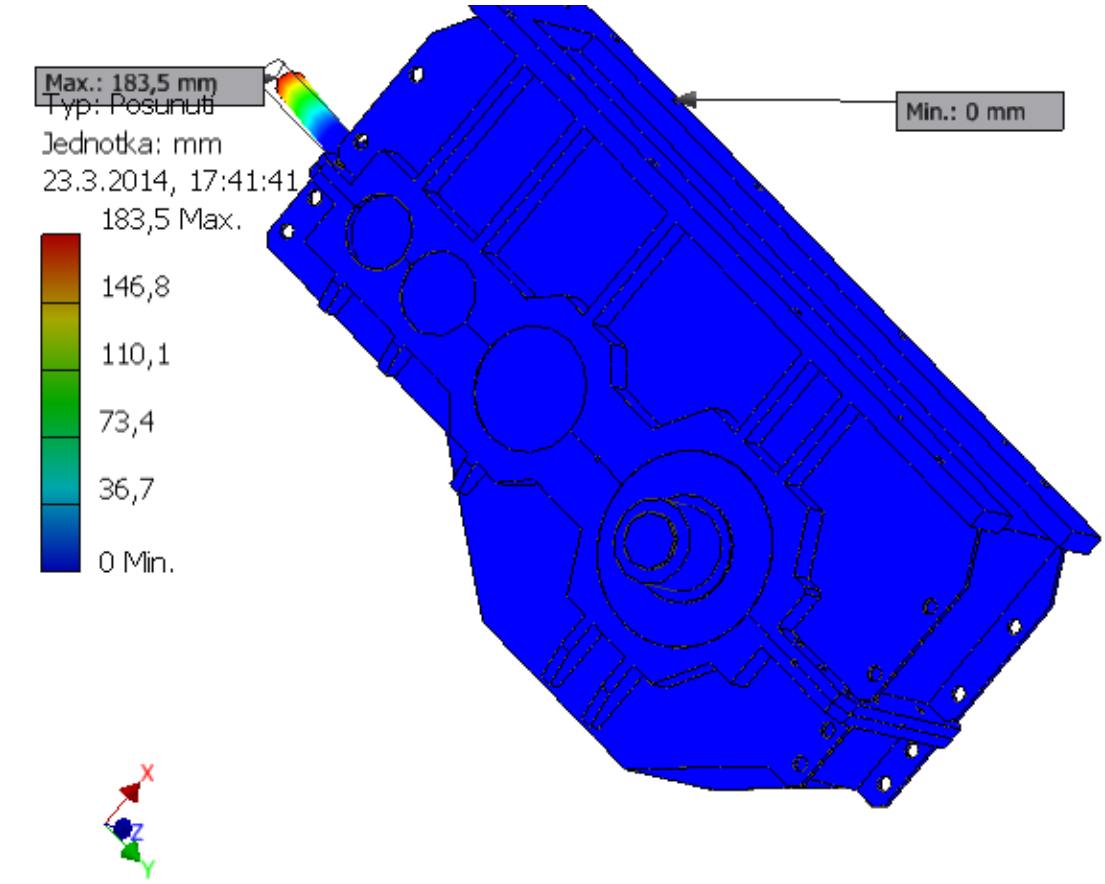
⊟ F4 313,22 Hz Posunutí



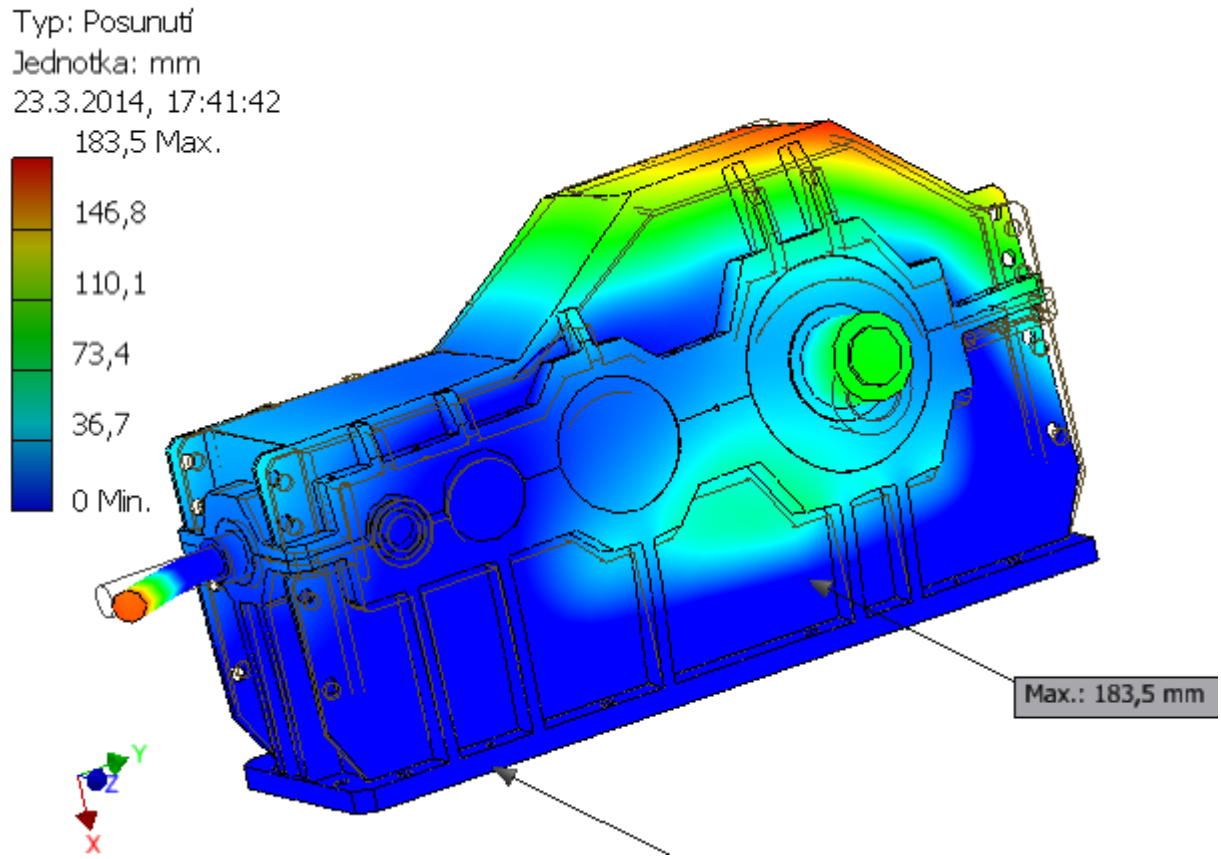


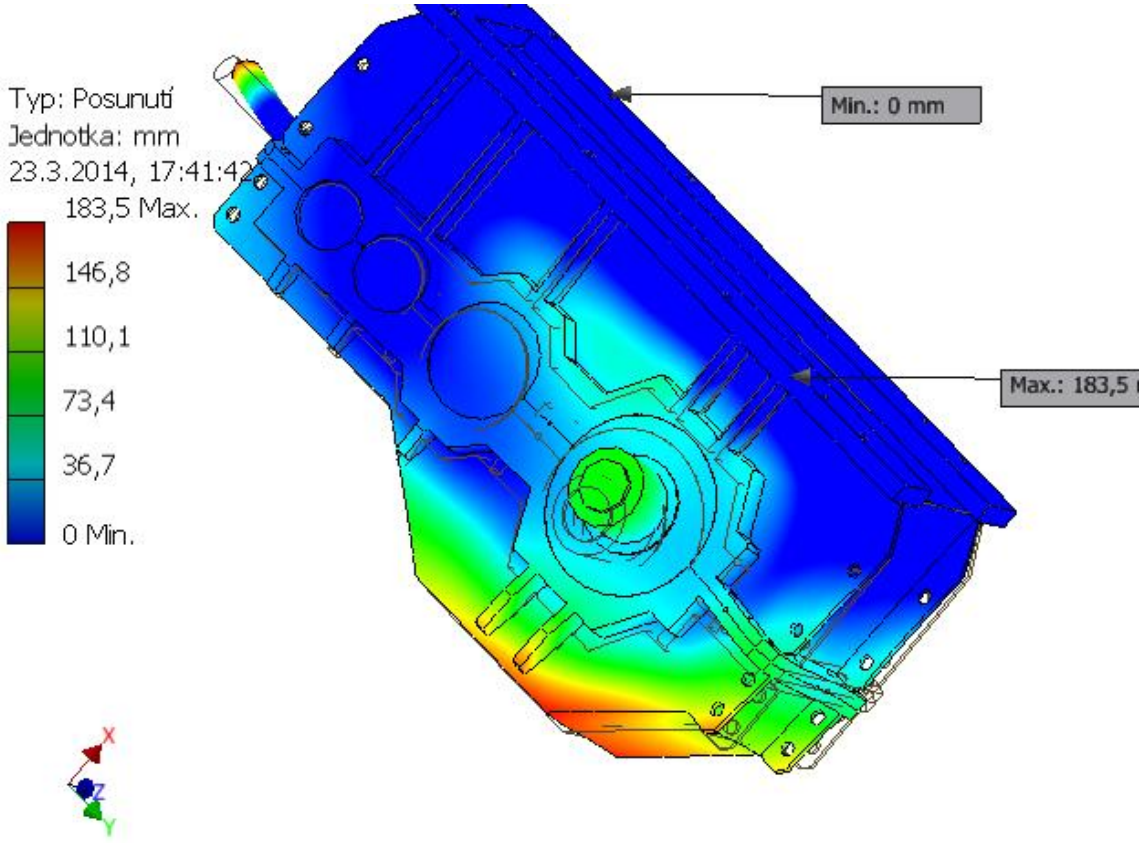
⊟ F5 318,77 Hz Posunutí



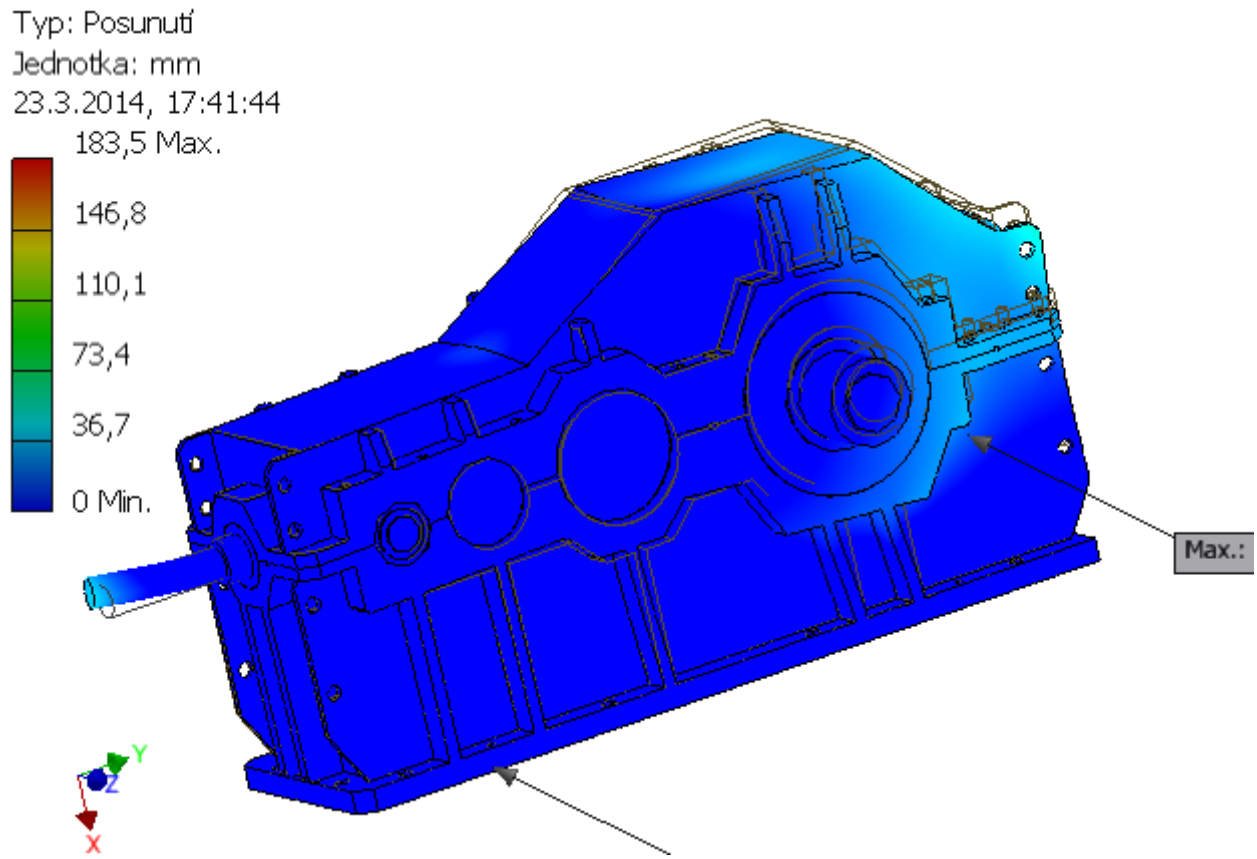


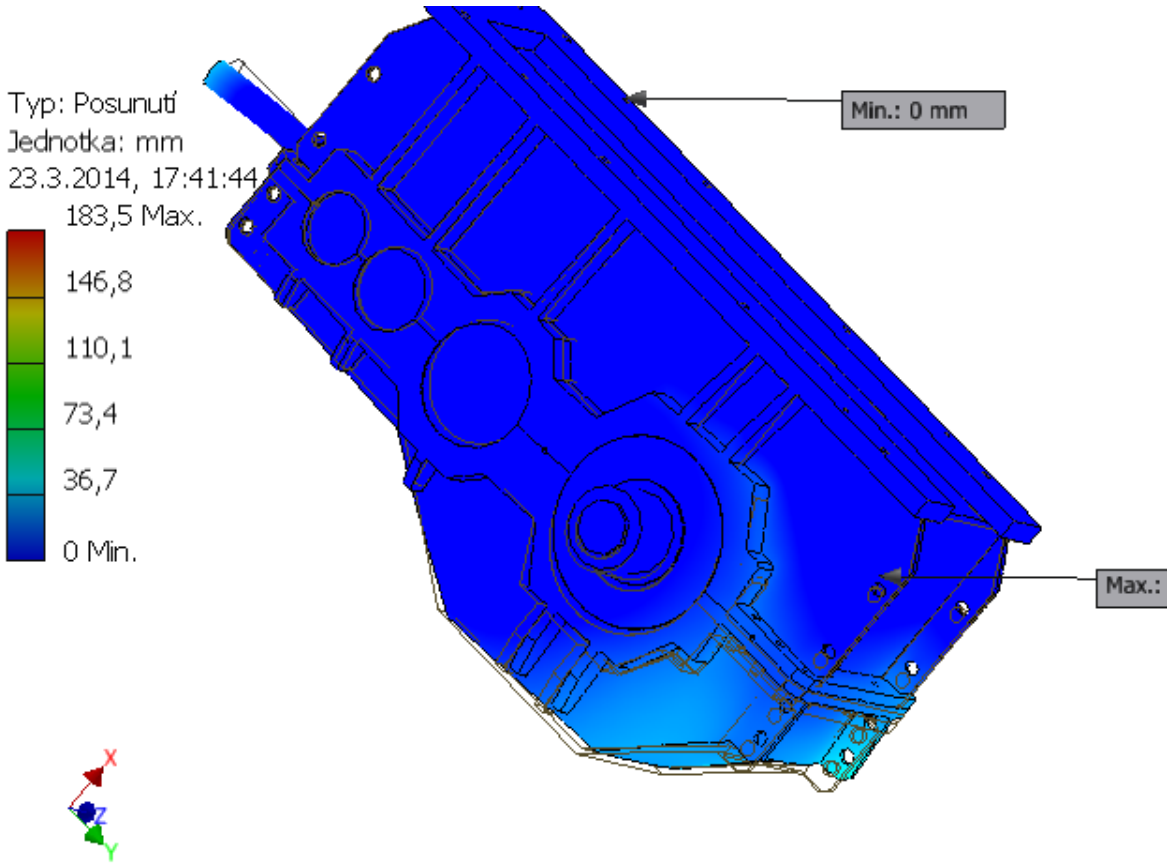
⊟ **F6 383,72 Hz Posunutí**



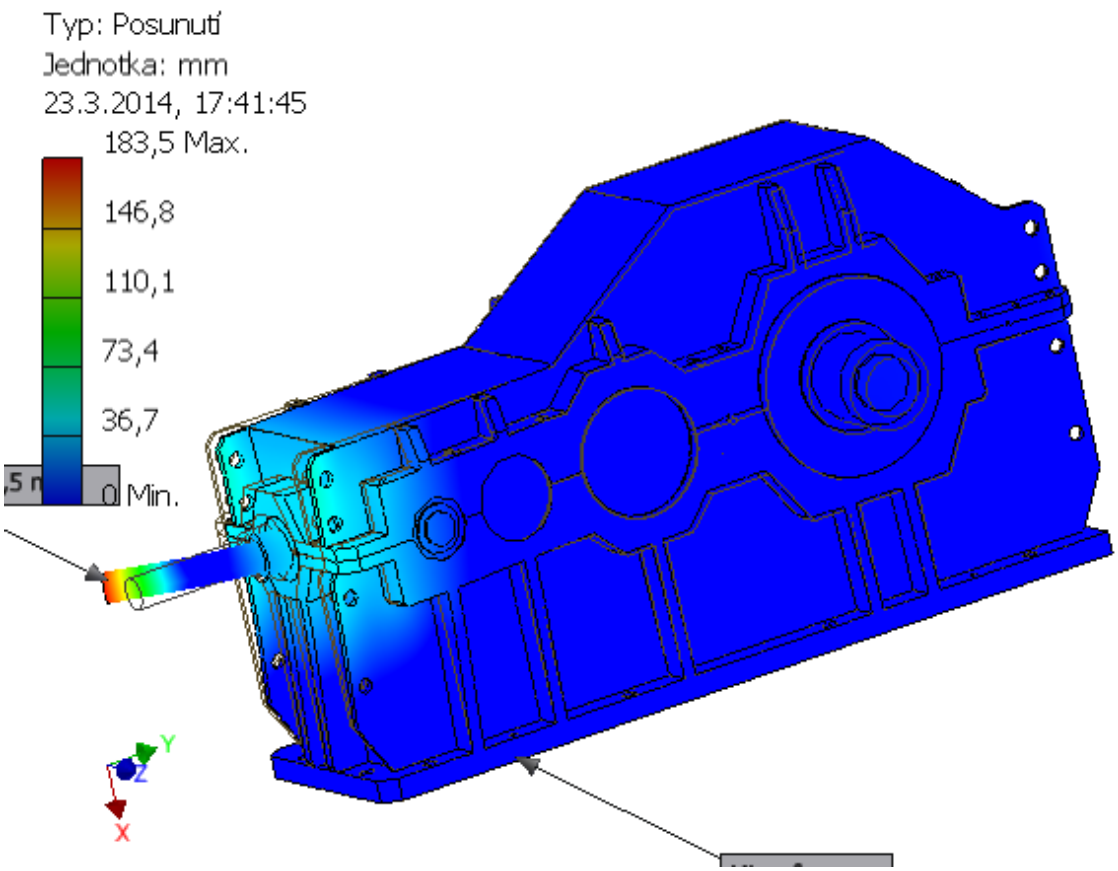


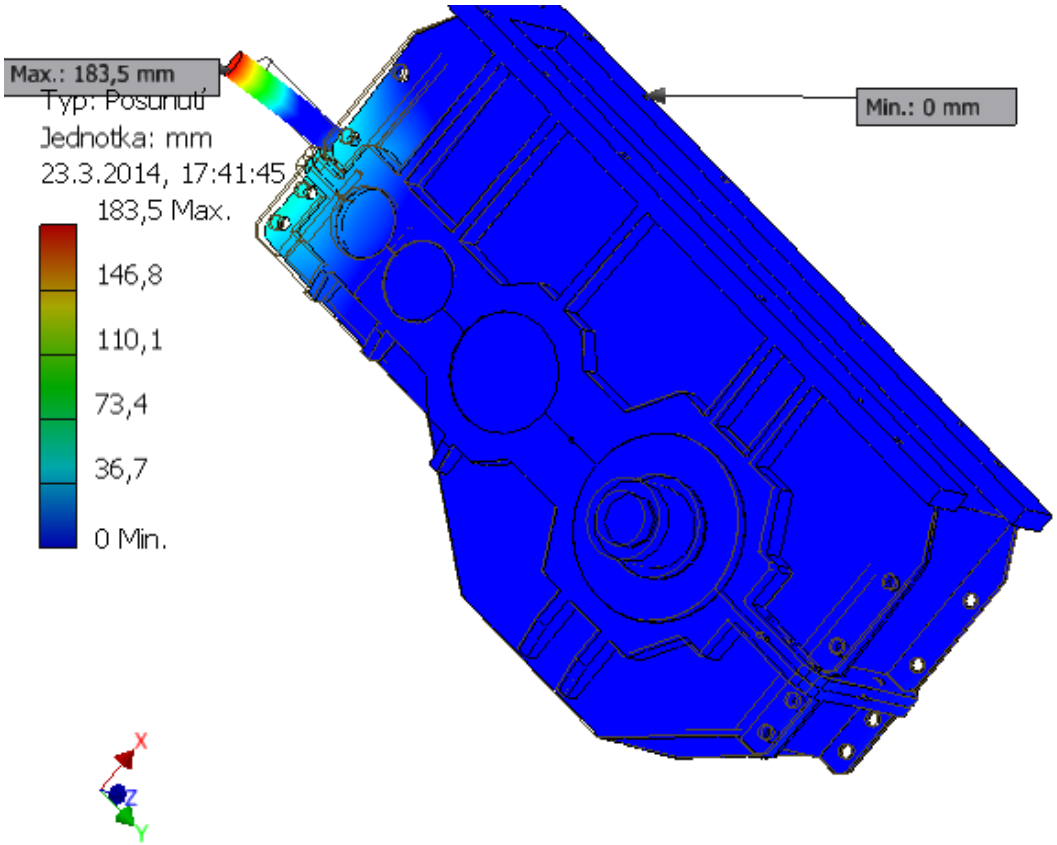
⊟ F7 405,67 Hz Posunutí





⊟ **F8 427,56 Hz Posunutí**





D:\Stary_disk\dokumenty_old\Inventor\DP\Skrin_nova_MKP_22_3.iam

Zpráva pevnostní analýzy

Autodesk®

Analyzovaný soubor:	Skrin_nova_MKP_26_3.iam
Verze aplikace Autodesk Inventor:	2013 (Build 170138000, 138)
Datum vyhotovení:	26.3.2014, 23:29
Autor simulace:	Lenka
Souhrn:	

⊟ Informace o projektu (iVlastnosti)

⊟ Projekt

Číslo součásti	Skrin_nova_MKP_26_3
Kreslil	Lenka
Náklady	0,00 Kč
Datum vytvoření	18.3.2014

⊟ Stav

Stav návrhu	Rozpracováno

⊟ Fyzické

Hmotnost	3910,17 kg
Plocha	29833600 mm^2
Objem	497477000 mm^3
Těžiště	x=178,935 mm y=-1293,49 mm z=0,353937 mm

Poznámka: Fyzikální hodnoty se mohou lišit od fyzikálních hodnot použitých v analýze MKP uvedené dále.

⊟ Simulace:1

Obecné cíle a nastavení:

Cíl návrhu	Jediný bod
Typ simulace	Statická analýza
Datum poslední úpravy	26.3.2014, 23:23
Zjistit a odstranit režimy tuhého tělesa	Ne
Oddělovat napětí na povrchu dotyků	Ne
Analýza pohybového zatížení	Ne

Nastavení sítě:

Prům. velikost prvku (zlomek průměru modelu)	0,03
Min. velikost prvku (zlomek prům. velikosti)	0,2
Součinitel zemních těles	1,5
Max. úhel pootočení	60 deg
Vytvořit zakřivené prvky sítě	Ne
Použít pro síť sestavy měření založená na součástech	Ano

⊟ Materiály

Název	Ocel, měkká, svařovaná	
Obecné	Měrná hmotnost	7,86 g/cm^3
	Mez kluzu v tahu	207 MPa
	Mez pevnosti v tahu	345 MPa
Napětí	Youngův modul	220 GPa
	Poissonova konstanta	0,275 ul
	Modul pružnosti	86,2745 GPa
Tepelné napětí	Koeficient roztažnosti	0,000012 ul/c
	Tepelná vodivost	56 W/(m K)
	Měrné teplo	460 J/(kg c)
Názvy součástí	Spodek_skrine_nový.ipt Viko_skrine_nove.ipt	

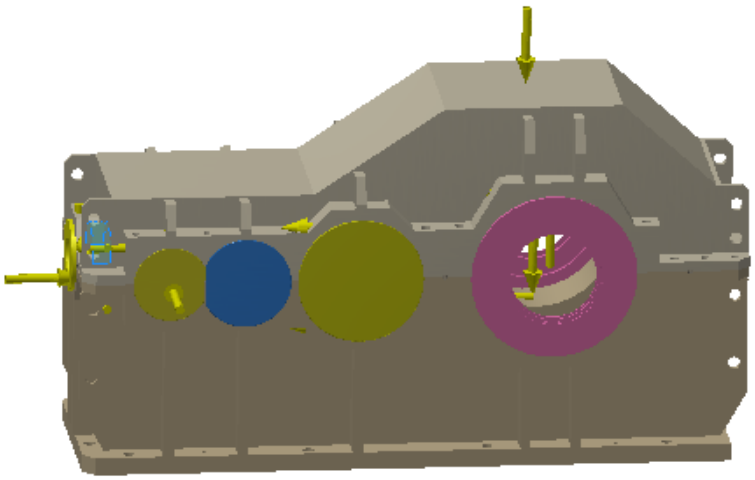
Název	Ocel, měkká

Obecné	Měrná hmotnost	7,86 g/cm^3
	Mez kluzu v tahu	207 MPa
	Mez pevnosti v tahu	345 MPa
Napětí	Youngův modul	220 GPa
	Poissonova konstanta	0,275 ul
	Modul pružnosti	86,2745 GPa
Tepelné napětí	Koeficient roztažnosti	0,000012 ul/c
	Tepelná vodivost	56 W/(m K)
	Měrné teplo	460 J/(kg c)
Názvy součástí	Krouzek_na_hridel_IV_novy.ipt Krouzek_na_hridel_IV_novy.ipt Vicko_k_hrideli_III_nove.ipt Vicko_k_hrideli_III_nove.ipt Vicko_k_hrideli_II_nove.ipt Vicko_k_hrideli_II_nove.ipt Vicko_k_hrideli_I_nove.ipt Vicko_k_hrideli_I_b_nove.ipt Vicko_k_hrideli_0_nove.ipt	

⊟ Provozní podmínky

⊟ Zatížení ložiska:1

Typ zatížení	Zatížení ložiska
Velikost	65400,000 N
Vektor X	-65400,000 N
Vektor Y	0,000 N

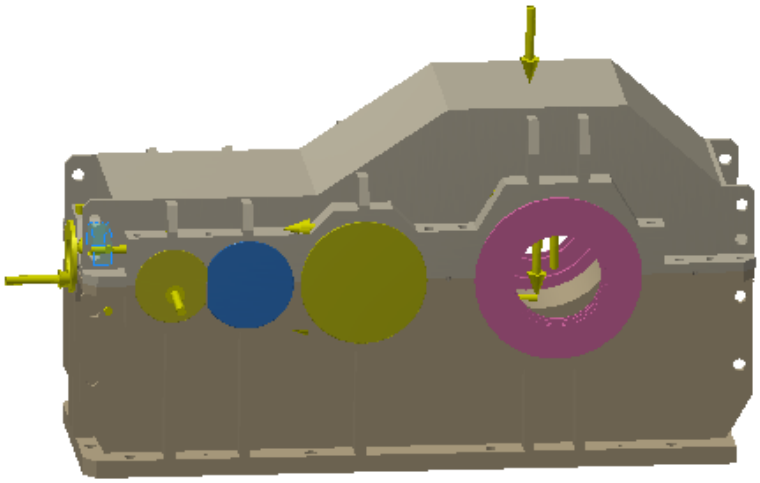


⊟ Vybrané plochy

⊟ Zatížení ložiska:2

Typ zatížení	Zatížení ložiska
Velikost	25750,000 N
Vektor X	0,000 N
Vektor Y	0,000 N

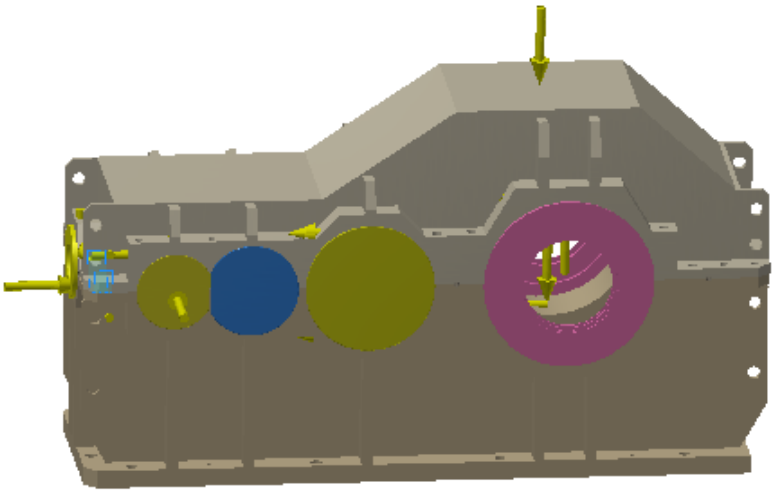
⊟ Vybrané plochy



⊟ Zatížení ložiska:3

Typ zatížení	Zatížení ložiska
Velikost	25750,000 N
Vektor X	0,000 N
Vektor Y	0,000 N

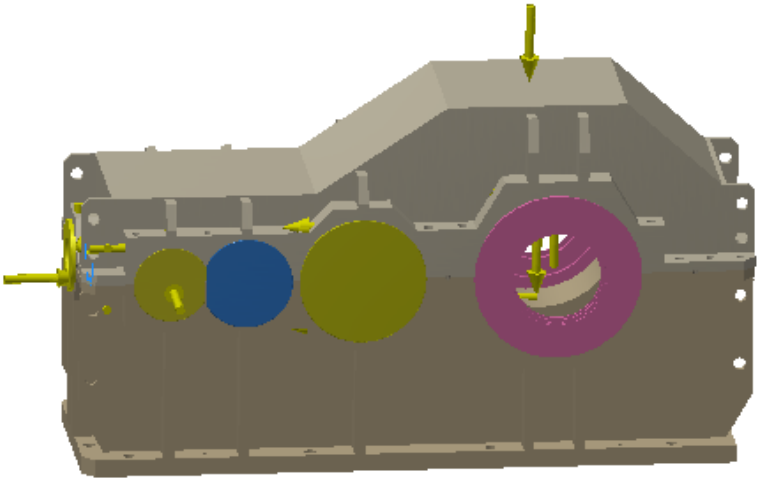
⊟ Vybrané plochy



⊟ Síla:1

Typ zatížení	Síla
Velikost	29700,000 N
Vektor X	0,000 N
Vektor Y	-29700,000 N
Vektor Z	0,000 N

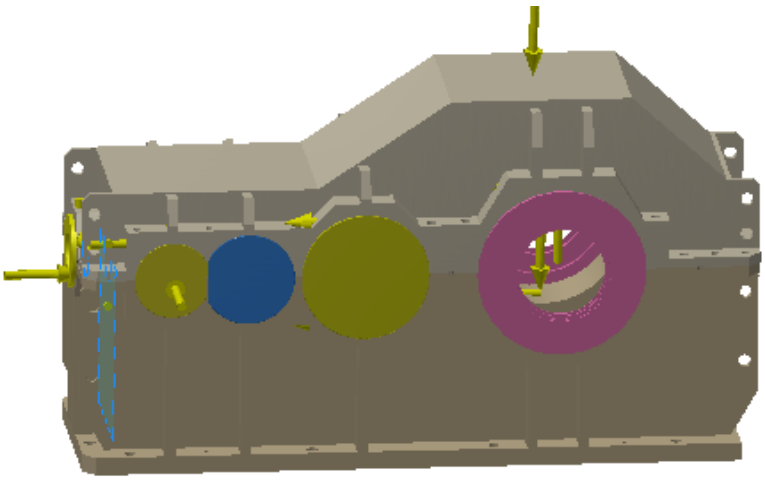
⊟ Vybrané plochy



⊟ Síla:2

Typ zatížení	Síla
Velikost	34400,000 N
Vektor X	0,000 N
Vektor Y	34400,000 N
Vektor Z	-0,000 N

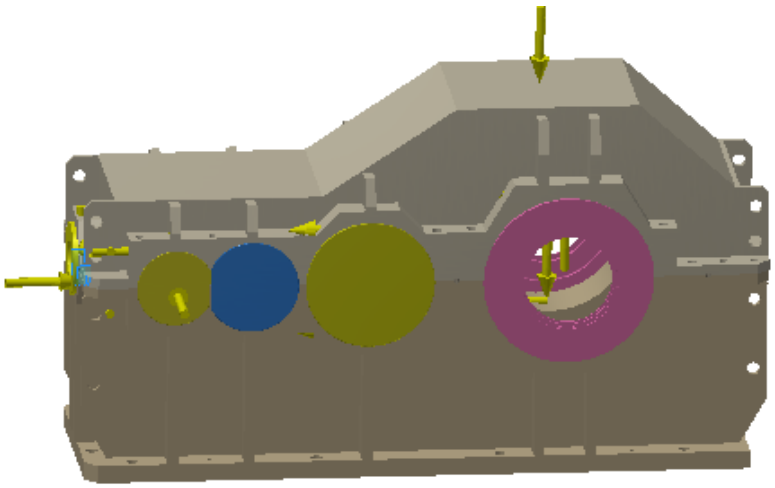
⊟ Vybrané plochy



⊟ Zatížení ložiska:4

Typ zatížení	Zatížení ložiska
Velikost	11000,000 N
Vektor X	0,000 N
Vektor Y	0,000 N
Vektor Z	11000,000 N

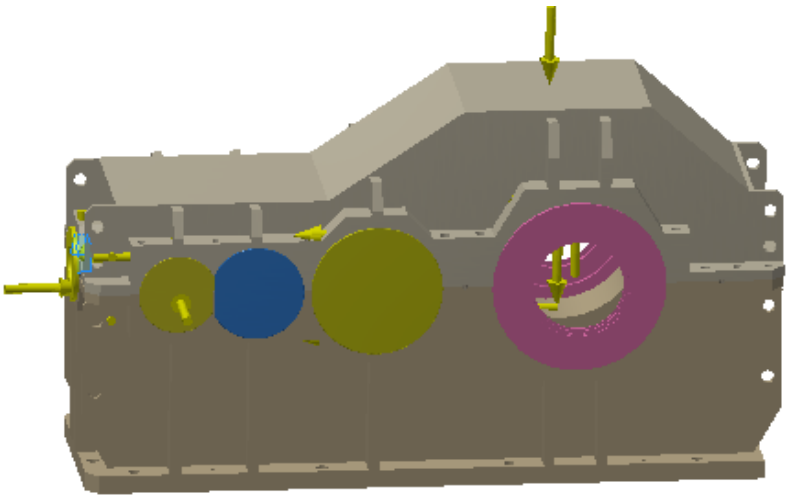
⊟ Vybrané plochy



⊟ Zatížení ložiska:5

Typ zatížení	Zatížení ložiska
Velikost	11000,000 N
Vektor X	0,000 N
Vektor Y	0,000 N
Vektor Z	11000,000 N

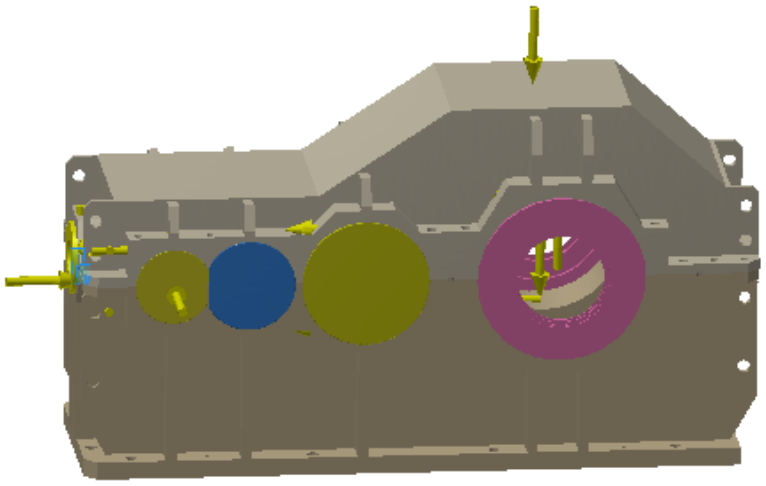
⊟ Vybrané plochy



⊟ Zatížení ložiska:6

Typ zatížení	Zatížení ložiska
Velikost	24500,000 N
Vektor X	24500,000 N
Vektor Y	0,000 N
Vektor Z	0,000 N

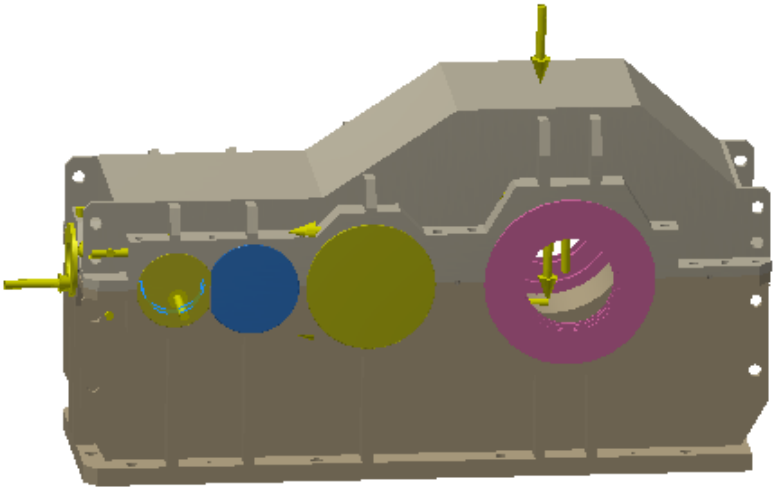
⊟ Vybrané plochy



⊟ Zatížení ložiska:7

Typ zatížení	Zatížení ložiska
Velikost	70000,000 N
Vektor X	70000,000 N
Vektor Y	0,000 N
Vektor Z	0,000 N

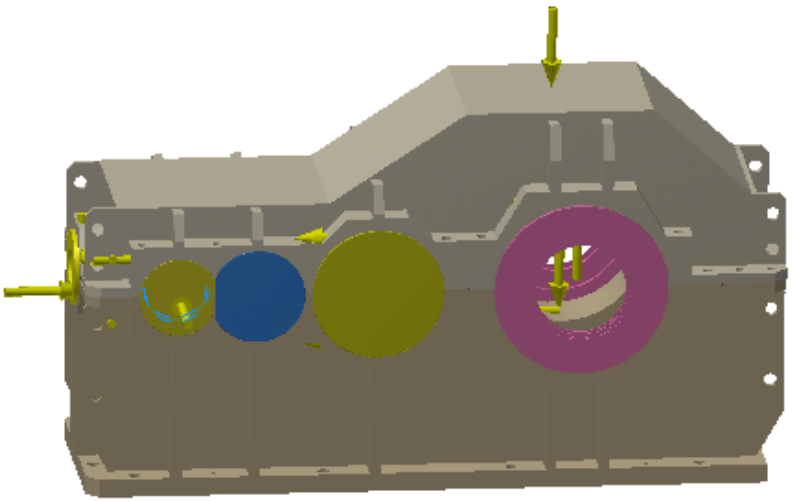
⊟ Vybrané plochy



⊟ Zatížení ložiska:8

Typ zatížení	Zatížení ložiska
Velikost	3000,000 N
Vektor X	0,000 N
Vektor Y	3000,000 N
Vektor Z	0,000 N

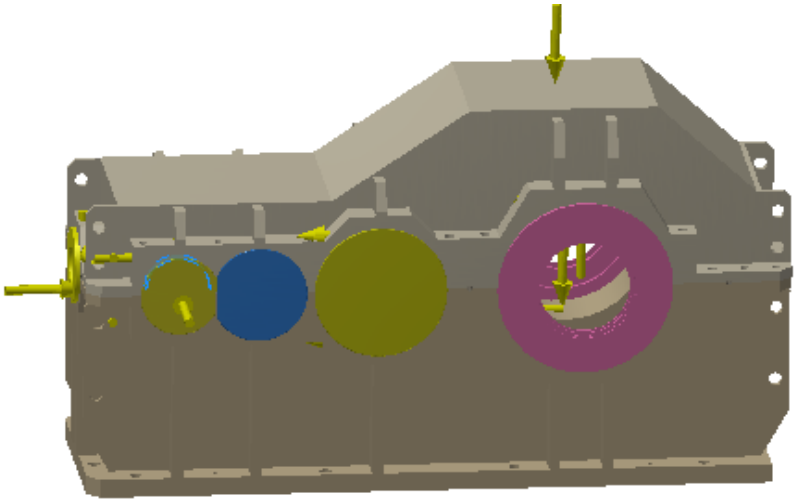
⊟ Vybrané plochy



⊟ Zatížení ložiska:9

Typ zatížení	Zatížení ložiska
Velikost	3000,000 N
Vektor X	0,000 N
Vektor Y	3000,000 N
Vektor Z	0,000 N

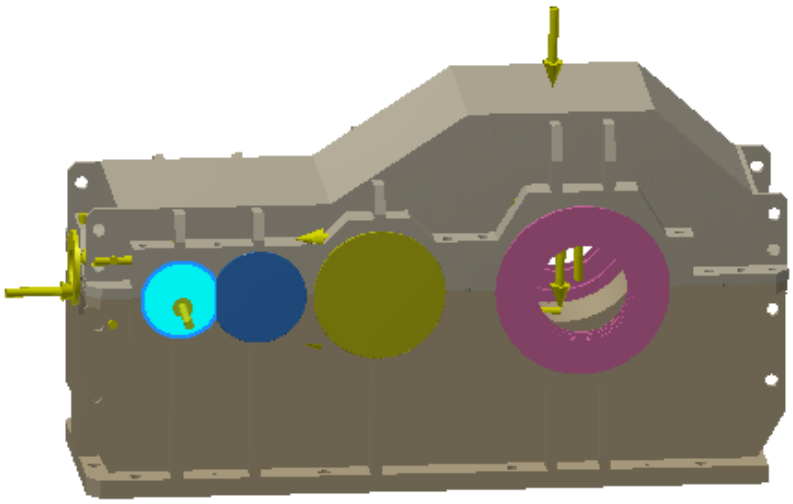
⊟ Vybrané plochy



⊟ Síla:3

Typ zatížení	Síla
Velikost	24000,000 N
Vektor X	0,000 N
Vektor Y	0,000 N
Vektor Z	-24000,000 N

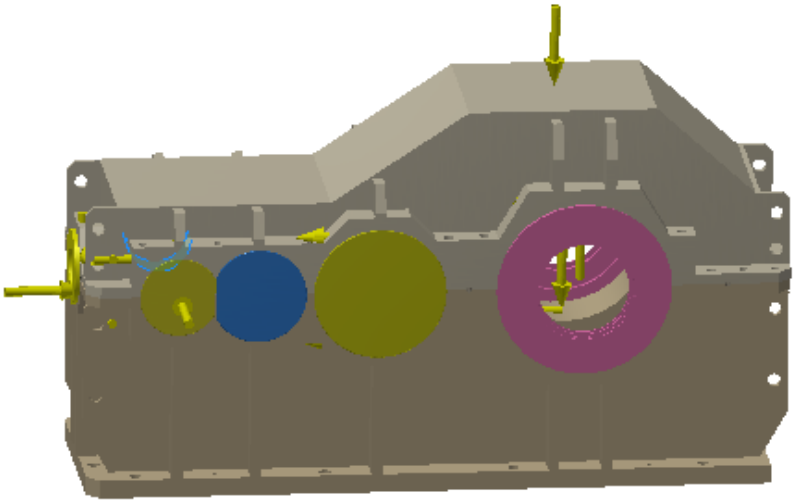
⊟ Vybrané plochy



⊟ Zatížení ložiska:10

Typ zatížení	Zatížení ložiska
Velikost	5000,000 N
Vektor X	0,000 N
Vektor Y	-5000,000 N
Vektor Z	0,000 N

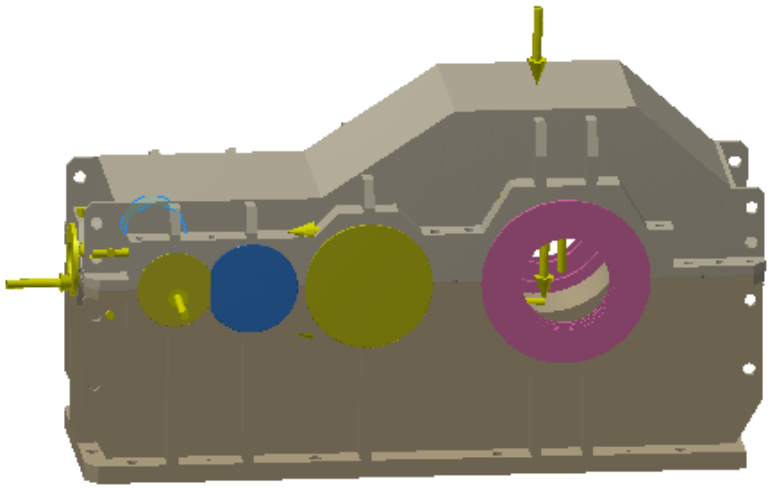
⊟ Vybrané plochy



Zatížení ložiska:11

Typ zatížení	Zatížení ložiska
Velikost	5000,000 N
Vektor X	0,000 N
Vektor Y	-5000,000 N
Vektor Z	0,000 N

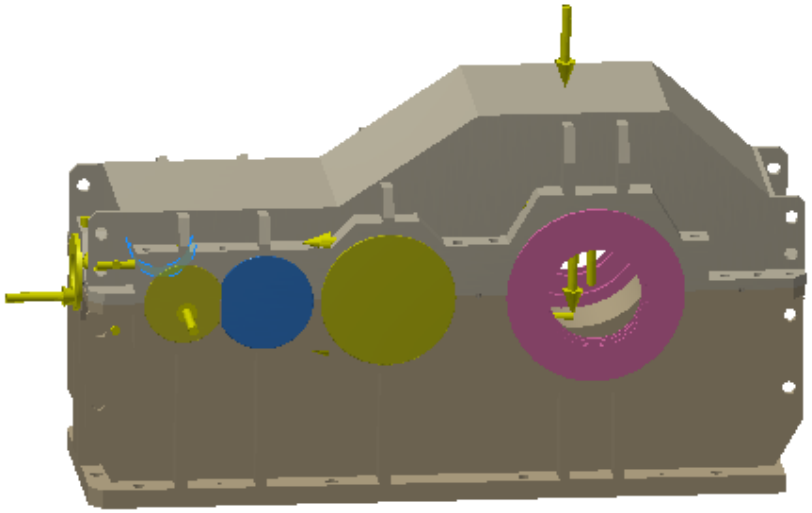
⊟ Vybrané plochy



⊟ Zatížení ložiska:12

Typ zatížení	Zatížení ložiska
Velikost	56000,000 N
Vektor X	56000,000 N
Vektor Y	0,000 N
Vektor Z	0,000 N

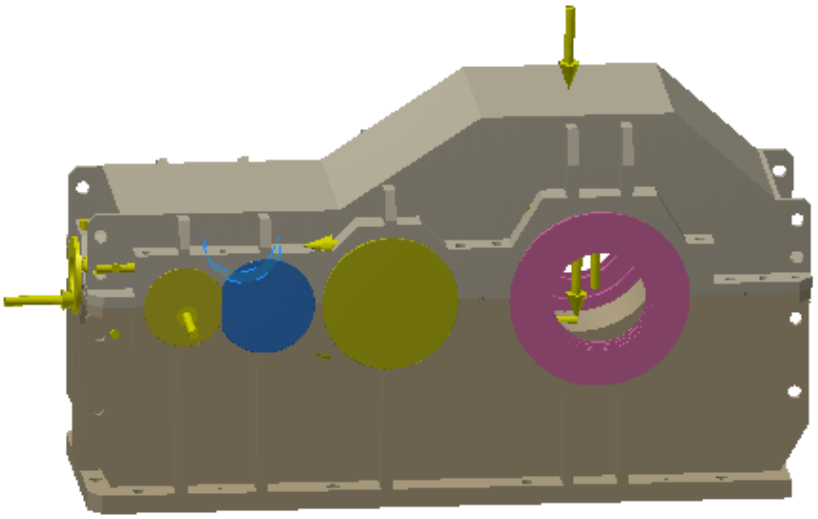
⊟ Vybrané plochy



⊟ Zatížení ložiska:13

Typ zatížení	Zatížení ložiska
Velikost	4000,000 N
Vektor X	0,000 N
Vektor Y	-4000,000 N
Vektor Z	0,000 N

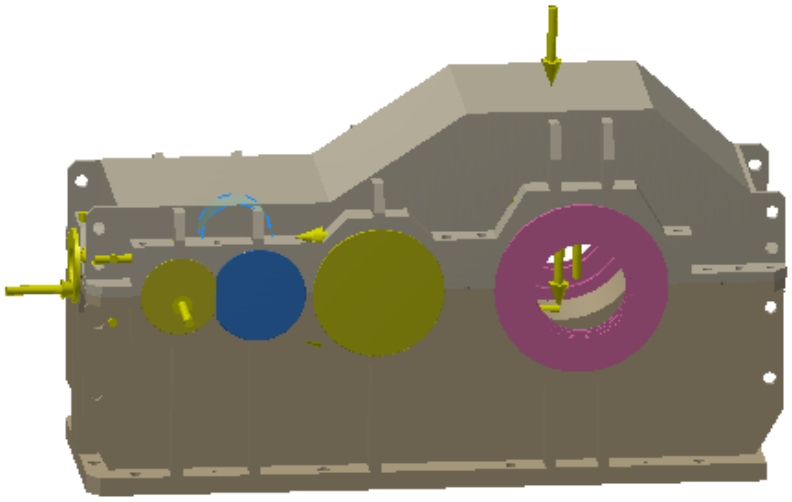
⊟ Vybrané plochy



⊟ Zatížení ložiska:14

Typ zatížení	Zatížení ložiska
Velikost	4000,000 N
Vektor X	0,000 N
Vektor Y	-4000,000 N
Vektor Z	0,000 N

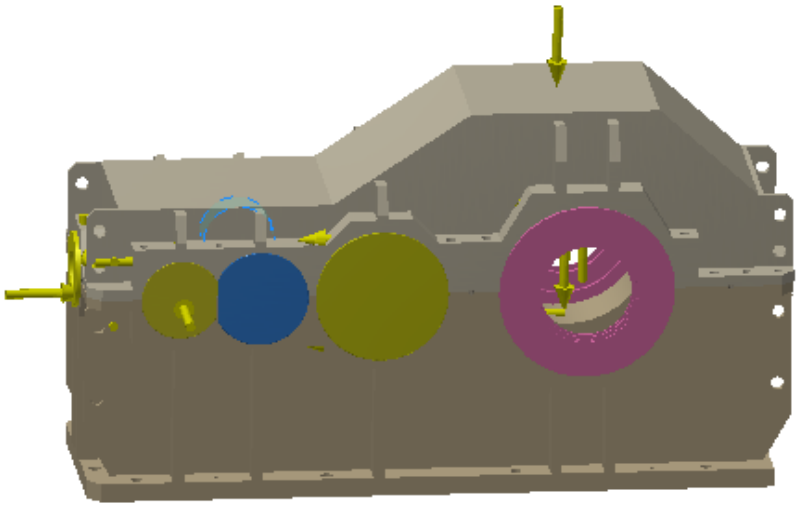
⊟ Vybrané plochy



⊟ Zatížení ložiska:15

Typ zatížení	Zatížení ložiska
Velikost	93400,000 N
Vektor X	-93400,000 N
Vektor Y	-0,507 N
Vektor Z	0,000 N

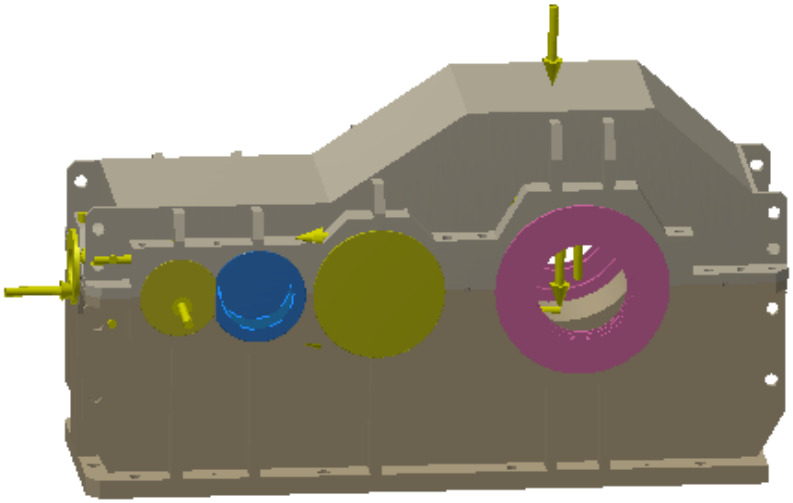
⊟ Vybrané plochy



⊟ Zatížení ložiska:16

Typ zatížení	Zatížení ložiska
Velikost	40350,000 N
Vektor X	0,000 N
Vektor Y	40350,000 N
Vektor Z	0,000 N

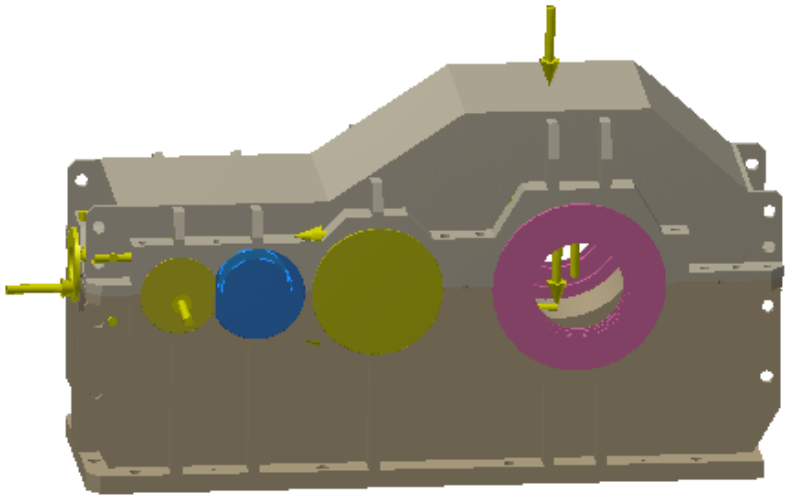
⊟ Vybrané plochy



⊟ Zatížení ložiska:17

Typ zatížení	Zatížení ložiska
Velikost	40350,000 N
Vektor X	0,000 N
Vektor Y	40350,000 N
Vektor Z	0,000 N

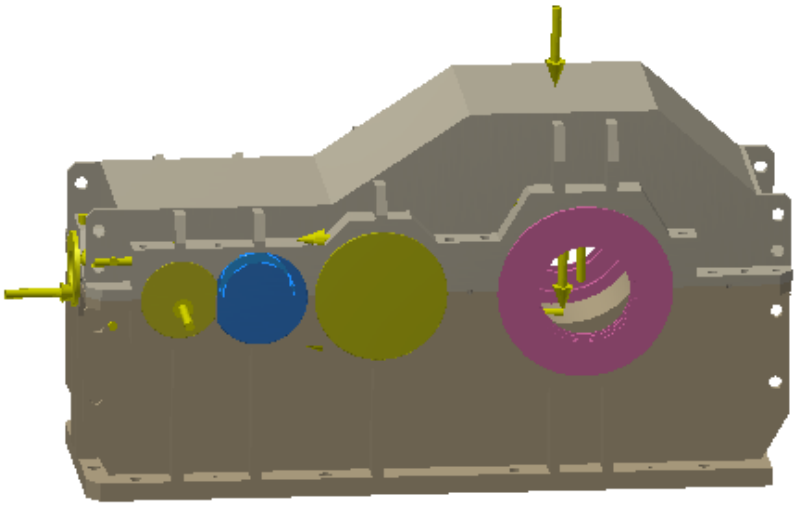
⊟ Vybrané plochy



⊟ Zatížení ložiska:18

Typ zatížení	Zatížení ložiska
Velikost	227000,000 N
Vektor X	-227000,000 N
Vektor Y	0,000 N
Vektor Z	0,000 N

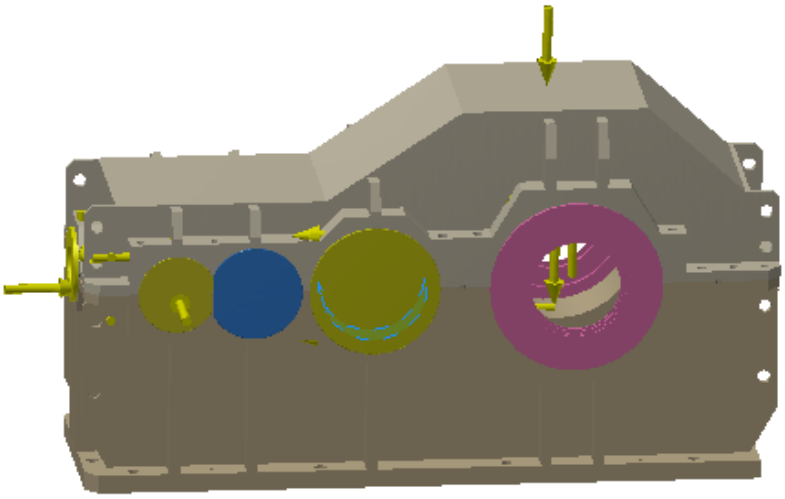
⊟ Vybrané plochy



⊟ Zatížení ložiska:19

Typ zatížení	Zatížení ložiska
Velikost	24500,000 N
Vektor X	0,000 N
Vektor Y	-24500,000 N
Vektor Z	0,000 N

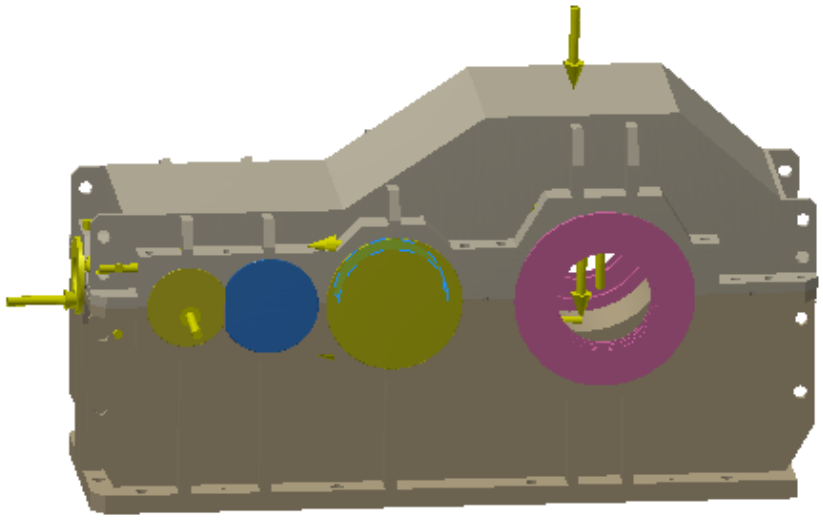
⊟ Vybrané plochy



⊟ Zatížení ložiska:20

Typ zatížení	Zatížení ložiska
Velikost	24500,000 N
Vektor X	0,000 N
Vektor Y	-24500,000 N
Vektor Z	0,000 N

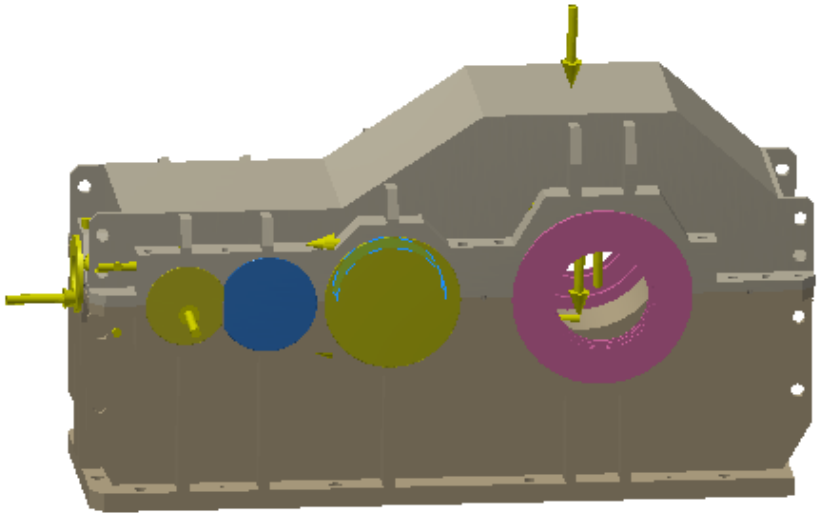
⊟ Vybrané plochy



⊟ Zatížení ložiska:21

Typ zatížení	Zatížení ložiska
Velikost	421400,000 N
Vektor X	-421400,000 N
Vektor Y	0,000 N
Vektor Z	0,000 N

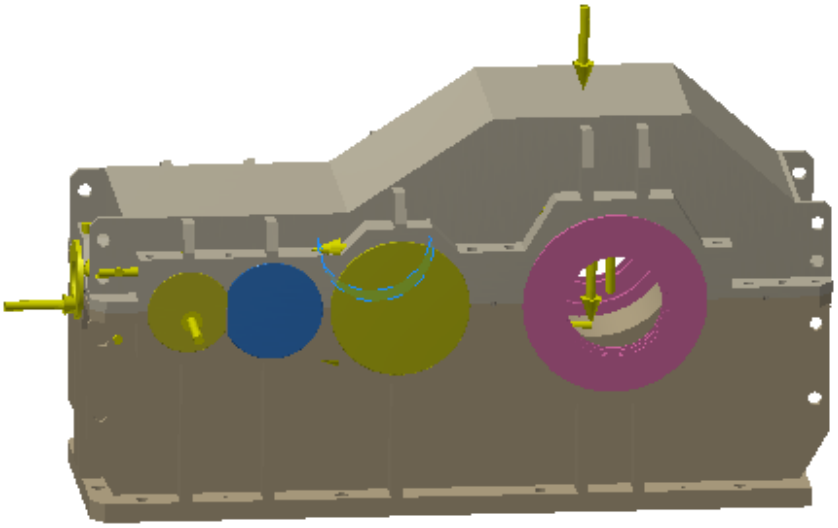
⊟ Vybrané plochy



⊟ Zatížení ložiska:22

Typ zatížení	Zatížení ložiska
Velikost	78700,000 N
Vektor X	0,000 N
Vektor Y	78700,000 N
Vektor Z	-0,000 N

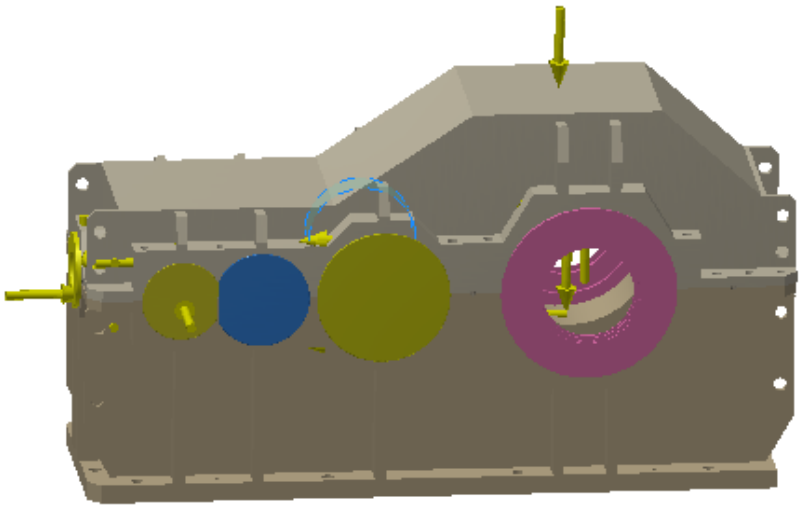
⊟ Vybrané plochy



⊟ Zatížení ložiska:23

Typ zatížení	Zatížení ložiska
Velikost	78700,000 N
Vektor X	0,000 N
Vektor Y	78700,000 N
Vektor Z	-0,000 N

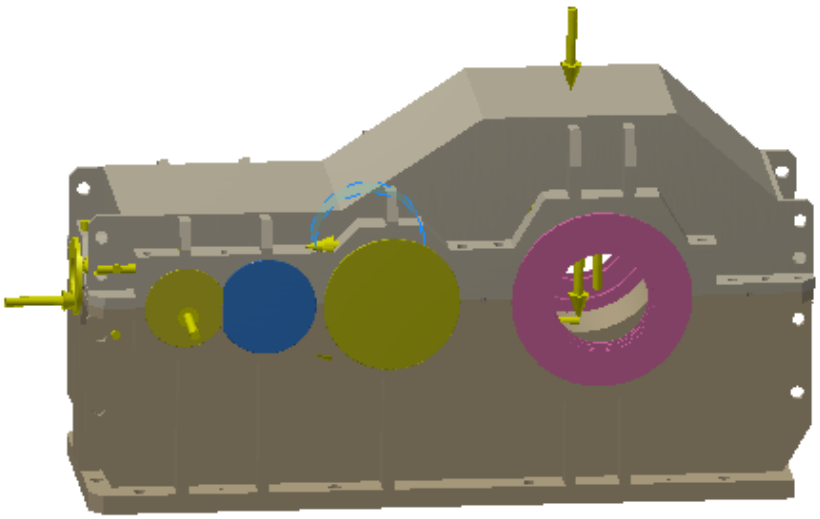
⊟ Vybrané plochy



⊟ Zatížení ložiska:24

Typ zatížení	Zatížení ložiska
Velikost	334600,000 N
Vektor X	-334600,000 N
Vektor Y	0,000 N
Vektor Z	0,000 N

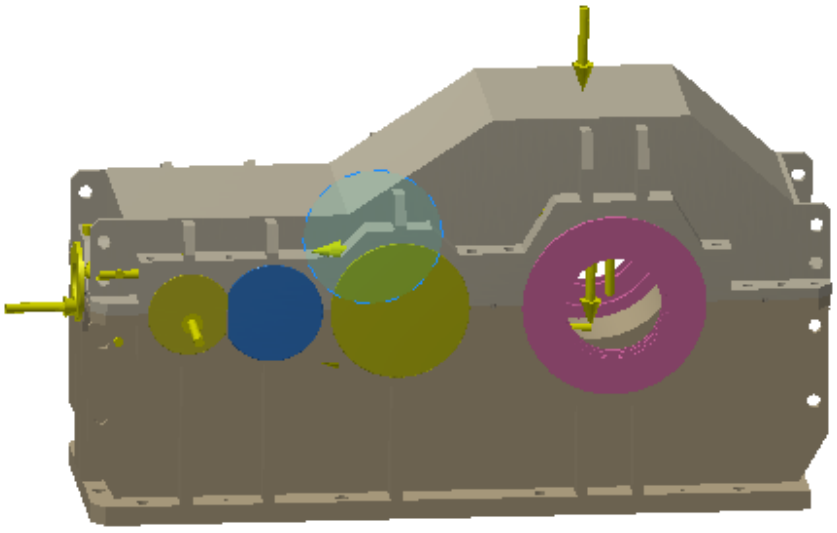
⊟ Vybrané plochy



⊟ Síla:4

Typ zatížení	Síla
Velikost	87400,000 N
Vektor X	0,000 N
Vektor Y	-0,000 N
Vektor Z	-87400,000 N

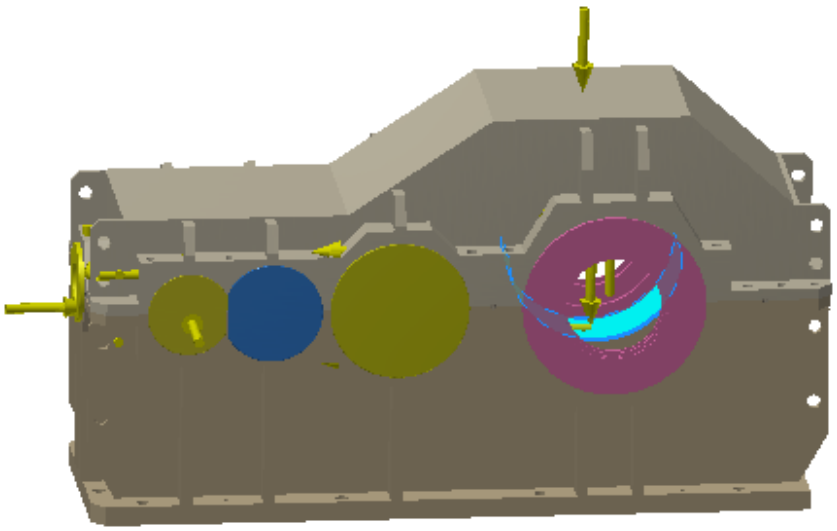
⊟ Vybrané plochy



⊟ Zatížení ložiska:25

Typ zatížení	Zatížení ložiska
Velikost	800000,000 N
Vektor X	0,000 N
Vektor Y	-800000,000 N
Vektor Z	0,000 N

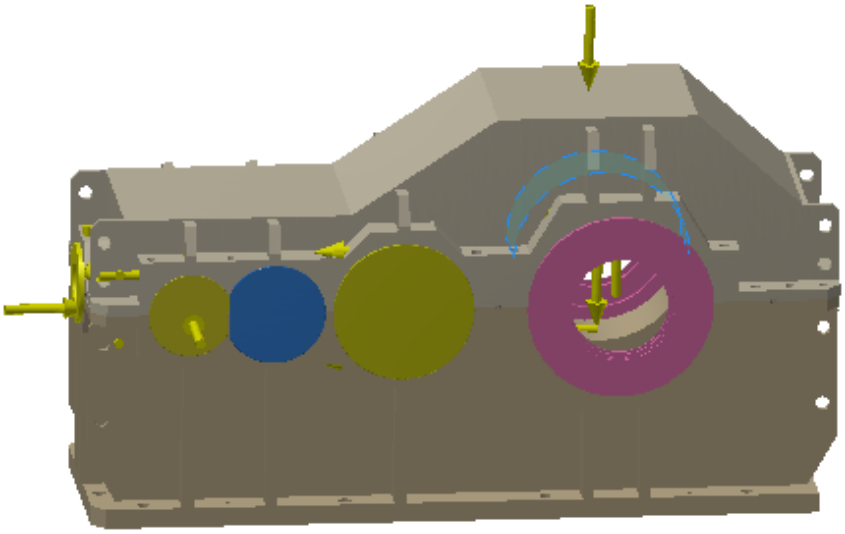
⊟ Vybrané plochy



⊟ Zatížení ložiska:26

Typ zatížení	Zatížení ložiska
Velikost	800000,000 N
Vektor X	0,000 N
Vektor Y	-800000,000 N
Vektor Z	0,000 N

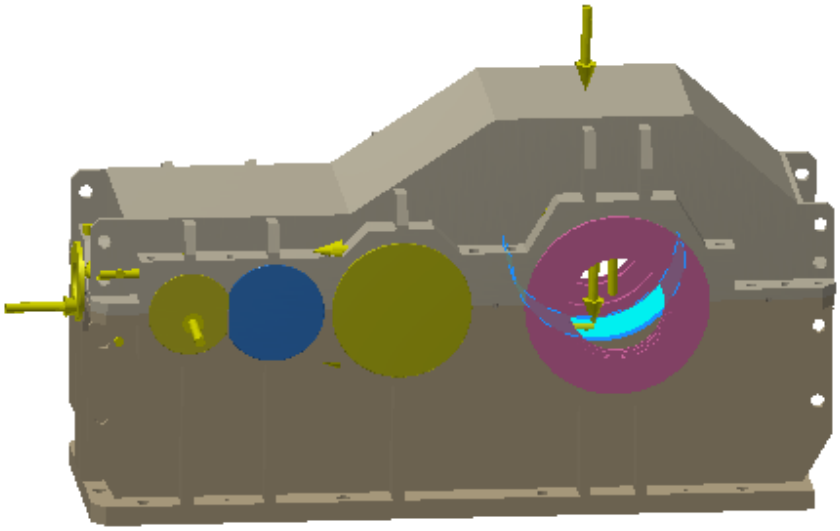
⊟ Vybrané plochy



⊟ Zatížení ložiska:27

Typ zatížení	Zatížení ložiska
Velikost	2679000,000 N
Vektor X	2679000,000 N
Vektor Y	0,000 N
Vektor Z	0,000 N

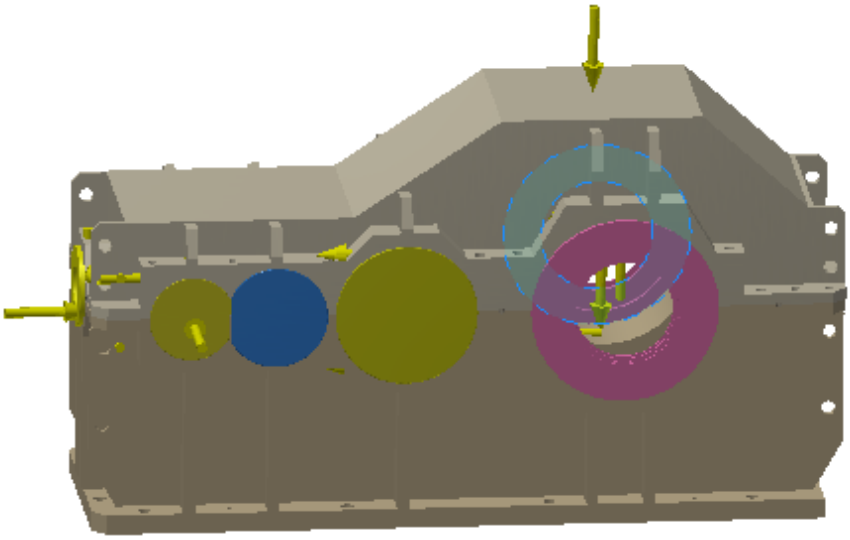
⊟ Vybrané plochy



⊟ Síla:5

Typ zatížení	Síla
Velikost	136000,000 N
Vektor X	0,000 N
Vektor Y	-0,000 N
Vektor Z	-136000,000 N

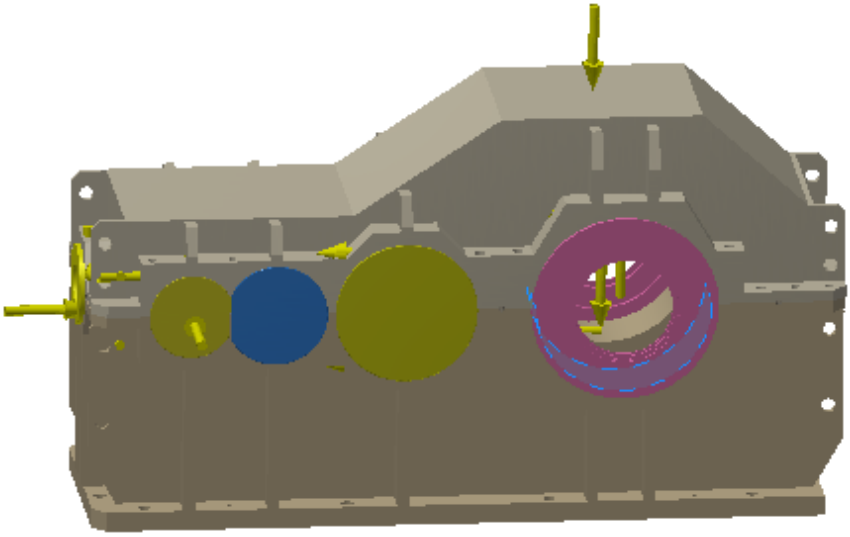
⊟ Vybrané plochy



⊟ Síla:6

Typ zatížení	Síla
Velikost	241500,000 N
Vektor X	0,000 N
Vektor Y	241500,000 N
Vektor Z	0,000 N

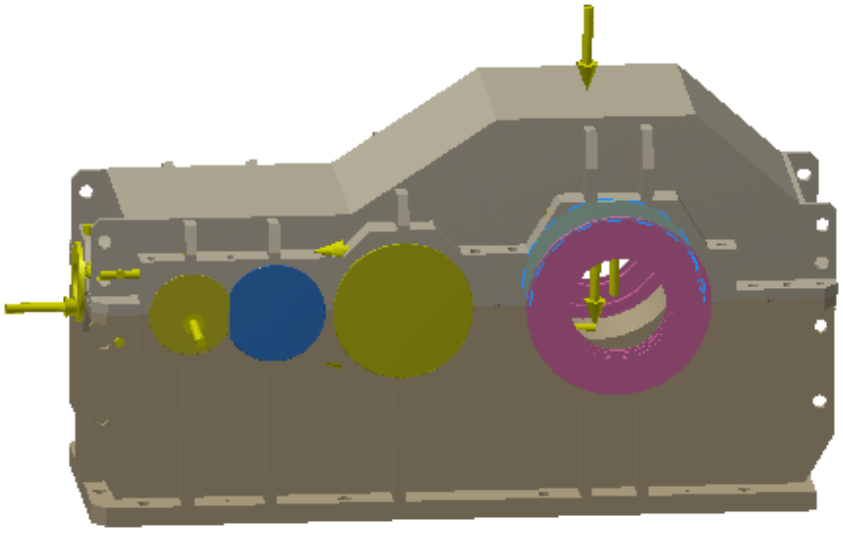
⊟ Vybrané plochy



⊟ Síla:7

Typ zatížení	Síla
Velikost	241500,000 N
Vektor X	0,000 N
Vektor Y	241500,000 N
Vektor Z	0,000 N

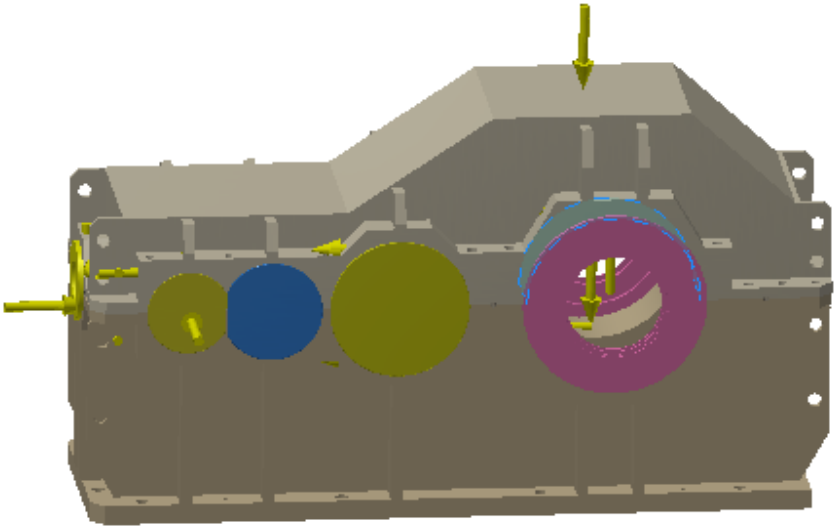
⊟ Vybrané plochy



⊟ Síla:8

Typ zatížení	Síla
Velikost	1165000,000 N
Vektor X	-1165000,000 N
Vektor Y	0,000 N
Vektor Z	0,000 N

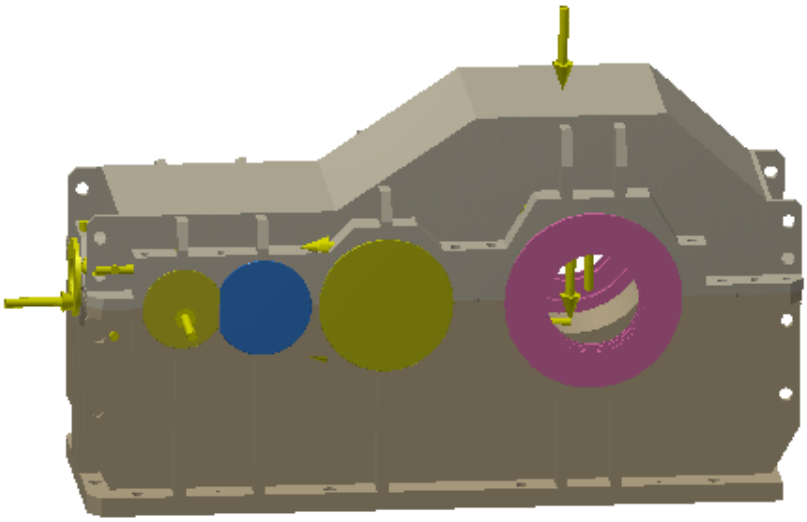
⊟ Vybrané plochy



⊟ Gravitace

Typ zatížení	Gravitace
Velikost	9810,000 mm/s^2
Vektor X	9810,000 mm/s^2
Vektor Y	-0,000 mm/s^2
Vektor Z	0,000 mm/s^2

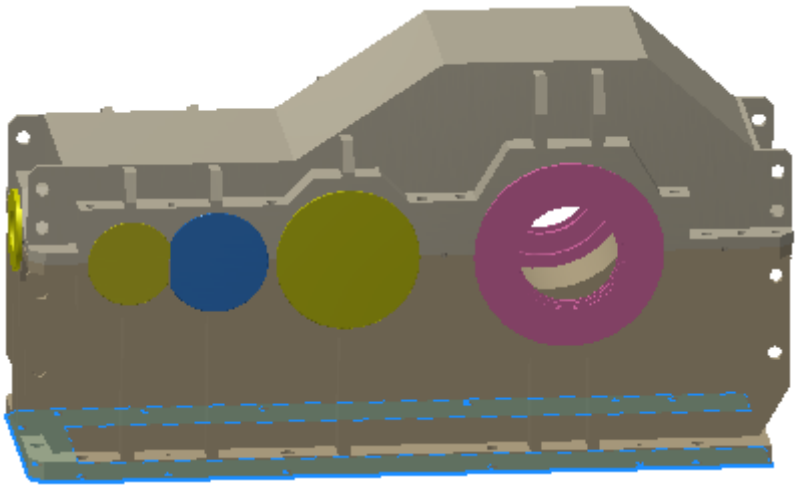
⊟ Vybrané plochy



⊟ Pevná vazba:1

Typ vazby	Pevná vazba

⊟ Vybrané plochy



⊟

Dotyky (Vázaný)

Název	Názvy součástí
Vázaný:1	Spodek_skrine_nový:1 Viko_skrine_nove:1
Vázaný:2	Spodek_skrine_nový:1 Viko_skrine_nove:1
Vázaný:3	Spodek_skrine_nový:1 Viko_skrine_nove:1
Vázaný:4	Spodek_skrine_nový:1 Viko_skrine_nove:1
Vázaný:5	Spodek_skrine_nový:1 Viko_skrine_nove:1
Vázaný:6	Spodek_skrine_nový:1 Viko_skrine_nove:1
Vázaný:7	Spodek_skrine_nový:1 Viko_skrine_nove:1
Vázaný:8	Spodek_skrine_nový:1 Viko_skrine_nove:1
Vázaný:9	Spodek_skrine_nový:1 Viko_skrine_nove:1
Vázaný:10	Spodek_skrine_nový:1 Krouzek_na_hridel_IV_novy:1
Vázaný:11	Spodek_skrine_nový:1 Krouzek_na_hridel_IV_novy:1
Vázaný:12	Spodek_skrine_nový:1 Krouzek_na_hridel_IV_novy:2
Vázaný:13	Spodek_skrine_nový:1 Krouzek_na_hridel_IV_novy:2
Vázaný:14	Spodek_skrine_nový:1 Vicko_k_hrideli_III_nove:1
Vázaný:15	Spodek_skrine_nový:1 Vicko_k_hrideli_III_nove:1
Vázaný:16	Spodek_skrine_nový:1 Vicko_k_hrideli_III_nove:2
Vázaný:17	Spodek_skrine_nový:1 Vicko_k_hrideli_III_nove:2
Vázaný:18	Spodek_skrine_nový:1 Vicko_k_hrideli_II_nove:1
Vázaný:19	Spodek_skrine_nový:1 Vicko_k_hrideli_II_nove:1
Vázaný:20	Spodek_skrine_nový:1 Vicko_k_hrideli_II_nove:2
Vázaný:21	Spodek_skrine_nový:1 Vicko_k_hrideli_II_nove:2
Vázaný:22	Spodek_skrine_nový:1 Vicko_k_hrideli_I_nove:1
Vázaný:23	Spodek_skrine_nový:1 Vicko_k_hrideli_I_nove:1
Vázaný:24	Spodek_skrine_nový:1 Vicko_k_hrideli_I_b_nove:1
Vázaný:25	Spodek_skrine_nový:1 Vicko_k_hrideli_I_b_nove:1
Vázaný:26	Spodek_skrine_nový:1 Vicko_k_hrideli_0_nove:1
Vázaný:27	Spodek_skrine_nový:1 Vicko_k_hrideli_0_nove:1
Vázaný:28	Viko_skrine_nove:1 Krouzek_na_hridel_IV_novy:1
Vázaný:29	Viko_skrine_nove:1 Krouzek_na_hridel_IV_novy:1
Vázaný:30	Viko_skrine_nove:1 Krouzek_na_hridel_IV_novy:2
Vázaný:31	Viko_skrine_nove:1 Krouzek_na_hridel_IV_novy:2
Vázaný:32	Viko_skrine_nove:1 Vicko_k_hrideli_III_nove:1
Vázaný:33	Viko_skrine_nove:1 Vicko_k_hrideli_III_nove:1
Vázaný:34	Viko_skrine_nove:1 Vicko_k_hrideli_III_nove:2
Vázaný:35	Viko_skrine_nove:1 Vicko_k_hrideli_III_nove:2
Vázaný:36	Viko_skrine_nove:1 Vicko_k_hrideli_II_nove:1
Vázaný:37	Viko_skrine_nove:1 Vicko_k_hrideli_II_nove:1
Vázaný:38	Viko_skrine_nove:1 Vicko_k_hrideli_II_nove:2
Vázaný:39	Viko_skrine_nove:1 Vicko_k_hrideli_II_nove:2
Vázaný:40	Viko_skrine_nove:1 Vicko_k_hrideli_I_nove:1
Vázaný:41	Viko_skrine_nove:1 Vicko_k_hrideli_I_nove:1
Vázaný:42	Viko_skrine_nove:1 Vicko_k_hrideli_I_b_nove:1
Vázaný:43	Viko_skrine_nove:1 Vicko_k_hrideli_I_b_nove:1
Vázaný:44	Viko_skrine_nove:1 Vicko_k_hrideli_0_nove:1
Vázaný:45	Viko_skrine_nove:1 Vicko_k_hrideli_0_nove:1

⊟ Výsledky

⊟ Reakční síla a moment na vazbách

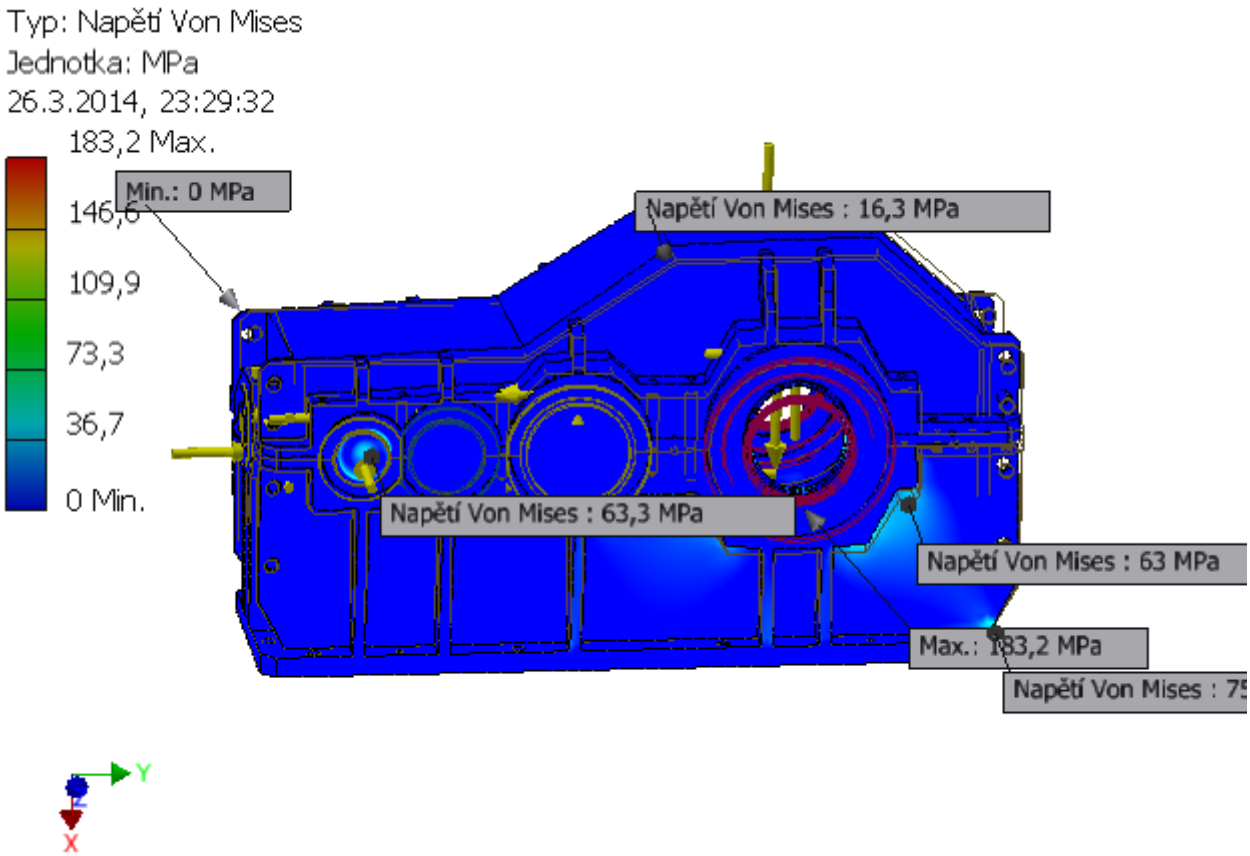
Název vazby	Reakční síla		Reakční moment	
	Velikost	Komponenta (X,Y,Z)	Velikost	Komponenta (X,Y,Z)
Pevná vazba:1	1125270 N	-561203 N	1503820 N m	554108 N m
		935201 N		1323930 N m
		276900 N		449047 N m

⊟ Souhrn výsledků

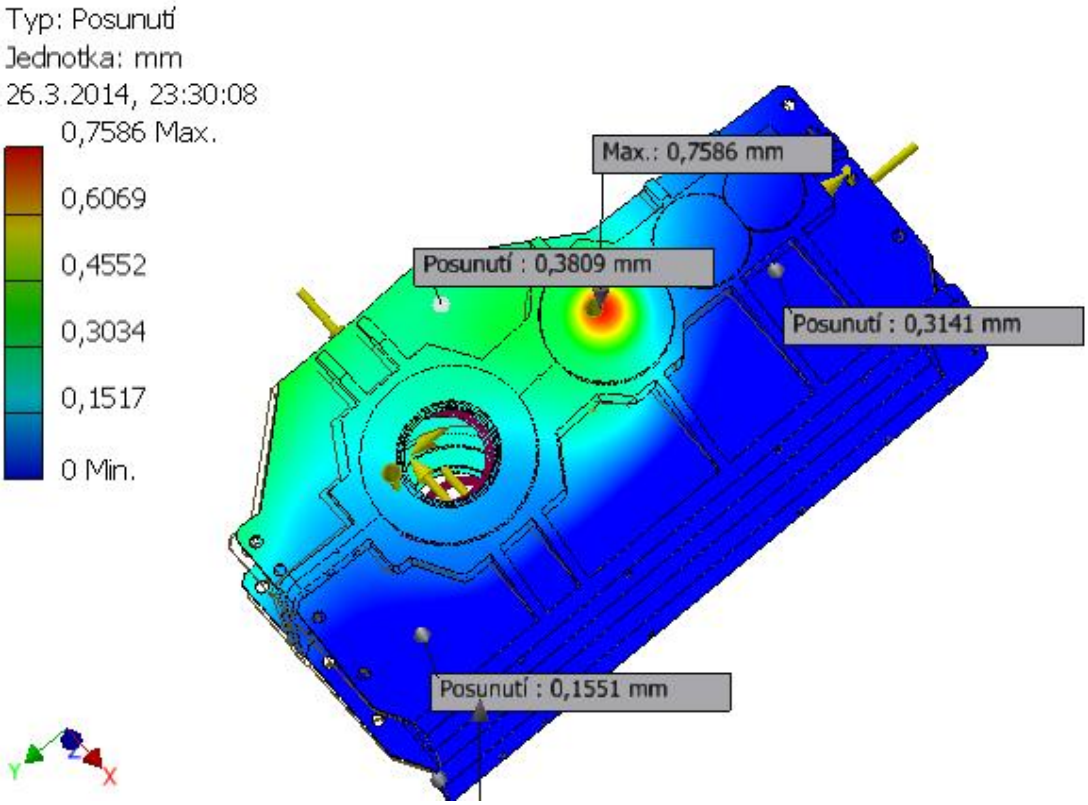
Název	Minimální	Maximální
Objem	497477000 mm^3	
Hmotnost	3910,17 kg	
Napětí Von Mises	0,0253468 MPa	183,23 MPa
První hlavní napětí	-25,5795 MPa	155,595 MPa
Třetí hlavní napětí	-193,616 MPa	22,818 MPa
Posunutí	0 mm	0,758603 mm
Součinitel bezpečnosti	1,12973 ul	15 ul
Napětí XX	-188,806 MPa	152,133 MPa
Napětí XY	-42,352 MPa	60,2442 MPa
Napětí XZ	-24,8819 MPa	39,656 MPa
Napětí YY	-93,571 MPa	94,7862 MPa
Napětí YZ	-36,7554 MPa	21,8895 MPa
Napětí ZZ	-57,7411 MPa	47,1117 MPa
Posunutí X	-0,227244 mm	0,161665 mm
Posunutí Y	-0,306691 mm	0,113568 mm
Posunutí Z	-0,742185 mm	0,00355918 mm
Ekvivalentní napětí (vnitřní)	0,0000000987625 ul	0,000734845 ul
První hlavní napětí (vnitřní)	-0,0000106733 ul	0,00067068 ul
Třetí hlavní napětí (vnitřní)	-0,000847215 ul	0,00000161524 ul
Napětí XX (vnitřní)	-0,000832741 ul	0,000650614 ul
Napětí XY (vnitřní)	-0,000245449 ul	0,000349143 ul
Napětí XZ (vnitřní)	-0,000144202 ul	0,000229825 ul
Napětí YY (vnitřní)	-0,000426915 ul	0,00035867 ul
Napětí YZ (vnitřní)	-0,000213014 ul	0,00012686 ul
Napětí ZZ (vnitřní)	-0,000221612 ul	0,000214376 ul
Stykový tlak	0 MPa	115,371 MPa
Stykový tlak X	-54,8316 MPa	72,6193 MPa
Stykový tlak Y	-55,8896 MPa	50,457 MPa
Stykový tlak Z	-89,5736 MPa	45,0538 MPa

⊟ Obrázky

⊟ Napětí Von Mises

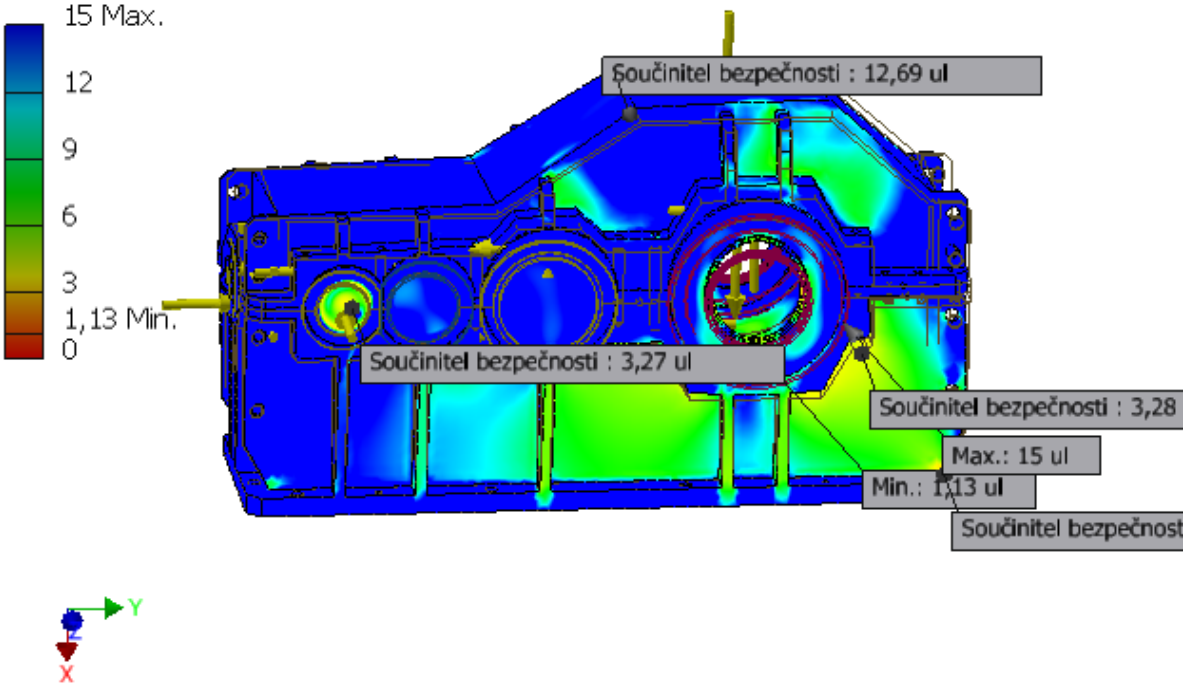


⊟ Posunutí

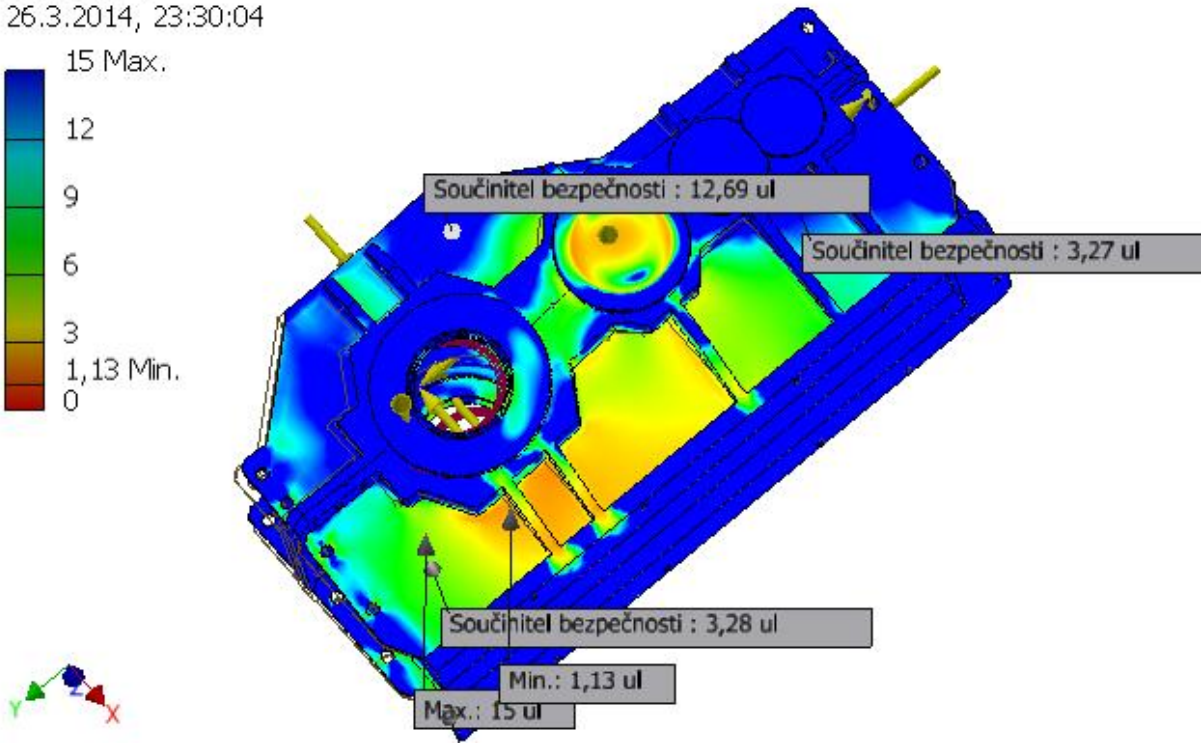


⊟ Součinitel bezpečnosti

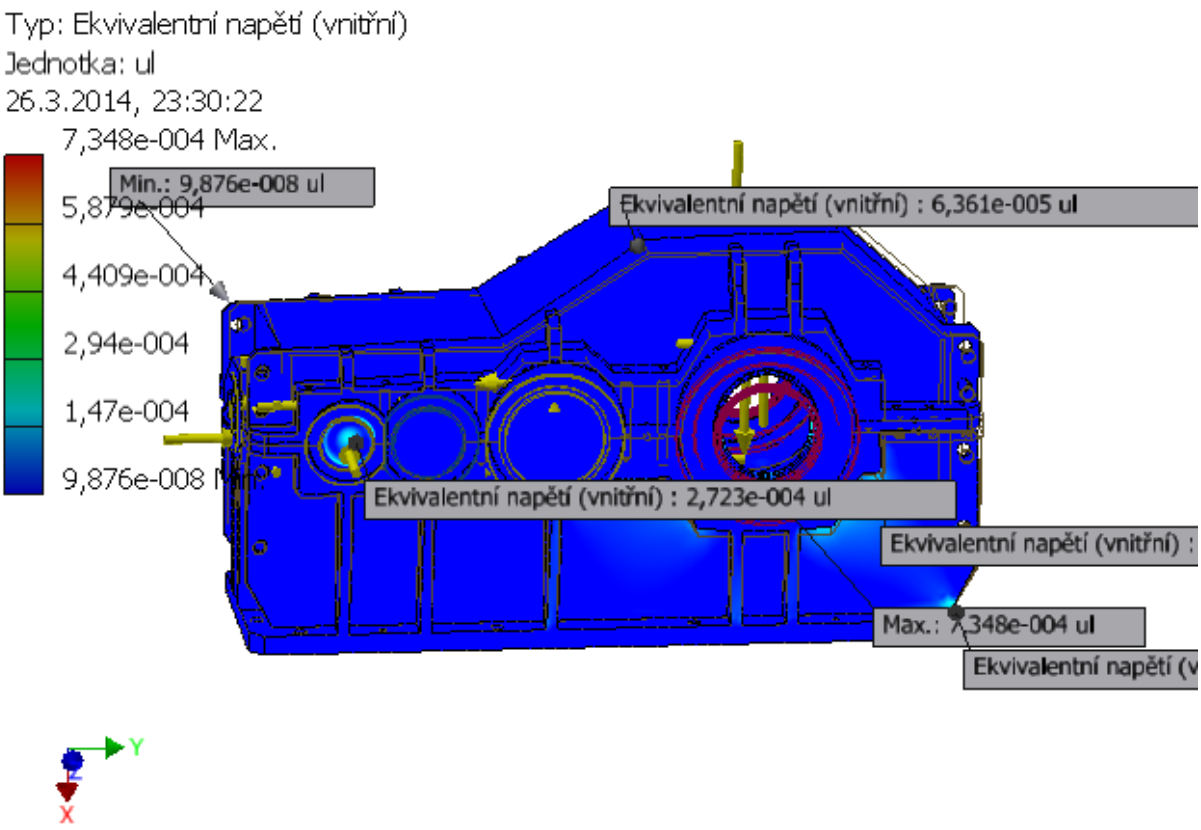
Typ: Součinitel bezpečnosti
Jednotka: ul
26.3.2014, 23:30:04

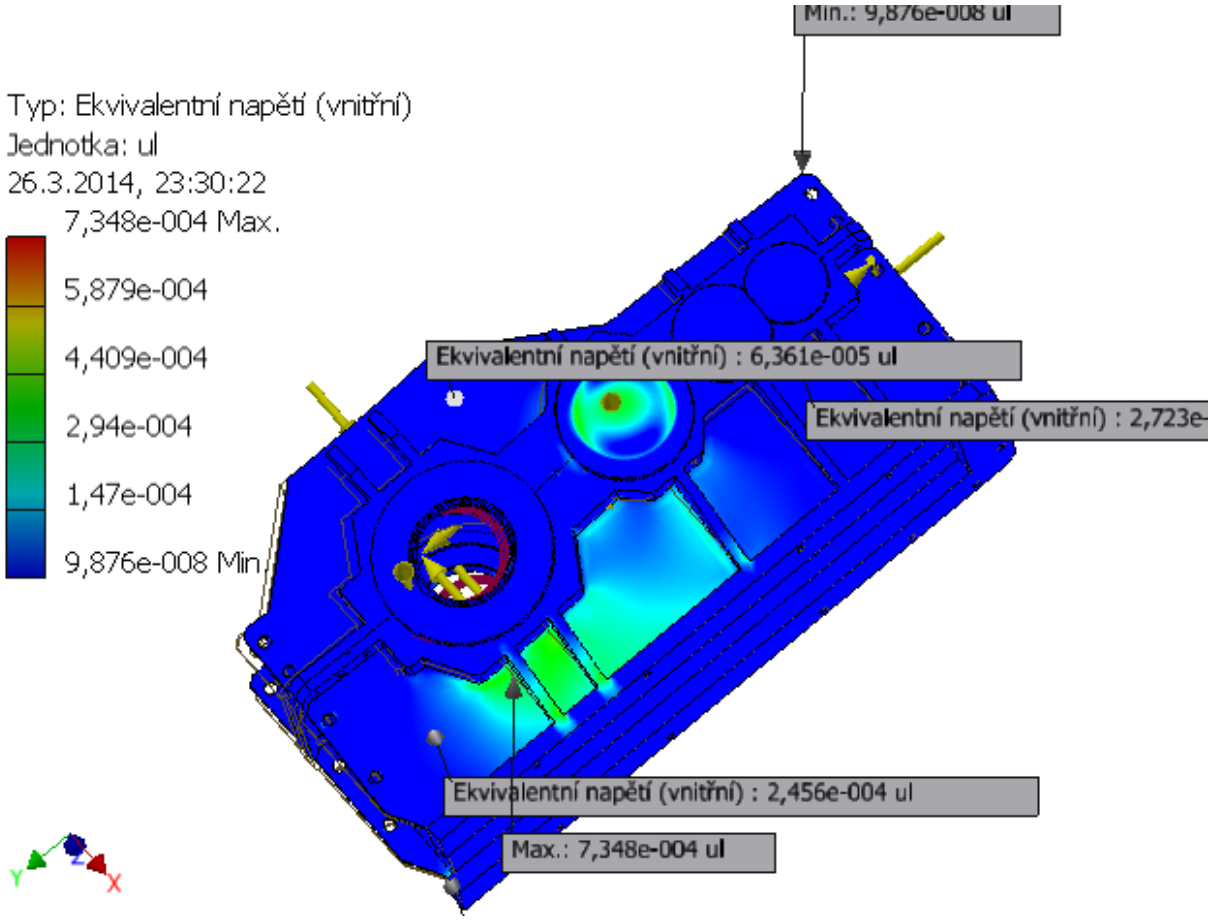


Typ: Součinitel bezpečnosti
Jednotka: ul
26.3.2014, 23:30:04

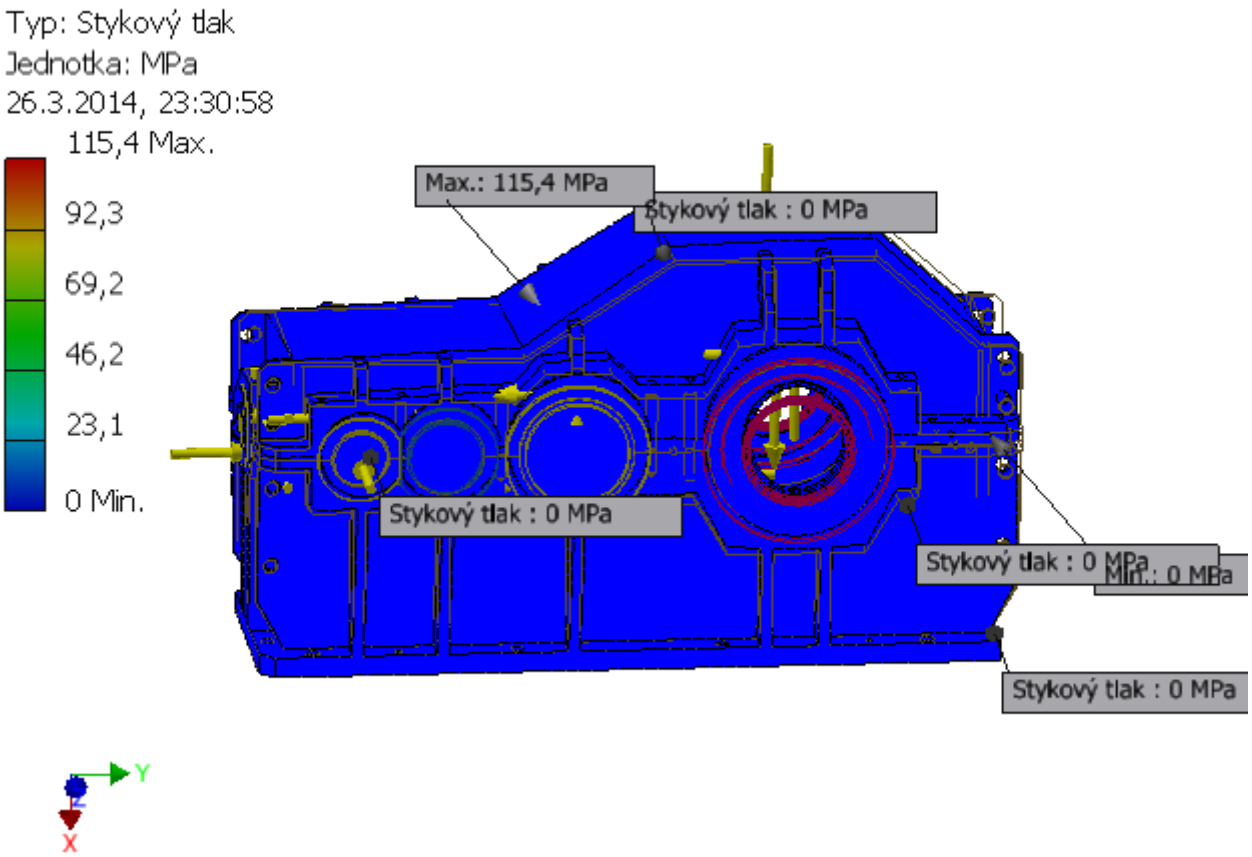


⊟ **Ekvivalentní napětí (vnitřní)**





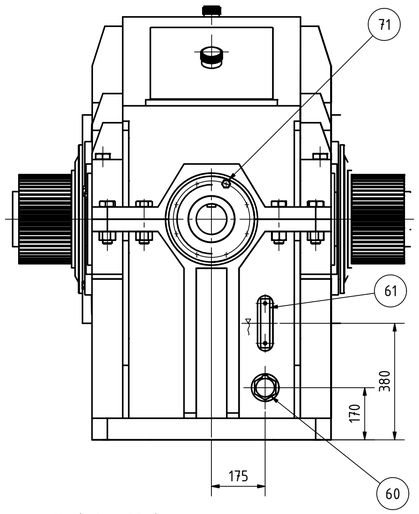
⊟ **Stykový tlak**



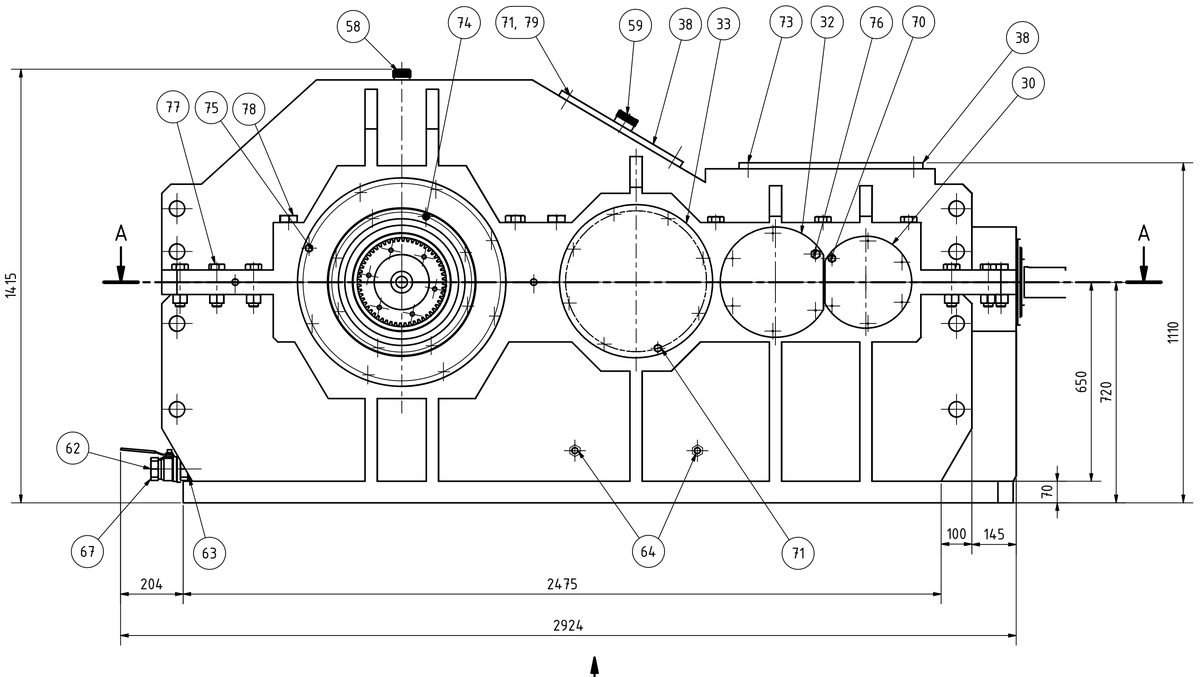
D:\Stary_disk\dokumenty_old\Inventor\DP\Skrin_nova_MKP_26_3.iam

VYTVOŘENO VE VÝUKOVÉM PRODUKTU SPOLEČNOSTI AUTODESK

TECHNICKÁ CHARAKTERISTIKA		
PŘEVOD	i	44,676 / 14,727
MOMENT	M_t [N]	6000
VSTUPNÍ OTÁČKY	n_1 [min^{-1}]	800
VÝSTUPNÍ OTÁČKY	n_2 [min^{-1}]	17,91 / 54,32
HMOTNOST	m [kg]	8681,49
MNOŽSTVÍ OLEJE	Q [l]	440
VISKOZITA OLEJE	v [mm^{2}s^{-1} (40°C]	150
TYP OLEJE	SHELL OMALA S4GX	
TYP MAZIVA	SHELL ALVANIA EP2	



B (1 : 10)



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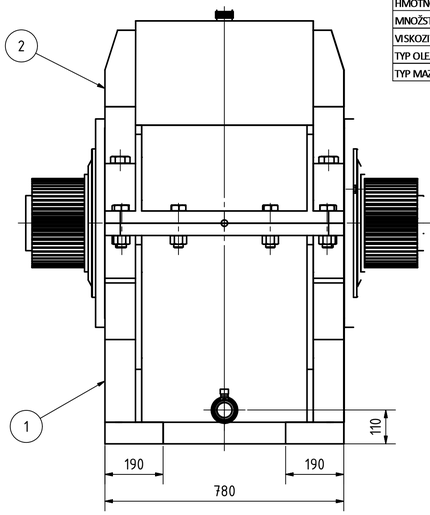

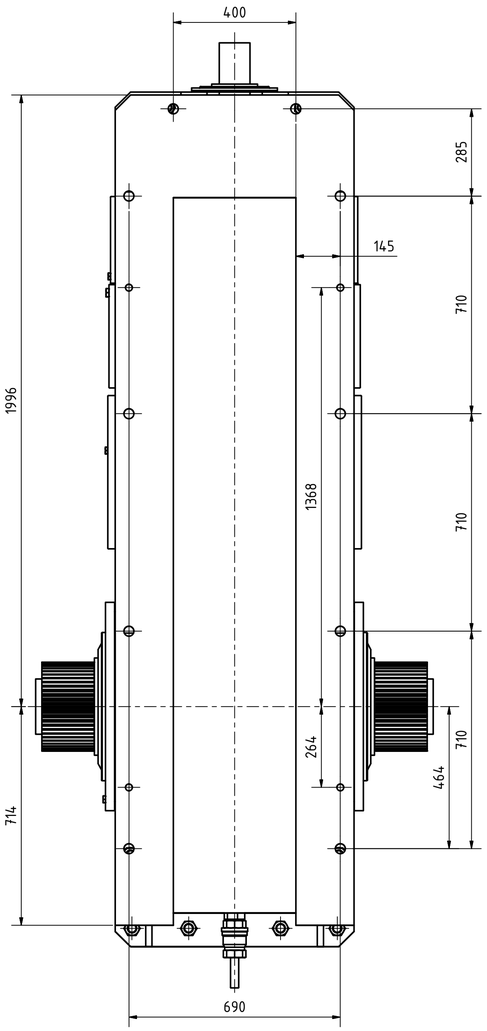

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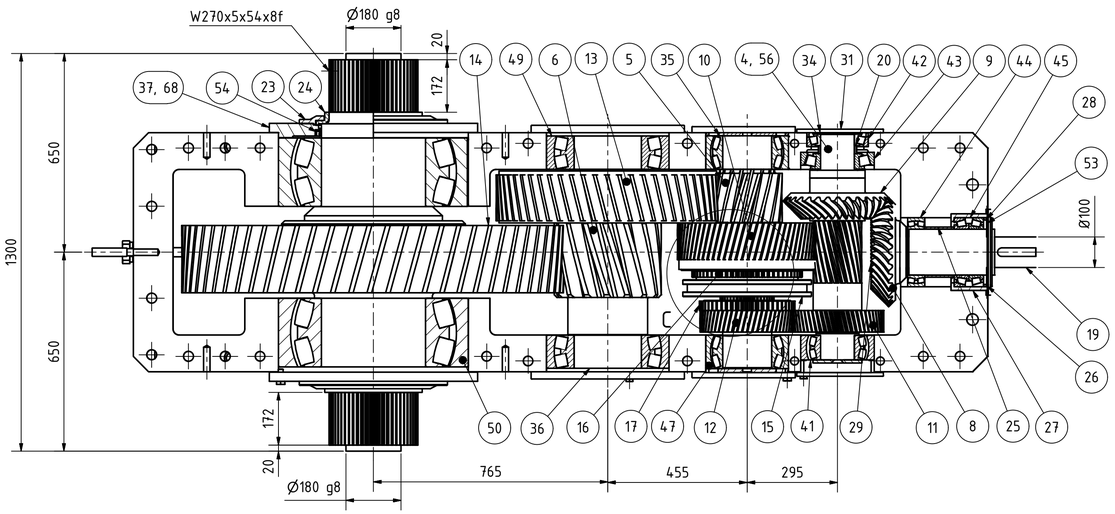

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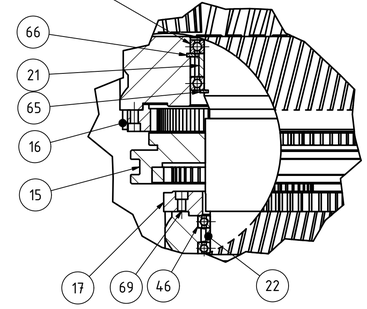
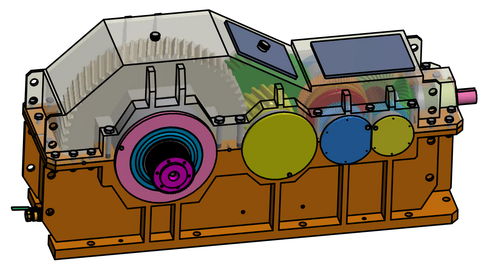




Měřítko 1:10	Hmotnost (kg) 8227,55 kg	Promítání	Formát A2
FAKULTA STROJNÍ ZÁPADOČESKÉ UNIVERZITY V PLZNI	Kreslil Lenka KARLOVÁ	Datum 2.5.2014	Název PŘEVODOVKA KC 3
	Schválil	Datum	Číslo dokumentu DP-KKS-2014-01
KKS KATEDRA KONSTRUOVÁNÍ STROJŮ	Druh dokumentu VÝKRES SESTAVY		List 1 Listů 1

VYTVOŘENO VE VÝUKOVÉM PRODUKTU SPOLEČNOSTI AUTODESK

VYTVOŘENO VE VÝUKOVÉM PRODUKTU SPOLEČNOSTI AUTODESK

ks	Název označení / Číslo výkresu – označení normy	Polotovar / Materiál	Hmotnost (kg)	Číslo výkresu	číslo polož.
1	SPODNÍ DÍL SKŘÍNĚ SVAŘENEC	11 343	2398,36		1
1	VÍKO SKŘÍNĚ SVAŘENEC	11 343	1482,75		2
					3
1	PASTOREK I VÝKOVEK	18CrNiMo7-6+Q 18CrNiMo7-6+A	83,72		4
1	PASTOREK V VÝKOVEK	18CrNiMo7-6+Q 18CrNiMo7-6+A	142,1		5
1	PASTOREK VII VÝKOVEK	18CrNiMo7-6+Q 18CrNiMo7-6+A	333,296		6
					7
1	KOLO OZUBENÉ KUŽELOVÉ 1 VÝKOVEK	18CrNiMo7-6+Q 18CrNiMo7-6+A	62,7		8
1	KOLO OZUBENÉ KUŽELOVÉ 2 VÝKOVEK	18CrNiMo7-6+Q 18CrNiMo7-6+A	36,7		9
1	KOLO OZUBENÉ 2 VÝKOVEK	18CrNiMo7-6+Q 18CrNiMo7-6+A	101,8		10
1	KOLO OZUBENÉ 3 VÝKOVEK	18CrNiMo7-6+Q 18CrNiMo7-6+A	27,68		11
1	KOLO OZUBENÉ 4 VÝKOVEK	18CrNiMo7-6+Q 18CrNiMo7-6+A	20,79		12
1	KOLO OZUBENÉ 6 VÝKOVEK	18CrNiMo7-6+Q 18CrNiMo7-6+A	394,32		13
1	KOLO OZUBENÉ 8 VÝKOVEK	18CrNiMo7-6+Q 18CrNiMo7-6+A	1791,87		14
1	KOLO SPOJKOVÉ VÝKOVEK	18CrNiMo7-6+Q 18CrNiMo7-6+A	48,26		15
1	OBJÍMKA SPOJKY PRO KOLO 2 VÝKOVEK	42CrMo4+QT 42CrMo4+QT	15,54		16
1	OBJÍMKA SPOJKY PRO KOLO 4 VÝKOVEK	42CrMo4+QT 42CrMo4+QT	11,61		17
	Hmotnost (kg) 8227,55				

FAKULTA STROJNÍ ZÁPADOČESKÉ UNIVERZITY V PLZNI

KKS KATEDRA KONSTRUOVÁNÍ STROJŮ

Kreslil: Lenka KARLOVÁ

Datum: 2.5.2014

Schválil:

Datum:

Druh dokumentu: SEZNAM POLOŽEK

Název: PŘEVODOVKY KC 3

Číslo dokumentu: DP-KKS-2014-01/K

List 1 Listů 5

VYTVOŘENO VE VÝUKOVÉM PRODUKTU SPOLEČNOSTI AUTODESK

VYTVOŘENO VE VÝUKOVÉM PRODUKTU SPOLEČNOSTI AUTODESK

VYTVOŘENO VE VÝUKOVÉM PRODUKTU SPOLEČNOSTI AUTODESK

VYTVOŘENO VE VÝUKOVÉM PRODUKTU SPOLEČNOSTI AUTODESK

ks	Název označení / Číslo výkresu – označení normy	Polotovar / Materiál	Hmotnost (kg)	Číslo výkresu	číslo položky
					18
1	HŘÍDEL VSTUPNÍ KR 105 – 525	ČSN 42 5510 11 353	32		19
1	KROUZEK K HŘÍDELI I TK KR 127x8 – 26	ČSN 42 5715 11 353	0,57		20
1	KROUZEK ROZPĚRNÝ TK KR 245x20 – 33	ČSN 42 5715 11 353	1,336		21
1	KROUZEK ROZPĚRNÝ TK KR 204x8 – 38	ČSN 42 5715 11 353	1,05		22
2	KROUŽEK K HŘÍDELI IV KR 485 – 41	ČSN EN 10060 12 050	12,4		23
2	KROUŽEK K HŘÍDELI IV KR 250 – 29	ČSN 42 0220 12 050	6		24
1	KROUZEK KRÁTKÝ TK KR 168x10 – 96	ČSN 42 5715 11 353	2,4		25
1	KROUŽEK OBJÍMKY KR 226 – 10	ČSN 42 0220 12 020	0,4		26
1	OBJÍMKA KR 280 – 121	ČSN 42 0220 12 020	10		27
1	PODLOŽKA KR 280 – 2	ČSN 42 0220 12 020	0,196		28
1	VÍČKO K HŘÍDELI 0 KR 160 – 10	ČSN 42 5510 12 020	1,5		29
1	VÍČKO K HŘÍDELI I KR 320 – 40	DIN 7527-6 12 050	6,9		30
1	VÍČKO K HŘÍDELI I KR 320 – 25	DIN 7527-6 12 050	5,1		31
2	VÍČKO K HŘÍDELI II KR 370 – 30	DIN 7527-6 12 050	11,3		32
2	VÍČKO K HŘÍDELI III PLO 510X40 – 510	DIN 59200 (A) 12 050	27,2		33
2	VÍČKO NA HŘÍDEL I KR 160 – 10	DIN 7527-6 12 050	1,2		34

Hmotnost (kg): 8227,55

FAKULTA STROJNÍ ZÁPADOČESKÉ UNIVERZITY V PLZNI

KKS KATEDRA KONSTRUOVÁNÍ STROJŮ

Kreslil: Lenka KARLOVÁ
Datum: 2.5.2014
Schválil:
Datum:
Druh dokumentu: SEZNAM POLOŽEK

Název: PŘEVODOVKY KC 3
Číslo dokumentu: DP-KKS-2014-01/K

VYTVOŘENO VE VÝUKOVÉM PRODUKTU SPOLEČNOSTI AUTODESK
VYTVOŘENO VE VÝUKOVÉM PRODUKTU SPOLEČNOSTI AUTODESK
VYTVOŘENO VE VÝUKOVÉM PRODUKTU SPOLEČNOSTI AUTODESK

VYTVOŘENO VE VÝUKOVÉM PRODUKTU SPOLEČNOSTI AUTODESK

ks	Název označení / Číslo výkresu – označení normy	Polotovar / Materiál	Hmotnost (kg)	Číslo výkresu	číslo polož.
2	VÍČKO NA HŘÍDEL II KR 190 – 20	DIN 7527-6 12 050	4,05		35
2	VÍČKO NA HŘÍDEL III KR 280 – 20	DIN 7527-6 12 050	9,1		36
2	VÍČKO NA HŘÍDEL IV KR 670 – 47	DIN 7527-6 12 050	80,6		37
1	VÍKO MALÉ P 350x20 – 460	DIN 59200(A) 12 040	23,9		38
1	VÍKO VELKÉ P 430x20 – 600	DIN 59200(A) 12 040	40,5		39
					40
1	LOŽISKO 22322E 110x240x80	SKF	16,89		41
1	LOŽISKO 30222 110x200x38	SKF	4,56		42
1	LOŽISKO 30322 110x240x50	SKF	9,73		43
1	LOŽISKO 23030CC/W33 150x225x56	SKF	7,05		44
1	LOŽISKO 32030X/DF 150x225x96	SKF	11,2		45
2	LOŽISKO 61832 160x200x20	SKF	1,15		46
2	LOŽISKO 24132CC/W33 160x270x109	SKF	24,59		47
2	LOŽISKO 61836 180x225x22	SKF	1,6		48
2	LOŽISKO 22244CC/W33 220x140x108	SKF	58,87		49
2	LOŽISKO 23268CA/W33 340X620X224	SKF	283		50
					51

Hmotnost (kg) 8227,55

FAKULTA STROJNÍ ZÁPADOČESKÉ UNIVERZITY V PLZNI

KKS KATEDRA KONSTRUOVÁNÍ STROJŮ

Kreslil Lenka KARLOVÁ

Datum 2.5.2014

Schválil

Datum

Druh dokumentu SEZNAM POLOŽEK

Název PŘEVODOVKY KC 3

Číslo dokumentu DP-KKS-2014-01/K

List 3 Listů 5

VYTVOŘENO VE VÝUKOVÉM PRODUKTU SPOLEČNOSTI AUTODESK

VYTVOŘENO VE VÝUKOVÉM PRODUKTU SPOLEČNOSTI AUTODESK

VYTVOŘENO VE VÝUKOVÉM PRODUKTU SPOLEČNOSTI AUTODESK

VYTVOŘENO VE VÝUKOVÉM PRODUKTU SPOLEČNOSTI AUTODESK

ks	Název označení / Číslo výkresu – označení normy	Polotovar / Materiál	Hmotnost (kg)	Číslo výkresu	číslo polož.
					52
1	KROUŽEK HŘÍDELOVÝ 150x180x15 NBR	ISO 6194/1	0,038		53
2	KROUŽEK HŘÍDELOVÝ 340x380x20 NBR	DIN 3760	0,21		54
					55
1	PERO 36x20x10		0,52		56
					57
1	ODVZDUŠŇOVAČ SFP 70-1 1/4	ELESA GANTNER	0,1		58
1	ODVZDUŠŇOVAČ SFP 57-1 1/2	ELESA GANTNER	0,1		59
1	TOPNÉ TĚLESO OM 100 2500W		0,4		60
1	OLEJOZNAK SLOUPCOVÝ HCX 127 – M12		0,6		61
1	VENTIL KULOVÝ	PARKER	2,1		62
1	PŘECHODKA	PARKER	0,45		63
4	ZÁTKA G 1/2-A4	DIN 910	0,3		64
1	KROUŽEK POJISTNÝ 180x4	DIN 471	0,169		65
1	KROUŽEK POJISTNÝ 230x5	DIN 471	0,26		66
1	KROUŽEK TĚSNICÍ DN32	ČSN 13 1655	0,01		67
2	V KROUŽEK 340 VRME-R	SKF	0,01		68

Hmotnost (kg): 8227,55

FAKULTA STROJNÍ ZÁPADOČESKÉ UNIVERZITY V PLZNI

KKS KATEDRA KONSTRUOVÁNÍ STROJŮ

Kreslil: Lenka KARLOVÁ

Datum: 2.5.2014

Schválil:

Datum:

Druh dokumentu: SEZNAM POLOŽEK

Název: PŘEVODOVKY KC 3

Číslo dokumentu: DP-KKS-2014-01/K

List 4 Listů 5

VYTVOŘENO VE VÝUKOVÉM PRODUKTU SPOLEČNOSTI AUTODESK

VYTVOŘENO VE VÝUKOVÉM PRODUKTU SPOLEČNOSTI AUTODESK

VYTVOŘENO VE VÝUKOVÉM PRODUKTU SPOLEČNOSTI AUTODESK

VYTVOŘENO VE VÝUKOVÉM PRODUKTU SPOLEČNOSTI AUTODESK

ks	Název označení / Číslo výkresu – označení normy	Polotovar / Materiál	Hmotnost (kg)	Číslo výkresu	číslo položky
8	ŠROUB M10x16	ISO 4017	0,04		69
14	ŠROUB M10x35	ISO 4017	0,045		70
6	ŠROUB M12x30	ISO 4017	0,05		71
12	ŠROUB M12x40	DIN 912	0,06		72
16	ŠROUB M12x45	ISO 4017	0,065		73
16	ŠROUB M16x50	ISO 4017	0,1		74
12	ŠROUB M16x60	ISO 4017	0,15		75
12	ŠROUB M20x50	ISO 4017	0,2		76
14	ŠROUB M30x120	ISO 4017	0,931		77
12	ŠROUB M30x260	ISO 4017	2,54		78
20	PODLOŽKA 12	ISO 7089	0,01		79
					80
					81
					82
					83
					84
					85

Hmotnost (kg) 8227,55

FAKULTA STROJNÍ ZÁPADOČESKÉ UNIVERZITY V PLZNI

KKS KATEDRA KONSTRUOVÁNÍ STROJŮ

Kreslil Lenka KARLOVÁ

Datum 2.5.2014

Schválil

Datum

Druh dokumentu SEZNAM POLOŽEK

Název PŘEVODOVKY KC 3

Číslo dokumentu DP-KKS-2014-01/K

List 5 Listů 5

VYTVOŘENO VE VÝUKOVÉM PRODUKTU SPOLEČNOSTI AUTODESK

VYTVOŘENO VE VÝUKOVÉM PRODUKTU SPOLEČNOSTI AUTODESK

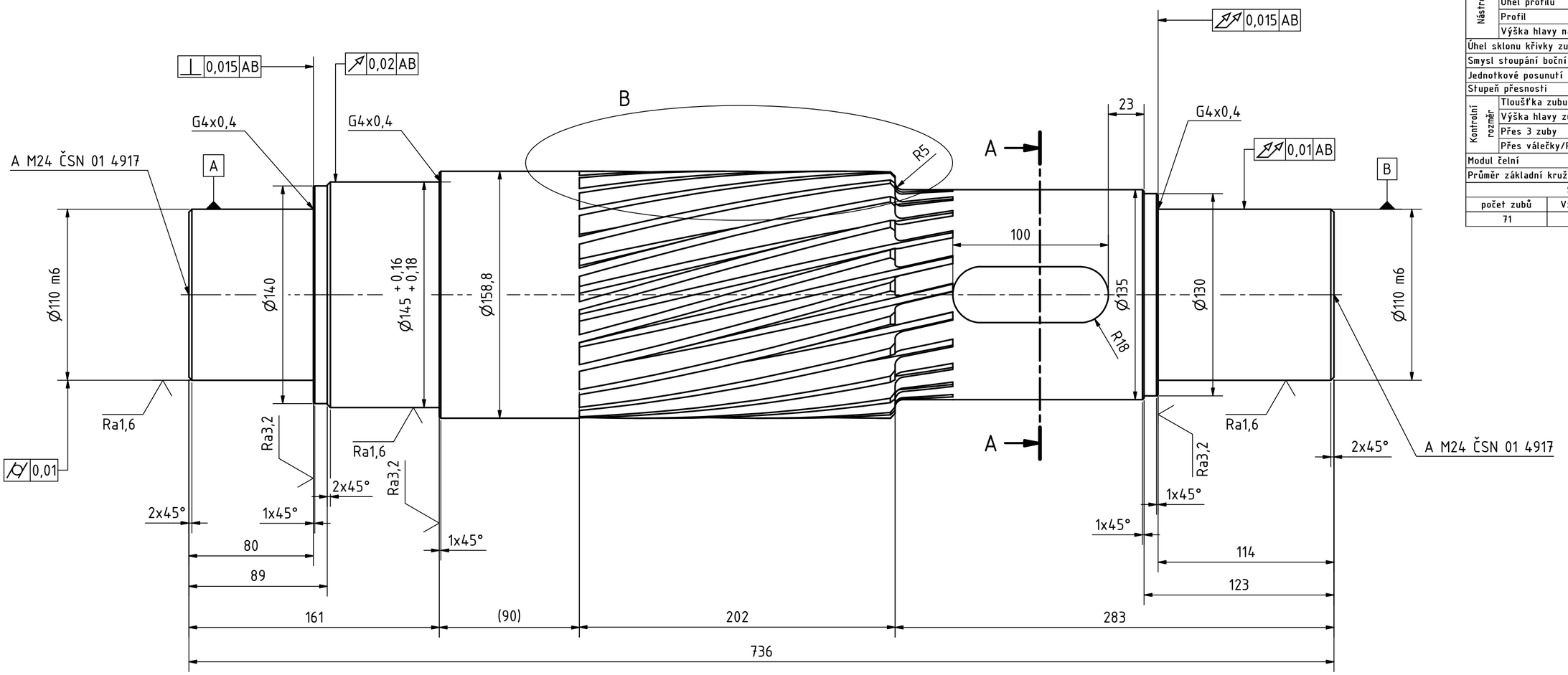
VYTVOŘENO VE VÝUKOVÉM PRODUKTU SPOLEČNOSTI AUTODESK

VYTVOŘENO VE VÝUKOVÉM PRODUKTU SPOLEČNOSTI AUTODESK

Ozubení (ČELNÍ, KUŽELOVÉ)			ČELNÍ
Zuby (PŘÍMÉ, ŠIKMÉ, ŠÍPOVÉ)			ŠIKMÉ
Počet zubů		z	23
Nástroj	Modul	m	6
	Úhel profilu	alfa	20°
	Profil		ČSN 014607
	Výška hlavy nástroje	hf	1,25
Úhel sklonu křivky zubu		beta	14°
Smysl stoupání boční křivky zubu			LEVÝ
Jednotkové posunutí		x	0,418
Stupeň přesnosti			6cd25 DIN3961
Kontrolní rozměr	Tloušťka zubu na tětivě	st	9,324 / 9,274
	Výška hlavy zubu nad tětivou	hc	5,922
	Přes 3 zuby	W	46,299 / 46,252
	Přes válečky/Průměr válečku 10,5	M	78,438 / 78,379
Modul čelní		mt	6,184
Průměr základní kružnice		db	133,164

Spoluzabírající kolo

počet zubů	Vzdálenost os aw	úhel os
71	295	0



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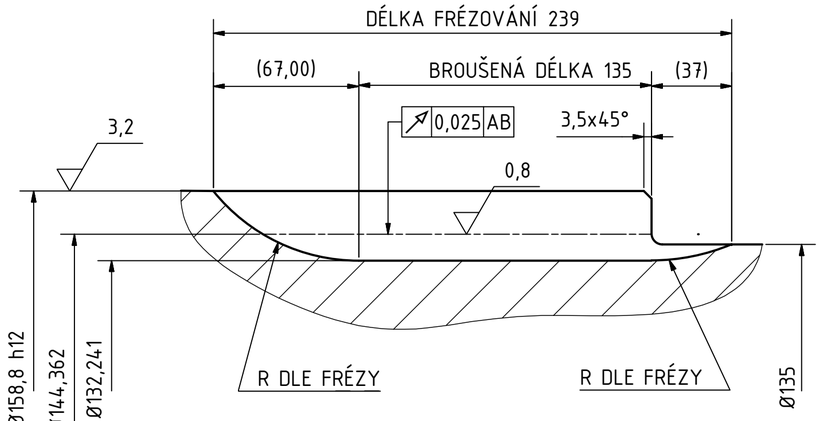
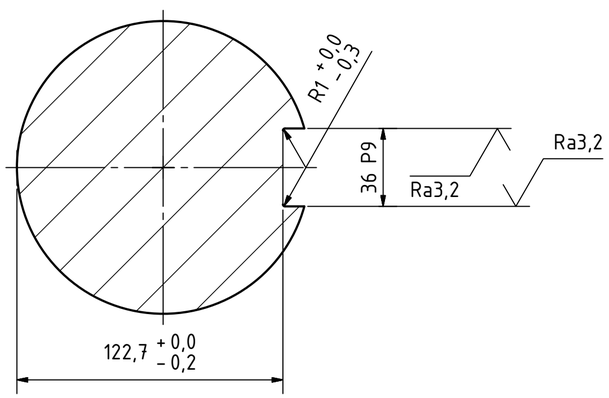
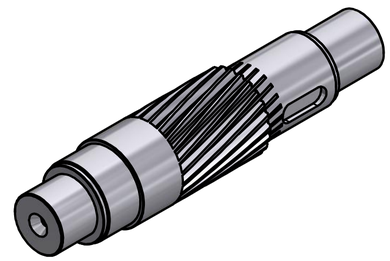


A–A





Textura povrchu: Ra 6,3	Hrany ISO 13715: −0,4 +0,4	Měřítko: 1:2	Přesnost: ISO 2768 – mK
		Hmotnost (kg): 83,7 kg	Tolerování: ISO 8015
			Promítání:
Materiál – Polotovar: 18CrNiMo7-6+A VÝKOVEK			Formát: A3
FAKULTA STROJNÍ ZÁPADOČESKÉ UNIVERZITY V PLZNI	Kreslil: Lenka KARLOVÁ Datum: 20.4.2014	Název: PASTOREK 1	
	Schválil: Datum:	Číslo dokumentu: DP-KKS-2014-02	
KKS KATEDRA KONSTRUOVÁNÍ STROJŮ	Druh dokumentu: VÝROBNÍ VÝKRES	List 1 Listů 1	

VYTVOŘENO VE VÝUKOVÉM PRODUKTU SPOLEČNOSTI AUTODESK