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DESIGN AND ANALYSIS OF HYBRID (METAL/COMPOSITE) UPPER CASE OF THE GEARBOX

O. Šedivý[1], Z. Padovec[2], V. Kulíšek[3], M. Růžička[4]

Abstract: Presented paper deals with possible design of metal/composite gearbox for electric car. Composite parts of the gearbox were manufactured by wet lay-up technology with the use of C/Epoxy fabrics, housings of the bearings were metal. Main goal is to reach equivalent stiffness and lower weight than the current version of gearbox (manufactured from duralumin). Computation was based on known bearing forces and it was done in FE software ANSYS.

Keywords: composite material; gearbox; FEM

1 Introduction

The paper is focused on the design and analysis of the upper case of composite gearbox for electric car. Current version of the gearbox is manufactured from duralumin nowadays. New design has to fulfil current dimensions (inner and outer), designed gearbox has to have higher or equivalent stiffness and also lower weight – current duralumin version has 2,46 kg. Design concept was done in cooperation with Compotech Plus which will manufactured prototype of the gearbox with the use of wet lay-up technology.

2 Duralumin version

In Fig. 1 and 2 you may see current duralumin version of the upper case of the gearbox (in model combined with rigid plate). Housing is loaded by the forces in bearings which are given by manufacturer (Fig. 3). Main goal of the model is to determine maximal and minimal stiffness values and their directions. Physical properties of duralumin which are used in computation are E = 72 000 MPa and ν = 0,3. Stiffness was computed as

$$k = \frac{F}{u}, \tag{1}$$

for each gear and direction (see Fig. 4). Values of directional stiffness for each hole can be seen in Table 1.

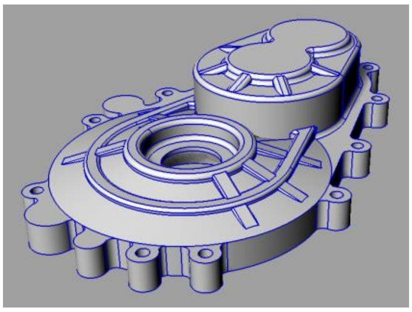


Figure 1: Upper case – outer view.

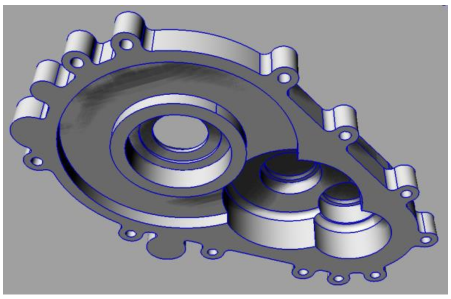
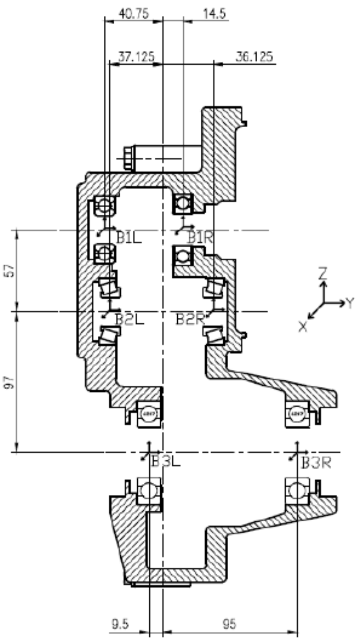


Figure 2: Upper case – inner view.

[1] Ondřej Šedivý; CTU in Prague, Faculty of Mechanical Engineering; ondrej.sedivy@fs.cvut.cz
[2] Zdeněk Padovec; CTU in Prague, Faculty of Mechanical Engineering; zdenek.padovec@fs.cvut.cz
[3] Viktor Kulíšek; CTU in Prague, Faculty of Mechanical Engineering; viktor.kulisek@fs.cvut.cz
[4] Milan Růžička, CTU in Prague, Faculty of Mechanical Engineering, milan.ruzicka@fs.cvut.cz



Bearing	Force [N]		
	x	y	z
B1L	717	1 034	1 327
B1R	78	0	931
B2L	1 379	2 336	-3 335
B2R	-246	-1 105	-3 750
B3L	-38	0	-3 900
B3R	2 047	-2 266	-920

Figure 3: Forces in bearings

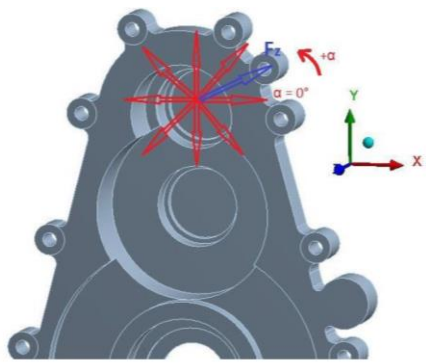


Figure 4: Sketch of direction for unit force loading

Angle [°]	*B1L Stiffness [N/mm]*	*B2L Stiffness [N/mm]*	*B3L Stiffness [N/mm]*
0	951 374	707 207	1 188 322
45	966 283	779 525	1 287 236
90	990 786	881 981	1 368 204
135	975 030	781 272	1 251 497
180	951 374	707 207	1 188 322
225	966 283	779 525	1 287 236
270	990 786	881 981	1 368 204
315	975 030	781 272	1 251 497
360	951 374	707 207	1 188 322
Axial (*z* axis)	1 101 911	510 343	475 448

Table 1: Values of directional stiffness for each hole

3 Composite version

According to the manufacturing process the shape of composite version of upper case is different than the shape of duralumin version (see Fig. 5 and 6). Mechanical properties of use materials can be seen in Tab. 2 and 3. First computation was done just for the upper case manufactured from fabrics. Other computations were done with the use of Biontec reinforcement (see [1] for details) which has similar function as ribs on metal version of the case. Boundary conditions were as same as in duralumin case, mesh was created by sweep with the use of continuum shell elements (*Solidshell 190)*. Directional stiffness was computed in similar way as in duralumin version and the values and comparison can be seen in Tab. 4. From the results can be seen that stiffness are from three to six time lower than duralumin stiffness. That´s why the Biontec reinforcement was applied.

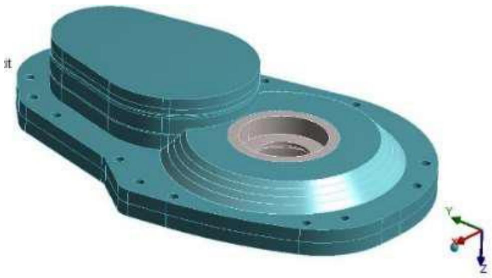


Figure 5: Composite upper case – outer view.

Figure 6: Composite upper case – inner view.

E_x[MPa]	E_y[MPa]	G_{xy}[MPa]	ν_{xy}[-]
54 450	48 940	4 730	0,2

Table 2: Mechanical properties of composite fabric [2]

E_x[MPa]	E_y[MPa]	G_{xy}[MPa]	ν_{xy}[-]
289 540	3 491,3	2 730,4	0,376

Table 3: Mechanical properties of Biontec reinforcement [1]

Angle [°]	*B1L Stiffness [N/mm]*	*Percentage of duralumin stiffness [%]*	*B2L Stiffness [N/mm]*	*Percentage of duralumin stiffness [%]*	*B3L Stiffness [N/mm]*	*Percentage of duralumin stiffness [%]*
0	291 866	31	315 158	45	474 096	40
45	355 182	37	375 322	48	535 399	42
90	488 089	49	490 486	56	604 830	44
135	353 442	36	374 727	48	520 449	42
180	291 863	31	315 154	45	474 093	40
225	355 172	37	375 306	48	535 380	42
270	488 066	49	490 449	56	604 798	44
315	353 439	36	374 720	48	520 437	42
360	291 866	31	315 158	45	474 096	40
Axial (z axis)	191 430	17	146 904	29	171 455	36

Table 4: Values of directional stiffness for each hole (without Biontec reinforcement)

3.1 Computation with Biontec reinforcement

Several versions of possible reinforcement with Biontec technology were investigated (and they were described in conference presentation) – application of Biontec just on housing of the case (hole B1L and B2L), application just around the bearing B3L and application on whole upper case. The last version will be described here (see Fig. 7 for details). Because of the computation time the comparison was done just for the displacements of bearing centres. Displacements for duralumin version can be seen in Tab. 5, displacements for composite version reinforced with Biontec in Tab. 6 and comparison in Tab. 7.

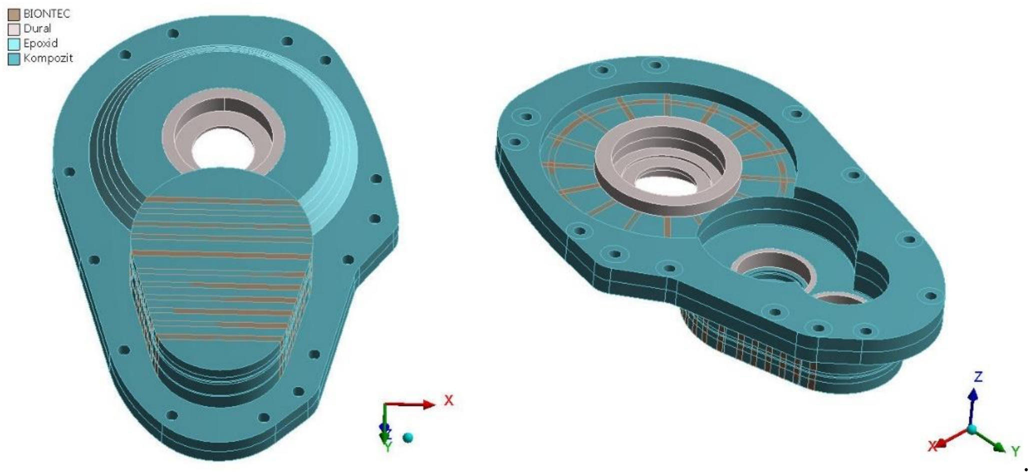


Figure 7: Application of Biontec

Displacement [mm]	*B1L*	*B2L*	*B3L*
u	-1,05E-03	-2,45E-03	-3,18E-03
v	5,61E-04	-9,34E-05	2,82E-03
w	-1,05E-03	-4,10E-03	-4,90E-03
Total	1,59E-03	4,78E-03	6,49E-03

Table 5: Displacements for duralumin version

Displacement [mm]	*B1L*	*B2L*	*B3L*
u	-3,44E-03	-6,08E-03	-7,30E-03
v	1,63E-03	6,74E-04	6,17E-03
w	-5,67E-03	-1,42E-02	-1,43E-02
Total	6,83E-03	1,54E-02	1,72E-02

Table 6: Displacements for composite version with Biontec reinforcement

Difference [%]	*B1L*	*B2L*	*B3L*
u	229	149	130
v	190	-821	119
w	439	246	191
Total	330	223	165

Table 7: Comparison of displacements

4 Results and discussion

From the table above, we may see that the application of Biontec reinforcement leads to improvement in displacements of bearing centres. On the other hand, we have to say that number of Biontec strips is quite high (38) and strips did not affect peaks of shear stress which appear locally on the case. Weight of the duralumin version of the upper case is 2 460 g. developed hybrid version weights 1 847 g (1 610 g for composite parts, 237 g for duralumin parts). It means 24,9 % spare of the weight. Future work may focus on optimization of the case parts (plate and housing thickness, etc…), use of unidirectional fabrics to improve directional stiffness or use of different manufacturing technology.

Acknowledgement

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