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Effects of hardenability on mechanical properties of tool steel 56NiCrMoV7 for forging die

M. Paulec, P. Kopas, M. Sága

Faculty of Mechanical Engineering, University of Žilina, Univerzitná 8215/1, 010 26 Žilina, Slovak Republic

1. Introduction

Hot forging is a way to preform metal parts quickly and at low cost. It belongs to the methods of mass forming of metals. The high strength of components produced by this method has drawn special attention to this method in various industries such as aerospace, marine, railway and automotive. Forging processes normally involve two dies that press the hot billet into the desired shape. Hot forging enables complicated geometry with a reduced amount of mechanical energy. Hot forging has two main disadvantages. The first disadvantage is a deformed billet, which due to the impossibility of surface quality and geometric tolerance (surface oxidation, thermal contraction, the possibility of phase transformation in some alloys, etc.). The second is the cost of heat forging dies. The cost of hot forging dies is generally estimated at 8 to 15% of all manufacturing costs. For small production runs, it can reach 30% or even 50% if unexpected damage is considered. [2]

Most unexpected failures of hot forging dies are caused by inappropriate die materials, die design, die manufacturing, or forging operations. In addition, there are insufficient forging ratio, insufficient cleanliness and heat treatment of the dies, small radius of corners, insufficient width and thickness of the die, insufficient surface treatment, repair of the weld surface of the die, insufficient preheating, insufficient surface of the die and lubrication. The main factors that lead to unexpected failure of hot forging dies. [3, 1]

Fig. 1. Broken part of forging die

2. Experimental materials and method

The frequently used tool steel 56NiCrMoV7 was used as the experimental material. A chemical analysis was conducted, and the outcomes are displayed in Table 1.

Table 1. Chemical composition of a fractured die made of 56NiCrMoV7 steel

Element	**C**	**Si**	**Mn**	**Cr**	**Mo**	**Ni**	**V**	**P**	**S**
Ratio in %	0.56	0.38	0.68	0.79	0.50	1.69	0.06	0.006	0.0015

The die material was supplied in the form of a forged and heat-treated steel block with dimensions of 670x480x320 mm, which was heat treated - hardened and tempered to a surface hardness of 44 HRC.

A static tensile test was used to detect the decrease in mechanical properties. In Fig. 2 is geometry and dimension of specimen for static tensile test.

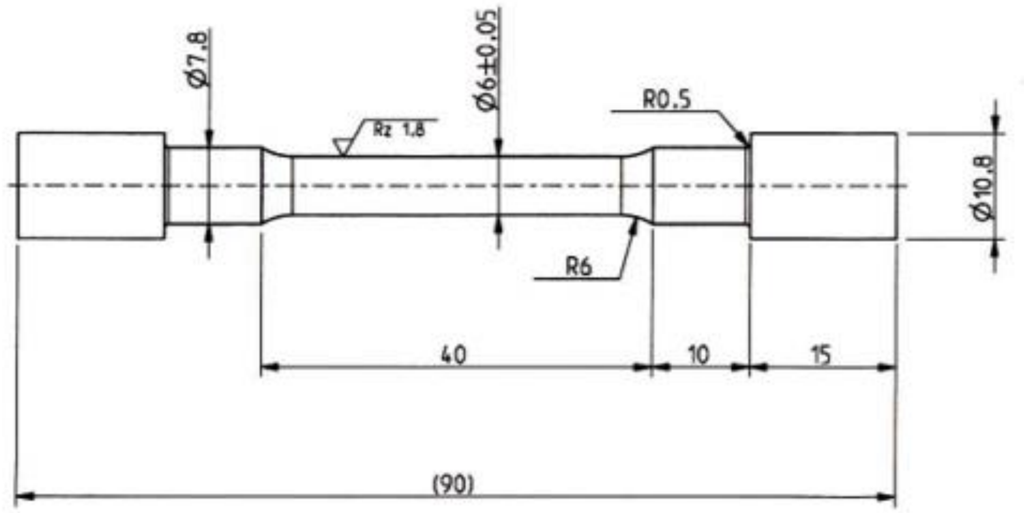

Fig. 2. Geometry and dimensions of specimen for static tensile test

A fatigue test was used to detect the decrease in mechanical properties. In Fig. 3 is geometry and dimension of specimen for static tensile test.

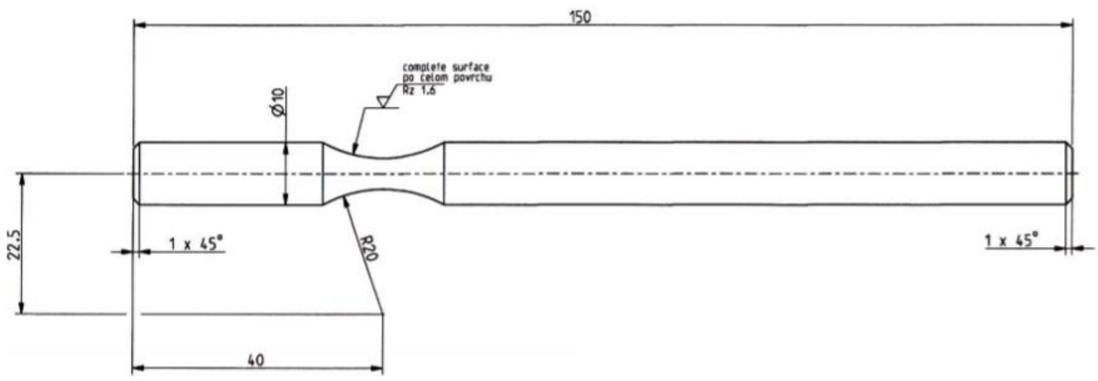

Fig. 3. Geometry and dimensions of specimen for fatigue test.

3. Results

The results of the static tensile test for a set of material 56NiCrMoV7 hardened and tempered to a hardness of 44 HRC are in Table 2. The average value of upper yield point is 1196 MPa. The average value of tensile strength is 1377 MPa. The average value of elongation is 10,4 % MPa.

Table 2. Mechanical properties of steel 56NiCrMoV7 hardened and tempered to the hardness of 44 HRC

Name	Upper yield point	Tensile strength	Elongation
Units	R_{eH} [MPa]	R_m [MPa]	**A** [%]
Measurement 1	1208	1394	10.8
Measurement 2	1185	1369	9.9
Measurement 3	1197	1375	10.3
Measurement 4	1177	1336	9.7
Measurement 5	1213	1411	11.3
Average	**1196**	**1377**	**10.4**

The results of the static tensile test for a set of material 56NiCrMoV7 hardened and tempered to a hardness of 34 HRC are in the Table 3. The average value of upper yield point is 789 MPa. The average value of tensile strength is 994 MPa. The average value of elongation is 12,6 % MPa.

Table 3. Mechanical properties of steel 56NiCrMoV7 hardened and tempered to the hardness of 34 HRC

Name	Upper yield point	Tensile strength	Elongation
Units	R_{eH} [MPa]	R_m [MPa]	**A** [%]
Measurement 1	775	971	11.5
Measurement 2	809	1027	13.7
Measurement 3	798	1013	13.1
Measurement 4	785	982	12.5
Measurement 5	778	977	12.2
Average	**789**	**994**	**12.6**

The hardness test results showed a decrease from 44 HRC to 34 HRC. The maximum drop of hardness was at a height of 160 mm from surface. The hardness drop graph can be seen in Fig. 4.

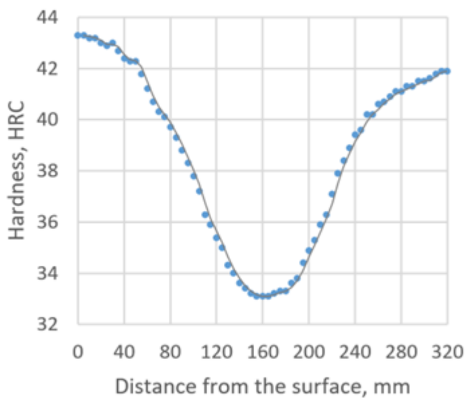

Fig. 4. Graph of drop hardness

The results of the fatigue test for a set of material 56NiCrMoV7 hardened and tempered to a hardness of 44 HRC and 34 HRC are in the Fig. 5. Based on the results, a decrease in fatigue can be seen.

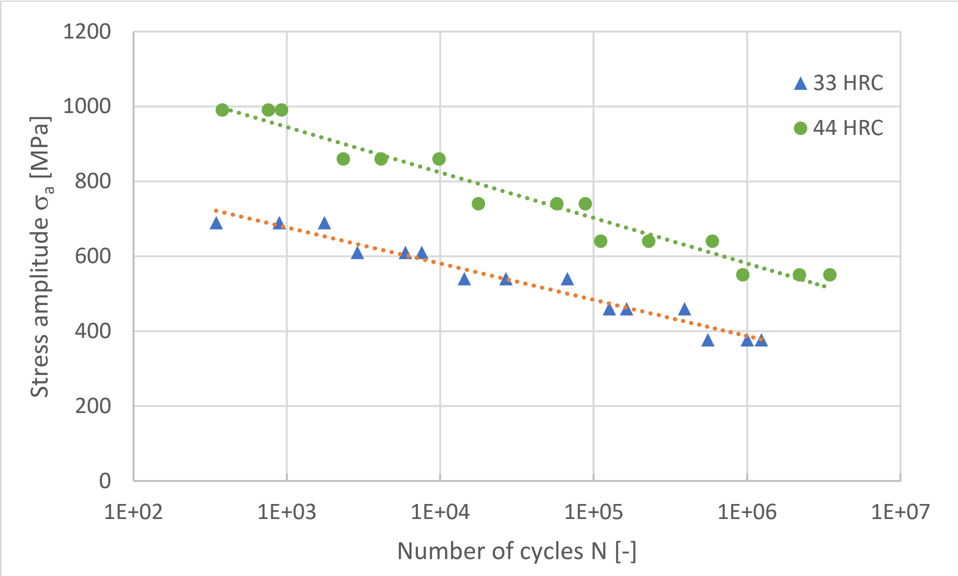

Fig. 5. Graph of decrease fatigue life

4. Conclusions

Based on research devoted to the issue of the decline of mechanical properties, the following can be said:

- the upper yield point drop is 33%,
- the tensile strength drop is 29%,
- the decrease in hardness due to hardenability is 25%.

Acknowledgements

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