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Experimental Mechanical Pulsation Tests of Gears with Different Case-Hardened Depth

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Abstract: The article describes the mechanical pulsation tests of carburized gears with different thickness of case-hardened depth and case-hardening technology, i.e. addition or removal of certain steps during the case-hardening process of the tooth flank and foot root. The comparison was made on six different process chemical-heat treatment, in two thicknesses of case-hardened depth and two pressure angles. Results are shown and compared in an S-N (Wöhler's) curve.

Keywords: Case-Hardened Depth; Experiment; Gears; Pulsation; Load Capacity; Wöhler's Curve.

1 Introduction

Experimental testing of gearing (gears) can be done in several ways, e.g. a pulsating or operating [2]. This article describes mechanical pulsation testing. The basis is design of the sample according to the methodology based on location of sample in the Wöhler's curve. Then was designed test procedure and testing device for pulsation testing (Fig. 1 and Fig. 3). During a pulsation testing is detected durability of fracture in tooth root. Fatigue fracture of the tooth from the area of the pitch circle (flank breakage), which is very dangerous, cannot be achieved during the pulsed testing, because for creation of flank breakage is very important combination of pressure and bending stress [1], which can be ensured by real roll during the working load.

2 Description of the Test Samples and Pulsation Testing

In Tab. 1 are described test samples. We are used two types of semi-product – rolled and forged bar, two types of case hardened depth and different technology (method of production) creation of case hardened layer. In the Tab. 1 is possible to see final values of experimental tests for each category of gear. In each category was five gears and each gear had five teeth (five samples).

Tab. 1: Summary of statistical values for case-hardened depth (CHD) set of gears according to technology (method of production) case hardened layer and a semi-product of gears.

Technology of case hardened layer		Arithmetic Mean [cycles]	Standard dev. [cycles]	Median [cycles]
Rolled bar, standard (CHD=0.4-0.6)		620 201	855 565	249 451
Forged bar	Standard (CHD=0.4-0.6)	323 462	301 637	183 800
	Without annealing, freezed out (CHD=0.7-0.9)	1 016 282	744 920	878 000
	Without annealing (CHD=0.7-0.9)	70 323	29 120	70 936
	Higher % C (CHD=0.7-0.9)	181 582	37 232	171 900
	Standard (CHD=0.7-0.9)	331 102	416 694	235 000

2.1 Design of Testing Device

Testing device (Fig. 1) is designed for testing of gears with module 6-8 with a maximum load of 95 kN. The testing device is made from steel C45+N and heat treated. The gear is in contact with the product through interchangeable hardened plates. The testing device was calculated using analytical and FEM calculations, Fig. 2 [2].

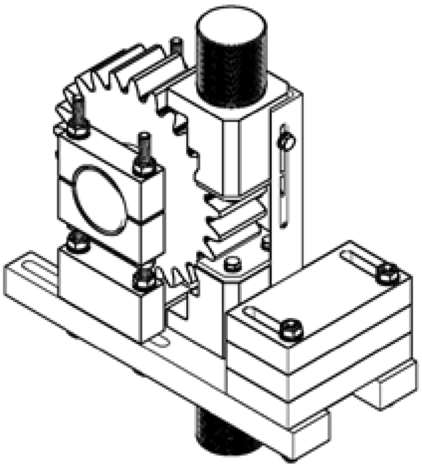


Fig. 1: 3D model of testing device.

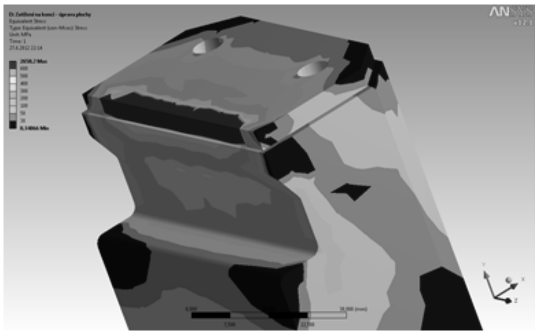


Fig. 2: FEA stress results – Load “tip” along the contact of the gear.

2.2 The Course of Pulsation Testing of Gearing

When determining the fatigue strength of the pulsation tests results based on the assumption that the loading cycle of driving and driven gears is passing. Gripping of samples must be done with prestress, thereby changing the cycle from passing to pulsing in tension, when R $\in$ (0; 1) – Fig. 4. Lower tension in the implementation should be as small as possible, so that cycle was the most similar assumption passing cycle. Prestress it must be sufficiently large, to enable do the course of the test, which is based on resonance principle. For pulsation testing is typical value of asymmetry cycle R = 0.1 (F_d = 7.5 kN; F_{hi} = 75 kN).

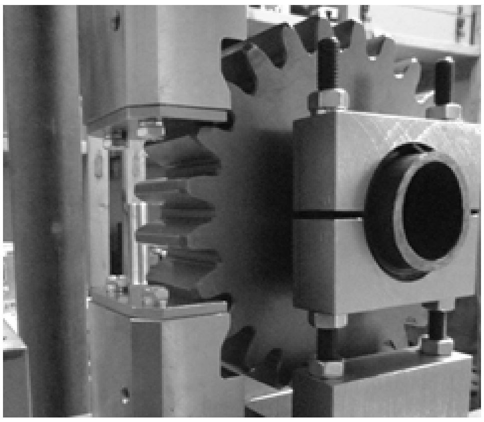


Fig. 3: Gears in pulsator.

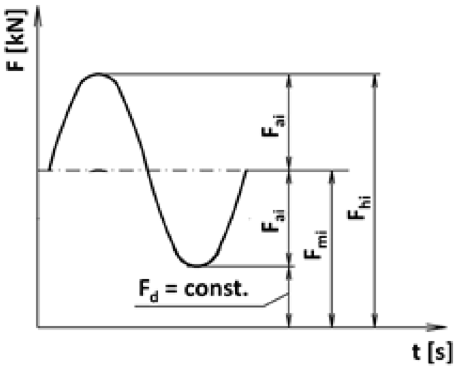


Fig. 4: Diagram for pulse loading of gearing according to the method D.

In Fig. 2 are shown sample fracture surface on the tooth for each category of gears. As you can see, each fracture surface is different, due to differences in chemical heat treatment and used semi-product.

3 Evaluation of the Conclusion of the Experiment

Data had a higher variance, but despite this fact the results are comparable and bring a number of important results, see Fig. 5. The first important result is higher load capacity of gears made from rolled bar versus forged

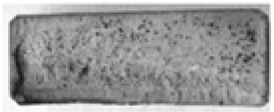
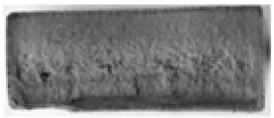
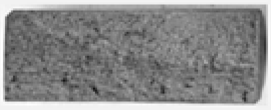
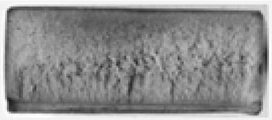
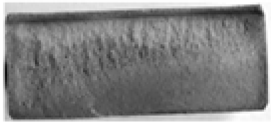
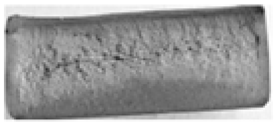
Technology of case hardened layer	Photo of fracture surface on the tooth	Technology of case hardened layer	Photo of fracture surface on the tooth
Rolled bar, standard (CHD=0.4-0.6)		Forged bar, without annealing (CHD=0.7-0.9)	
Forged bar, standard (CHD=0.4-0.6)		Forged bar, higher % C (CHD=0.7-0.9)	
Forged bar, without annealing, freezed out (CHD=0.7-0.9)		Forged bar, standard (CHD=0.7-0.9)	

Fig. 5: Sample fractures surface on the tooth from pulsation testing.

bar. From the perspective of chemical heat treatment are the best gears with freeze out and the worst are gears without annealing.

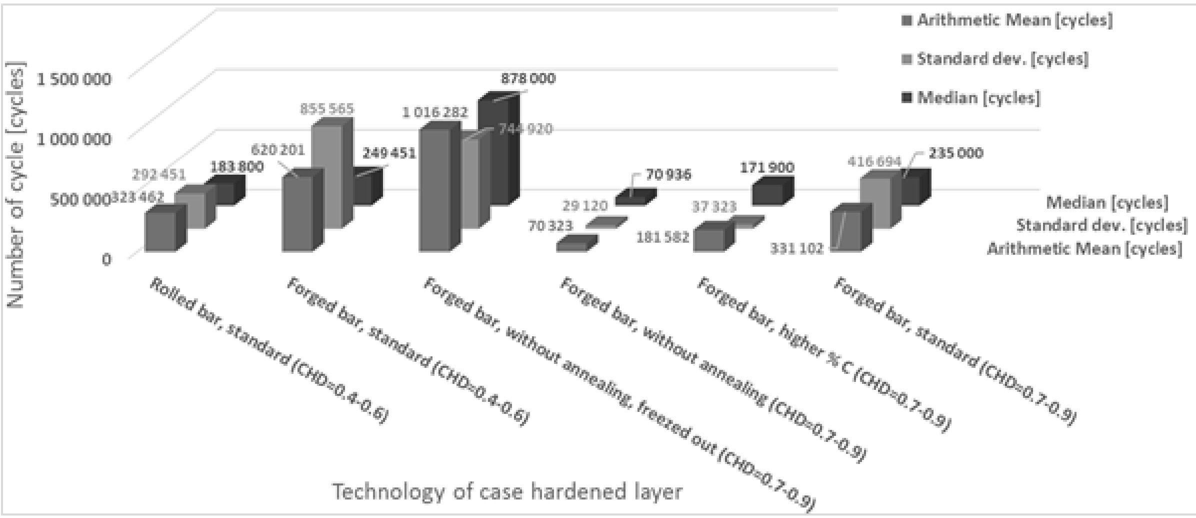


Fig. 6: Graphical representation of statistical parameters for each technology (method of production) hardened layer case hardened layer and a semi-product of gears.

In the Fig. 6 is shown theoretical S-N (Wöhler's) curve, which is based on standards ISO 6336-5:2003 and DIN 3990:1987 Method B for material 18CrNiMo7-6. Points around curves show medians (50 % of the samples) of the results of load capacity of the individual sets of gears (teeth).

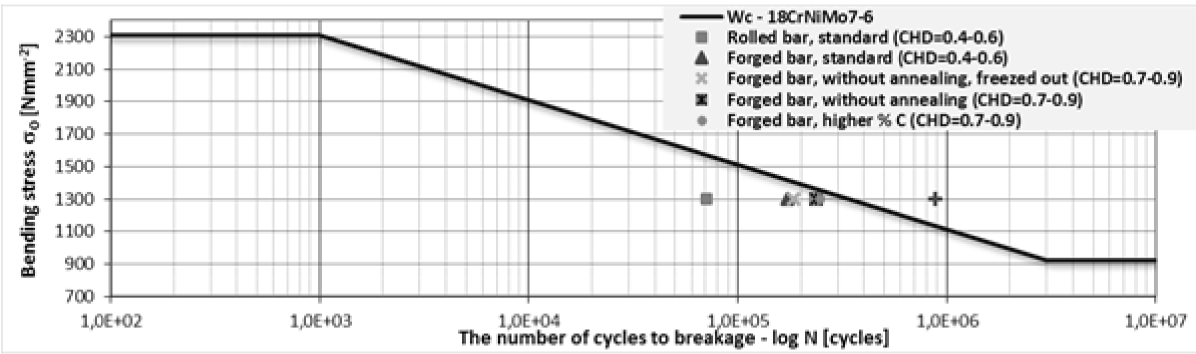


Fig. 7: Summary of individual CHD set gears and compared with the Wöhler's curve – mat. 18CrNiMo7-6.

4 Conclusion

From the results of pulse testing and placement into the Wöhler's (S-N) curve we can see, that as a semi-product is better to use rolled bar than a forged bar (Fig. 5). When comparing sets of gears, which have the same technology of CHD and the same semi-products, but different thicknesses of CHD shows the following: higher thickness of CHD benefit. Greatest benefit for resistance in the tooth root (about 300 %) have gears with technology applications - freeze out (-80 °C) during creation of hardened layer. Omission of the intermediate operations annealing is not appropriate. Used higher percentage of carbon (C) to increase the resistance to breakage of the tooth root did not work.

Acknowledgement

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