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STUDY OF WEAR BEHAVIOR OF A HELICAL GEAR

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ABSTRACT

This work is based on the study of damage causes in a DIN 16MnCr5 steel pair of helical gears. Vickers micro hardness tests were carried out and an in-depth study of two zones of the material in question was studied: hardness analysis of the material composing the gear body and analysis of the hardness of the teeth in the area of head of the tooth and study of the hardness along the profile of the tooth. A study of the distribution of defects in depth in 4 gear samples was performed, where the numbers of defects were counted, and the respective areas were measured through processing of optical microscopy (OM) imaging. Finally, wear tests were carried out on the material and its behavior on dry and lubricated wear was evaluated using a pin-on-disc test machine.

Keywords: gears, hardness, manufacturing defects, pin-on-disc testing, wear.

INTRODUCTION

Gear transmissions play a key role in modern technology, as they transfer both power and motion with high efficiency. The interaction between gear teeth in a transmission may be affected by wear in a negative fashion causing non-uniform gearing rate, decreasing efficiency and severe tooth failure (Flodin and Andersson, 1997). This work aimed to study the behaviour of the DIN 16MnCr5 steel pair of helical gears, considering the service conditions to which they were subjected. Such conditions were: an input power to the gear motor of 5.5kW at 1500rpm, a gear ratio of 27.88 and a torque at the output shaft of 800Nm at 50rpm. A total of 9 Vickers microhardness tests were performed on a set composed of 3 circular samples with 25mm of diameter obtained from the gear body, on which 3 teeth were tested in the contact zone and other 3 teeth in the tooth profile region. Sample surface preparation and testing method followed the ASTM E384-16 standard (ASTM E384-16, 2016). For the defect analysis, 4 circular samples also of 25mm diameter were obtained from the inner material of the helical gear. Other 9 samples of the same size were obtained from that region for pin-on-disc wear testing. Sample surface preparation and testing were performed in accordance with ASTM G99-95a standard (ASTM G99-95a, 2000).

RESULTS AND CONCLUSIONS

In the body of the helical gear, the average Vickers hardness value obtained was 294,82HV, with a value of 671,60HV recorded for the gear tooth flanks. Regarding the study of the hardness along the profile of the tooth, a decrease in hardness as the distance to the top of the

tooth increased was observed, leading to conclude for the influence of carburization. On average, the hardness values tend to become constant after 1mm to 1,5mm from the top of the tooth.

On the defect analysis performed with the software ImageJ, it was concluded that most of the defects present in the studied samples have an area in the range of [1×10^{-6} mm^2 to 1×10^{-5} mm^2], which represent about 46.38% of the total defects observed. It was also possible to identify areas with more manufacturing defects than others, which led to infer that there is a lack of homogeneity of the material, intrinsic to the manufacturing process.

First pin-on-disc dry test (Test-1) was made to estimate a loss rate of material [mm^3], to both sample and pin (equations (1) and (2))11, with a 41,14N load applied, at a rotation speed of 350rpm, with a 50 minutes test period. Stops were made each 10 minutes to weight both sample and pin.

$$\Delta V_a = 0{,}0018 \times t + 0{,}0183 \quad (1)$$

$$\Delta V_p = 0{,}0015 \times t - 0{,}0024 \quad (2)$$

Second pin-on-disc dry test (Test-2) evaluated the volume loss in the material under different applied loads (16.93N, 30.84N, 34.35N and 41.14N), during 40 minutes at 350 rpm. The values of the friction coefficient registered were in the range 0.5 to 0.75, as expected. Equations (3) and (4) were obtained for the specimen and pin, relating the volume loss of material [mm^3] to the different applied loads.

$$\Delta V_a = 0{,}006 \times e^{0{,}1144\times F_N} \quad (3)$$

$$\Delta V_p = 0{,}0031 \times e^{0{,}1036\times F_N} \quad (4)$$

A third pin-on-disc test was performed with old lubricant, during 40 minutes at 350rpm, with an applied load of 82.75N. The volume losses were insignificant to both specimen and pin. It was concluded that the friction forces, friction coefficients and the temperature close to the tip of the pin decreased, in average, 20N, 0.6 and 11℃, respectively.

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