THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI.
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N^{0}. 1 – 2012, ISSN 1453 – 083X

A TEST FOR RAPID TRIBOLOGICAL CHARACTERIZATION OF BEARING STEELS

Constantin GHEORGHIES, Mihaela BUCIUMEANU, Dan SCARPETE, Livia GHEORGHIES, Dorian BOLD
„Dunarea de Jos" University of Galati
email: constantin.gheorghies@ugal.ro

ABSTRACT

In this paper is a study the influence of the material and heat treatment on the changes of the fine structure parameters of the superficial layer of triboelements during the first cycles of rolling contact process. The tests were conducted by using a four-roller testing machine. The specimens (rollers) were made of case-hardening, through hardening and high frequency hardening steels. In order to induce different stress distributions in the superficial layer of the specimen specific treatments were applied. Using X-ray diffractometry can be appreciated that the durability of rolling tribosystems can be determined by an optimal relationship between studied parameters. The observed correlation can be used as a fast method to estimate the fatigue life of rolling bearing materials.

KEYWORDS: fine structure, steel, X-ray diffractometry, contact fatigue

1. Introduction

Generally, in the rolling tribosystems the durability is conditioned by the stress state and structure of the superficial layer. According to [1] for certain values of the Hertzian stress (σ_0>3.5GPa) the most important changes in the behaviour of the material occur during the first testing cycles (N<10). Residual stresses appear during this period. These stresses are added to the stresses due to the previous technological process. Such cases occur during thermal or thermochemical treatments performed in order to obtain a hard superficial layer.

The distribution of the thermal and structural stresses in the superficial layer of the material is presented in the figure 1 (S-surface, C-core) [2].

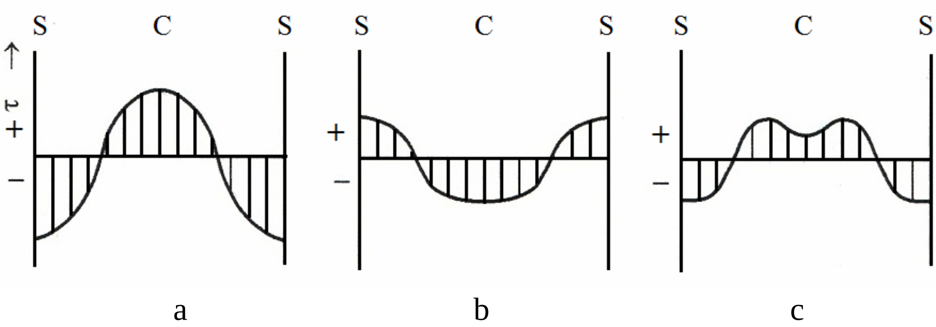


Fig. 1. *Distribution of the stresses in the superficial layer: a-thermal stress; b-structural stress; c-resultant stress.*

It is worth to mentioning that the total stress in the superficial layer can be either compressive (-) or tensile (+). It depends on the relation between those two types of stresses.

In this paper we propose a fast tribologial characterisation of some steels when they are subjected to rolling contact fatigue processes.

2. Experimental procedure

2.1. Materials

The specimens (cylindrical rollers) used in this study were machined from three different materials that are used in rolling bearing manufacturing (21MoMnCr12XS steel, 41MoCr11 steel and RUL 1 steel). The loading rollers were manufactured from 21MoMnCr12XS steel. The materials and the treatments applied to induce different stress distribution in the superficial layer are presented in Table 1.

Table 2 shows the chemical composition of the materials used in this study.

Table 1. *Materials and applied treatments*

Materials	**Treatment**	**Hardness,** HRC
21MoMnCr12XS	C+H+LT	62±3
41MoCr11	FH+LT	54±2
RUL 1	H+LT	62±2
21MoMnCr12XS	C+H+LT	62±2
C-carburizing; H-hardening; LT-low tempering; FH-high frequency hardening		

Table 2. *Chemical composition of the materials*

Materials	**Elements, %**							
	C	**Mo**	**Mn**	**Cr**	**Si**	**Ni max**	**S max**	**P max**
21MoMnCr12XS	0.18-0.24	0.20-0.30	0.80-1.20	1.00-1.40	0.17-0.37	-	0.035	0.035
41MoCr11	0.38-0.45	0.15-0.30	0.40-0.80	0.90-1.30	0.17-0.37	-	0.025	0.025
RUL 1	0.95-1.10	max 0.08	0.25-0.45	1.35-1.65	0.17-0.37	0.30	0.002	0.027

2.2. Experimental test setup

In order to carry out the test a pitting testing machine having four pressing rollers has been used [3].

The contact Hertzian stress was 4 GPa. The tests were performed by loading from 0 to 12 cycles, in steps of 2 cycles. The schematic representation of the test machine is presented in Figure 2. The fine structural changes [4-6] in the superficial layer of the tested materials have been estimate during testing cycles.

These structural changes were obtained by X-ray diffraction method, using a DRON-3 equipment (u=40kV, I=20mA, λ=0.70926 Å) [4].

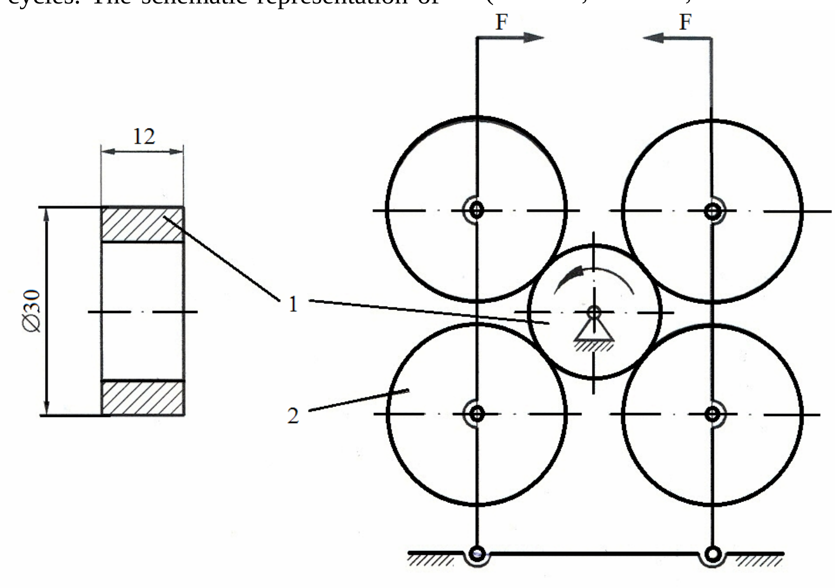


Fig. 2. *Schematic representation of test setup: 1-specimen roller; 2-loading (pressing) roller*

3. Experimental results and discussion

3.1. Evolution of the fine structural changes

The fine structure of the ferrite phase in tested steel specimens was determined by the X-ray diffraction method. The distribution of $B_{(110)}$ size vs. number of cycles is presented in Figure 3. $B_{(110)}$ is inversely proportional to the dimension of the mosaic blocks within the ferrite phase.

The evolution of the mosaic blocks for the tested steel samples is the same.

The decreasing of the dimension of the mosaic blocks is due to the fragmentation of the crystalline lattice under loading. The RUL 1 steel specimens present smaller mosaic blocks. This shows that RUL 1 steel has superior strength.

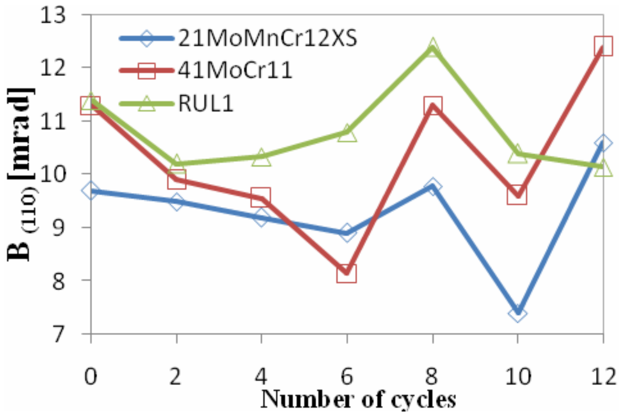


Fig. 3. *Distribution of $B_{(110)}$ size vs. number of cycles*

The distribution of $B_{(220)}$ size vs. number of cycles is presented in Figure 4. $B_{(220)}$ is directly proportional to inner second order stresses.

The carburizing and through hardening steels have a similar behaviour from the point of view of the inner second order stresses and show higher stability. The high frequency hardening steel presents important changes when the number of testing cycles increases.

These changes can be explained taking in account the presence of a meta-stabile tension state induced by the initial thermal treatment.

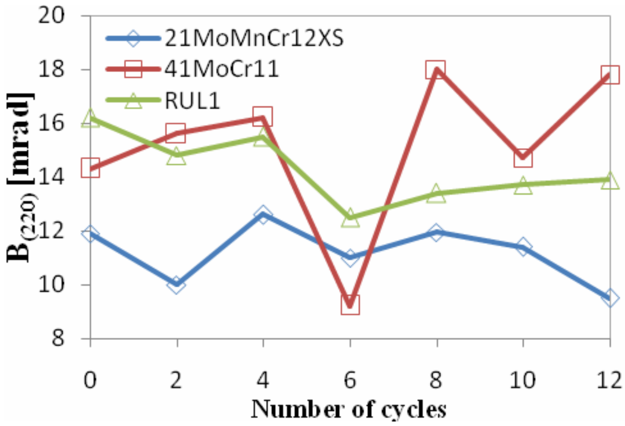


Fig. 4. *Distribution of $B_{(220)}$ size vs. testing cycles*

The distribution of $(I_{bkg}/I_{max})_{220}$ ration vs. number of cycles is presented in Figure 5. This parameter is directly proportional with the dislocation density level. The evolution of the density level in the ferrite phase during the testing process is the same for all the tested steels. As the number of testing cycles increases the level of density dislocation shows a common value. This confirms that the superficial layer presents an energetically stabilised state.

The distribution of $2(\Delta\theta)_{220}$ vs. number of cycles is presented in Figure 6. This is directly proportional with the first order tension. For the RUL 1 steel there is an initial tensile state that varies relatively less than high frequency hardening and carburizing steels.

These different stress states in the superficial layer of tested steels have a favourable influence on their durability.

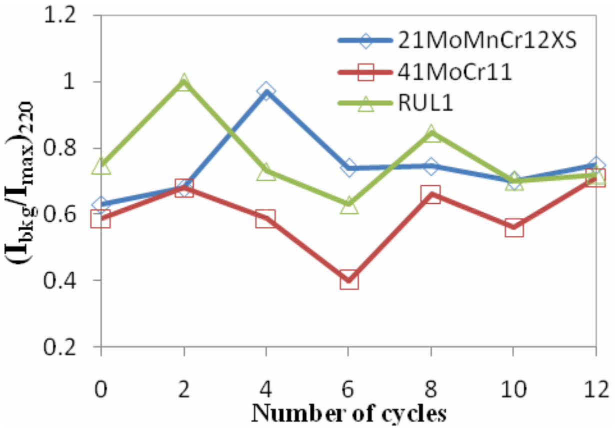


Fig. 5. *Distribution of $(I_{bkg}/I_{max})_{220}$ ratio vs. testing cycles*

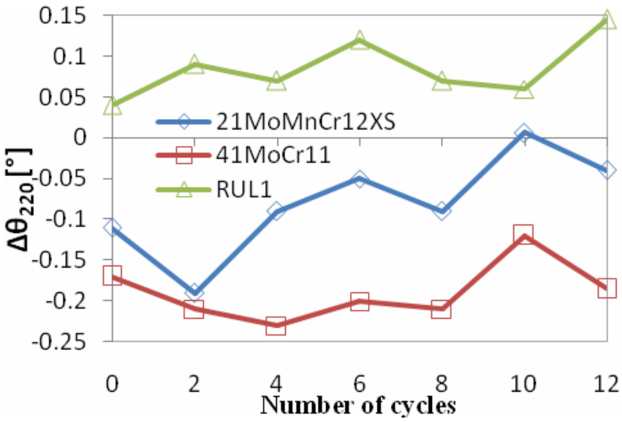
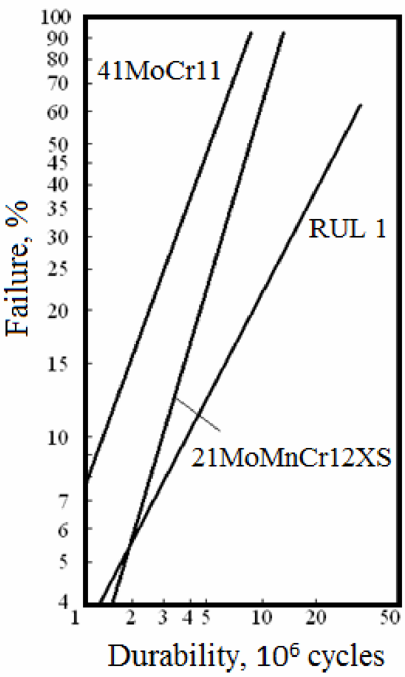


Fig. 6. *Distribution of $2(\Delta\theta)_{220}$ vs. testing cycles*



Material	**L_{10}, 10^6 cycles**
21MoMnCr12XS	2.55
41MoCr11	1.24
RUL 1	3.47

Fig. 7*. Estimation of L_{10} durability for the tested materials*

3.2. Fatigue tests

Contact fatigue experimental tests were made using the four-roller testing machine (Figure 2). To detect and record the rolling contact microcracks without destroying the steel, a special type of non-symmetrical ring was used for the specimens [6].

For each material 10 specimens were tested. All tests were conduced at ambient temperature, in a laboratory environment, with a Hertzian pressure of 1520MPa and at specimen rolling speed of 4000rpm. The Hertzian pressure was calculated neglecting the end effect. The lubricant was mineral oil T80EP2 recirculated at the temperature of 52^{o}C.

The fatigue life for each observed specimen was recorded. Figure 7 shows the fatigue life data used to estimate L_{10} of Weibull distribution (Figure 7).

4. Conclusions

The main conclusion of this research can be drawn as follows:

-from the structural point of view the response of the tested steels is relative identically during the first loading cycles, but RUL 1 steel showed superior durability;

-the evolution of the inner second order tensions shows a superior behaviour for RUL 1 and carburised steels;

-the Hertzian rolling contact loading leads to the same level of dislocation density in the superficial layer for all tested steels. A superficial energetic equilibrium occurred and in corrosive environments the steels will have the same behaviour.

-the initial first order stress state does not change the sign during testing process.

-the structural and stress states changed in the superficial layer in the first 12 loading cycles.

These were concluded based on the X-ray diffraction method. It allows to state that the durability of the rolling tribosystem is conditioned by an optimal relationship between the parameters studied.

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