THE INFLUENCE OF NON-CONVENTIONAL TREATMENTS ON THE DURABILITY OF BEARINGS

MIRELA GHEORGHIAN, DORU CIUCESCU

University of Bacau

Abstract: The durability represents the main criterion, which imposes itself in the definition of the reliability and of the competition of the bearings. The rotation precision and the functional role of the bearings are realized if it is a good dimensional stability and proper mechanical properties during the running. To fulfill these conditions it is necessary to establish the technological parameters of the processes of primary heat treatment, hot or cold plastic deformation, intermediate heat treatment, mechanical processing, final heat treatment and heat treatment below $0^{o}C$ or in ultrasonic field.
The comparative evaluation of different variants of heat treatment – classic or non-conventional (cryogenic or ultrasonic) which are applied on bearing steels from the point of view of durability have revealed significant increases of the values of real and median durability for non-conventional heat treated steels.

Keywords: residual austenite, cryogenic cooling, heat treatment, bearings.

1. INTRODUCTION

The increasing of the reliability of the systems constitutes an extremely important problem. Usually, the exploiting cost of a system surpasses much farther the cost of the system itself. From this point of view the efforts have to be oriented, especially, to the creation of systems with a high level of reliability, level which can be obtained if are taken measures to increase the reliability on all the phases in which all system passes, namely, design, manufacturing and exploitation.

The accelerated economic development has conducted to the realization of some technical systems of great complexity, which are susceptible, at the same time, of relatively frequent damages, some of them with extremely grave consequents. The problem of exploiting safety is made in the case of special purposes bearings production (destined to terrestrial, naval and aerospace transport); in this case, the classical heat treatment being not more sufficient for a proper dimensional stability and a high reliability [1].

2. TYPES OF RELIABILITY TESTS FOR BEARINGS

The estimation of the reliability parameters may be realized both by studying in exploitation of the different elements and by different types of tests. Vary different domains of usage and the high obtained durability make that in the case of bearings the estimation of reliability parameters to be realized, especially, on the base of laboratory tests.

After the testing procedure, in function of initial established term for ceasing the tests, it may be distinguished:
-Complete tests, till at the deterioration of all the bearings submitted to tests;

-Censured tests at the *r* level at which the durability test is considered finished after the deterioration of a number (r) of bearings, number established before in function of the total number of bearings (n) which are submitted simultaneously to the test; the censured tests conduct to important economies of time and energy; to ensure of a high trust number, it is recommended that the established number of bearings (r) deteriorated during the tests to be calculated as r = n/2 + 1;

-The trunked tests, at which the durability test is finished after an established time;
-sequential or progressive tests, at which the decision to halt the tests may be taken in every moment in function of the number of deteriorations and the summed duration of tests;

After the type of applied compulsions, it may be distinguished:
-normal tests, at which the exploiting conditions are similar with tests conditions;
-accelerated tests or forced, at which the bearings are submitted on more sever condition than in exploitation;
-step by step tests, which are, in fact, accelerated tests, hypotheses non valid in the case of deteriorations by contact fatigue [2].

Due to the fact that the major advantage of accelerated (forced) tests is the economy, it is putting the problem of establishing of the upper limits of the solicitation, so that the increasing of the speed of deterioration not to be accompanied by modifications in the structure of materials having as consequences the changing of the real character of the deteriorations as well as the nature of the their dispersion law.

The durability represents the main criterion imposing itself in the definition of reliability and the competition of bearings. The durability tests are made for studying the quality of mass production, as well as for the validation of a constructive, technological or material improvement. In order to obtain of a high trust number, are necessary tests on lots with a great number of bearings in each lot, resulting a high cost of tests due to the long duration and to the high energy, material and manual work consumption.

The durability tests of bearings are presented in the society standard SF 28103 – 2001.
The reliability of bearings has an extremely importance in the extensive exploiting of machines and installations. This aspect has conducted at the determination by calculation of estimative durability of bearings, taking into consideration some probabilities of deterioration.

3. THE MATHEMATICAL MODEL FOR STUDYING THE RELIABILITY

The mathematical model use d for the study of the reliability of cryogenic and ultrasonic treated bearings is the Weibull distribution function (theoretical distribution which is near the empirical distribution on the base of experimental data).

This distribution depends on three parameters:
-deterioration intensity (1):

$$\lambda(t) = \frac{k}{\theta}\left(\frac{t-\gamma}{\theta}\right)^{k-1} \tag{1}$$

-reliability function (2):

$$R_{(t)} = \exp\left[-\left(\frac{t-\gamma}{\theta}\right)^{k}\right] \tag{2}$$

-distribution function (3):

$$F_{(t)} = 1 - \exp\left[-\left(\frac{t-\gamma}{\theta}\right)^{k}\right] \tag{3}$$

-probability density (4):

$$F_{(t)} = \frac{k}{t}\left(\frac{t-\gamma}{\theta}\right)^{k-1} \cdot \exp\left[-\left(\frac{t-\gamma}{\theta}\right)^{k}\right] \tag{4}$$

where: t = the life durability of bearings (10^6 rotation or hours):
k = size parameter in the Weibull distribution (Weibull slope);
θ = scale parameter in Weibull distribution;
γ = placing parameter in Weibull distribution.

These parameters satisfies the following relations: $k, \theta \in R^+$, $\gamma \in R$, $t \geq \gamma \Rightarrow F(t) = 0$.
The placing parameter γ has no influence on the dispersion state, it representing the minimal duration from which appears the possibility to have deteriorations and permits to change or to advance in time of the origin.
If it is considering γ =0, Weibull distribution becomes two-parametrical.

In the reliability evaluations of bearings are used the both variants of Weibull distribution (two- or three-parametrical), according to the obtained experimental values, to the evolution in the line [3]. The three-parametrical variant is more accurate.

4. THE CALCULATION METHODOLOGY OF THE DURABILITY. THE TESTING PLAN

The reliability (in the context of durability) of an individual bearing or of a lot of apparently identical bearings and running in normal conditions represents the probability of functioning, according to the pre-established parameters and specifications, so that the bearings could reach or surpass the durability L_{calc} obtained in the running conditions of the bearing / bearings.

The test are laboratory type classified according to the Decision 34/2004 (replacing partially ARAS R 12007-81), on two types of bearings: radial ball-bearings 6024 UG and cylindrical roller-bearings NU 205 ES.
Because the testing times are very great, it was adopted for the accelerate testing plan, respectively for censured tests at *r* level, when the durability test is considered after the deterioration of a *r* elements from *n* submitted to testing elements.
The recommended testing plan for accelerated type tests is:

$$r/n = 8/20$$

Two bearings could exit from use from other independent running conditions (deviations from the manufacturing technical conditions / deviations in functioning of testing installation etc.). These two bearings are excluded from the appreciation of the results of tests.

For this testing plan, the size of the lot is of 30 bearings, so that each of 8 bearings (deteriorated by contact fatigue, being relevant deterioration) to be replaced, at which are added
The reliability tests were realized for bearings from 100Cr6 steel, which are classical treated (variant A), cryogenic treated at -30^{o}C + tempering at 170^{o}C (variant B_1), cryogenic treated at -60^{o}C + tempering at 170^{o}C (variant B_2), ultrasonic heat treated (variant C_1).

The lots of 30 bearings each for r/n = 8 / 20 have formatted as follows:

The witness-lots (variant A):
- A_1 – bearings 6205 UG;
- A_2 – bearings NU 205 ES;

The lots (variant B_1):
- B_{11} - bearings 6205 UG;
- B_{12} - bearings NU 205 ES;

The lots (variant B_2):
- B_{21} - bearings 6205 UG;
- B_{22} - bearings NU 205 ES;

The lots (variant C):
- C_1 - bearings 6205 UG;
- C_2 - bearings NU 205 ES.

The testing method is with an internal ring in rotation moving, and at external ring (non-rotary) is applied the charge. The used installations: LBT 3000 for bearings 6204 UG and MA 910 for bearings NU 205. The kinetic schema of LBT 3000 installation is given in figure 1.

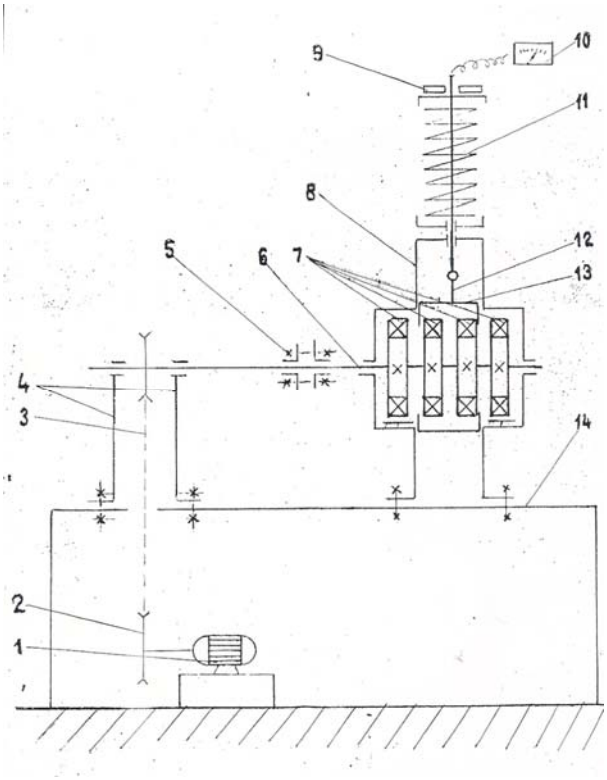

Fig. 1.The testing installation for cylindrical roller-bearings

The scheme to charge is presented in figure 2.
For the calculation of charges applied to bearings, which are submitted to the reliability tests, are recommended the following relations:

a. Radial ball-bearings C/P = 3;
b. Radial roller-bearings C/P = 10/3.

The number of rotations of internal ring, meaning of the port-bearing axe, at the reliability tests in the installation is taken between the limits $n = (0,4…0,6)n_l$, where n_l is the limit of the number of rotations.

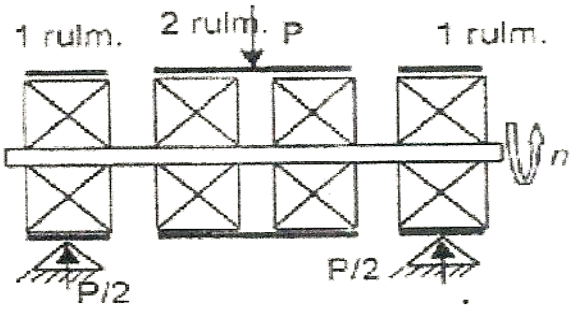

Fig. 2 The charging schema at the measuring the durability for the radial ball / roller bearings

5. FINAL RESULTS

The values of durability obtained according to the methodology are centralized in table 1.

Table 1 The values of durability of the lots of bearings

The type of bearings	The variant of treatment	Lot	L_{10}		L_{50}	
			[hours]	[%]	[hours]	[%]
6204 UG	A - clasic	A_1-witness	144	100	451	100
	B_1 - 30ºC	B_{11}	165	114,6	524	116,2
	B_2 - 60ºC	B_{12}	193	134	608	134,8
	C - ultrasonic	C_1	176	122	580	128,6
NU 205 ES	A - clasic	A_2-witness	3867	100	12528	100
	B_1 - 30ºC	B_{21}	4478	115,8	14202	113,4
	B_2 - 60ºC	B_{22}	5048	130,5	16243	129,6
	C - ultrasonic	C_2	4862	125,7	15725	125,5

Analyzing the results from the table 1, it may be remarked for both 6204 UG and NU 205 ES types of bearings an increase of the durability as follows:

-for the bearings 6204 UG:

-at the variant B_1: L_{10} increases with 14,6%
L_{50} increases with 16,2%

-at the variant B_2: L_{10} increases with 34,6%
L_{50} increases with 34,8%

-at the variant C: L_{10} increases with 22%
L_{50} increases with 28,6%

-for the bearings NU 205 ES:

-at the variant B_1: L_{10} increases with 15,8%
L_{50} increases with 13,4%

-at the variant B_2: L_{10} increases with 30,5%
L_{50} increases with 29,6%

-at the variant C: L_{10} increases with 25,7%
L_{50} increases with 25,5%

6. CONCLUSIONS

For the analyses of the durability was chosen the time as a random variable till the relevant defection of the bearing like a Weibull distribution.

The determination of the parameters of the Weibull distribution was made having in view the methods of the theory of estimation, which permits the determination of numerical values of parameters. For a good approximation the method of the maximal plausible ness was used.

The contact fatigue resistance was considered as a factor of deterioration for the exit from usage of bearings.

The appearing of pitting type of contact fatigue is pointed out by the modification of the noise emitted by bearings (heard with amplifiers) or of vibrations registered with accelerometer.

The heat treatments with cooling in the domain of negative temperature or in ultrasonic field increase the durability of bearings.

The increase of durability by applying the variant B_1 were between 14,6 % and 16,2% for L_{10} and between 13,4 şi 16,2% for L_{50}.

The increase of durability by applying the variant B_2 were between 30,5 % and 34,6% for L_{10} and between 29,6% and 34,8 % for L_{50}.

The increase of durability by applying the variant C were between 22 % and 25,7% for L_{10} and between 22% and 25,7 % for L_{50}.

The increase of durability has as effect: 1) the diminution of the quantity of residual austenite from 10...15% at 6...8%; 2) the finishing of carbides; 3) the increase of small carbides (under μm).

5. REFERENCES

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