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REGARDING ON NEW BALL-BEARINGS HAVING A MODIFIED INTERNAL GEOMETRY (Part 2)

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ABSTRACT

In this paper there are presented some considerations regarding theoretical and experimental researches in the field of loading capacities determination and researches on materials used in ball-bearings rings construction

Keywords: ball-bearings, geometry, capacities

1. INTRODUCTION

The ball-bearings built as seen in Figure 2 were tested using a stand existing in Ball-bearing Factory from Braşov, România.

2. EXPERIMENTAL LOADING CAPACITIES DETERMINATIONS

The construction of the testing head is presented in Figure 1, where: 1, 1' - tested ball-bearings; 2, 2' - fixed housings; 3 - mobile charging housing.

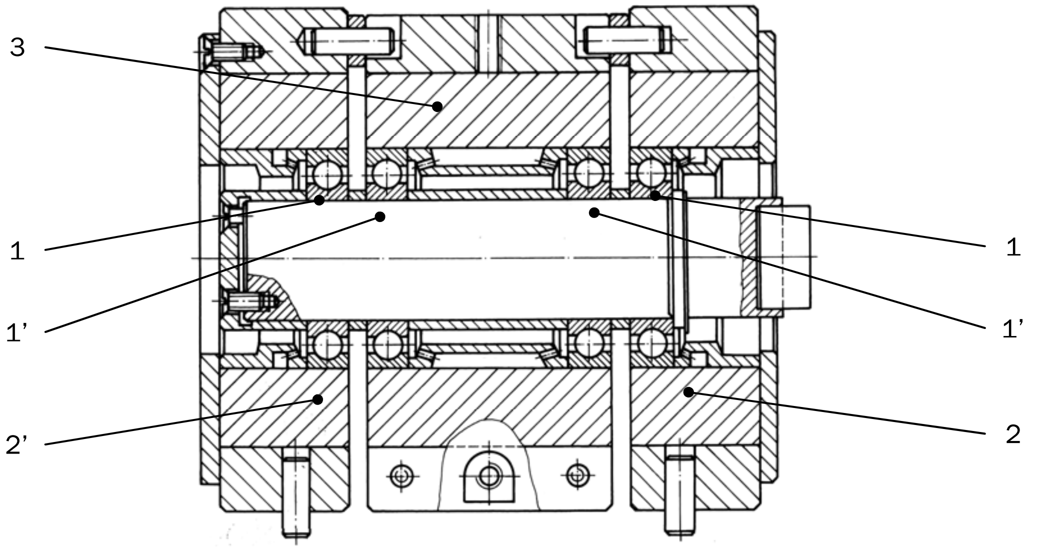

Figure 1. The construction of the testing head.

The entire stand consist 5 identically testing heads putted into rotation by 5 electric motors. The charge is realised using a hydraulic installation. In these conditions it is possible to test 20 ball-bearings simultaneous.

The testing conditions were:

- 20 ball-bearings of each type;
- radial loading $P = 17.59$ kN (1/3 of $C_{catalogue}$);

- revolution speed n = 3500 rpm;
- testing duration 800 hours.

The experimental results are presented in Table 1.

Table 1. Experimental results.

Ball-bearing	6309 URB	6309 M2	6309 M4
Hours	262	282	310
	350	320	380
	410	400	410
	550	650	680
	750	720	800

The number of hours from Table 1 represent the stand's function durations after that the pitting had appeared (vibrations and noises). Using this experimental results and a logarithmic scale it was possible to establish the L_{10} durability, presented in Table 2.

Table 2. L_{10} results.

Ball-bearing	L_{10}, hours
6309 URB	165
6309 M2	172
6309 M4	212

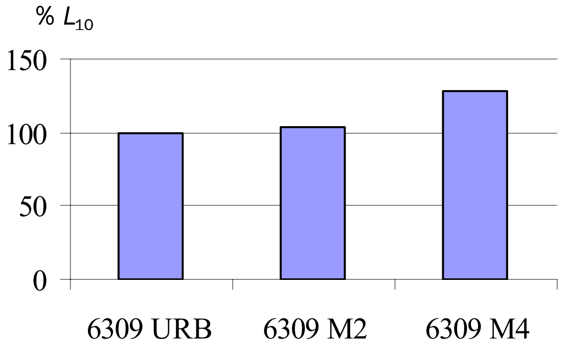

Figure 2. Percentage variation.

The percentage variation is presented in Figure 2.

The comparison between the theoretical results on loading capacities and the experimental L_{10} durability is resented in Table 3 and Figure 3.

Table 3. C_r and L_{10} comparison.

Ball-bearing	6309 URB	6309 M2	6309 M4
C_r, kN	52.77	57.26	63.20
	0	+ 8.59	+ 20
L_{10}, hours	165	172	212
	0	+ 4.24	+ 28.4

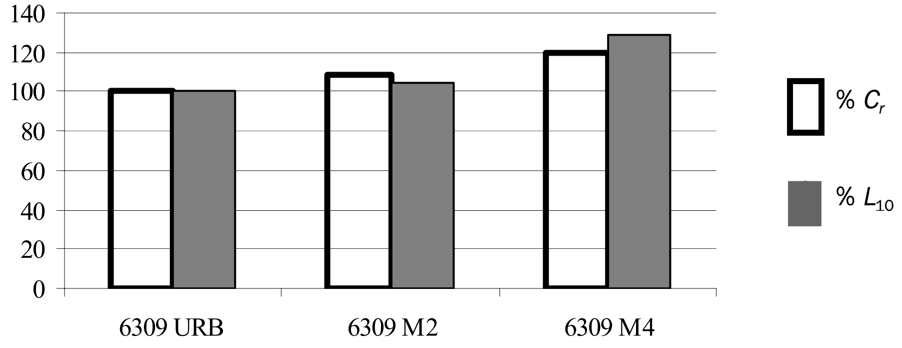

Figure 3. C_r and L_{10} percentage comparison.

3. CONSIDERATIONS REGARDING THE STRESS PARAMETERS IN RINGS

In the case of ball-bearings having modified internal geometry with thin rings it's very important to regard on the stress parameters in contact.

For the 6309 M4 ball-bearing it is possible to determine the contact area dimensions, the maximum pressure and the elastic compression.

The dimensions of the tribomodel used in the researches are presented in Figure 4.

The contact curvatures are:

r_{11} = 29.500 mm; r_{21} = 26.831 mm;
r_{12} = 10.731 mm; r_{22} = 10.938 mm.

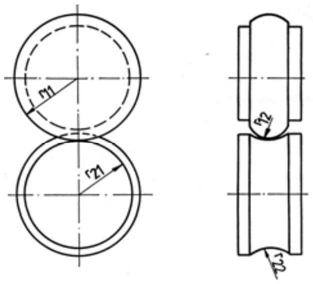

Figure 4. Rolls dimensions.

Using the relations from the literature [12] it is possible to establish the contact elliptical area dimensions, *a* and *b*, the pressure, p_{max}, and the elastic compression δ as follows:

$$a=\alpha\left(\frac{F\rho}{K_0}\right)^{\frac{1}{3}}=0.02022\,F^{\frac{1}{3}}\ \text{[mm]};\tag{1}$$

$$b=\beta\left(\frac{F\rho}{K_0}\right)^{\frac{1}{3}}=0.01799\,F^{\frac{1}{3}}\ \text{[mm]};\tag{2}$$

$$p_{\max}=\frac{3F^{\frac{1}{3}}}{2\pi\,a\,b}=137.45\,F^{\frac{1}{3}}\ \text{[MPa]};\tag{3}$$

$$\delta=\lambda\left(\frac{F^2}{K_0^2\rho}\right)^{\frac{1}{3}}=3.454\cdot10^{-4}\,F^{\frac{1}{3}}\ \text{[mm]},\tag{4}$$

where the values α, β, ρ, K_0 coefficients are done in Table 4 [12].

Table 4: Coefficients' values.

α	β	λ	ρ	K_0
1.061	0.944	1.996	2.1015	$1.15 \cdot 10^5$

Admitting the Huber - Mises - Henky hypotheses is possible to establish the depth of the maximum $\sigma_{ED\,(\lambda)}$ and $\tau_{45\,D}$ strains, depending on $b/a = 0.8897$ ratio, as follows:

$$\sigma_{ED\,(\lambda)} = 0.6291\,p_{max}\ \text{[MPa]};\tag{5}$$

$$\tau_{45\,D} = 0.2166\,p_{max}\ \text{[MPa]};\tag{6}$$

$$z_{\sigma\,ED} = 0.4991\,b\ \text{[mm]};\tag{7}$$

$$z_{45\,D} = 0.3611\,b\ \text{[mm]}.\tag{8}$$

From K. L. Johnson [14] the *a* and *b* dimensions, p_{max} and δ are:

$$a = 0.014265\,F^{1/3}\ \text{[mm]};\tag{9}$$

$$b = 0.015039\,F^{1/3}\ \text{[mm]};\tag{10}$$

$$p_{max} = 222.67\,F^{1/3}\ \text{[mm]};\tag{11}$$

$$\delta = (9\,F^2 / 16\,R_e\,E^{*\,2})^{1/3} = 2.823\cdot10^{-4}\,F^{2/3}\ \text{[mm]},\tag{12}$$

where: $R_e = (r_{12}\cdot r_{22})^{1/2}$ is the equivalent radius; the equivalent elasticity modulus is

$$\frac{1}{E^*}=\frac{1-\upsilon_1^2}{E_1}+\frac{1-\upsilon_2^2}{E_2}\,.\tag{13}$$

From Palmgreen [12, 14] the specific force K_0 is establish in function of the HV hardness

$$K_0 \le 1.8\left(\frac{HV}{750}\right)^3\left(\frac{\xi}{\psi}\right)^{\frac{3}{2}}\delta^{\frac{1}{2}}\ \text{[N]}. \tag{14}$$

From Stribeck [12, 14] the maximum Hertzian pressure is

$$p_{\max} = \left(\frac{K\square E^2}{4.28}\right)^{\frac{1}{3}}\ \text{[MPa]}. \tag{15}$$

The ξ and ψ coefficients are given in literature [14], values presented in Table 5, and δ is depending on curvatures as follows:

$$\delta = \frac{2}{1+\frac{r_{11}}{r_{12}}+\frac{r_{11}}{r_{21}}+\frac{r_{11}}{r_{22}}}\ \text{[mm]}. \tag{16}$$

Table 5. ξ ,ψ and δ coefficients' values.

ξ	ψ	δ
1.088	1.0825	0.3628

Depending on charging force F, using the relations (14) … (21) were established the geometric elements and the strains in the case of roll - internal ring contact (Table 6).

Table 6. Geometric elements and strains on roll - internal ring contact.

F, [N]	$2a$, [mm]	$2b$, [mm]	p_{max}, [MPa]	δ, [µm]	σ_{ED}, [MPa]	$z_{\sigma\, ED}$, [mm]	$\tau_{45\, D}$, [MPa]	$z_{\tau\, 45\, D}$, [mm]
2000	0.30008	0.36013	2798.3	3.51	1760	0.08	606	0.060
3000	0.44203	0.41214	3202.9	4.06	2014	0.10	693	0.070
4000	0.47629	0.45367	3524.9	4.46	2217	0.11	763	0.081
5000	0.51289	0.4886	3796.8	4.81	2388	0.12	822	0.088

4. CONCLUSIONS

The paper gives a vision about the testing comportment of ball-bearings having other internal geometry and some theoretical aspects on stress parameters for the rolling contact.

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