ANALELE UNIVERSITĂȚII
"EFTIMIE MURGU" REȘIȚA
ANUL XIX, NR. 1, 2012, ISSN 1453 - 7397

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Contact Pressure Analysis on Radial Ball Bearings

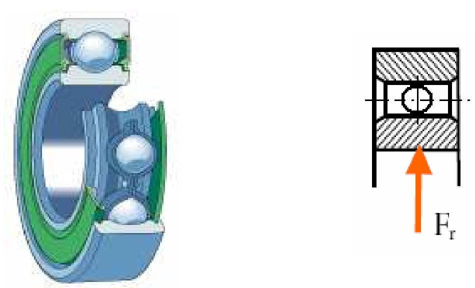
The paper analyze the value of the maximum Hertzian pressures developed at the contact between 12,7 mm bearing balls, the upper ring, the lower ring and the rolling track. We verified three types of ball bearings with the ball number equal with 8, 10 and 12, at a maximum force F, constant on the most strained ball, with values between 1100 N and 1500 N, at nine loading cycles which add 50 units per cycle.

Keywords*: radial bearing, axial bearing, contact pressure, bearing ball*

1. Introduction

Radial ball bearings are the most common bearings (fig. 1.a). Beside the radial load they can also take over an axial load, but this should not exceed 70% of the unused radial load (fig. 1.b) [1], [2], [3].

The axial ball bearings (on one row or two rows) are presented in fig. 2.a and fig. 2.b, whereas fig. 3 shows the plane strain of the bearing balls encountered in the lapping technological operation and during their fatigue testing [1], [3].



a. b.

Figure 1. Radial ball bearing: 3D representation (a) and main load (b)

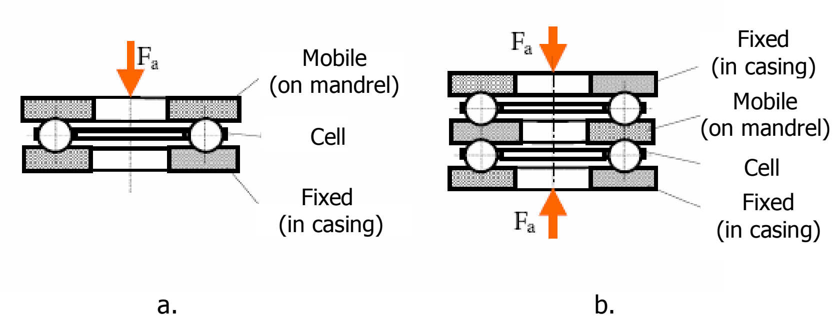


Figure 2. Axial ball bearing: one row (a) and two rows (b)

Figure 3. Plane strain of the axial ball bearing

In fig. 1, F_r represents the bearing radial load force, while F_a represents the axial force (fig. 2)

2. Constructive Elements

The contact between the bearing ball with diameter d_b, the upper ring and the lower ring at the radial bearing and a plane surface at the axial bearing is presented in fig. 4.

Between following component elements of a radial bearing (fig.5.a),

D – the diameter of the exterior ring,
d – the diameter of the interior ring,
d_b – the ball diameter,
z – the number of balls
r_c – the radius of the rolling track,

there are certain relations, presented as equations (1) to (3).

$$d_b = 0.3(D - d) \tag{1}$$

$$z = 2.9\frac{D + d}{D - d} \tag{2}$$

$$r_c = 1.03\frac{d_b}{2} \tag{3}$$

The rolling track (fig.5.b) is also called groove.

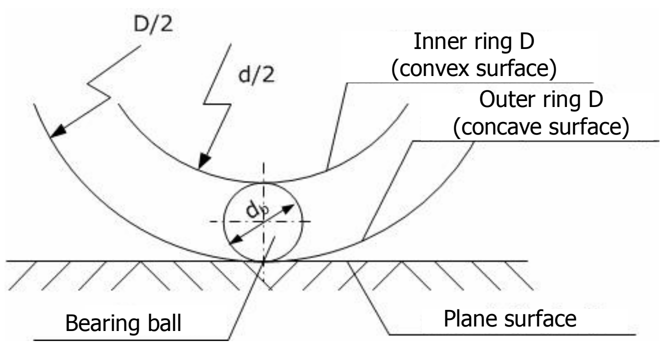


Figure 4. Contacts between the ball and the inner and outer rings

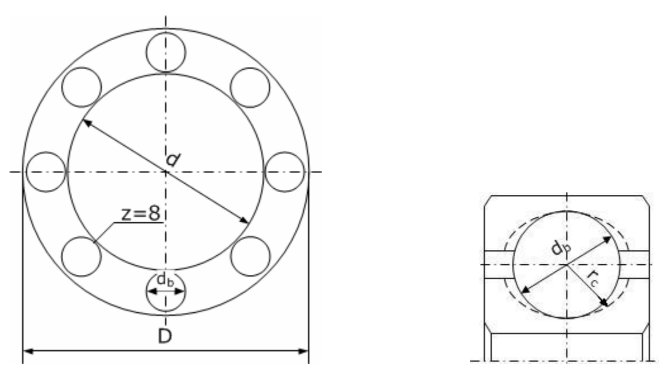


Figure 5. Geometrical characteristics of the radial ball bearing

3. The calculus of the contact pressure

The paper studies, from the analytical viewpoint [4], the maximum contact pressure occurring at a radial loading (fig.1.b), with the force F_r constant for each bearing ball. We used nine loading steps ranging between 1100 [N] and 1500 [N], the force increasing by a step of 50 [N].

For the static or hypothetically designed study, three types of bearings were used with the ball numbers z = 8, 10 and 12 balls. Based on the calculation relations (1) to (3) the initial data of the radial ball bearings are presented in table 1.

Table 1.

Type of bearing	z	d_b mm	D mm	d mm
1	8	12.7	75.99	37.22
2	10	12.7	94.147	51.817
3	12	12.7	108.74	66.41

The contact between the ball bearing and the upper ring is made on a concave surface and with the inner ring on a convex surface. The contact between the ball and the rolling track (fig. 5.b) is concave both for the upper ring and for the lower ring. The data were processed on the basis of Hertz's relations [5],[6] and written down in following tables. Table 2 present the contact between the bearing ball and the surface of the upper ring (convex) - P_s.

Table 2.

CONTACT BALL / OUTER RING								
RING 1			RING 2			RING 3		
z_1		8	z_2		10	z_3		12
d_b	mm	12.7	d_b	mm	12.7	d_b	mm	12.7
D	mm	79.55	D	mm	94.147	D	mm	108.74
P_{s1}	MPa	3699.194	P_{s1}	MPa	3771.482	P_{s1}	Mpa	3823.915
P_{s2}	MPa	3754.414	P_{s2}	Mpa	3827.781	P_{s2}	Mpa	3880.996
P_{s3}	MPa	3808.056	P_{s3}	Mpa	3882.471	P_{s3}	Mpa	3936.447
P_{s4}	MPa	3860.227	P_{s4}	Mpa	3935.662	P_{s4}	Mpa	3990.377
P_{s5}	MPa	3911.026	P_{s5}	Mpa	3987.453	P_{s5}	Mpa	4042.888
P_{s6}	MPa	3960.538	P_{s6}	Mpa	4037.933	P_{s6}	Mpa	4094.069
P_{s7}	MPa	4008.842	P_{s7}	Mpa	4087.181	P_{s7}	Mpa	4144.002
P_{s8}	MPa	4056.009	P_{s8}	Mpa	4135.269	P_{s8}	Mpa	4192.76
P_{s9}	MPa	4102.104	P_{s9}	Mpa	4182.265	P_{s9}	Mpa	4240.409

Table 3 presents the contact between the ball and the inner surface (concave) – P_i

Table 3.

CONTACT BALL / INNER RING								
RING 1			RING 2			RING 3		
z_1		8	z_2		10	z_3		12
d_b	mm	12.7	d_b	mm	12.7	d_b	mm	12.7
d	mm	37.22	d	mm	51.817	d	mm	66.41
P_{i1}	MPa	5052.021	P_{i1}	MPa	4807.665	P_{i1}	Mpa	4668.008
P_{i2}	MPa	5127.435	P_{i2}	Mpa	4879.432	P_{i2}	Mpa	4737.69
P_{i3}	MPa	5200.694	P_{i3}	Mpa	4949.148	P_{i3}	Mpa	4805.38
P_{i4}	MPa	5271.945	P_{i4}	Mpa	5016.953	P_{i4}	Mpa	4871.216
P_{i5}	MPa	5341.321	P_{i5}	Mpa	5082.973	P_{i5}	Mpa	4935.318
P_{i6}	MPa	5408.94	P_{i6}	Mpa	5147.321	P_{i6}	Mpa	4997.797
P_{i7}	MPa	5474.909	P_{i7}	Mpa	5210.099	P_{i7}	Mpa	5058.752
P_{i8}	MPa	5539.325	P_{i8}	Mpa	5271.4	P_{i8}	Mpa	5118.272
P_{i9}	MPa	5602.278	P_{i9}	Mpa	5331.308	P_{i9}	Mpa	5176.439

Table 4 presents the contact between the bearing ball and the plane surface – $P_{max.}$ while table 5 presents the contact between the bearing ball and the surface of the rolling tracks – P_j

Table 4.

CONTACT OF THE BEARING BALL WITH A PLANE SURFACE		
P_{max1}	MPa	4153.998
P_{max2}	MPa	4216.007
P_{max3}	MPa	4276.244
P_{max4}	MPa	4334.83
P_{max5}	MPa	4391.874
P_{max6}	MPa	4447.473
P_{max7}	MPa	4501.716
P_{max8}	MPa	4554.682
P_{max9}	MPa	4606.444

Table 5.

CONTACT OF THE BEARING BALL WITH THE ROLLING TRACK		
P_{j1}	MPa	393.2382
P_{j2}	MPa	399.1083
P_{j3}	MPa	404.8106
P_{j4}	MPa	410.3566
P_{j5}	MPa	415.7567
P_{j6}	MPa	421.02
P_{j7}	MPa	426.1549
P_{j8}	MPa	431.1689
P_{j9}	MPa	436.069

Diagrams plotted in figures 6-9 represent the variation of maximum pressure, almost linear, in accordance with the contact of the bearing ball: rolling track (fig. 6); outer ring (fig. 7); plane (fig. 8) and inner ring (fig. 9).

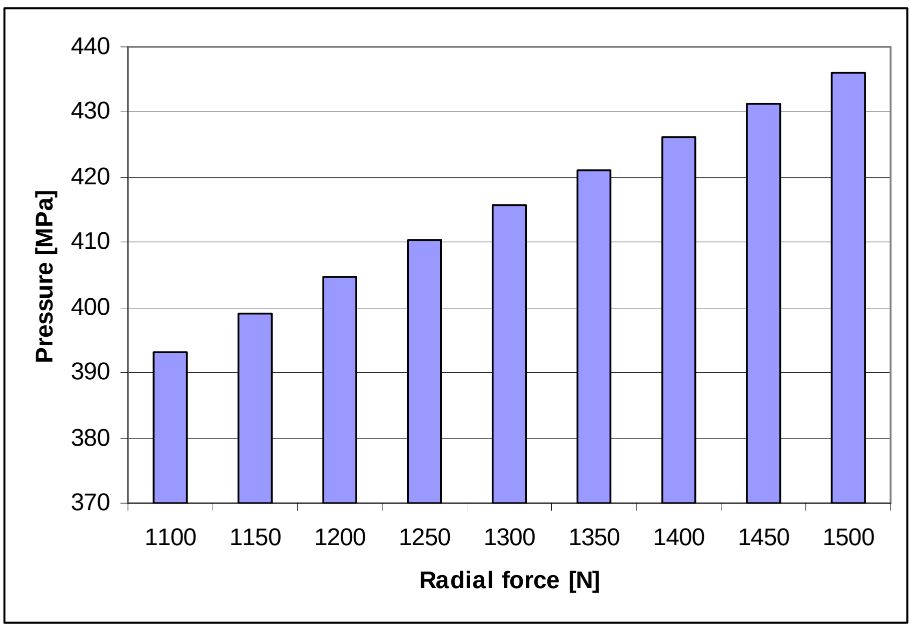


Figure 6. Contact pressure for the bearing ball with the rolling track

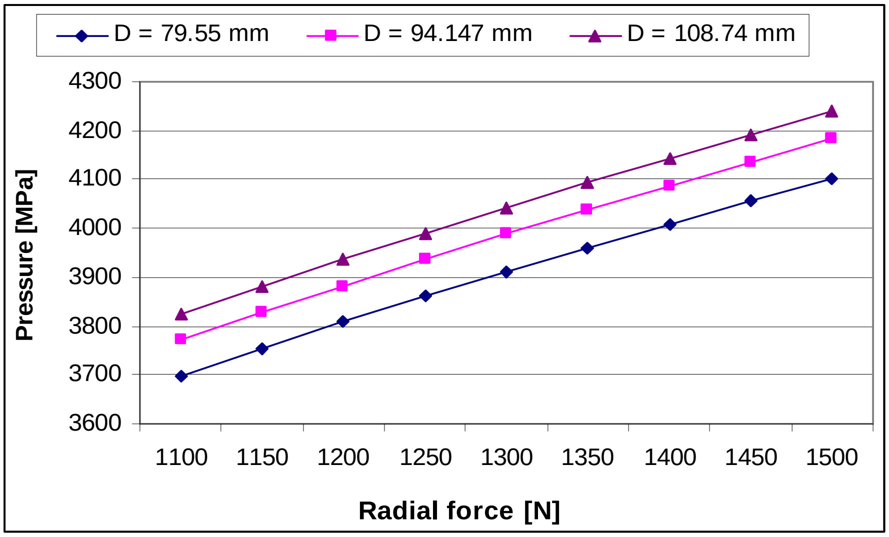


Figure 7. Contact pressure for the bearing ball with the outer ring

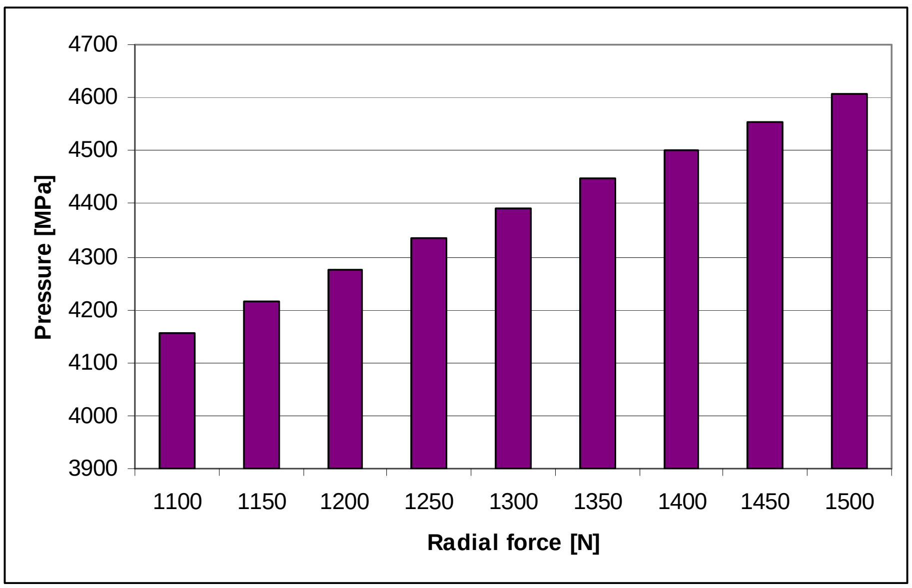


Figure 8. Contact pressure for the bearing ball with the plane surface

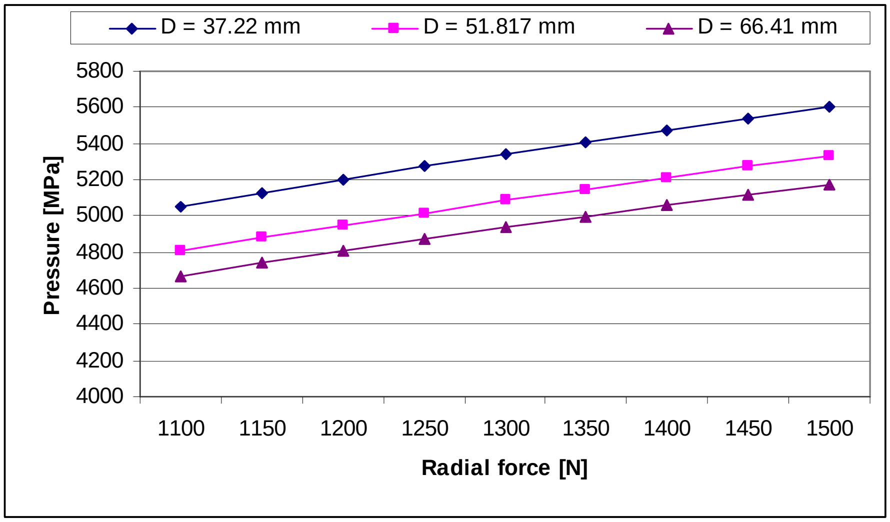


Figure 9. Contact pressure for the bearing ball with the inner ring

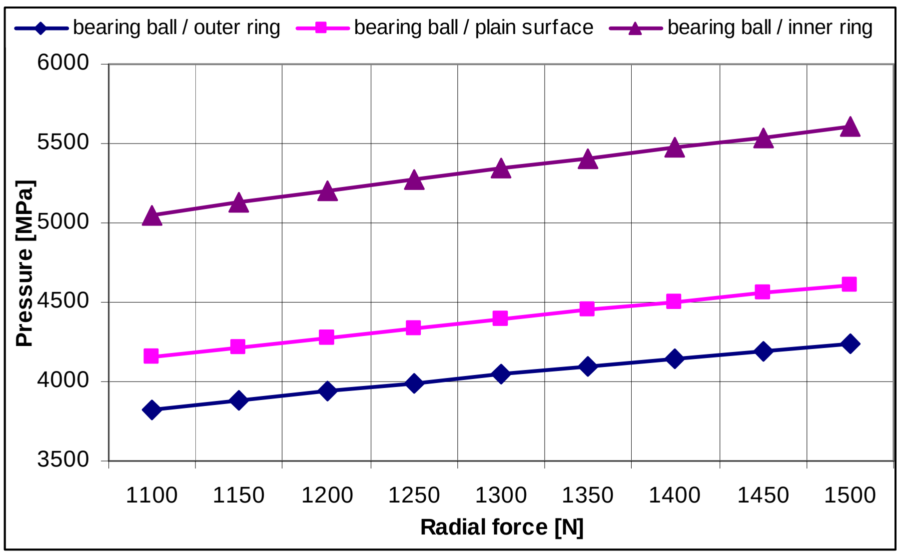


Figure 10. Contact pressure for the most unfavorable contact cases between bearing ball and plane surface or bearing rings

Figure 10 present a comparison involving the most unfavorable situations for the contact between a bearing ball and a plane surface, and inner and outer ring respectively.

4. Conclusion

The maximum values of contact pressure calculated analytically are high, and consequently we consider this calculation insufficient for obtaining conclusive data in the elastic - plastic domain, the non-linear phenomenon [7], [8], [9] occurring at the contact of the bearing ball with the rolling tracks. In many cases the wear and tear of the rolling track is much more poignant compared with the balls of the radial or axial bearing.

As regards the data from tables 2-5 corroborated with figure 4 and diagrams presented in figures 6 to 10, we find that the maximum pressure has lower values for the contact between the ball and the concave surface of the inner ring, the contact ball / plane surface representing the upper maximum limit, compared with the contact of the ball with the convex surface of the inner ring; here the values are higher than in the first case, the contact ball / plane surface representing the lower limit.

In order to experimentally determine the duration of operation in good conditions of a bearing, it is necessary to determine its high wear and tear degree with the help of certain devices able to identify the vibrations occurring in exploitation [10], [11], [12].

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