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REGARDING ON NEW BALL-BEARINGS HAVING A MODIFIED INTERNAL GEOMETRY (Part 1)

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ABSTRACT
In this paper there are presented some considerations regarding ball-bearings' rings construction, assembling conditions, loading capacities, new constructions of ball-bearings having other number of balls or other dimensions of them in the way to have improved loading capacities.
Keywords: ball-bearings, geometry, capacities.

1. INTRODUCTION
There are papers [1, 3, 7] in which there are presented possibilities to influence the static and dynamic loading capacities of ball-bearings. A proper example is to modify the internal geometry of the rings, in the way to have other number of balls, z or other dimensions of them D_w respecting the external diameter, D, and the width B. It is important in some applications, where we can reach to other (bigger) dimensions of the internal diameter of the ball-bearing, d (i.e. gear boxes, car axles, industrial robots). The dimensions of 6309 ball-bearing are 45x100x25 with D_w = 17.462 mm and z = 8.

2. BALL-BEARINGS CONSTRUCTION
It is known that [1, 3] ring dimensions, presented in Figure 1, are determined with the following relations:

- primitive diameter: $P_w = 0.55D + 0.45d$; (1)
- external rolling way diameter: $E = P_w + D_w$; (2)
- internal rolling way diameter: $F = E - 2\,D_w$; (3)
- external ring collar diameter: $D_1 = E - k_1\,D_W$; (4)

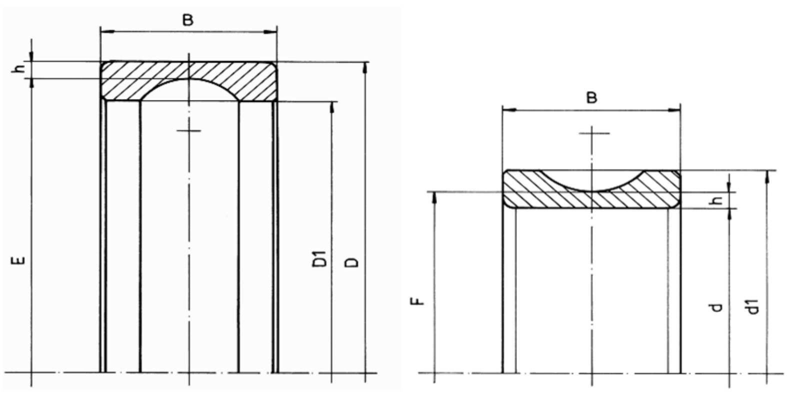


Figure 1. Rings dimensions.

- internal ring collar diameter: $d_1 = F + k_1\,D_W$; (5)
- effective filling angle: $\varphi_{ef} = 2\left(z-1\right)\arcsin(D_w / P_w)$; (6)

- number of balls: $z = [\varphi_{ef} / 2\arcsin D_W / P_W)] + 1$. (7)

This study is made on 6309 ball-bearing having some different constructions with different internal geometry, presented in Table 1.

Table 1. 6309 Ball-bearing constructions.

Ball-bearing	d	B	D	D_w	z	E	F	h
6309 URB	45	25	100	17.462	8	89.962	55.037	5.02
6309 M1	55			17.462	8	94.962	60.038	2.52
6309 M2	53.4			18.256	8	94.956	58.444	2.52
6309 M3	51.8			19.050	7	94.956	56.850	2.52
6309 M4	48.6			20.638	7	94.938	53.662	2.53
6309 M5	56.6			16.669	9	94.969	61.631	2.51

As it can be seen all the ball-bearings have the same external diameter D = 100 mm and the same width B = 25 mm. The differences among them are the number of balls z = 7 … 9 and the diameter of balls D_w.

All the constructions respect the assembling filling angle (φ_{ef} < 197º) for the heavy series (6309) and presented in Table 2.

The thickness of the external rings is h = 2.519 … 5.02 mm (see Table 1). These dimensions are limited by the technological reasons.

In Figure 2 are presented ball-bearings built and used in applications.

The loading capacities, static or dynamic, are determined with the following relations:

$$C_{0r} = f_0\, z\, D_w^2 \ . \tag{8}$$

$$C_r = 1.3\, f_c\, z^{\frac{2}{3}}\, D_w^{1.8} \ . \tag{9}$$

Table 2. 6309 Ball-bearing.

Ball-bearing	P_w	φ_{ef}	D_1	d_1
6309 URB	72.5	195.1	83.0	61.8
6309 M1	77.5	182.3	88.0	67.1
6309 M2	76.7	192.8	87.7	65.7
6309 M3	75.9	174.4	87.3	64.5
6309 M4	74.3	193.5	86.7	61.9
6309 M5	78.3	196.7	88.3	68.3

Figure 2. Ball-bearings constructions.

For 6309 ball-bearing and its variants the theoretical loading capacities are presented in Table 3:

Table 3. 6309 Ball-bearings' loading capacities.

Ball-bearing	C_0, kN	%	C_r, kN	%
6309 URB	29.51	0	52.77	0
6309 M1	29.51	0	53.19	+ 0.89
6309 M2	32.26	+9.3	57.26	+ 8.59
6309 M3	30.73	+ 4.1	56.07	+ 6. 03
6309 M4	36.11	+ 22.3	63.20	+ 20.00
6309 M5	30.25	+ 2.5	53.19	+ 0.89

In Figure 3 and Figure 4 there are presented the variations of the internal ball-bearing diameter d, depending on the considered variants, 6309 URB, 6309 M1 and 6309 M5.

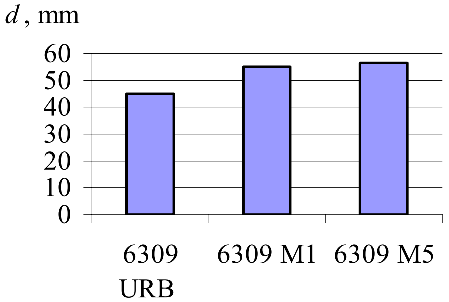


Figure 3. The *d* variation.

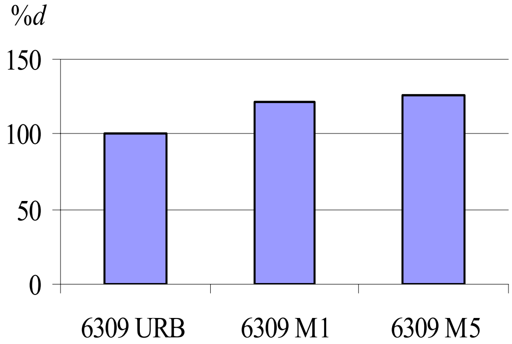
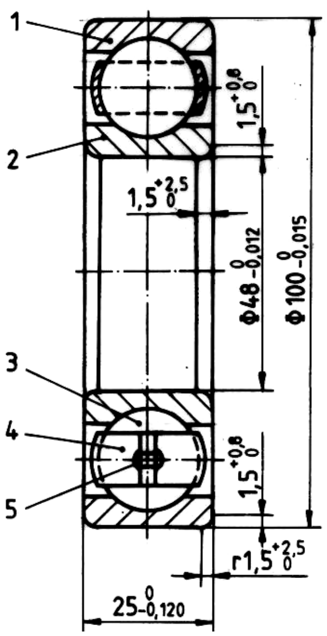


Figure 4. % *d* variation.

3. CONCLUSIONS

Studying the theoretical results presented in Table 1 and Table 3 it can be considered that the variant 6309 M4 is an equilibrated construction, presented in Figure 5.



Legend:
1 - External ring - D = 100; D_1 = 86.7; E = 94.938;
2 - Internal ring - d = 48.6; d_1 = 61.9; F = 53.662;
3 - Balls - z = 7; D_w = 20.638 mm (13/16)
4 - Cage
5 - Rivet 2.27 x 7.4 - 7 pieces

Technical and functional characteristics:
- Basic radial dynamic loading capacity: C_r = 63.2 kN
- Basic radial static loading capacity: C_{0r} = 36.1 kN

Figure 5. The bearing assembly draw.

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