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Influence of Operating Parameters and Selected Design Parameters of Ball Bearing on the Friction Torque

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Abstract. Tests were carried out to determine the influence of selected parameters under designated working conditions on ball bearings friction torque. Such parameters include roundness outline and waviness of inner and outer raceways/rings, as well as curvature ratio. In the case of operating parameters, speed and axial load were taken into account. The research presented in the article shows that these parameters have a significant impact, mainly in the case of low loads and medium speeds, and that the parameters of the inner raceway have a much greater impact on the final result of the friction torque than the parameters of the outer raceways. The studies presented below are part of a larger study aimed at creating a mathematical model to determine the theoretical values of the friction torque in rolling bearings.

Introduction

Roller ball bearings are simple structural elements that consist of four elements: two rings (inner and outer), rolling elements, and a cage. Such a simple structure and yet so many different factors that can affect the length of work (durability) and the quality of work (vibrations and friction torque).

The friction torque relates to the performance of the bearings. The greater the value of the friction torque, the worse the quality of work - movement resistance between the different parts of the bearing. The greater the resistance, the greater the loss of energy in the form of heat. As a consequence, this may lead to faster wear of the bearing [6,7].

The factors that theoretically affect the value of the friction torque are for example: rotation speed; axial and radial load; clearances; curvature ratio (wo_{pz}, wo_{pw}, wo_c); runout (*Kia, Kea, Sia, Sea, Sd*); raceway roundness outline (*ΔZ, Zp, Zv, O, Z3, Za, Zq*); raceway waviness (*Wt, Wp, Wv, W5, Wa*) [8-14].

Research and Results

In order to analyze the influence of selected design parameters on the friction torque, tests were carried out on 100 pieces of rolling bearings 6203. On each of the bearings, 12 measurements were carried out in which the rotational speed (8 000 rpm, 10 000 rpm, 12 000 rpm, 16 000 rpm) and axial load (100 N, 150 N, 200 N) were changed.

The main goal is to determine which parameters (operating and design) and how they influence the final value of the friction torque in rolling bearings. Based on a series of studies, some of which are presented in the following articles [2-4], the following parameters were taken into account for the analysis: *wo, ΔZ, W5, Wa* for both the inner raceway (*ir*) and outer raceway (*or*). The raceways are located on the inner and outer rings, correspondingly. Table 1 contains the results of the performed analysis. It contains the results of coefficient of determination R^2, adjusted R^2 and p for particular combinations of parameters, speed and axial load. The most important are the combinations of parameters which R^2 and adjusted R^2 results are the highest [1].

Table 1. Sample results of the preliminary analysis of selected parameters.

		8 000 [rpm]	**10 000 [rpm]**	**12 000 [rpm]**	**16 000 [rpm]**
***or* 100N**	$\boldsymbol{R^2}$	0.1906	0.2042	0.1593	0.0355
	Adjusted $\boldsymbol{R^2}$	0.1430	0.1581	0.1106	-0.0153
	$\boldsymbol{p}$	0.0056	0.0030	0.0163	0.5951
***ir* 100N**	$\boldsymbol{R^2}$	0.0885	0.1132	0.0727	0.0449
	Adjusted $\boldsymbol{R^2}$	0.0348	0.0618	0.0190	-0.0054
	$\boldsymbol{p}$	0.1719	0.0777	0.2592	0.4722
***or* 150N**	$\boldsymbol{R^2}$	0.1833	0.1884	0.1919	0.0732
	Adjusted $\boldsymbol{R^2}$	0.1359	0.1414	0.1451	0.0245
	$\boldsymbol{p}$	0.0068	0.0056	0.0049	0.2102
***ir* 150N**	$\boldsymbol{R^2}$	0.5222	0.5731	0.5541	0.0901
	Adjusted $\boldsymbol{R^2}$	0.4945	0.5483	0.5282	0.0422
	$\boldsymbol{p}$	0.0000	0.0000	0.0000	0.1224
***or* 200N**	$\boldsymbol{R^2}$	0.1282	0.1347	0.1358	0.0782
	Adjusted $\boldsymbol{R^2}$	0.0791	0.0859	0.0871	0.0296
	$\boldsymbol{p}$	0.0425	0.0341	0.0327	0.1802
***ir* 200N**	$\boldsymbol{R^2}$	0.3312	0.4000	0.3340	0.1811
	Adjusted $\boldsymbol{R^2}$	0.2935	0.3662	0.2964	0.1380
	$\boldsymbol{p}$	0.0000	0.0000	0.0000	0.0040

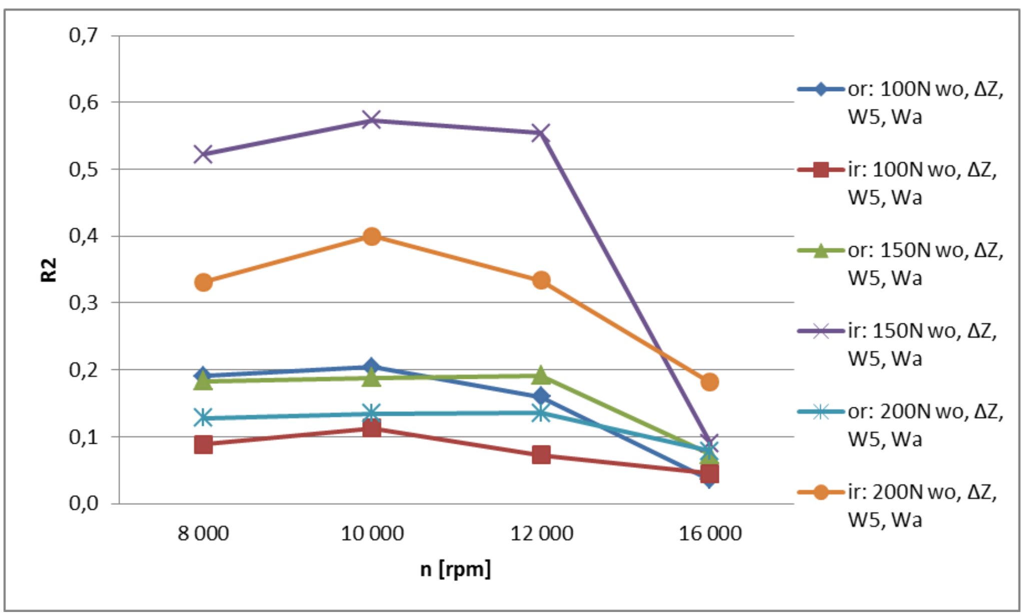

Fig. 1. *Values of* R^2 *linear regression analysis.*

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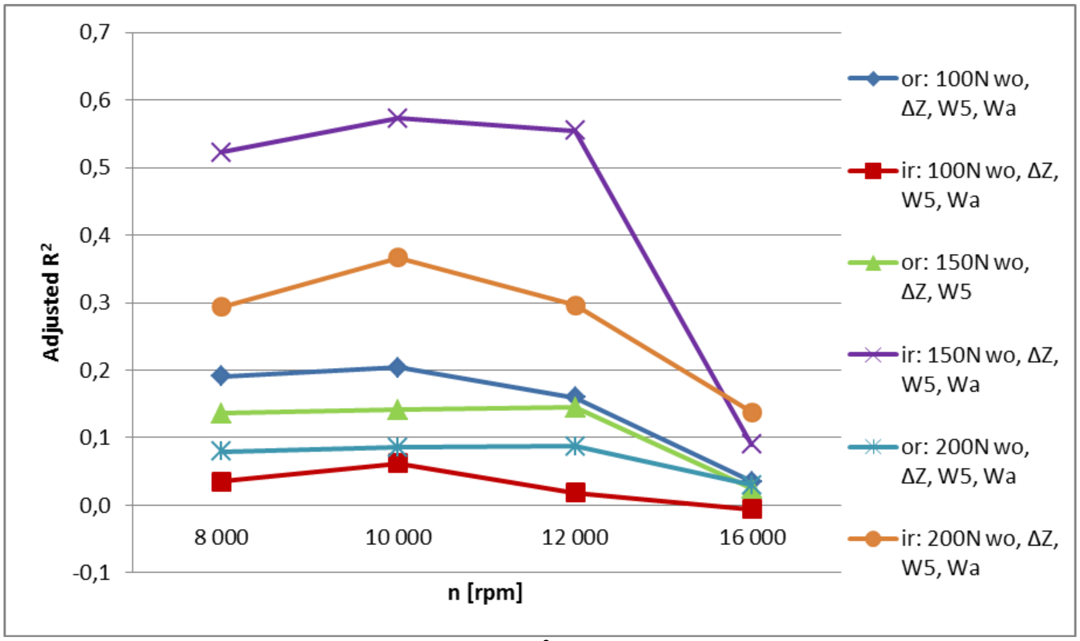

Fig. 2. *Values of adjusted R^2 linear regression analysis.*

Fig. 1 and Fig. 2 show the impact (R^2 and adjusted R^2) of different combinations of operating parameters and design parameters: *wo, ΔZ, W5, Wa – ir* and *or* on the final results of the friction moment.

Conclusions

Based on the results presented above, the following conclusions were drawn:

1. The parameters obtained in the measurement of the inner raceway are more important than the parameters of the outer raceway. The values of R^2 for the analysis of the outer raceway parameters did not exceed 0.2. This means that the selected combinations of parameters did not explain even 20% of the friction torque results.

2. The selected design parameters do not have a significant influence on the resistance torque when the rotational speed is very high. The selected design parameters for the rotational speed of 16 000 rpm reach values of R^2 about: ~ 0.037; ~ 0.074 and ~ 0.166 respectively for 100 N, 150 N, 200 N. This does not completely exclude these parameters from further analysis for operating conditions, including 16 000 rpm. The results of R^2 for the inner raceway at operating conditions of 200 N and 16 000 rpm are significantly higher than the others.

3. As in the case of the rotation speed of 16 000 rpm, the parameters for the axial load of 100 N have little influence on the final result. The values of R^2 for 100 N are below 0.2. On the one hand, these results show that, at low loads, the selected parameters have a minimal effect on the final value of the friction torque. But on the other hand, these results can still be used in further analysis to determine the causes of such significant differences between the design parameters of the inner and outer raceways, such as curvature ratio, raceway roundness outline, raceway waviness.

4. As previously observed, the selected design parameters do not have a significant impact on the final results of the torque with an axial load of 100 N. But comparing the results between the inner and outer rings we can observe a different trend than in the case of the other two loads. Namely, the values of R^2 and adjusted R^2 are twice as large in favor of the outer ring.

5. Depending on the operating conditions, the selected design parameters have a different influence on the friction moment. This can be seen from the values of R^2 of the inner raceway. 3 groups of results were obtained: ~ 0.07; ~ 0.55; ~ 0.35, which correspond to the loads of 100 N, 150 N and 200 N respectively (without taking into account the speed of 16 000 rpm). This shows that for low and medium operating conditions, these parameters explain about 7% of the final value of the friction torque. R^2 reaches its highest value for the operating parameters of 150 N and 10 000 rpm, then with the increase of both operating parameters, the values of R^2 decrease.

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