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A MORE ACCUARATE EVALUATION OF THE FRICTIONAL TORQUE IN ANGULAR CONTACT BALL BEARINGS

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Summary

Field experience supports the idea that the available analysis and design tools of rolling bearings require increased sophistication.
To obtain the load distribution in the general case of angular-contact ball bearing a quasi-static equilibrium model was developed, as a first step of the analysis. The effects induced by the centrifugal forces, gyroscopic moments and misalignments between bearing's rings were included. The lubricant parameters, traction forces and fluid drag acting on both balls and races have been further included in a advanced quasi-dynamic model. The distinctive idea of the model is the ability to quantify the presence of the misalignment and its influence on internal load distribution, as well as on power losses.
The quasi-dynamic model has been validated by comparisons achieved with results mentioned in the open literature, as well, as with experimental results obtained by authors.
A new formula for the evaluation of frictional torque is finally proposed to consider the influence of rings misalignment.

1. INTRODUCTION

To appreciate the friction torque of rolling bearing some rather simple equations are presented in literature: Palmgren [1959], Ragulskis [1974], Niemann [1976], **FAG** Company [1980], **SKF** Company [1989], Harris [1991].

Cretu and Damian [1994] proved that even for similar working conditions these equations led to very different values of the friction torque. Furthermore, the mentioned equations are not able to consider the misalignment between inner and outer rings of the bearing. However, a certain value of this misalignment exists in any mechanical design, the shaft flexibility and the manufacturing errors being the main responsible factors. The effect of misalignment is the alteration of both, the load distribution inside the bearing and cage - rolling bodies kinematics which cause primary the increase of the friction torque and secondly the diminish of the bearing's life.

2.THE QUASI – DYNAMIC MODEL

To obtain the load distribution in the general case of angular-contact ball bearing a quasi-static equilibrium model was developed, as a first step of the analysis Oancea, Damian, Cretu [1998]. The effects induced by the centrifugal forces, gyroscopic moments and misalignments between bearing's rings were included. The lubricant parameters, traction forces and fluid drag acting on both balls and races have been further included in a advanced quasi-dynamic model Damian, Oancea, Olaru , Cretu [1999]. The model includes the main working parameters as: radial and axial loads, rotation speed, oil viscosity, but also the misalignment between the bearing's rings, as a distinctive parameter.

The validation of the model has been accomplished by comparing the value obtained using the developed model with results furnished by the open literature. A computer code has been written to perform the necessary analysis and simulations. To validate the ability of the model to incorporate the misalignment effects an experimental program has been carried out. The necessary experimental values have been obtained by using a special designed device that allows to introduce the desired value of the misalignment, Damian [2002].

3.THE FRICTION TORQUE EQUATION

The theoretical analyses and simulations carried out with the improved quasi-dynamic model led to a new equation to evaluate the friction torque on the outer ring of a rolling bearing. The new equation has a similar structure with that developed by **SKF** Company, but contains a new term to consider the misalignment:

$$Me = \left(0.8 + 0.25 \cdot \gamma_y^{0.35}\right) M_{SKF} \qquad (1)$$

where:

M_e - the friction torque evaluated on bearing's outer ring;

M_{SKF} - the friction torque obtained by using SKF methodology;

γ_y - misalignment between the bearing rings in ['']

According to **SKF** General Catalogue [1989] the friction torque M_{SKF} is obtained as a sum of two components:

$$M_{SKF} = M_0 + M_1 \qquad (2)$$

where:

M_0 - the component of the independent friction torque of loading in [Nmm],

M_1 - the component of the dependent friction torque of loading in [Nmm] .

The two components of the friction torque are given by the following relations:

$$M_0 = 10^{-7} f_0 (\nu \cdot n)^{2/3} dm^3 \quad \text{if: } \nu \cdot n \geq 2000 \qquad (3)$$

$$M_0 = 160 \cdot 10^{-7} f_0 dm^3 \quad \text{if: } \nu \cdot n < 2000$$

$$M_1 = f_1 \cdot P_1^a \cdot dm^b \qquad (4)$$

where:

dm - the average diameter of the bearing [mm],

f_0 - the factor which depends on the type of the bearing and lubricant ,

n - the rotation of the inner ring [rot/min],

ν - kinematic viscosity of the lubricant at the working temperature [mm^2/s],

f_1 - factor depending on the type of the bearing and loading ,

P_1 - the equivalent load which determines the friction torque,

a, b - exponents depending on the type of the bearing.

4. COMPARATIVE RESULTS

For the case of **7012 CTA P4** radial-axial ball bearing the results, obtained by the using equation (1) and the **SKF** General Catalogue equation, have been compared with the values experimentally measured. The comparisons have been performed for different values regarding the working conditions (rotation speed, radial and axial load, oil viscosity) and four value of the misalignment γ_y (0'; 5'; 10'; 15'). Some of the results are presented in Figure1 and Figure 2.

The good concordance between the measured values and those obtained by using the new quasi-dynamic model is pointed out.

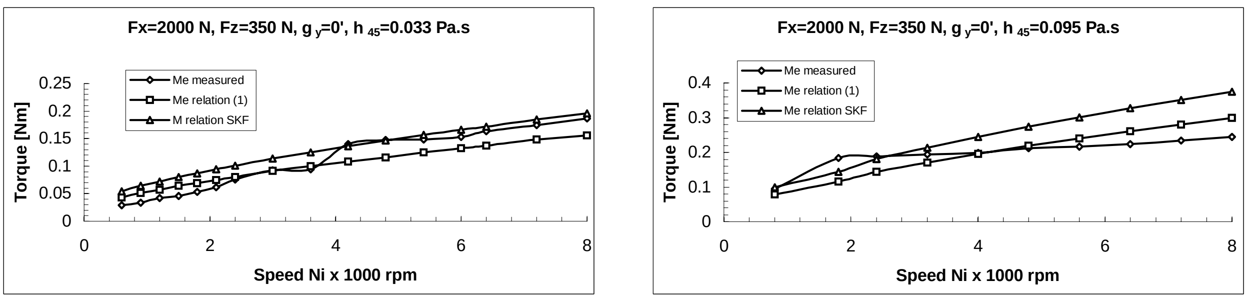

Fig.1

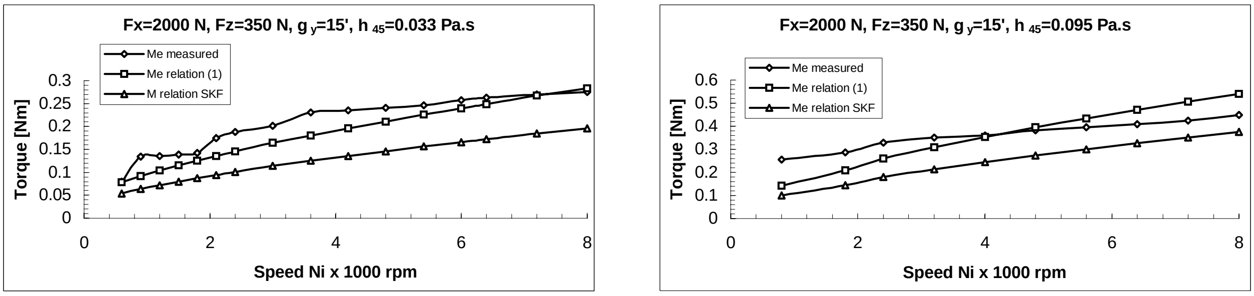

Fig.2

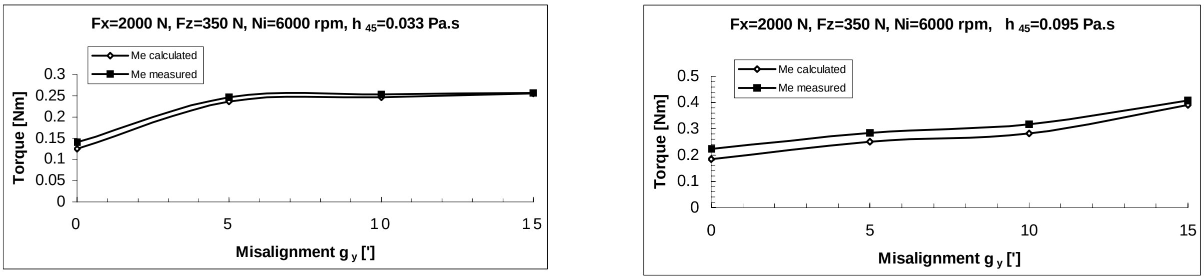

Fig.3

5. THE INFLUENCE OF THE MISALIGNMENT

The influence of the misalignment is distinctive plotted in Figure 3

The data plotted in Figure 3 point out that as long as the value of the misalignment is maintained under a certain limit (γ_y < 5') the influence of this parameter is sufficiently low to be neglected.

But, for greater values of the misalignment its influence has to be considered to obtain a better evaluation of the friction torque.

6. CONCLUSIONS

1. The existing equations to evaluate the friction torque in rolling bearings are not able to consider the misalignment between inner and outer rings of the bearing.
2. To obtain the load distribution in the general case of angular-contact ball bearing a quasi-static equilibrium model was developed, as a first step of the analysis. The effects induced by the centrifugal forces, gyroscopic moments and misalignments between bearing's rings were included. The lubricant parameters, traction forces and fluid drag acting on both balls and races have been further included in a advanced quasi-dynamic model.
3. The distinctive idea of the model is the ability to quantify the presence of the misalignment and its influence on internal load distribution, as well as on power losses.
4. A good concordance between the measured values and those obtained by using the new quasi-dynamic model has been obtained and validated the model..
5. As long as the value of the misalignment is maintained under a certain limit (γ_y < 5') the influence of this parameter is sufficiently low to be neglected. But, for greater values of the misalignment its influence has to be considered to obtain a better evaluation of the friction torque.

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