FEASIBILITY STUDY OF IMPEDANCE ANALYSIS FOR MEASURING ROLLING BEARING LOADS

Contact Mechanics II

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INTRODUCTION

The electric impedance of roller bearings is a research topic since more than a decade. Recent topics were the measurement of the lubrication film thickness in elasto hydrodynamic contacts [1] and the mechanisms of induced currents damaging roller bearings [2]. The model to calculate the bearing impedance includes all contact zones between rolling elements and bearing raceways in the load zone of a bearing. Every contact zone forms a capacitor depending on the lubrication film thickness and the Hertz'ian area. An application example of the measured bearing impedance is the use of a bearing as a load sensor, the knowledge of the bearing loads is an important factor in many industrial applications. Operators of manufacturing plants benefit by load and process monitoring. The advantage of load monitoring is the prevention of machine downtimes [3], because maintenance planning can be based on actual measured loads instead of assumptions made during the design of the machine. The advantage of process monitoring is ensuring a more constant process quality. Assuming as an example a rolling process which forms raw material it is obvious that geometrical deviations in the process lead to additional bearing forces, hence the knowledge of bearing forces enables an early inline quality control.

BASICS

The calculation of the electric impedance of a roller bearing [4] consists of the impedance of the different contact zones between inner ring, outer ring and rolling elements in the electric circuit, see figure 1 left. The overall impedance of the bearing is dominated by the contacts in the load zone, the contact zones out of the load zone can be neglected. The impedance of a contact zone consists of capacity and parallel resistance. Both depend on lubrication film thickness h_0, Hertz'ian area A_{Hz} and electric properties of the lubricant. The Hertz'ian area presents the plate and the lubrication film thickness the distance between the plates of a plate capacitor, figure 1. In addition the permittivity of the lubricant ε_r and a small area around the Hertz'ian area influence the capacitor. The additional area increases the capacity by a constant value k_{Rand}. In literature there is the approach of Gemeinder [5] who proposes $k_{\mathrm{Rand}} = 1.1$ while Furtmann [6] suggests $k_{\mathrm{Rand}} = 3.5$,

$$C = k_{\mathrm{Rand}} \cdot \varepsilon_0 \cdot \varepsilon_r \cdot \frac{A_{Hz}}{h_0}.$$

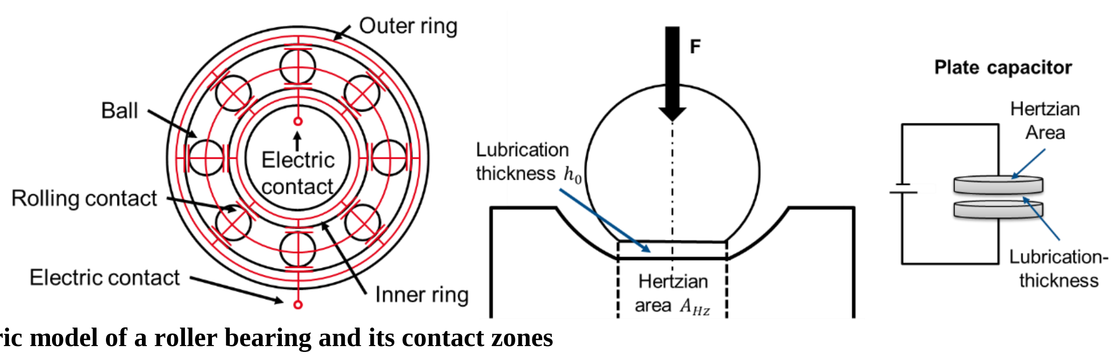

Figure 1: Electric model of a roller bearing and its contact zones

The calculation of the resistance of a contact zone is analogous. It is a resistance with the length of the lubrication film thickness, the area of the Hertz'ian area and the specific resistance of the lubricant. The calculation model neglects the non-flat geometry of the contact zone and the resistance of the bearings rings and the rolling elements.

EXPERIMENTAL SETUP

The test rig for the experiments consists of three bearings mounted on a shaft. The two outer bearings support the shaft and have an electric isolation at the outer ring. The third bearing (type 6205 C3) is in the electric circuit and has also an electric isolation at the outer ring. The network analyzer contacts the outer ring of the third bearing and closes the electric circuit through bearing, shaft and slip ring. An actuator loads the third bearing with a radial force F. In addition there are sensors for bearing load, temperature and speed, figure 2.

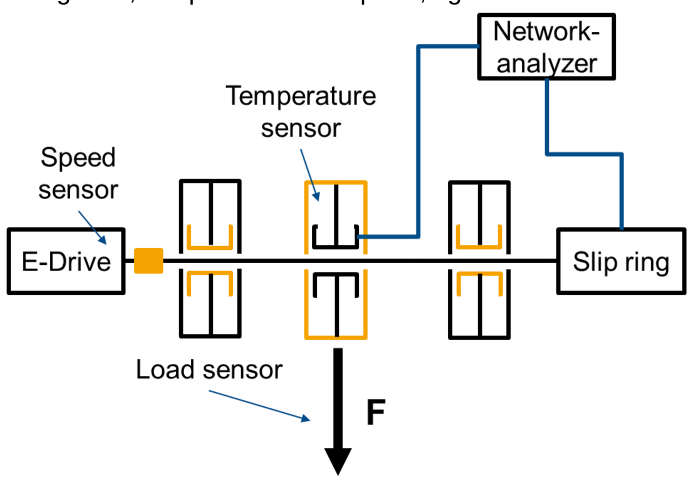

Figure 2: Schematic view of the test rig

The experiments investigate the influence of different bearing temperatures on the relationship between bearing load and electric impedance. Therefore the speed is constant at 3000 rpm and the signal frequency of the network analyzer is 200 kHz. The steps of increasing bearing load are 100 N and the temperature increases from 40 to 65 °C in steps of 5 °C.

EXPERIMENTS AND RESULTS

The results of the experiments reveal a big difference between the impedance calculated according to the established models by both Gemeinder and Furtmann, and the measured impedance in the load range below 400 N. Figure 3 shows one of these test results. Like in [7], the results agree better with the approach of Furtmann in the load range above 400 N.

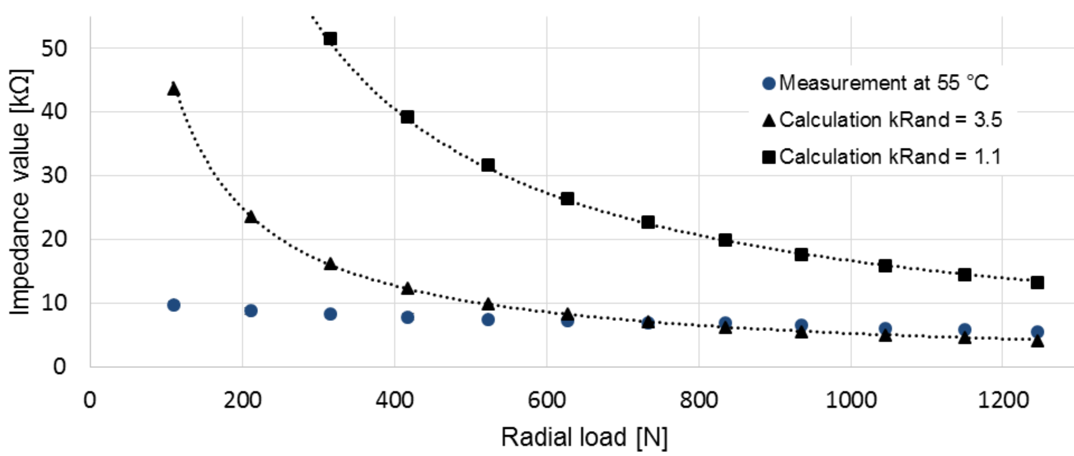

Figure 3: Comparison of the test results to the approaches of Gemeinder ($k_{Rand} = 1.1$) and Furtmann ($k_{Rand} = 3.5$)

Comparing test results at lower and higher temperatures, figure 4, the established model of the bearing impedance does not take the influence of the temperature into account correctly. The calculation in figure 4 follows the approach of Furtmann, which fits better to the tests. The plot of the 45 °C tests has a different slope than predicted by the established model, while the slope of the 65 °C plot fits quite well to the established model. Investigations of the influence of different speed conditions [7] show comparable results, the fit between tests and established models is better at lower speeds. Both, decreasing speed and increasing temperature, lead to a smaller lubrication film thickness. Therefore, it seems like the state of the art does not take the lubrication film thickness correctly into account.

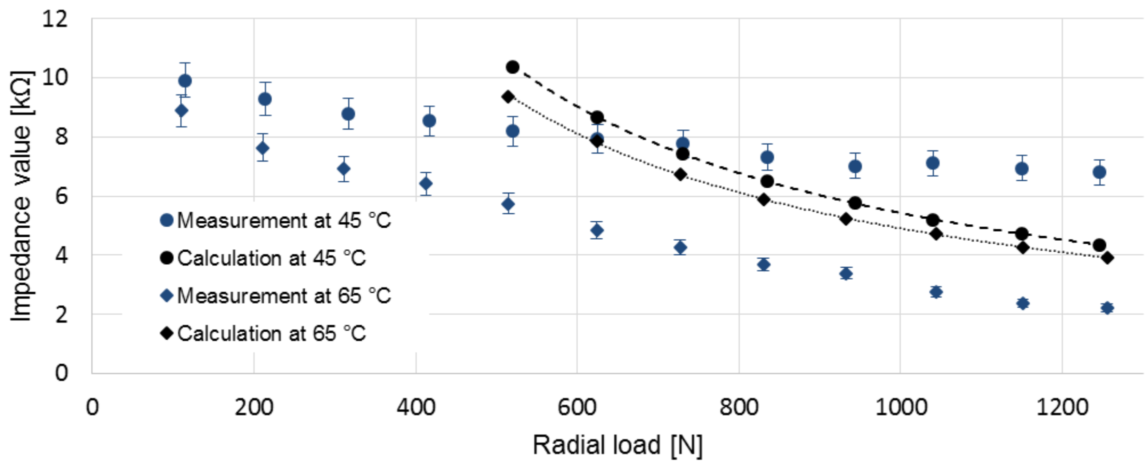

Figure 4: Comparison of lower and higher temperatures test results in the range of load over 400 N

SUMMARY

The test result confirms the examination of [7] that the actual calculation model of the bearing impedance doesn't take small load ranges correctly into account. Possible explanations are a load dependency of the k_{Rand} factor, or the model of a capacitor with flat plates does not represent the actual contact zone geometry with adequate accuracy. Another insight is the increasing accordance of the slope to the calculation model with decreasing lubrication film thickness. Considering other examinations [7] the actual calculation model needs further investigation concerning the lubrication film thickness.

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KEYWORDS

Maintenance: Equipment Monitoring, Rolling Bearings: Ball Bearings, Computation: Data Acquisition.