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DESIGN CRITERIA FOR OIL RING LUBRICATORS TO IMPROVE MAINTAINABILITY OF ROLLING BEARINGS

TRACK OR CATEGORY

Rolling Element Bearings VI

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INTRODUCTION

Maintainability plays a decisive role in terms of operating costs for rolling bearings. Particularly in case of unfavorable operating conditions oil lubrication can provide longer maintenance intervals than grease lubrication. In order to feed the rolling bearing with oil the use of a ring lubricator is an advantageous option due to its reliability and its compact and simple design.

Some previous studies on ring lubricators dealt primarily with the potential to increase oil delivery rate. Thereby, the ring was used to supply a journal bearing with oil [1] [2]. However, feeding rolling bearings with oil, the ring lubricator requires different operating characteristics, such as lower oil delivery rates, to ensure long oil life und thus long maintenance intervals [3]. This presentation covers which design criteria for a ring lubricator can affect oil life and how some of these variables advantageously must be quantified in the design process. In this context a range of results is presented which have been obtained by experiments on a test rig as well as initial simulations.

TEST RIG SETUP AND ROLLING BEARING SYSTEM

To build up broader understanding and to validate results derived from simulations a test rig was developed, enabling experiments with a rolling bearing system (see figure 1 a)).

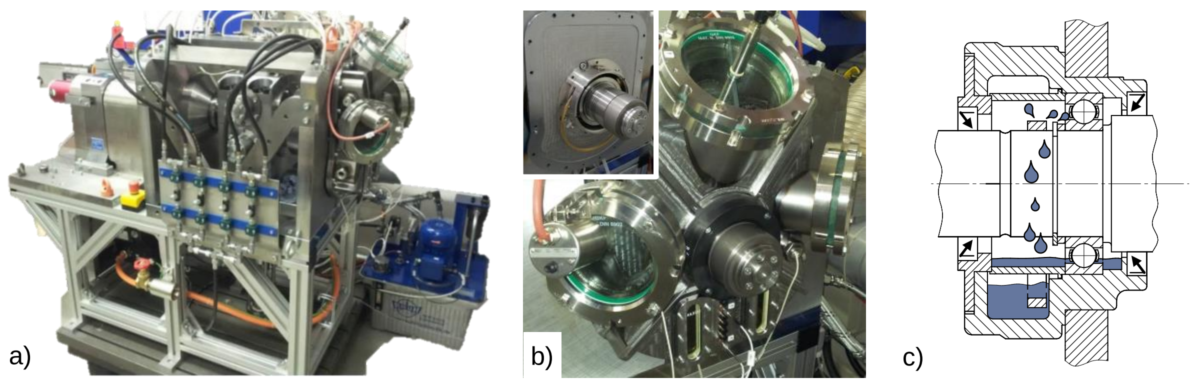

Figure 1: a) Overall view of test rig. b) Test bearing unit. c) Sectional view of test bearing arrangement.

Variables such as ring movement, oil dispersion, oil flow and foaming can be observed by sight glasses attached to the test bearing housing. The test bearing unit is shown in figure 1 b). Heating elements, which are placed in the bearing plate and the shaft make it possible to set temperature of the oil and thus oil viscosity. A sectional view of the test bearing unit is shown schematically in figure 1 c). It consists of the following two main components: the rolling bearing, which is lubricated by dipping into an oil sump, and the lubricating ring, which lies loosely on the shaft and feeds the oil sump. The amount of oil reaching the oil sump is one of the key factors with regard to oil life and can be measured during operation.

CRITERIA INFLUENCING OIL LIFE

There are several criteria affecting oil life, such as oil temperature, foaming and particle content. Figure 2 gives a general overview of design parameters determining operating characteristics and which have an impact on oil life. On closer examination, the ring lubricator becomes complex due to lots of influencing parameters. Not least this fact makes simulations advantageous for a better understanding of processes as oil flow and ring dynamics. Own researches as well as studies performed by other authors have already covered the effect of some of these design parameters by experiments, as for example ring immersion depth, oil viscosity, shaft speed or ring dimensions and materials. In the following it will be focused on the correlation between ways of axial ring guidance and oil delivery. Furthermore preliminary simulation approaches are presented, including dynamic simulation of ring start-up characteristics and CFD simulation of flow formation in the reservoir.

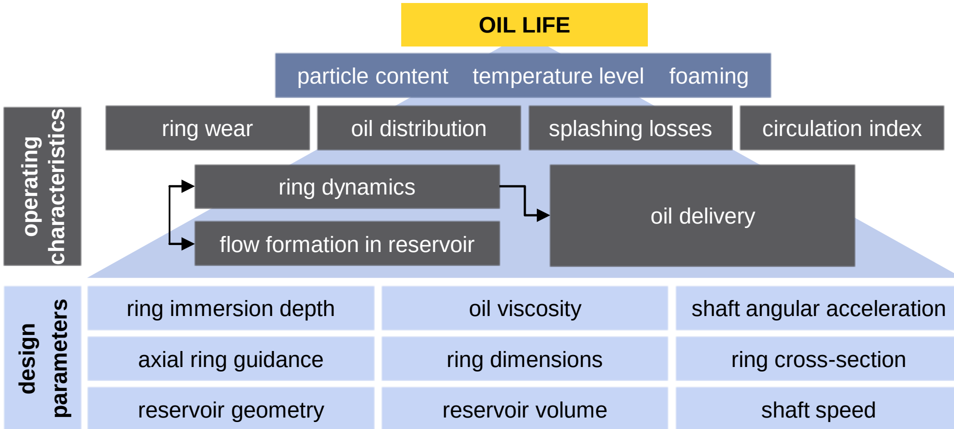

Figure 2: Design parameters influencing operating characteristics and thus oil life.

AXIAL RING GUIDANCE

In terms of oil life and axial ring guidance, two aspects are of particular interest: on the one hand oil delivery, affecting foaming and splashing losses, and on the other hand ring wear, leading to oil contamination. Two basically designs have been analyzed: a circumferential groove in the shaft, guiding the ring or fixed guide elements, being integral parts of the housing. In Figure 3 data of oil delivery is plotted for both designs. As it can be seen axial ring guidance plays a decisive role in terms of oil delivery, thus should be considered in favor of a long oil life. Regarding this criterion, fixed guide elements are the preferred solution due to a sufficient and over wide range lower oil delivery rate. Latter is caused by the additional drag force of the fixed guide elements, leading to a significant lower ring speed and less foaming and splashing.

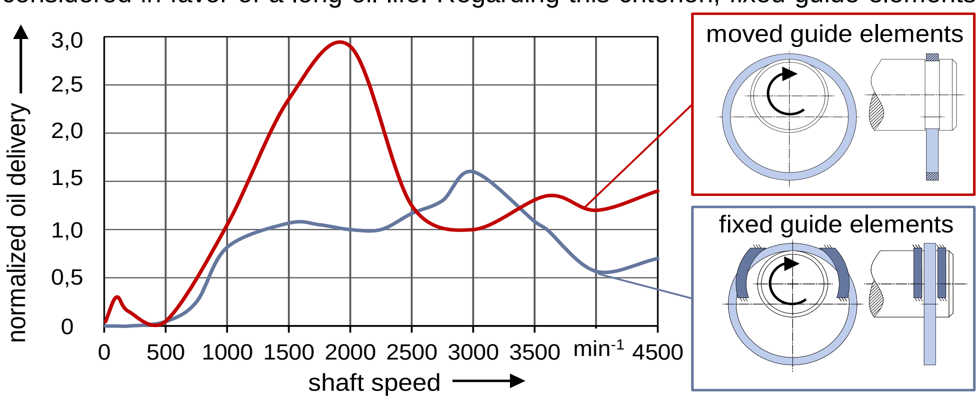

Figure 3: Effect of axial ring guidance on oil delivery.

SIMULATION OF RING START-UP CHARACTERISTICS

Apart from rotating around its center point, the ring performs other kinds of motions which can lead to increasing ring wear, foaming and splashing losses. Multi-body dynamic simulations have been performed and evaluated with respect to ring deflection and acceleration to derive design criteria influencing ring movement during start-up. Moreover, ring deflection of the real system has been compared to the virtual model by a qualitative optical analysis. Figure 4 a) shows center point displacement of the ring over time at start-up. Figure 4 b) shows oscillation time and maximum displacement of center point over friction coefficient in shaft-ring-contact.

As it can be seen, ring dynamics at start-up show a characteristic behaviour, which can be classified in three stages: first is transient oscillation, characterized by gradually increasing rotational ring speed and oscillating motion of ring. Second is attenuating oscillation, being reached when circumferential ring speed equals circumferential shaft speed. This stage is characterized by more and more decreasing oscillations till reaching stationary state, indicating the third stage. Furthermore, it is shown that friction coefficient between ring and shaft has major effect on oscillation time and maximum displacement at ring start-up. Reasons for this behavior and the influence of further identified parameters will be discussed in the presentation.

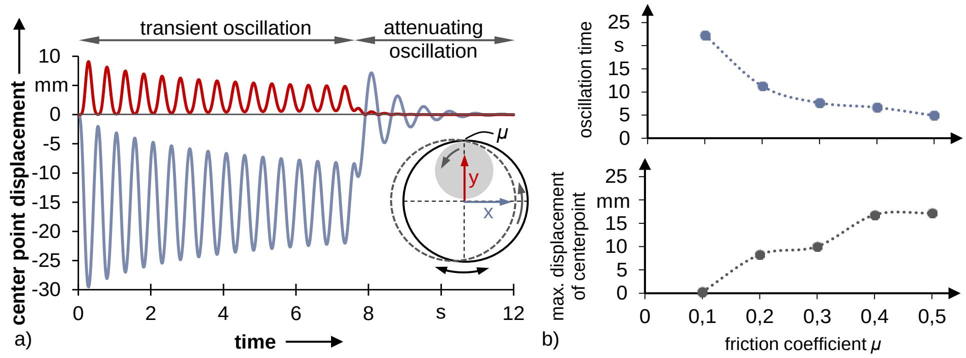

Figure 4: a) Center point displacement over time at start up. b) Time until reaching steady state and maximum center point displacement over friction coefficient.

SIMULATION OF FLOW FORMATION IN THE RESERVOIR

With regard to foaming and ring dynamics, flow formation in reservoir can play a decisive role. On the one hand, vortices and high velocity of flow can support inclusion of air and thus oil oxidation. On the other hand, flow formation interacts with the ring and impacts forces, reaching beyond the tangential force induced by fluid drag. These additional flow forces can lead to oscillating motions of the ring and thus influence oil life. To obtain initial information on flow formation in the reservoir and potential influencing parameters, CFD simulations have been performed and evaluated by means of DoE. As expected, ring speed and immersion depth have a strong influence on flow formation and ring forces. Apart from these parameters, reservoir design also has an effect on these parameters and may not be neglected in further studies as well. So for example adapting reservoir geometry to ring shape, leads to significantly more advantageous streamlines without any swirling (see figure 5).

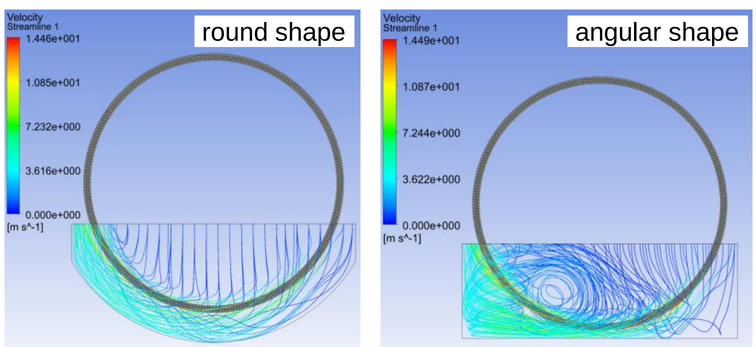

Figure 5: Flow formation in round shaped and angular shaped reservoir.

CONCLUSION

To realize long maintenance intervals for rolling bearings and thus reducing operating costs, the use of a ring lubricator for oil delivery can be advantageous. Understanding system behavior is of particular importance to positively affect oil life, specially influenced by ring dynamics, oil delivery and flow formation. It was shown, that axial guidance of the ring has major influence on oil delivery and thus plays a key role in lubricator design. Initial simulation approaches provided influencing parameters regarding ring start-up characteristics and flow formation in the reservoir. These simulations are integral parts of further refinements in modelling characteristics of the ring lubricator, aiming for a virtual display of the entire system.

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KEYWORDS

Rolling Element Bearings, Ring Lubrication, Maintainability, Lubricant Degradation.