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Sliding effects in rolling bearings life

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ABSTRACT – The effects of kinematic sliding of Hertzian contacts are studied from three different standpoints. i) by analysing the combination of sliding speed and contact pressure giving rise to seizure, i.e. high instantaneous contact temperatures leading to film collapse, ii) by assessing the possible effects of sliding to surface traction and fatigue, iii) by discussing other possible effects of sliding in heavily loaded lubricated contacts as the concurrent damage mechanism caused by wear and rolling contact fatigue. It is found that only the first and the third mechanisms might have a direct relationship between high sliding and reduced rolling bearing life.

1. INTRODUCTION

Czischos and Kirschke [1], conducted experiments in sliding contacts lubricated with different oils and at different temperatures to map load and sliding speed conditions of contact failure. They reported diagrams of critical failure triplets (load, sliding velocity and oil bulk temperature). In every case before failure they observed a sudden increase in friction. For that characteristic point they introduced the term of “transition points of failure”. Later this type of diagrams was described, in the technical literature, as “transition diagrams”. A schematics of transition diagram of contact failure by seizure is shown in Figure 1. Because of this sharp and significant increase of friction, Czischos and Kirschke concluded that a lubricant film failure must have occurred producing a sudden increase of adhesive wear in the contact, i.e. seizure.

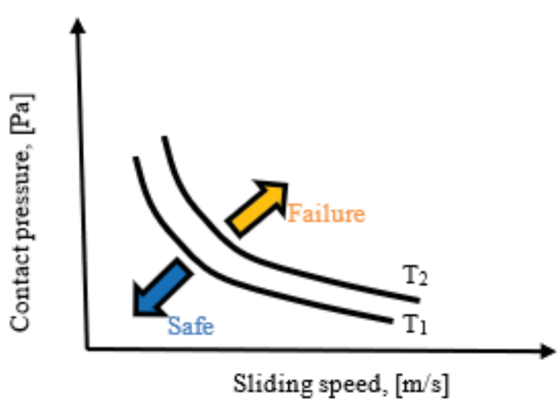

Figure 1 Schematics of a transition diagram of contact failure by seizure.

Another aspect of micro-slip and its possible effect on fatigue is as follows. High sliding in an EHL contact with rough surfaces would tend to increase asperity fatigue due to the increase of load micro-cycles [2,3] (asperity micro-cycles). This is caused by the higher relative velocity of one surface respect to the other. However, this effect might also increase mild wear that would remove the outer fatigued layers of material, thus reducing damage accumulation and/or reducing the asperity heights. Therefore, this mechanism does not show a clear cause-effect relationship between sliding and fatigue if wear is considered.

Once discussed the general elastohydrodynamic contact situation respect to sliding, it is worth to focus on rolling bearings. All rolling bearings have some degree of sliding, either in the raceway contacts or in the flange-roller end contacts. This is why it is important to understand the true role of sliding in these mechanical components, especially nowadays where higher efficiency and environmental trends push mechanical components to work under tougher operating conditions, with higher speeds, higher temperatures and loads, and thinner lubricating films.

The objective of the present paper is to discuss several aspects of sliding occurring in EHL contacts of rolling bearings. This to assess the true dimension of possible detrimental effects of sliding on the fatigue life and general performance of rolling bearings. Hopefully, this will clarify some of the misconceptions existing in this area among engineers and researchers.

2. ROLLING BEARINGS SEIZURE RISK

Seizure failures in rolling bearings can be difficult to distinguish from micropitting, specially because, it is believed, that when the bearing operates close to the transition point, the transition from fatigue to seizure can be gradual. The high temperatures in the contact will reduce the fatigue strength of the material first, but if the application moves to even higher sliding conditions or higher load then at some point, the film thickness fails, and the failure becomes immediate and catastrophic. Often it is possible to see some coloration on the raceway due to the presence of oxygen and high temperatures.

2.1 Modelling of seizure in rolling bearings

The flow chart shown in Figure 2 depicts the model used to account for seizure risk which includes kinematic starvation. Besides this, a series of experimental cases tested in-house are plotted in a “transition diagram” similar to Figure 1. The results are depicted in Figure 3 showing nominal (static) maximum Hertzian contact pressure versus rolling speed (measured as a multiplication of the mean bearing diameter d_m in [mm] and the rotational speed n measured in [rpm]).

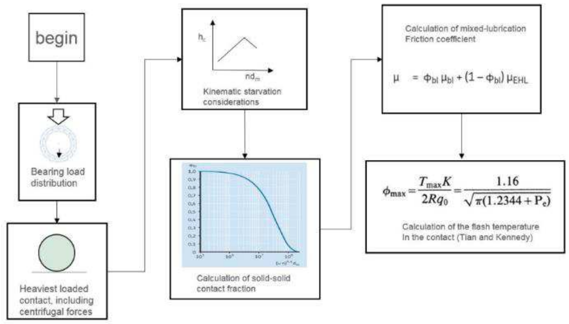

Figure 2 Flow chart depicting the model used to assess the risk of seizure in rolling bearings.

From Figure 3 it can be seen that hybrid bearings clearly have advantage over steel-steel bearings, the reasons very likely being that, on one hand at high speeds the centrifugal contact forces generated by the ceramic balls are well below the forces generated by the steel-steel balls. On the other hand, hybrid contact tribology is more benign than steel-steel tribology [4].

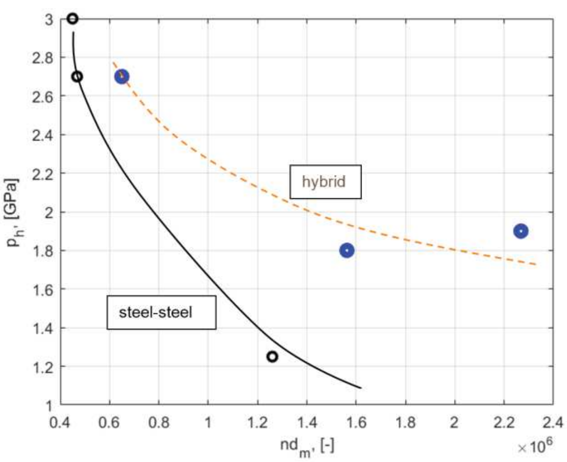

Figure 3 Maximum Hertzian pressure versus speed in the cases of experimental ball bearings with signs of raceway overheating. Superimposed sketched lines indicating the possible location of the onset of seizure failures for steel-steel and hybrid bearings.

3. OTHER EFFECTS ON FATIGUE FROM SLIDING

3.1 Surface tractions

Depending on the applied stress criterion (Tresca or von Mises) and on the contact configuration (line or point) Johnson [5] predicts that a contact with a Coulomb friction coefficient of $\mu \approx 0.3$ the yield point will move from the subsurface to the surface. In fatigue, it means that high friction coefficients will tend to move the zone of failure from subsurface to the surface. Of course, this is very relative since the failure point depends also on many aspects (e.g. roughness, inclusions, manufacturing, etc.). A friction coefficient on the surface also increases the stresses at the subsurface according to [5].

Many authors have shown that in a lubricated contact, even under boundary lubricating conditions the friction coefficient [2] does not usually go higher than say $\mu_{bl} = \mu = 0.11$, this value will hardly modify the subsurface stresses.

3.2 Combined wear-fatigue effect

Finally, sliding brings the possibility of having wear in the contacts of rolling bearings. In general sliding is non-uniform, this in abrasive environments produces non-uniform wear, which in turn, will modify the original raceway profiles. This modification might produce stress concentrations on the surface followed by surface distress and eventually spalling due to fatigue. This process can be modelled.

4. SUMMARY

The following conclusions can be drawn:

a) From the modelling and analysis of experimental cases it is found that the combination of high speeds (i.e. high sliding speeds) with high contact pressures seems indeed possible the shift the failure mode of the rolling contact from fatigue to seizure. This is mainly due to thermal effects in the lubricant film.

b) Abrasive wear and rolling contact fatigue in combination with sliding can be an important element that might reduce the life of a rolling bearing. This requires the presence of abrasive particles or very poor lubrication conditions. Non-uNon-uniform distribution within the Hertzian contact also contributes to the development of stress risers that can eventually shorten the fatigue life expectancy of the bearing.

REFERENCES

[1] Czichos, H., & Kirschke, K. (1972). Investigations into film failure (transition point) of lubricated concentrated contacts. *Wear*, *22*(3), 321-336.

[2] Morales-Espejel, G. E., & Brizmer, V. (2011). Micropitting modelling in rolling–sliding contacts: application to rolling bearings. *Tribology Transactions*, *54*(4), 625-643.

[3] Morales-Espejel, G. E., Rycerz, P., & Kadiric, A. (2018). Prediction of micropitting damage in gear teeth contacts considering the concurrent effects of surface fatigue and mild wear. *Wear*, *398*, 99-115.

[4] Brizmer, V., Gabelli, A., Vieillard, C., & Morales-Espejel, G. E. (2015). An experimental and theoretical study of hybrid bearing micropitting performance under reduced lubrication. *Tribology Transactions*, *58*(5), 829-835.

[5] Johnson, K. L. (1985). Contact Mechanics Cambridge Univ. *Press, Cambridge*.