Surface Star Defect Tolerance Assessment on finished Silicon Nitride balls in Rolling Contact

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Abstract

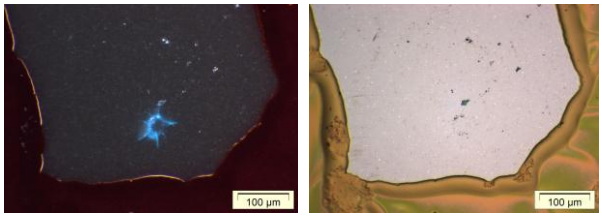
Surface defects are the main limiting factor for the use of silicon nitride in hybrid ball bearings applications. So-called star features are surface defects created during ball lapping/finishing by coarse diamond grit indenting the ball surface. They can offer different morphologies involving cracks, incipient chips and chips or remnant central pit. This experimental studies focus on the performance of silicon nitride rolling elements having different morphologies of star defects in rolling contact with different lubricants.

1. Introduction

The main limiting factor of silicon nitride in hybrid rolling element bearing applications is the presence and sensitivity of surface defects with relatively low fracture toughness. Surface defects may be of different forms including star-like cracks, C or ring cracks, inclusions, and missing material. An experimental study [1] confirmed a failure mechanism by spalling due to crack propagation from the existing crack. Lubrication, crack location and orientation within the contact path also play a very important role in the rolling contact fatigue of silicon nitride. Ueda [2] produced theoretical study on the surface cracks caused by artificial indenter. Most recent study [3] conducted on C or ring cracks in silicon nitride modelled subsurface stress field, predicted potential cracks shapes, possible maximum stress intensity factors locations and critical flaw size. Karazewski [4] concluded that crack/defect size and oil additives play an important role in rolling contact fatigue of silicon nitride. Depending on how late in the ball lapping process, a coarse diamond indents the ball surface, the resulting star feature morphology can vary with how much material is further lapped/polished away. With limited stock removal, the resulting star can retain similar damage than Vickers indentation with central dent, radial and lateral cracks or even associated small flakes. In this study, naturally occurring surface star features were tested in rolling contact for highlighting their potential failure mode.

2. Experimental results

Lubricated 4-ball rolling contact tests were conducted on Si3N4 balls with mild morphology of star, Fig.1, presenting the star like crack branches with no or very small associated pits, missing material. The star feature was placed in the rolling contact of the top ball and tested against bottom bearing steel balls, and subjected to rolling contact with medium to high contact pressure but no special care was taken for its orientation to the rolling direction.



a) **b)**

Fig. 1: Natural star Defects (a) under UV illumination (b) under white light illumination

Rolling contact tests on these star features in different lubricants showed no damage processes or changes with thick oil, while thinner oils and grease lubrication could lead to surface material loss within the confine of the original star extent within few millions overrolling cycles (8 to 30 Millions). These damages were small and did not trigger vibrations increase that would be a sign of rolling function loss at this stage. However, these results indicated that such star feature do present a damaged (weaker) initial shallow zone that quickly develop into a missing material by internal fracture, and subsequent chipping at an early stage of rolling. Thinner lubrication film can contribute to higher contact friction and/or higher surface/near surface stresses acting on the star features and promoting cracking on the weak pre-damaged star zone. Due to the pre-existing shallow weak star zone, crack branching and breaking to the surface lead to the formation of a missing material at the ball surface which is further exposed to rolling contact.

3. Conclusion

A mild morphology of naturally occurring stars on Si3N4 balls from ball finishing process, presenting star like radial cracks from usually a central ring were shown prone to develop into missing material by internal fracture over the extent of the star in lubricated rolling contact. Lubrication quality or film thickness can influence this mechanism. The orientation of the pre-existing cracks to the rolling direction may also influence the damage process and severity.

4. References

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