Exploring the Impact of Defect Geometry on Bearing Dynamic Behavior Using Spall and Indentation Models

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Abstract

Dynamic modeling of bearings has been proven as an effective tool for investigating the behavior of bearings under various operating conditions. These models offer valuable insights that are not easily attainable through direct experimentation, including information about internal forces and the positions of rolling éléments[1][2]. By simulating faulty bearings, researchers can comprehensively examine the impact of defect shapes on the dynamic behavior of bearings. Understanding the correlation between defect severity and observable outcomes, such as outer ring vibrations, is crucial for the development of diagnostic techniques aimed at assessing bearing conditions during operation[3].

This study presents a comprehensive analysis of two types of defect geometries incorporated into a previously validated deep-groove dynamic model. The first type of defect incorporated to the model is an enhanced spall model, which represents the entrance and exit of the spall as linear-like slopes (figure 1). As the spall propagates the geometry of the defect changes. The slope of the exit and entrance would be affected by the detached chip and the accumulated plastic deformation[4]. Different slope angles may affect the bearing dynamics due to the direction and size of the normal force generated when the ball hits the defect. For example, at mild exit slopes the normal direction has a relatively large radial component that does not resist the tangential movement of the ball as much as a steep slope would. Therefore the material would experience less stress and is expected to deteriorate slower. By simulating spalls with varying angles, it is possible to further research their effects on the overall bearing dynamics.

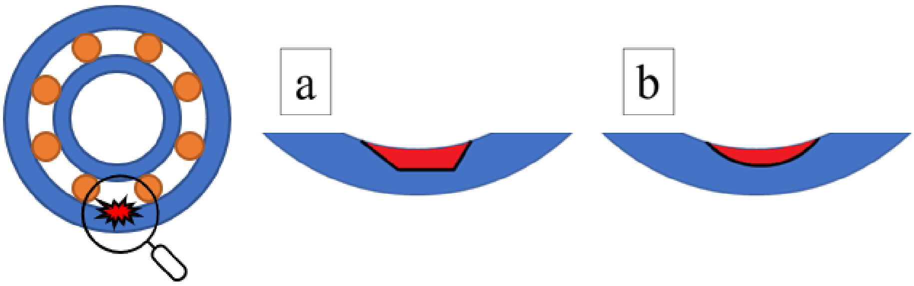

Figure 1: modeled defects geometries: a. updated spall. b. indentation

In contrast to spalls that naturally propagate during bearing operation, the second type of defect introduced in the model occurs abruptly when significant forces act on the bearing, pushing the balls onto the rings and producing a circular-like indentation[5]. Studying indentations may give insights into the lasting effects of the dynamic behavior that a sudden event creates because the indentation geometry is highly dependent on the force applied, The larger the force the deeper and wider the indentation. While the indentation itself is unlikely to cause catastrophic damage, it can lead to a bearing failure as the initial indentation transforms into a spall of significant size[6]. The time needed for the bearing condition to reach such size by means of natural spall propagation is greatly reduced due to the indentation, which implies that the RUL of the bearing is reduced.

Our findings indicate that both indentation and spall defects exhibit similar patterns of dynamic behavior under the examined conditions. The ball-defect interaction initiates with an entry event where the ball separates from the rings. During this stage, the slope of the spall's entrance does not influence the bearing dynamics. As the ball passes through the entrance, it falls freely towards the defect's bottom and moves with the cage rotation toward the exit, yet the rate of falling is too slow to allow the ball to follow the profile of the entrance, therefore no interaction with it occurs. In cases where the defect length is large enough, the ball may strike the defect floor once or more at the mid-stage of the interaction. Conversely, in shorter defects, the ball does not contact the rings until it interacts with the exit, resulting in a rattling event characterized by multiple impulses in the normal forces between the ball and the rings. The slope of the spall's exit significantly determines the duration of the ball-defect interaction and the maximum force on the outer ring. However, when analyzing only the intermediate range of exit slopes, the effect on bearing dynamics becomes negligible. This can be attributed to the relatively larger size of the ball compared to the defect depth, causing it to strike the same location at the edge of the spall's exit.

While comparing the interaction between spall and indentation defects of similar lengths and depths, the overall pattern remains unchanged. However, the duration and amplitude vary due to the differences in defect geometry. Therefore, relying solely on length and depth estimations for diagnosing defect severity may be insufficient, and more factors should be considered. Even though the defect geometry impacts the bearing dynamics, and notably the level of the normal forces which have a significant effect on the rate of deterioration.

References

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