Experimental study on condition indicators for severity estimation of growing spalls in roller bearings

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Abstract

Rolling element bearings are essential components for the proper functioning of many types of rotating equipment. Diagnosing faults in bearings has traditionally been done using signal processing techniques inspired by physics, where acceleration signals are analyzed using time-frequency analysis methods. One of the key challenges in classifying the spall severity in practical applications is that changes in acceleration signatures, which are related to the size of the spall, are hard to detect due to low signal-to-noise ratios (SNRs).

The objective of this research is to study and characterize the effect of spall propagation on acceleration signatures to classify and identify the spall severity. To overcome the challenge of low SNRs, we focus on changes in signal trends rather than identification of events in the time domain of single measurements. Experiments were conducted to gather data from endurance tests with growing faults on the outer ring of cylindrical roller bearings. The data collected includes measurements of acceleration, rotating speed and load at various operating conditions.

One benefit of conducting endurance tests is that they allow for the natural propagation of spall. However, the extent of spall severity during the test remains uncertain. It was observed in previous studies that the vibration signal would drastically change if the test rig was disassembled and reassembled repeatedly which can impact the identification of trends in the acceleration signal. To address this issue, a novel algorithm was developed to assess the spall size based on low-speed load measurements [1], [2]. This algorithm enables the identification of the angle at which the rolling element is interacting with the spall and does not carry the load. The algorithm has been validated through visual inspections in the first experiment. The algorithm makes it possible to estimate the spall length without the need for visual inspection in subsequent experiments. Although a load-cell is not available in practical applications it is used in our research as the “ground truth” to validate the acceleration-based algorithms.

A new condition indicator (CI) for classifying spall severity is proposed. The new CI is based on the acceleration signal. To emphasize the bearing tones, in the signal processing stage calculations of angular resampling, Dephase, and power spectral density were used [3]. Furthermore, due to slippage, the bearing tones can deviate from their analytic location. To overcome this a bearing tone location algorithm was used [4] to detect the bearing tone and its harmonics. The new CI was derived through analysis of vibrations energy trends, extracted from the order domain signatures. The analysis revealed crucial points in the trends that corresponds to specific spall lengths. The new CIs enable the identification of several stages of spall severity prior to reaching the critical point, where beyond asset operation is no longer acceptable. The effectiveness of this new algorithm was demonstrated using three different endurance tests, with results compared against those obtained from the load signal. Noisy simulated trends have been used to demonstrate its robustness.

References

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