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Review

DEM ball bearing model and defect diagnosis by electrical measurement

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A B S T R A C T

We propose in this paper a new method for the monitoring and diagnosis of bearing defects which utilises the sensitivity and the richness of the local electrical signature of the ball bearings. Experimental results show the capability of the electrical measurement to betray the existence of defect. A new model of ball bearing is presented based on Discrete Element Method (DEM), in which the mechanical behavior of ball bearing is reproduced correctly. Numerical simulations are carried out to highlight the influence of angular velocity on the electrical signal of healthy ball bearing. Moreover, the numerical simulations are performed in the case of defected ball bearing. The electrical signals obtained are in good agreement with theoretical frequencies. The numerical study underscore the capability of electrical response to detect geometrical defects.

Contents

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1. Introduction

Rolling bearings are one of the most important and frequently encountered components in domestic and industrial rotating machineries. Statistical studies show that these bearings are considered as critical mechanical components which represent between 40% and 50% of malfunction in rotating machineries. An undetected defect in a bearing can lead to catastrophic failure of rotating machines. Therefore, in order to ensure the availability of industrial systems and the safety of goods and persons, the monitoring and diagnosis of bearing defects are of prime importance. Thus, defect detection in rolling elements bearings has been the subject of extensive research. Different experimental methods have been proposed for detection and diagnosis of bearings which may be broadly classified as vibration and acoustic measurements, temperature measurements, defect signatures in the stator current of motors, wear debris and lubricant analysis. Among these, vibration measurements are the most widely used. A lot of research have been done on several approaches for the detection and diagnosis of bearing defects by vibration measurements along with signal processing techniques in both time and frequency domains. Vibration in the time domain can be measured through parameters such as the overall Root-Mean-Square (RMS) level of acceleration, crest factor, probability density of acceleration and kurtosis. Vibration measurements in the frequency domain or spectral analysis have the advantage that it can detect the location of the defect. However, the direct vibration spectrum from a defective bearing may not indicate the defect at the initial stage. Therefore, high frequency resonance technique has been proposed with the disadvantage that advanced defect is difficult to detect with this method. The wavelet transform method has been proposed to extract very weak signals for which Fast Fourier Transform (FFT) becomes ineffective. Automated data processing methods such as the pattern recognition technique, neural networks, genetic computation and fuzzy logic have been applied to data obtained from vibration measurements for the detection of defects in rolling element bearings. A review of vibration and acoustic measurement methods for the detection of defects in rolling element of bearing is presented in [1].

To detect and diagnose the localized defects through the vibration response generated by ball bearing, a lot of numerical work have been done in order to describe the impulse generated by a ball bearing passing over a local defect on the race. The simulated vibrational response of the bearing with different local defects is used to test the suitability of signal processing techniques. A literature review of various defect models is given in [2]. These defect models are implemented in the framework of multibody dynamic models of rolling element bearings such as lumped mass-spring-damper systems with governing equations of dynamic motion formulated for different coupled degrees of freedom [3]. These numerical models developed with the assumption that the dynamic and vibrational behaviors of the defected bearing as a function of the rotation and of the loading distribution in the bearing are represented by coupled degrees of freedom such as the bearing structure elasticity, the oil film characteristic, the transfer path between the bearing and the sensor [2,4,5]. In [6,7], the authors propose a multibody model devoted to investigations of the influence of axial load on the behavior and the vibration signal of ball bearings with localized defects using a 3D dynamic model. In [8] a lumped mass-spring model of a ball bearing is developed to obtain the vibration response due to localized defects with a deformable outer ring modelled with finite elements and which can be coupled with a finite element model of the housing structure. In [9,10] dynamic loading models for healthy and defective rolling element bearings are developed in order to create the nodal excitation functions used as external loading in a finite element vibration analysis of the outer ring and housing. The rotating radially distributed load is applied on the nodes of the outer ring [11]. A local defect is simulated by amplifying the magnitudes of the radial forces defined for the nodes which are in the defective area. The proposed approaches can be used to determine the ideal sensor position and the optimum signal processing method considering the rotational speeds, structural effects, clearance and loading conditions. In addition to methods based on changes in the stator current, a method for experimentally generating bearing defects that employs an externally applied shaft current to initiate a bearing defect in accelerated time has been developed [12,13].

As seen above, to realize the monitoring and the diagnosis of the bearings a signal approach can be used by considering the analysis and processing of different measurable quantities. While many research works have been conducted in the monitoring of the bearing defects by the analysis of vibratory signals, the studies conducted by the authors have shown that the use of local electrical measures on the bearings is a promising approach underexploited by the scientific community. Therefore, in the context presented above, the objective of this paper is to propose a new method for the monitoring and diagnosis of bearing defects which utilises the sensitivity and the richness of the local electrical signature of the bearings.

Indeed, an experimental device is developed in the laboratory in order to underscore the feasibility and the capability of the local electrical signature of the bearing to exhibit the existence of a defect (Fig. 1(a) and (b)). Experimental tests are under way to highlight the influence of different parameters (rotation speed, mechanical loading, etc.) on the local electrical signature of healthy and defective ball bearings. A constant electrical current is imposed on the outer race which is electrically insulated from the experimental device, in order to allow electric current to pass through the ball bearing (Fig. 1 (a) and (b)). The voltage and electrical resistance are then measured between the outer race and base of the experimental device. The applied electrical current being 100 *mA*, we suppose that this low value does not induce any degradation of the race surface. The first measurements performed on the experimental device are successful from the electrical signals[1] point of view. The difference between these electrical signatures obtained on two ball bearings, of which one is defective are very promising (Fig. 1(c)). From these encouraging results, we can conclude that electrical signals betray the presence of flaking defect on the outer race, confirming that the richness of these signals in terms of ball bearing defects leads to an alternative

[1] Variation of equivalent electrical resistance of ball bearing R_{eq} according to time.