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Experimental Investigation for Distributed Defects in Ball Bearing using Vibration Signature Analysis

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Abstract

Bearing play a pivotal role in rotating machinery. Failure analysis of the bearing is mostly studied by creation of artificial defect on various elements of the bearing and analysis is made with vibration signature tool for monitoring its condition. As localized bearing fault grows, becoming a distributed one, generate random signal with non-stationary components. In present paper effect of surface roughness on the vibration response of outer race of the ball bearing is analysed. Vibration spectrum produced by the single roughness defect under pure radial load at various locations on outer race of bearing is studied. Effect of roughness size, speed and load on the vibration response has been investigated. Results are presented in time and frequency domain. The experimental results are compared with ball pass frequency of outer race. Frequency response obtained from the experimental results is found identical with the theoretical ball pass frequency of outer race.

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Keywords: Ball bearing; Distributed Defect; Surface roughness; Vibration analysis.

1. Introduction

Rolling element bearings are essential parts of rotating machinery. A machine could be seriously harmful if faults occur in the bearings during service. Their movement & dynamic contributes to the overall vibration in a machine. Radially loaded rolling element bearings generate vibration even if they are geometrically perfect. This is because of the use of a finite number of rolling elements to carry the load [1].

The number of rolling elements and their position in the load zone change with bearing rotation, giving rise to a periodical variation of the total stiffness of the bearing assembly. This variation of stiffness generates vibrations commonly known as varying compliance vibrations [3]. However, the presence of a defect causes a significant

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increase in the vibration level. Bearing defects may be categorized as distributed or local. Distributed defects include surface roughness, waviness; misaligned races and off-size rolling elements. They are usually caused by manufacturing error, improper installation or abrasive wear [4, 5].Local defects include cracks, pits and spalls on the rolling surfaces. The dominant mode of failure of rolling element bearings is spalling of the races or the rolling elements, caused when a fatigue crack begins below the surface of the metal and they propagates towards the surface until a piece of metal breaks away to leave a small pit or spall [7]. Whenever, a local defect on an element interacts with its mating element, abrupt changes in the contact stresses at the interface result, which generates a pulse of very short duration. This pulse produces vibration and noise which can be monitored to detect the presence of a defect in the bearing. Even when local defect grows, it becomes distributed one, generate more complex signal with strong non-stationary contents. Time and frequency domain methods are used for monitoring the health of bearings; however correlation with the prediction of amplitude of spectral components with the extent of defect is necessary for diagnostic purpose [12].

It has been proposed that the surface irregularity is one geometric imperfection due to manufacturing error may come due to wear induces vibration. Hence the detection of these defects is important. The rolling element comes in contact with defect, results in excitation of the bearing system. This causes variation in contact force between rolling elements & raceway resulting in significant increase in the vibration level [13]. The studies carried out by several researchers related to vibration analysis of local defects in the bearing. Literature survey also indicates vibration studies considering the single defect on races. There is scope to study the vibration analysis of distributed defects on bearing. Many researchers have worked on bearing fault detection; however there is need to correlate the amplitude of spectral components to the extent of defect. There is scope for the analysis of prediction of amplitude of vibration due to distributed defect on the outer race of ball bearing.

1.1. Characteristic defect frequencies

The vibration generated by bearing appears at different frequency range. Periodically occurring transient pulses are produced at frequencies determined by the bearing geometry and speed. The frequencies of transient pulses depend on the characteristic frequencies of the bearing. The vibrations of ball bearing with defect can be detected at various characteristic defect frequencies is given by:

$$f_c = \frac{f_s}{2}\left[1 - \frac{d}{D}\cos\alpha\right] \tag{1}$$

Where d & D are the rolling element diameter and pitch diameter respectively. If there is a defect on the inner race, it strikes the balls which are revolving at the speed of $f_{c.}$ But the inner race itself is revolving with the shaft speedfs. During the time the bearing makes one complete revolution, the defect comes in to contact with certain numbers of the balls (z). Hence inner race defect frequency is given by

$$f_i = \frac{z \times f_s}{2}\left[1 + \frac{d}{D}\cos\alpha\right] \tag{2}$$

In case of defect on the outer race, z number of balls strikes the defect with the cage speed of fc. . Hence the outer race defect frequency is z times the cage frequency which is given by

$$f_o = \frac{z \times f_s}{2}\left[1 - \frac{d}{D}\cos\alpha\right] \tag{3}$$

The rolling element and outer race fault experience variation in load while passing through the load zone. This has effect of modulating the impulse train by either the ball pass outer race frequency or the cage speed. For roughness fault it is no longer impulsive, but rather has a randomly distributed phase, since the rolling elements are on different position on the rough surface discrete multiple points for every revolution.