Accepted Manuscript

A new model for rolling element bearing defect size estimation

Aoyu Chen, Thomas R. Kurfess

PII: S0263-2241(17)30584-5
DOI: http://dx.doi.org/10.1016/j.measurement.2017.09.018
Reference: MEASUR 4968

To appear in: *Measurement*

Received Date: 16 May 2017
Revised Date: 18 July 2017
Accepted Date: 11 September 2017

Please cite this article as: A. Chen, T.R. Kurfess, A new model for rolling element bearing defect size estimation, *Measurement* (2017), doi: http://dx.doi.org/10.1016/j.measurement.2017.09.018

A new model for rolling element bearing defect size estimation

Aoyu Chen* and Thomas R. Kurfess
George W. Woodruff School of Mechanical Engineering
Georgia Institute of Technology
Atlanta, Georgia, USA
Corresponding author* at: Room 104, Love Building, Georgia Institute of Technology, GA 30332, USA
E-mail addresses: achen75@gatech.edu (Aoyu Chen), kurfess@gatech.edu (Thomas R. Kurfess).

Abstract

A new model based on the Hertzian contact theorem is proposed to estimate the size of a line spall defect located on the bearing's outer race. The entry point can be determined from the ball-race geometry relation, while the exit point can be identified from the time domain signal. Therefore, the defect size can be estimated from the vibration signal without requiring additional bearing load and stiffness measurements. Experiments were performed on a 3-axis CNC machine tool at speeds ranging from 500-3000rpm and three line spall defects were estimated using the proposed method. The proposed model is demonstrated to estimate defect size with minimal speed related error, offset error, and standard deviation.

Keywords: Bearing diagnostics; Condition based maintenance; Defect size estimation; Machine monitoring

1. Introduction

Condition Based Maintenance (CBM) is an effective method to prevent unnecessary maintenance cost and downtime resulting from unanticipated machine failure[1, 2]. Bearing diagnostics are a valuable tool for CBM, as they provide information related to a bearing's health in rotary machines including spindles [3, 4]. Recently, researchers have proposed that when a rolling element passes a line-spall defect on the raceway, a repeatable low-frequency entry event and a high-frequency exit event can be identified from the vibration response[5]. Based on dynamic models of the bearing system and experiment results, it has been proposed that the time difference between the entry and exit events can be used to estimate the size of the defect [6-8]. Calculating from the entry and exit events is a promising method to quantify the severity of a spall-like damage for a CBM algorithm. However, because the moment when the ball center pass through the entry edge is hard to determine in the vibration pattern, previous studies use indirect methods to estimate defect size [5, 9]. "Indirect methods" in this paper refer to estimation of the entry point without using information from the entry signal. In these indirect methods, the ball travel distance during the entry event is either ignored or calculated from bearing maximum load and stiffness. Thus, the estimation results in prior work suffer from speed related error, large offset error, and significant standard deviation. Therefore, a more comprehensive model that transfers the time information of the vibration signal into the defect size is critical to improve the estimation. A new defect size estimation model is proposed based on the Hertzian contact theorem. In the proposed model, the duration of the entry event is measured to locate the entry point in the vibration signal, based on the bearing geometry and material property. Therefore, measuring the bearing maximum load and stiffness is not required to calculate the defect size. Because bearing load and stiffness is difficult to determine and changes over time for an actual bearing system, the proposed method is a viable candidate for CBM.

In this paper, prior work is summarized in Section 2 and describes the vibration pattern due to a localized defect and estimation methods proposed by previous research. Section 3 introduces the new estimation model and the formula to estimate the defect size. The experimental setup and estimation results are