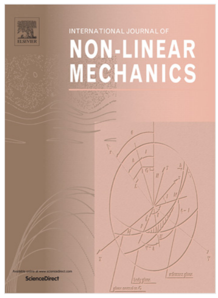
# Accepted Manuscript

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PII: S0020-7462(17)30239-1
DOI: https://doi.org/10.1016/j.ijnonlinmec.2018.03.011
Reference: NLM 2995

To appear in: *International Journal of Non-Linear Mechanics*

Received date : 30 March 2017
Revised date : 12 March 2018
Accepted date : 26 March 2018

# Advantages of pulse force model over geometrical boundary model in a rigid rotor ball bearing system

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**Abstract:** For a local defect modeling in a defective bearing-rotor system, there mainly exist two types of commonly-used models. One is a description of the geometrical boundary simulating a real local defect (GB model), while the other one is a depiction of the consequence — the pulse force produced by a rolling element striking the local defect (PF model). Dynamic equations of defective ball bearing-rotor system based on the two local defect models are established. The defective systems depending on the two defect models reflect the similar dynamic characteristics such as the defect frequencies, the primary resonance and the super-harmonic resonance. However, compared to the GB model, the PF model based governing equation is more suitable to be processed by the classical method for nonlinearities which exists in a defective bearing-rotor system. A frequency-domain method — harmonic balance (HB) method which can obtain the semi-analytical solution is utilized to solve the PF model based governing equation and prove the calculation efficiency. Besides, a rigid rotor ball bearing experiment system is established, the phenomena such as the defect frequencies, resonance and super-harmonic resonances in theoretical analysis reflected together by two defect models are verified qualitatively. Therefore, it can be concluded that the PF model has an advantage over the GB model for the dynamic analysis. Moreover, the discoveries in this paper may supply some clues for diagnosis of a defective rolling bearing system.

*Keywords*: local defect modelling comparison; ball bearing-rotor system; harmonic balance method; resonance characteristics

## 1 Introduction

A rolling bearing element is one of the critical components which determines the healthy functioning and performance of the rotating machinery, however, a failure is inevitable. The localized defects such as a pit or a spall on the raceway or balls, are among the common failure types. The localized defects are usually initiated by sub-surface fatigue cracks that appear during the operation even when the bearing is good condition. The sub-surface cracks will grow and break through to the surface causing a spall or a crack, it develops into more significant damages extending across a larger section of the raceway with the increase of service time [1].

For local defect modeling, Singh et al. [2] sorted the local defect modeling into four broad categories: periodic impulse-train models, quasi-periodic impulse-train models, nonlinear multi-body dynamic models, finite element models; while the local defect modeling was classified into geometrical defect function, force defect function and defect function in the Thalji and Jantunen's review [3]. Based on their work, we think the local defect models might be classified into two types for dynamic modeling: one is a consideration of the pulse force produced by a local defect during the striking process while the other one tries to depict the geometrical boundary of a local defect. The former one is defined as the PF (pulse force) model, and the latter one is defined as the GB (geometrical boundary) model in this paper. The PF model is mainly promoted by McFadden and Smith [4], Tandon and Choudhury [5,6]. McFadden and Smith proposed a vibration model to describe a single point defect on the inner raceway of a rolling element bearing under radial load, and the influence of the local defect is modeled as the product of a series of impulses [4]. Tandon and Choudhury [5,6] thought of the impact as an impulse because of the short duration in the striking process, they utilized the mode superposition method to acquire the frequency spectrums of ball bearings with a local defect on outer raceway, inner raceway and on a ball under radial and axial loads considering finite width triangular, rectangular