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# Detection of Damage of Rotor-Bearing Systems using Experimental Data Analysis

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**Abstract**

Rolling element bearings are critical components and widely used in many rotating machines such as automobiles, aerospace, weaving, machine tools that frequently fail. The vibration of the bearing-rotor influences the security, performance of the rotating machines and working life of the whole plant. In the present research work, a mathematical model of the vibration amplitude of the bearing is established through experimental data based analysis (EDBA). A new mathematical model technique for rotor-bearing systems is established. Furthermore, a model analysis on bearing system is carried out by using EDBA, the defect frequencies and vibration amplitude responses of the rotor-bearing system are obtained, and experimental result has been validated. The Neural Network (NN) is tested to verify the validation of the new EDBA. The method proposed in this paper for vibration characteristics calculation of a rotor-bearing is credible and save time and costs by timely detection of eminent bearing failure

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*Keywords:* experimental data based analysis, neural network, defects, bearing

## 1. Introduction

Rolling element bearings are an integral part of many rotating machines. A bearing fault can result in unscheduled maintenance and in extreme cases, plant shutdown. In fact it was reported in [1] that rolling bearing faults accounts for almost 30% of faults in rotating machinery. These failures can be quite costly in industries. As such there is a growing demand for a robust failure diagnosis scheme for rolling element bearings. Condition based monitoring of bearing faults is typically implemented using experimental data based vibration analysis [2,3,4,5]. As an neural

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network (NN) method have been proposed in the literature for a variety of fault diagnosis applications [6,7]. The purpose of this paper is to provide a brief but effective introduction to the experimental data based analysis, so that more researchers could get familiar with its functioning and enormous capabilities in model development and empirical analysis. From the review of the relevant literature on vibration detection and analysis in rolling element bearings, it is noticed that no effort has been made in the application of experimental data based analysis using FLTθ method. The key challenge to fault diagnosis is the improvement of diagnostics accuracy based on a given amount of information. A huge work has been done on ball bearings and to identify the combination of defects in rolling bearing elements is limited. A little effort has been reported on rolling element bearings. This research paper provides an in-depth study of vibration responses in rotor bearings under single and multiple defect conditions in both inner and/or outer races using the Experimental Data Analysis (EDA). In this paper we extract feature from the time-domain vibration data and use to train a neural network (NN) and demonstrates how EDA, and NN is the most powerful, effective and efficient method for pinpointing the exact cause for bearing failure

**Nomenclature**

| | |
|---|---|
| EDA | experimental data analysis |
| NN | neural network |
| EDM | electric discharge machine |

## 2. Model by Experimental Data Analysis

The functional dependence of vibration amplitude on the parameters can be estimated by performing a dimensional analysis on the Buckingham's π-theorem. For this problem, the involved parameters and their fundamental quantities are described in Table 1.

**Table 1.** Bearing studied parameters and related dimensions.

| Parameter | Symbol | Unit | Dimension |
|---|---|---|---|
| Bore diameter | $d$ | $mm$ | L |
| Ball diameter | $d_b$ | $mm$ | L |
| Inner race diameter | $d_i$ | $mm$ | L |
| Outer race diameter | $d_o$ | $mm$ | L |
| Pitch diameter | $d_m$ | $mm$ | L |
| Number of balls | $Z$ | --- | --- |
| Internal radial clearance | $C_r$ | $mm$ | L |
| Size of defect | $d_s$ | $mm$ | L |
| Speed of rotor | $N_r$ | $rpm$ | $T^{-1}$ |
| Radial load | $P$ | $N$ | $F$ |
| Damping factor | $c$ | $\frac{Ns}{m}$ | $FL^{-1}T^{1}$ |
| Mass of rotor | $m_r$ | kg | $FL^{-1}T^{2}$ |
| Mass of the inner race | $m_i$ | kg | $FL^{-1}T^{2}$ |
| Mass of the outer race | $m_o$ | kg | $FL^{-1}T^{2}$ |
| Mass of the ball | $m_b$ | kg | $FL^{-1}T^{2}$ |
| Cage frequency | $f_c$ | Hz | $T^{-1}$ |
| Ball spinning frequency | $f_b$ | Hz | $T^{-1}$ |
| Inner race defect frequency | $f_{id}$ | Hz | $T^{-1}$ |
| Outer race defect frequency | $f_{od}$ | Hz | $T^{-1}$ |
| Ball defect frequency | $f_{bd}$ | $Hz$ | $T^{-1}$ |
| Young's Modulus | $E$ | $\frac{N}{m^2}$ | $FL^{-2}$ |
| Density of bearing | $\rho$ | $\frac{\mathrm{kg}}{\mathrm{m}^3}$ | $FL^{-4}T^{2}$ |
| Vibration amplitude | $V$ | $\frac{mm}{s}$ | $LT^{-1}$ |