VIBRATION STUDY OF DEEP GROOVE BALL BEARING BY CONSIDERING SINGLE AND MULTIPLE DEFECTS IN RACES

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ABSTRACT

A dynamic model is reported herein for the study of vibrations of deep groove ball bearings having single and multiple defects on surfaces of inner and outer races. The model provides the vibrations of shaft, races in time and frequency domains. Computed results from the model are validated with experimental results, which are generated using healthy and defective deep groove ball bearings. Characteristic defect frequencies and its harmonics are broadly investigated using both theoretical and experimental results. Comparison of vibration spectra for the cases having single and multiple (two) defects on races reveals relatively higher velocity amplitudes with two defects. Good correlations between theoretical and experimental results are observed.

Keywords: Vibration, Single Defect Multiple Defects, Time Domain, Frequency Domain.

I INTRODUCTION

1.1 Preamble

Ball bearings are widely use in small as well as big industrial machines. Performances of such machine are greatly influence by quality of bearings used in it. In spite of perfect geometry of ball bearing, vibrations are commonly generated through the interaction of the rolling element during the motion. There are many localized defects are generated during bearing operation, which are pits, spalls etc. Most of the engineering applications such as electric motors, bicycles and roller skates use these bearings, which enable rotary motion of shafts apart from complex mechanisms in engineering such as power transmissions, gyroscopes, rolling mills and aircraft gas turbines. [2] In general ball bearings are made of four different components, an inner ring, an outer ring, the ball element and the cage. The cage element helps in separating the rolling elements at regular intervals and also it holds them in place within the inner and outer raceways to allow them to rotate freely. In order to prevent bearing failure there are several techniques in use. Such as, oil analysis, wear debris analysis, vibration analysis and acoustic emission analysis. Among them vibration and acoustic emission analysis is most commonly accepted techniques due to their ease of application. The time domain and frequency domain analysis are widely accepted for detecting malfunctions in bearings. [4]

 ISBN: 978-93-86171-12-2

1.2. Relevance / Motivation of Research

The faulty installation, poor maintenance and handling practices or surface fatigue of deep groove ball bearing eventually leads to the formation of various types of defects like cracks, pits and spalls. Unnoticed and undesirable defects in their early stage may results in higher noise and vibrations and finally leading to failure of bearing system causing machinery breakdown, significant economic losses in certain situations. Detection of defects in deep groove ball bearing by monitoring the dynamic behaviour and accurate physical modelling of rotating components is extremely important in order to prevent catastrophic damages.

II LITERATURE REVIEW

2.1. General

The rolling elements bearings are widely used in industrial and domestic machines. The existence of even tiny defects on the mating surfaces of the bearing components can lead to failure through passage of time. Their failure leads to economic losses. The vibration monitoring technique is mostly used in the industries for health monitoring of bearings. From a review of dynamic models of healthy and faulty rolling element bearing it has been observed that the vibration amplitude of the defective bearing are more compare to the healthy bearing.

2.2. Literature Review

Singh and Howard [1]

In this paper focused on a review of literature concerned with the vibration modelling of rolling element bearings that have localized and extended defects. An overview is provided of contact fatigue, which initiates subsurface and surface fatigue spalling, and subsequently leads to reducing the useful life of rolling element bearings. To investigate the effects on the vibration characteristics of defective rolling element bearings, a full parametric study could be conducted that could include a matrix of parameters, which can be varied.

Shaha [2]

Studied the rolling bearing, with outer ring fixed, is a multi-body mechanical system with rolling elements that transmit motion and load from the inner raceway to the outer raceway. Modern trend of Dynamic analysis is useful in early prediction. Dynamic analysis has become a very powerful tool for the betterment of the actual performance of the system. The methodology for prediction and validation of dynamic characteristics of bearing rotor system vibration is studied. The proposed simulation method is used to determine the vibration signal response for various shaft speeds and loading condition, which is compared with experimental result. It is found simulated vibration pattern has similar characteristic compare to experimental results. The deviation in amplitude of acceleration is may be due to variation of mesh density in the region near to defect and also deviation in frequency occurs due to uncontrolled parameters during experimentation.

Viramgama [3]

Focused on increased usage and the increased sophistication mechanical design came to necessity to predict their endurance capability. In this paper an effort has been put to analyse the ball bearing using finite element analysis the stress level or displacement behaviour of ball bearing. The main target is to find the most influencing parameters for radial stiffness of the bearing under an axial load.

III SENSING EQUIPMENT

3.1 Accelerometer

An accelerometer is a sensing element that measures acceleration; acceleration is the rate of change of velocity with respect to time. It is a vector that has magnitude and direction. Accelerometers measure in units of g, a g is the acceleration measurement for gravity which is equal to 9.81m/s². Accelerometers have developed from a simple water tube with an air bubble that showed the direction of the acceleration to an integrated circuit that can be placed on a circuit board. Accelerometers can measure: vibrations, shocks, tilt, impacts and motion of an object. Accelerometer used is as shown in Figure.1

Figure.1.Accelerometer

IV EXPERIMENTAL SETUP

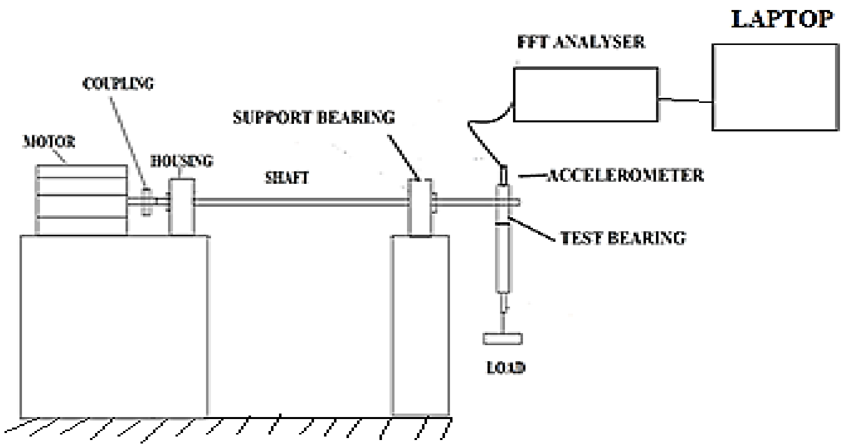

Figure.2. Imaginary experimental setup

V READINGS& DISCUSSIONS

5.1Frequency Domain

Table.1. Frequency domain analysis at different radial load & different bearing defects conditions

CONDITION	LOAD	FREQUNECY(Hz)	RMS (mm/s)
HEALTHY BEARING	5 KG	25 Hz	1.47
	6 KG	25 Hz	1.35
	7 KG	25 Hz	1.27
SINGLE DEFECT ON INNER RACE (250 µm)	5 KG	124 Hz	0.383
	6 KG	124 Hz	0.533
	7 KG	124 Hz	0.401
SINGLE DEFECT ON OUTER RACE (250 µm)	5 KG	74 Hz	0.327
	6 KG	74 Hz	0.339
	7 KG	74 Hz	0.276
DOUBLE DEFECT ON INNER RACE (250 µm) DEFECT ANGLE=30°	5 KG	124 Hz	0.248
	6 KG	124 Hz	0.215
	7 KG	124 Hz	0.222
DOUBLE DEFECT ON OUTER RACE (250 µm) DEFECT ANGLE=30°	5 KG	74Hz	0.202
	6 KG	74 Hz	0.269
	7 KG	74 Hz	0.185

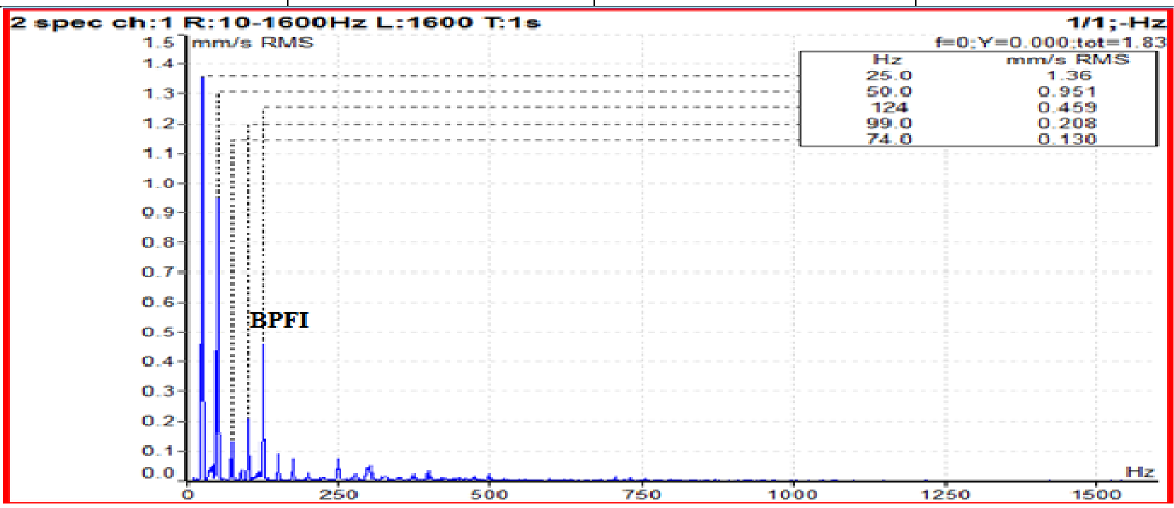

Figure. 3.Frequency Spectrum Analysis of Single defect on inner race bearing

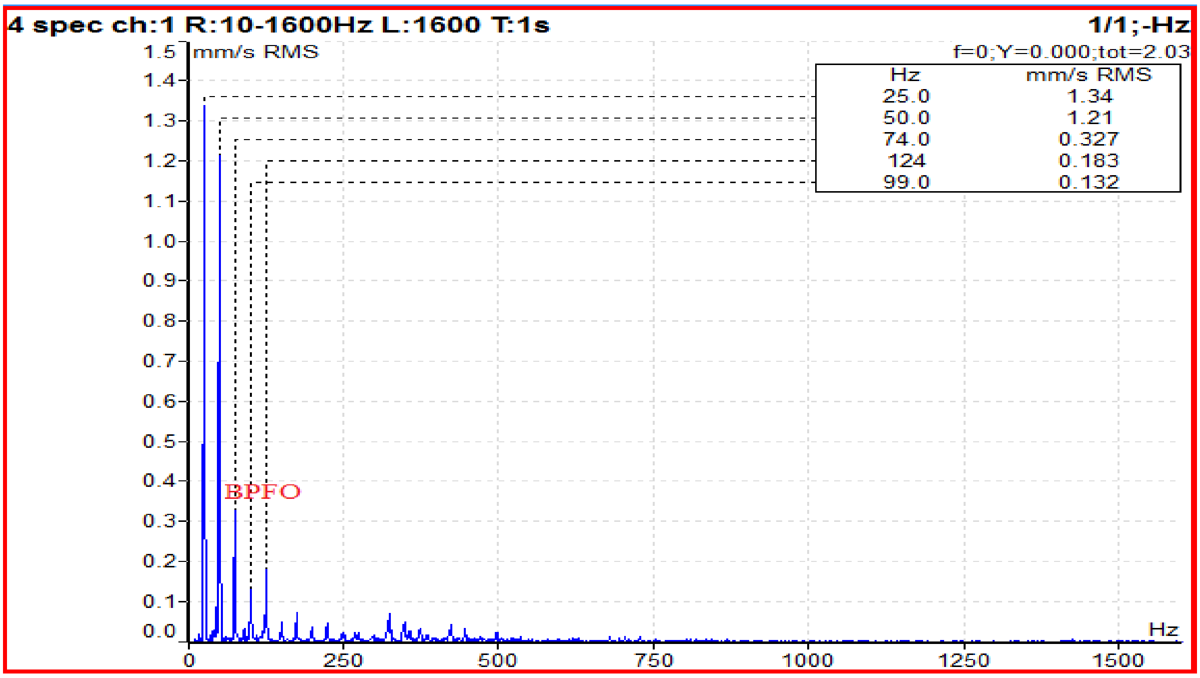

Fig. 4.Frequency Spectrum Analysis of Single defect on outer race bearing

5.2Characteristics Defective Frequencies:

- Single Defect

Single Defect on Inner Race

$$BPFI = \left(\frac{Nb}{2}\right) * \left(\frac{Ns}{60}\right) * \left(1 + \frac{d}{D}\right)$$

$$= \left(\frac{9}{2}\right) * \left(\frac{1330}{60}\right) * \left(1 + \frac{9}{39.1}\right)$$

= 122.71 Hz.

Single Defect on Outer Race

$$BPFO = \left(\frac{Nb}{2}\right) * \left(\frac{Ns}{60}\right) * \left(1 - \frac{d}{D}\right)$$

$$= \left(\frac{9}{2}\right) * \left(\frac{1330}{60}\right) * \left(1 - \frac{9}{39.1}\right)$$

= 76.78 Hz.

- Multiple Defects

Multiple Defects on Inner Race

$$BPFI = \left(\frac{Nb}{2}\right) * \left(\frac{Ns}{60}\right) * \left(1 + \frac{d}{D}\right) * \cos(\alpha)$$

$$= \left(\frac{9}{2}\right) * \left(\frac{1330}{60}\right) * \left(1 + \frac{9}{39.1}\right) * \cos(10)$$

= 120.84 Hz.

Multiple Defects on Outer Race

$$\text{BPFO} = \left(\frac{Nb}{2}\right) * \left(\frac{Ns}{60}\right) * \left(1 - \frac{d}{D}\right) * \cos(\alpha)$$

$$= \left(\frac{9}{2}\right) * \left(\frac{1330}{60}\right) * \left(1 - \frac{9}{39.1}\right) * \cos(10)$$

= 75.62 Hz.

Table.2. Comparison of vibration amplitudes and characteristics frequencies

DEFECT LOCATION	SIMULATED RESULTS	EXPERIMENTAL RESULTS
Single defect on outer race	BPFO=76.78 Hz	BPFO=74 Hz
Single defect on inner race	BPFI=122.71Hz	BPFI=124Hz
Multiple defects on outer race	BPFO=75.62Hz	BPFO=74 Hz
Multiple defects on inner race	BPFI=120.84Hz	BPFI=124 Hz

VI CONCLUSIONS

The conclusions of experiment of dynamic model of deep groove ball bearing at different radial load and different defects on the races of deep groove ball bearing are as follows,

1. Vibration based method for the dynamic model of deep groove ball bearing is very useful for the defects or faults identifications.
2. As load increase the Amplitude, RMS value (velocity mm/s) is increases & decreases for healthy bearing.

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