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Vibration analysis of ball bearing using Finite Element Analysis

N.S.R. Apandi[1], R. Ismail[1,2,*], M.F.B.Abdollah[1,2]

[1)] Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[2)] Centre for Advanced Research on Energy, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

*Corresponding e-mail: rainah@utem.edu.my

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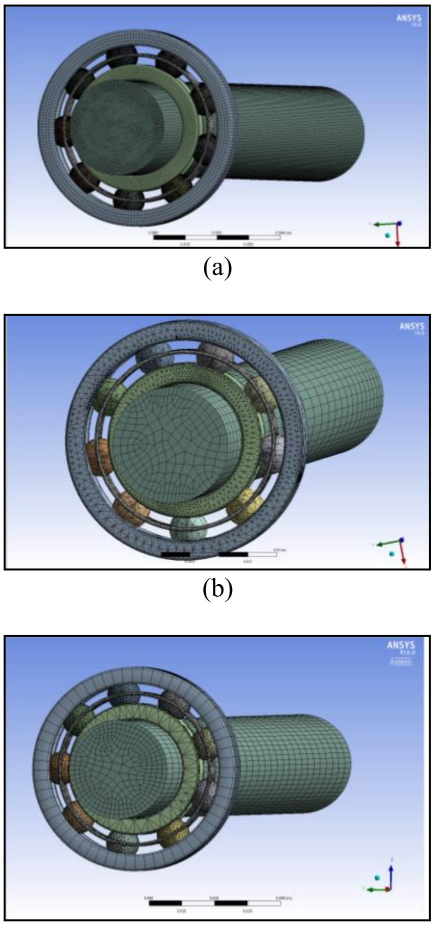
ABSTRACT – This paper presents a numerical approach on the frequency characteristics of a new and defected bearings. A 3D model of bearing system with 0.5 mm artificially defects including outer and inner race was modelled by using CATIA software. The numerical simulation was completed by employing ANSYS WORKBENCH 16.0. The simulation result shows the existence of significant and non-synchronous peaks which represent the new and defected bearing defaults with the frequency characteristics of the system.

1. INTRODUCTION

Ball bearing provides a rotational freedom and relative positioning while transmitting a load between two contact surfaces with a minimum friction [1]. Over the time, bearing failure will lead to mechanical system breakdown because of the misalignment, defect on bearing elements, unsuitable lubricants, and unbalanced force. Eventually, these problems will become a reason for undesirable vibration. This phenomenon can be examined from the early stages of bearing defects. The defects that occur on bearing element such as inner race, outer race and ball spin can be detected by their own vibration frequency characteristic. Monitoring and analysing the vibration signal of the bearing defects give researchers the fastest way to distinguish the existence of faults and the worseness of the system condition. As stated in paper published by Liu et al. [2] the localized defects can propagate the effects on the speed, radial load, and defect shape in pulse waveform characteristic. The other studies were also conducted by Li et al. [3] and Singh et al [4] which using explicit dynamic finite element analysis to study the vibration characteristic of rolling bearing. However, there is no significant studies which using the Modal and Harmonic Response analysis to analyse the vibration characteristic of rolling bearing. Thus, in this study the vibration characteristics of a bearing defect is obtained when bearing system is operated under hBN nanoparticles mixed with diesel engine oil lubricant through ANSYS WORKBENCH 16.0.

2. METHODOLOGY

Bearing system consists of a single deep groove ball bearing 6206 and the shaft with a length of 500 mm are modelled in CATIA software. The artificial defect of 0.5 mm hole is also created on the inner and outer race of bearing element. The focus of this paper was to determine the vibration characteristic on the new and defected bearings. Hence, a structural steel bearing system is modelled as deformable body by inserting the material properties density, ρ = 7800 kg/m^3, the modulus elasticity, E = 206 GPa and Poisson's ratio, υ = 0.33. For simulation purpose, three conditions are taken into consideration which are new bearing, 0.5 mm outer defected bearing and 0.5 mm inner defected bearing as shown in Figure 1. The detailed dimension of the bearing model was also shown in Table 1.



(a)

(b)

(c)

Figure 1 The meshed model for bearing system. (a) Meshed model of new bearing, (b) meshed model of 0.5mm outer defected bearing and (c) meshed model of 0.5 mm inner defected bearing.

Table 1 Dimensions of bearing system model.

Feature name	Dimension (mm)
Outer diameter, OD	62.0
Inner diameter, ID	30.0
Ball diameter, D	8.0
Pitch diameter, PD	35.6
Breadth, B	16.0
Ball number, N	9
Length of defect, Ld	0.50
Depth of defect, Dd	0.25
Shaft diameter, Os	30.0
Length shaft,Ls	500

In this analysis, the friction force, F_f which indicate the lubricant, is applied with the value of 2.0 N and 5 Nm of torque produced by DC motor.

2.1 *Bearing frequencies*

The physical defects can occur on bearing elements such as inner race, outer race, ball and cage. The defects will cause a high amplitude of vibration. Each element has variant characteristic frequencies such as fundamental frequency, ball spin outer frequency, (BPOF) and ball spin inner frequency, (BPFI) can be calculated by using the formula below:

$$BPFO = \frac{N_b}{2} f_s \left(1 - \frac{B_d}{P_d}\cos\phi\right) \tag{1}$$

$$BPFI = \frac{N_b}{2} f_s \left(1 + \frac{B_d}{P_d}\cos\phi\right) \tag{2}$$

where N_b is the number of balls, f_s is shaft speed in rpm, P_d is the pitch diameter in mm, B_d is ball diameter in mm and contact angle, ϕ. For the bearing model in this paper, the theoretical value for new bearing is 25 Hz, f_{BPFO} is 87 Hz and for the f_{BPFI} is 130 Hz.

3. RESULTS AND DISCUSSION

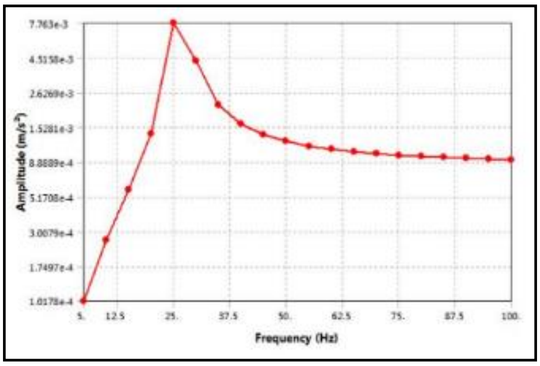
The frequency response graph for the new and defected bearings are shown in Figure 2.

From the theoretical formula, the defect frequencies can be detected by the significant peaks that appeared on the frequency graph. Particularly for BPOF, the non-synchronous peak is detected at 3X and BPFI is appeared at 5X non-synchronous peak. Meanwhile, the new bearing is observed at 1X significant peak which is equivalent to the fundamental frequency. From the simulation findings, it is found that the non-synchronous peaks which are 3X and 5X for both inner and outer defected bearings are noticed as theoretical value.

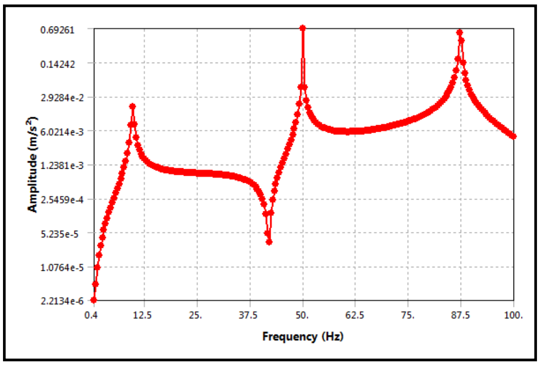
From Table 2, it is found that the frequencies from the simulations are similar with the theoretical values. It can be seen that significant peak on new bearing and non-synchronous peaks appeared on the inner and outer defected bearings shows good predictive agreement with the experimental results published by Apandi [5].

4. CONCLUSION

It is found that the proposed numerical approach is applicable to determine the early deterioration of the bearing system that occur in outer and inner race of bearing element.



(a)



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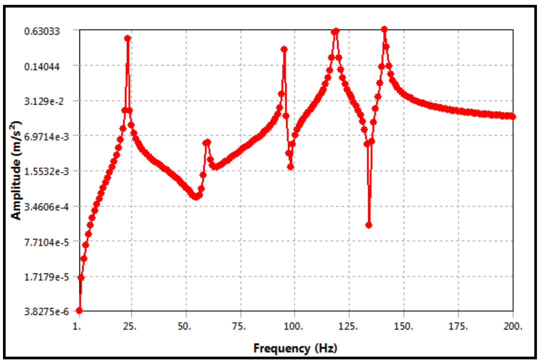

(c)

Figure 2 Frequency response graph of (a) new bearing, (b) outer defected bearing and (c) inner defected bearing.

Table 2 Bearing frequencies

Types of bearing	Peaks	Frequency (Hz)
New bearing	1X	25.0
Outer defected bearing	3X	89.7
Inner defected bearing	5X	130.5

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