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Experimental Study of Effect of Surface Defect on Vibration Response of Ball Bearing

#1 Amol A. Swami, #2 S.R.Patil

[1]amolswami77@gmail.com

[2]srpatil.sae@sinhgad.edu

#1 PG Student, Mechanical Engg .Dept., SAOE Kondhwa, Pune-411048

#2 Assistant Professor, Mechanical Engg .Dept., SAOE Kondhwa, Pune-411048a

ABSTRACT

Ball bearings are very important element in a large number of machinery to support the load. Their proper working is very essential for the application like automotive industries, aerospace, industrial processes, etc. These bearings are designed to take radial as well as axial loads. They have huge effect on the dynamic performance of rotating machine and acts as source of vibration and noise. Increasing performance of ball bearings is required to prevent sudden breakdown of machinery and its related economic and other effects. This paper is helpful for the understanding of effect of surface defect on vibration response of ball bearing. In this work surface defect on outer race is focused and size of defect is varied during experimentation. This paper explains the experimentation carried out to study effect of surface defect on vibration response of ball bearing. The actual measurements of vibration signals for healthy, defective bearing has been carried out by using FFT analyzer and signal analysis has been done in comparative manner. Effect of speed and load on vibration response of ball bearing is also studied .From the signal analysis it is observed that defect size, speed and load has significant effect on vibration response.

Keywords— **Ball bearing, experimental study, surface defect, vibration response.**

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I. INTRODUCTION

Bearings are the fundamental part of rotating machineries. Failure of the bearings leads to the complete breakdown of the machines. In any industry breakdown of machinery causes loss in terms of money as well as time. To avoid this, the system must give early warning of failure of bearings. Such system works on principle of condition monitoring. Condition monitoring of rotating machinery containing bearings is primarily done by vibration analysis. Vibration analysis of such system is most easy and adopted tool. A vibration signal contains information about the defects; but differentiating between defects, finding out the severity of defects and its location is very difficult. Various signal processing techniques assist in solving this difficulty. Signal processing techniques like time domain, frequency domain and statistical methods are used mostly for vibration analysis.

II. BEARING CHARACTERICTICS FREQUENCIES

A machine with a rolling element bearing is running at certain speed; now a defect begins to develop, the vibration spectrum changes produced in bearing. The occurrence frequencies of the shocks resulted from the defects in the bearings are called bearing defect frequencies or bearing characteristics frequencies. Each bearing element has a bearing characteristic frequency. The peaks will occur in the spectrum at these frequencies due to increase in vibration energy. Initiation and progression of defects or faults on rolling element bearing generate specific and predictable characteristic of vibration. Defects in components of rolling element bearing such as inner race, outer race, rolling elements and cage generate a specific defect frequencies calculated theoretically from the below equations(1)-(4):

1] Ball-pass frequency for the inner race (Fi):-

$\frac{n}{2} Fr[1 + (BD/PD) \cos \beta]$………… (1)

2] Ball-rotational Frequency (Fb):-

$\frac{PD}{BD} Fr[1 - (BD/PD)^2 \ (\cos^2 \beta)]$……….. (2)

3] Ball-pass frequency for the outer race (Fo):-

$\frac{n}{2} Fr[1 - (BD/PD) \cos \beta]$………….. (3)

4] Fundamental train frequency (Ft):-

$\frac{1}{2} Fr \ [1 - (BD/PD) \cos \beta]$………… (4)

Where:
n:-No. of balls ,
Fr:-Shaft Rotation Frequency,
BD:-Ball Diameter,
β:-Contact angle,
PD:-Pitch Diameter

The in reality there exist some sliding. If there is sliding contact between rolling elements and the races the actual assumption made that there is no sliding and only pure rolling contact between the rolling elements and the races but characteristics defect frequencies slightly different from the calculated, but mostly dependent on speed of the shaft, the type of fits and type of bearing.

For early detection of bearing problem, particular attention must be given to FFT spectrum and bearing defect frequencies.

III. RESULT AND DISCUSSION

Early identification of bearing failure can be done by using the condition monitoring based on vibration technique. In order to avoid the catastrophic failure of machine, surface defects of bearing should be analysed in early stage only.

The desired experimental setup is made for present study and experiments have been carried out to examine the effect of surface defect on outer race of ball bearing. The vibration spectra for both healthy and defective bearings are obtained using FFT analyser (DEWE-43A) and accelerometer (Dytran3185 D).Defect on outer race of ball bearing is purposefully made for experimentation with EDM technique (as schematically shown in figure 2).Theoretically calculated defect frequencies at various speeds is shown in table 1.

The experimental results of both healthy and defective bearings are compared to illustrate effect of presence of defects in ball bearing, speed of shaft and load on vibration spectra.

IV. EXPERIMENTAL SETUP

The experimental setup is developed to study the effect of surface defect in ball bearing as shown in figure 1.It consists of three deep groove ball bearings, coupling, electric motor, shaft, load arrangement, speed control device and rigid base plate.

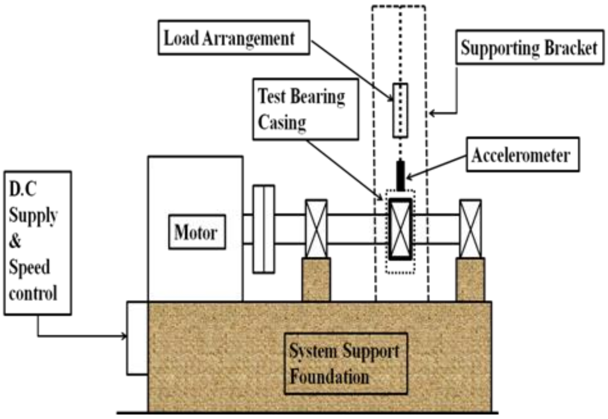

Fig.1 Experimental setup

Experimental setup consists of a shaft supported on healthy pedestal bearings and driven by a variable speed motor. The test bearing placed on the shaft between two healthy pedestal bearings. The drive to test rig is provided with DC motor through rigid coupling .A variable speed is expected from control panel of DC motor. The signatures of the vibration are collected for various running parameters using the FFT analyser and have an accelerometer as a sensor. The sensor is directly attached to casing which is fitted on outer race of defective bearing. Casing on outer race make it fix, so inner race is rotating with the shaft. The readings are obtained in the form of acceleration.

Test bearing used is single row deep groove polyamide cage DFM-85 ball bearing. Three phase D.C motor of SIEMENS with 0.75 kW rated output power is used to get different rpm speed. Specially made speed control device is used to achieve desired speeds. Turnbuckle with load cell is used to get different loads.

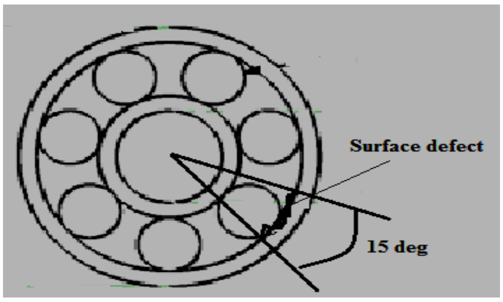

Fig.2. Schematic of surface defect and its location in experiment

Sr. No	Speed in RPM	Rotational Frequency (Hz)				
		Fs	Ft	Fo	Fb	Fi
1	300	5	1.74	12.18	14.94	22.81
2	600	10	3.48	24.37	29.89	45.63
3	1200	20	6.96	48.74	59.77	91.25

TABLE I
THEORETICALLY CALCULATED BEARING DEFECT FREQUENCIES

The defect is created on outer race of ball bearing and vibration spectrums are acquired for various defect size. Two test bearings are used for this purpose. Defect size of 4 ampere and 8 ampere (current passed while EDM) are created on ball bearing for 15degree angular groove of outer race (as schematically shown in figure 2).Above two cases are examined for various speeds as 300,600 and 1200 rpm. Also loads are taken in to consideration as 5, 10 and 20 kg.

The experiment is carried out to investigate how the peak amplitude (acceleration) of vibration of bearing changes with defect size, speed and load.

A vibration spectrum for each case of healthy and defective bearings is studied and results are put in the form of line graphs as follows.

A. *Effect of change of speed*

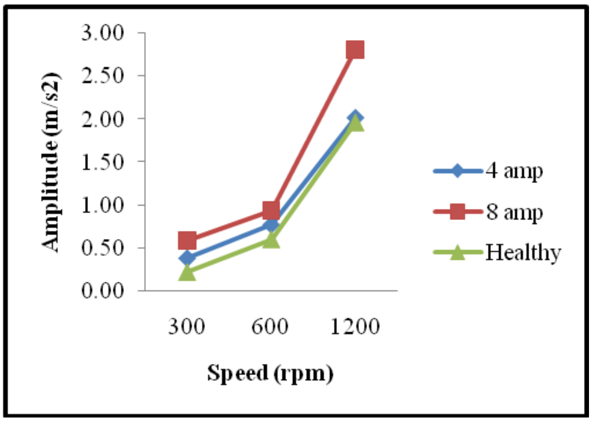

Fig.3. Variation of peak amplitude with speed at 5 kg load

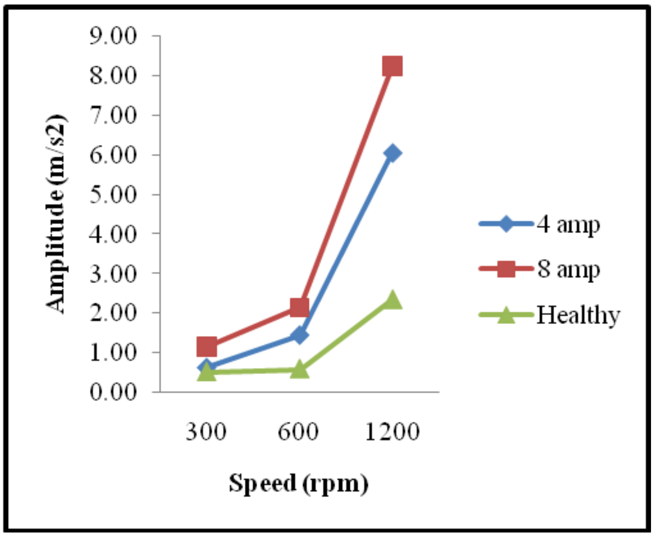

Fig.4. Variation of peak amplitude with speed at 10 kg load

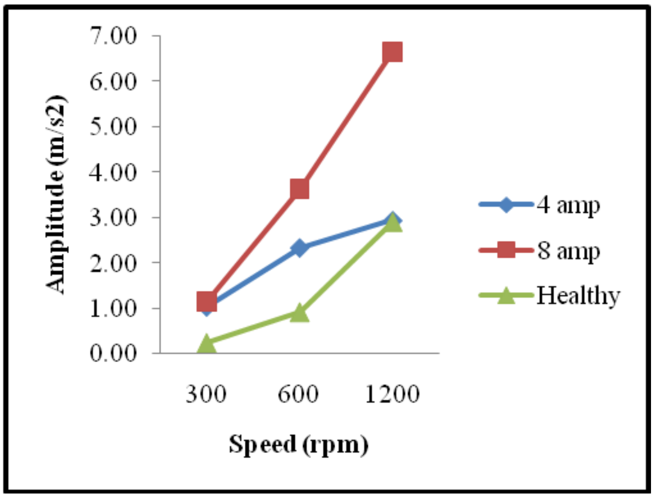

Fig.5. Variation of peak amplitude with speed at 20 kg load

Figure 3-5 shows the line graphs of variation of peak amplitude (acceleration in m/s^2) of vibration for healthy, 4 ampere defect and 8 ampere defect bearing with speed at constant load of 5, 10 and 20 kg respectively.

It is clearly observed from the figure that as defect is introduced in to the bearing, value of peak amplitude increases. Also value of peak amplitude increases as defect size in increased.

At any constant load as the speed increases from 300 to 600 rpm (i.e. making speed twice the initial)the peak amplitude values (m/s2) increases gradually but when speed increases from 600 to 1200 rpm (i.e. making speed four times the initial)the peak amplitude values (m/s2) increases suddenly.

B. *Effect of change of load*

Figure 6-8 shows the line graphs of variation of peak amplitude (acceleration in m/s^2) of vibration for healthy, 4 ampere defect and 8 ampere defect bearing with load at constant speed of 300, 600 and 1200 rpm respectively.

As in case of constant load, here at constant speed also it is clearly observed from the figure that as defect is introduced in to the bearing, value of peak amplitude increases. Also value of peak amplitude increases as defect size in increased.

At any constant speed for defective bearing, as the load increases from 5 to 20 kg the peak amplitude values (m/s^2) increases gradually at lower speed up to 600 rpm. But for a higher speed of 1200 rpm the peak amplitude values (m/s^2) increases as load change from 5 to 10 kg (i.e. twice the initial) while it decreases as load changes from 10 to 20 kg (i.e. four times the initial).

At any constant speed in case of healthy bearing, for a lower speed of 300 rpm the peak amplitude values (m/s^2) increases as load change from 5 to 10 kg (i.e. twice the initial) while it decreases as load changes from 10 to 20 kg (i.e. four times the initial).But at speed from 600 to 1200 rpm, as the load increases from 5 to 20 kg the peak amplitude values (m/s^2) increases gradually.

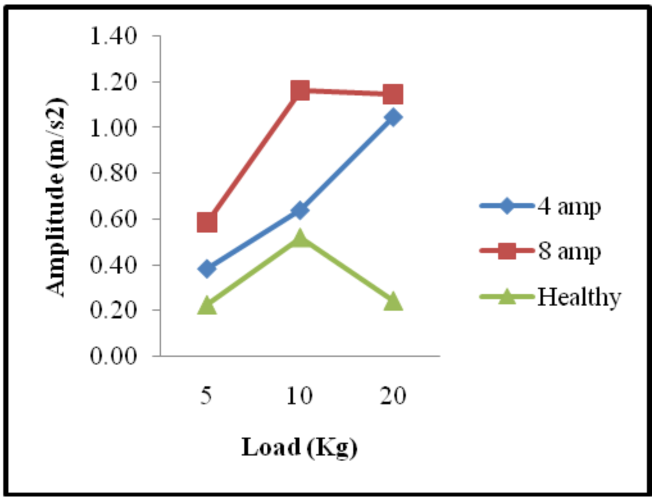

Fig.6. Variation of peak amplitude with load at 300 rpm speed

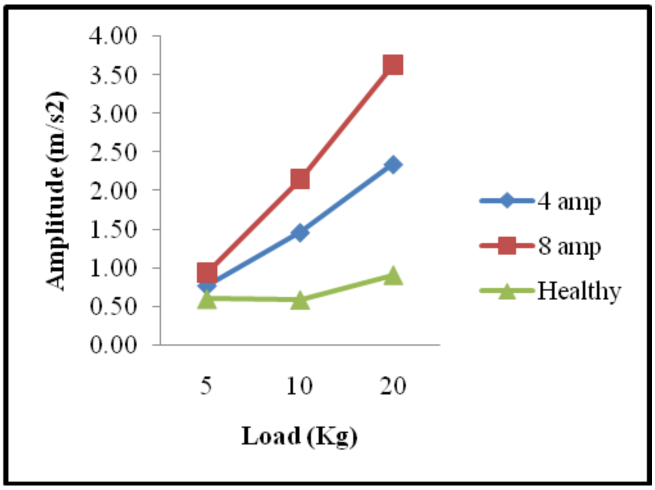

Fig.7. Variation of peak amplitude with load at 600 rpm speed

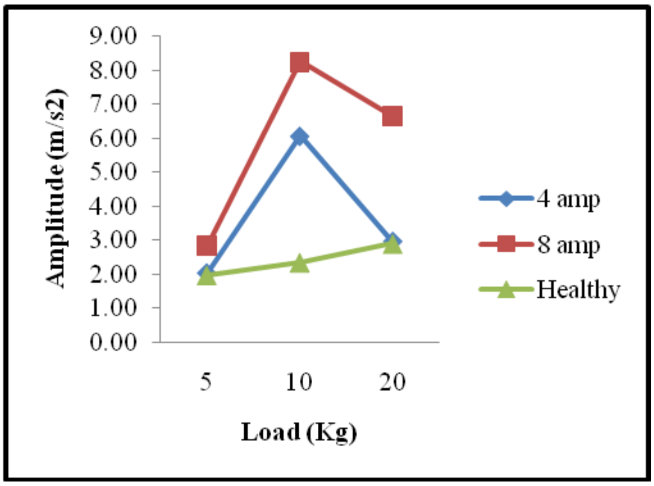

Fig.8. Variation of peak amplitude with load at 1200 rpm speed

V. CONCLUSION

The experimental setup is designed and fabricated to study effect of surface defect on outer race of ball bearing on vibration spectrum. The vibration spectrums are obtained for both healthy and defective bearing by using a accelerometer along with DEWE Soft 7 signal analyser. Following conclusion are made from this study,

1) Bearing with outer race defect shows higher peak amplitude than healthy bearing.

2) Defect size, speed of shaft and load on bearing affects the vibration spectrum.

3) Amplitude of vibration increases, as defect size increases for constant load or speed.

4) Amplitude of vibration increases, as speed increases for constant load.

5) Amplitude of vibration may increase or decrease with load at constant speed, it depends on load and speed combination.

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