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Experimental Vibrational Analysis of Antifriction Bearing

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Abstract - *Bearing play vital role in rotating machinery. Many author's studied failure analysis of the bearing by experimentally and numerically by creating defect in outer race, inner race, rolling element and keeping clearance between shaft -sleeve, sleeve- inner race and outer race-pedestal block. This causes increase in vibration in machine as a whole. In this paper square hole with different depth of cut is created on ball by EDM and also clearance is developed between ball and outer race. Frequency spectra is obtained by FFT Analyzer. Experiment is conducted with different speeds and single load. Experimental results shows that peak amplitude of vibration increases with increase in speed. Peak vibrational amplitudes also increases with increase in depth of cut for same clearance. Clearance has little effect in changing vibrational amplitudes. Harmonics in terms of ball spin frequency is clearly observed.*

Keywords - *ball spin frequency, clearance, depth of cut, FFT, Vibrational analysis*

I. INTRODUCTION

Rolling element bearings, are chiefly used in rotating machinery across various industries which includes aerospace, construction, mining, steel, paper, textile, railways, and renewable energy. The damage and failure of rolling element bearings is a dominant factor that contributes to machinery breakdown, consequently causing significant economic losses and even loss of human lives. Ball bearing are also used for moderate loaded and high speed application whereas Roller bearings are suitable in supporting heavier loads applications. Moreover, radial bearings are preferred when load applied is in radial direction and to carry axial load thrust bearings are preferred. But, most of the ball bearings can support both radial and thrust load. Bearing defects may be categorized as distributed or local. Distributed defects include surface roughness, waviness; misaligned races and off-size rolling elements. They are usually caused by manufacturing error, improper installation or abrasive wear [1, 2].Local defects include cracks, pits and spalls on the rolling surfaces. The dominant mode of failure of rolling element bearings is spalling of the races or the rolling elements, caused when a fatigue crack begins below the surface of the metal and they propagates towards the surface until a piece of metal breaks away to leave a small pit or spall [3]. Whenever, a local defect on an element interacts with its mating element, abrupt changes in the contact stresses at the interface result, which generates a pulse of very short duration. This pulse produces vibration and noise which can be monitored to detect the presence of a defect in the bearing. Even when local defect grows, it becomes distributed one, generate more complex signal with strong non-stationary contents. Vibration monitoring has now become a well-accepted part of many planned maintenance regimes and relies on the well-known characteristic vibration signatures which rolling bearings exhibit as the rolling surfaces degrade. However, in most situations bearing vibration cannot be measured directly and so the bearing vibration signature is modified by the machine structure, this situation being further complicated by vibration from other equipment on the machine, i.e. electric motors, gears, belts, hydraulics, structural resonances etc. This often makes the interpretation of vibration data difficult other than by a trained specialist and can in some situations lead to a mis-diagnosis, resulting in unnecessary machine downtime. Fault detection in the rolling element bearing was studied experimentally and theoretically by Taha and Dung [4]. In an experimental analysis single point fault on outer raceway is created i.e. 2mm in diameter and depth by using EDM.RMS and peak to peak signal parameters are studied and observed increase level of vibration in high frequency range of the spectrum. From reading it is seen that there is big difference between defected and healthy bearing readings. Review of vibration and acoustic measurement methods for the detection of defects in rolling element bearings was carried out by Tandon and Choudhry [1]. Detection of both localized and distributed categories of defect are considered. They are concluded that vibration measurement in the frequency domain has the advantage over time domain because it can detect the location of the defect. Patel et al. [5] have done the theoretical and experimental vibration studies of dynamically loaded deep groove ball bearings having local circular shape defects on either race. It was seen that vibration enhances in presence of local defects on outer race in comparison to inner race. Acoustic emission method was used to study experimentally defect diagnosis in rolling bearing [4]. Results clearly show that whenever the roller roll over the defect point acoustic emission is released and acoustic emission signal is periodic impact characteristics. and validation analysis of fault diagnosis of ball bearing related to rotor system was Studied by Tarle et al.[6]. They concluded that amplitude at BPFO is higher than BPFI and BSF. And is least in BSF. Kulkarni and Wadkar [7] have analyzed the effect of surface roughness on the response of outer race of the ball bearing. They found that at constant speed and constant load with different defect sizes on outer of rolling elements influence on rigid rotor vibrations in unloaded rolling element bearing was performed. They concluded that the BPF linearly increases with the increase of number of rolling elements. With the increase of the internal radial clearance, the value of amplitude increases linearly. The increase gets much bigger as the total number of rolling elements decreases. Chavan et al. [9]. This paper gives the importance of vibration monitoring technique and its implementation in sugar industry and also explains some

Further reading show that intensity of acoustic emission increases with increasing load and speed. Experimentation ring, amplitudes of vibration vary with increase in the defect size.Tomovic et al. [8] studied the vibration response of rigid rotor in unloaded rolling element bearing. By the application of the defined modal, the parametric analysis of the effect of internal radial clearance value and number

case studies of sugar industry related to bearing vibration problems. The case studies shows that whenever looseness is present in the bearing assembly then predominant peak is occurred at 2*RPM of machine. Result shows the whenever bearing fault occurs, there is increase in vibration to higher level. Based on above literature review the objective of the paper is to study experimentally the vibration response of faulty bearing with square hole with different depth of cut on ball and its comparison with healthy bearing.

II. EXPERIMENTATION

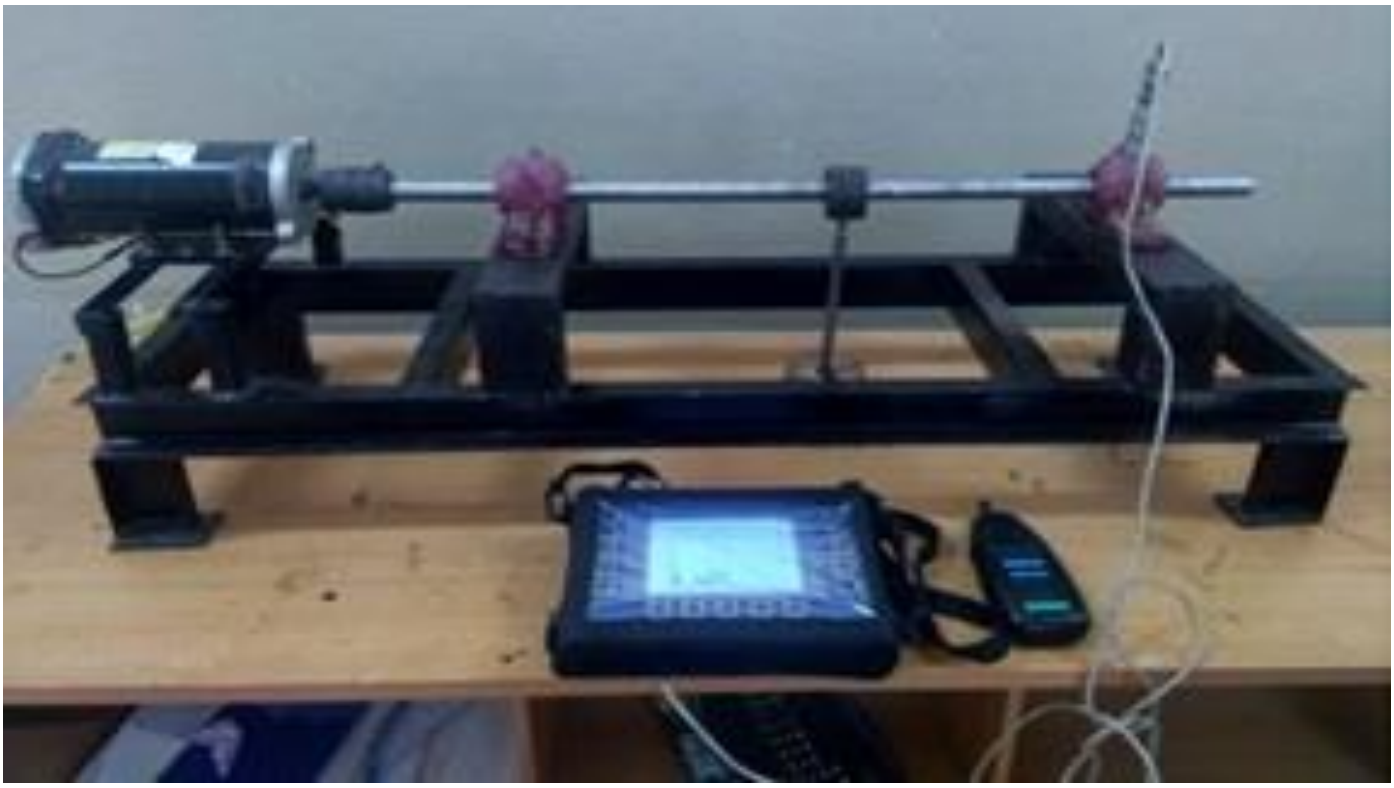

Fig.1 Experimental set up

The experimental set up shown in Fig. 1 is designed and fabricated to investigate the vibration characteristics of ball bearings. Experimental set up has electrical motor which vary speed from 0 rpm to 2000rpm.Motor is connected to shaft through coupling. Test specimen of healthy bearing and faulty bearing is fitted on the non-driving end of shaft. The fault on the ball i.e. rolling element of self-aligned bearing is created by electric discharge machining (EDM).Square hole of different depth i.e.1mm, 1.5mm, 2mm and 2.5mm is produced. When bearing is mounted in sleeve a clearance of 0.04mm is maintained by feeler gauge between ball and outer race. Whole set up is placed on rubber cushion to reduce vibrations. Experiments on healthy and faulty bearing is carried out under different speeds and single load. Load is acted on shaft at the middle. Vibration analysis is investigated through FFT analyser and accelerometer mounted in vertical position. Parameters chosen for experimentation is shown in Table 1 and Specification of used Self aligned 1206K bearing is given in Table 2.

Table 1 Parameters for experimentation

Depth of cut on ball	**Spacing between ball and outer race**	**Speed of shaft in rpm**
Nil i.e. healthy bearing	Nil	500,700,900,1100
1mm	0.04mm	500,700,900,1100
1.5mm	0.04mm	500,700,900,1100
2mm	0.04mm	500,700,900,1100
2.5mm	0.04mm	500,700,900,1100

Table 2 Properties of Self aligning ball bearing 1206K.

Bearing number	1206k
Size in mm	30x62x16
Bore Diameter in mm	30
Outer Diameter in mm	62
Width in mm	16
Number of balls	28
Ball Diameter in mm	7.94

III. RESULT AND DISCUSSIONS

A. Frequency response of healthy bearing

Fig.2 and Fig.3 shows frequency spectrum of healthy bearing for 700rpm and 900rpm respectively. In these figures peak amplitude of vibrations are 1.12mm/s and 1.28mm/s .

In Fig.2 harmonics of vibrations are observed and are present at shaft frequency (N) of 6*N to 8*N .Similarly in Fig.3 it is at 2*N, 4*N and 7*N. They are small in magnitude and may be due to unbalances present in the system.

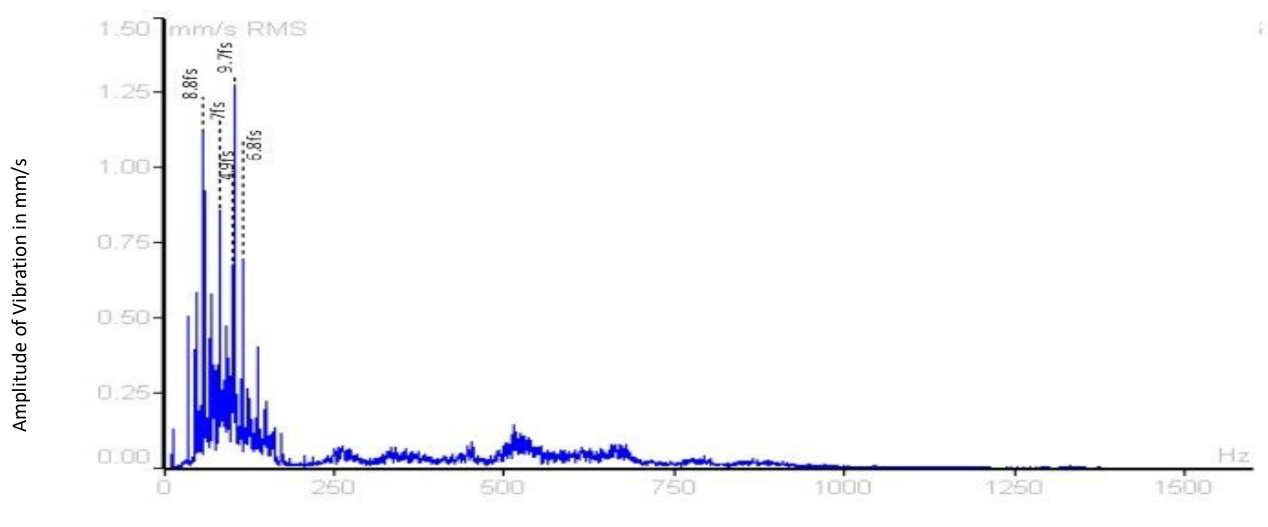

Fig.2 Frequency spectrum for healthy bearing at 700rpm

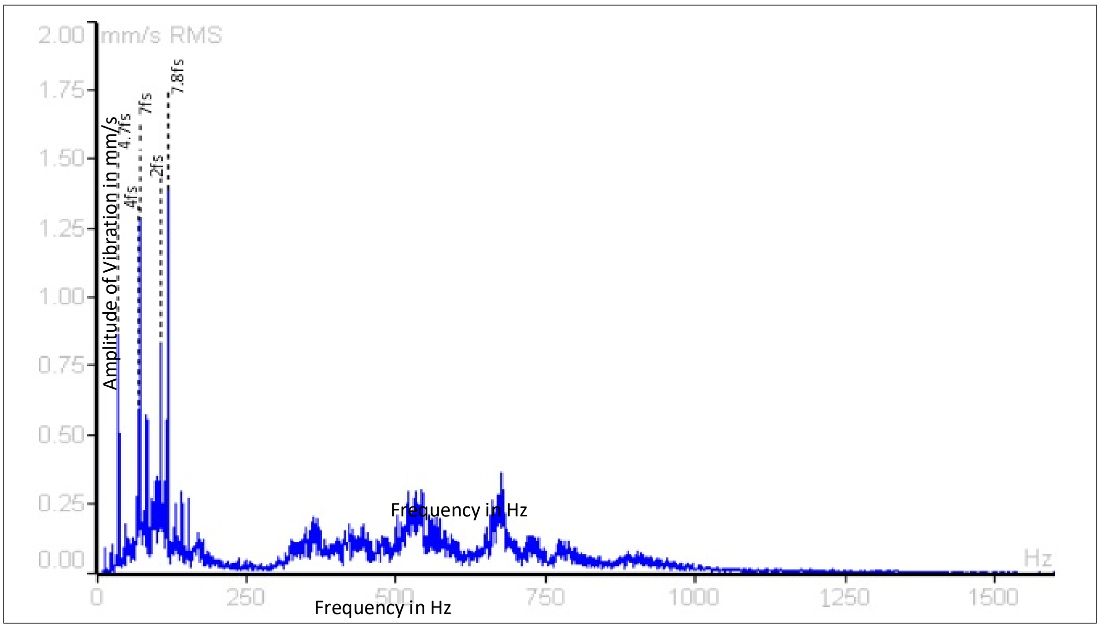

Fig.3 Frequency spectrum for healthy bearing at 900rpm

B. Frequency response of faulty bearing with 1mm depth and 0.04mm clearance

Frequency spectra for this case under speed of 700rpm and 900rpm is shown in Fig.4 and Fig.5. Vibration amplitudes are increasing with shaft speed. It is 1.25mm/s at 700 rpm,4.31mm/s at 900rpm .At shaft speed(fs) at 700 rpm (11.67Hz) and all defect frequency(fbd) 33.8Hz amplitude of vibration is 0.082mm/s. Frequency spectra associated with harmonic peaks is as fs+1.03fbd, fs+1.37fbd, fs+1.72fbd and fs+2.76fbd at shaft speed of 700rpm. Likewise harmonics are associated with other shaft speed is shown in Fig.5.

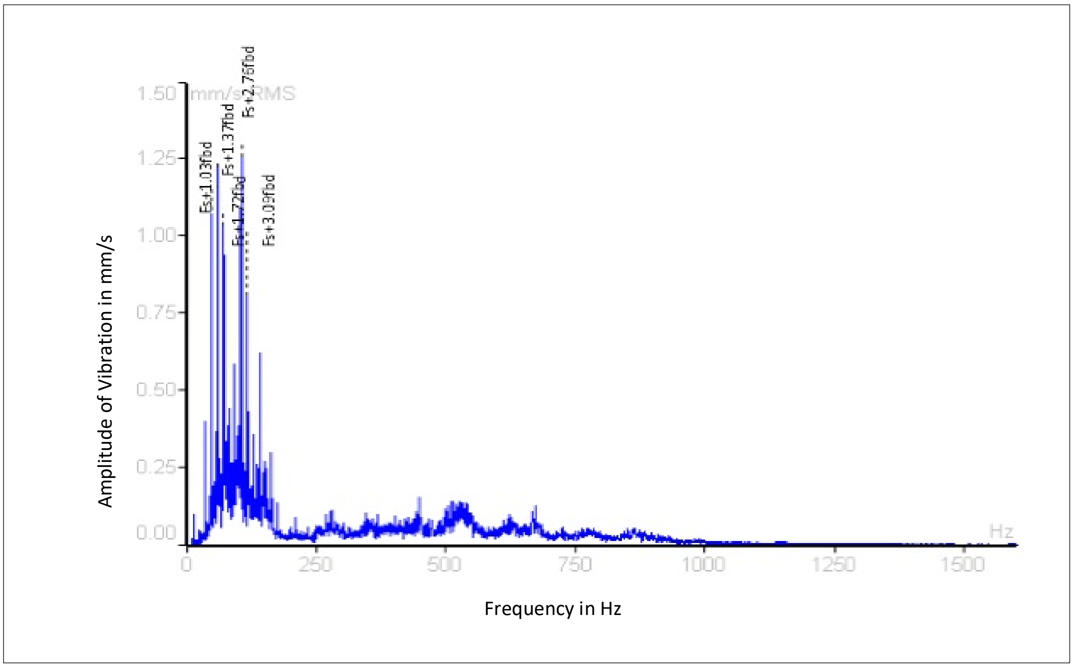

Fig.4 Frequency spectrum for faulty bearing at 700rpm

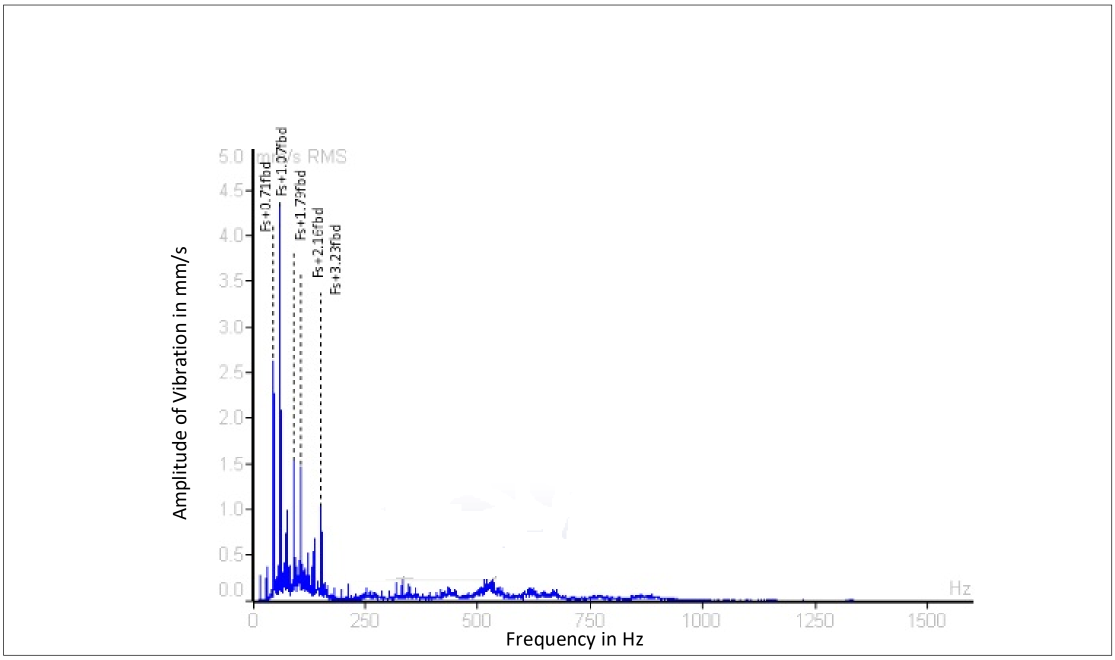

Fig.5 Frequency spectrum for faulty bearing at 900rpm

C. Frequency response of faulty bearing with 1.5mm depth and 0.04mm clearance

FFT spectra for faulty bearing with depth 1.5mm and 0.04mm clearance are shown in Fig.6 to Fig.7.Here also vibration harmonics with side band are observed. At 900rpm i.e.15Hz ,ball defect frequency is 42.15Hz at which amplitude of vibration is 0.340mm/s. Harmonics obtained are fs+0.75fbd,fs+1.12fbd,fs+2.23fbd and fs+2.59fbd at 900rpm.Magnitude of vibration level is higher than healthy and faulty with 1mm depth.

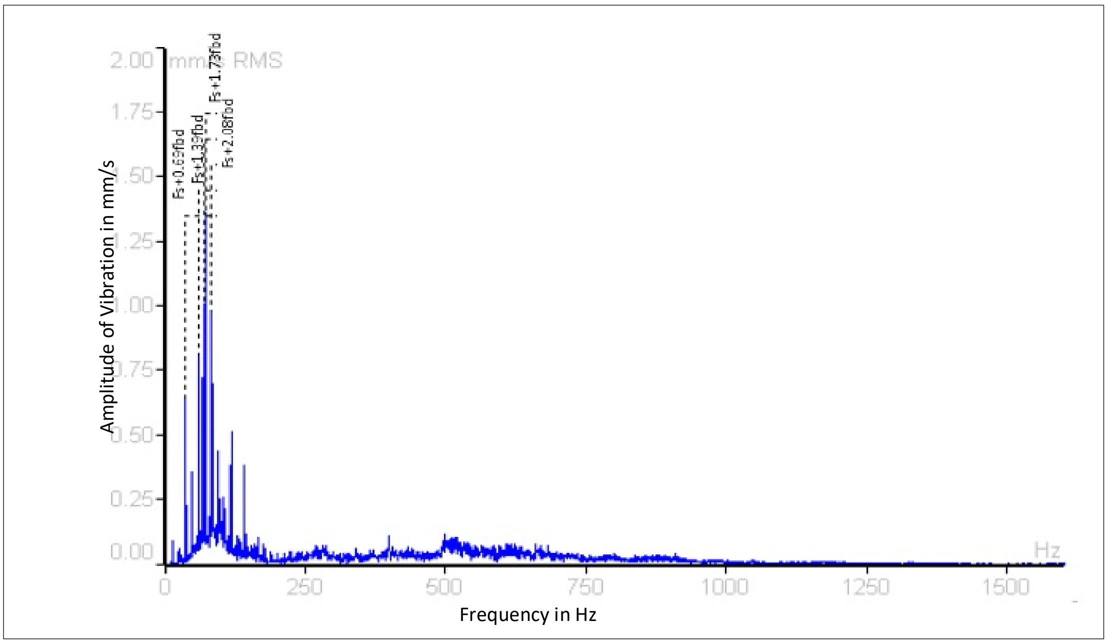

Fig.6 Frequency spectrum for faulty bearing at 700rpm

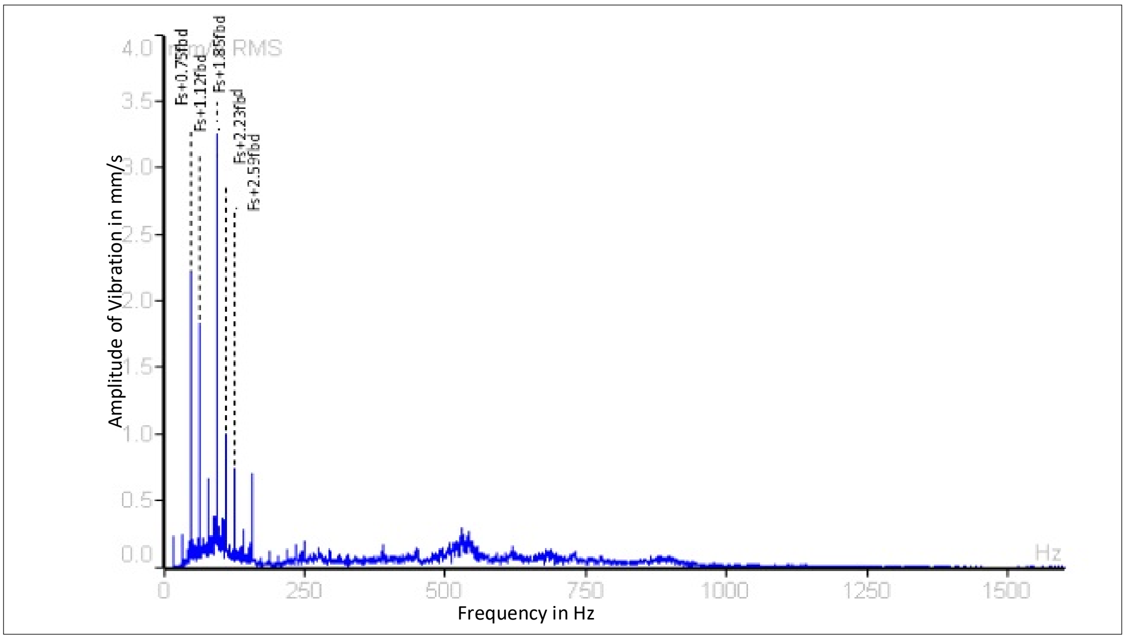

Fig.7 Frequency spectrum for faulty bearing at 900rpm

D. Frequency response of faulty bearing with 2mm depth and 0.04mm clearance

Amplitude of vibration versus frequency is shown in Fig.8 and Fig.9.Ball defect frequency for shaft speed 700rpm(11.67Hz) is 33.8Hz.At this frequency amplitude of vibration noted is 0.07mm/vibration harmonic observed is fs+1.06fbd, fs+1.41fbd, fs+1.67fbd, fs+2.11fbd and fs+2.36fbd at 700rpm.Similarly vibration modulation is shown in Fig.9

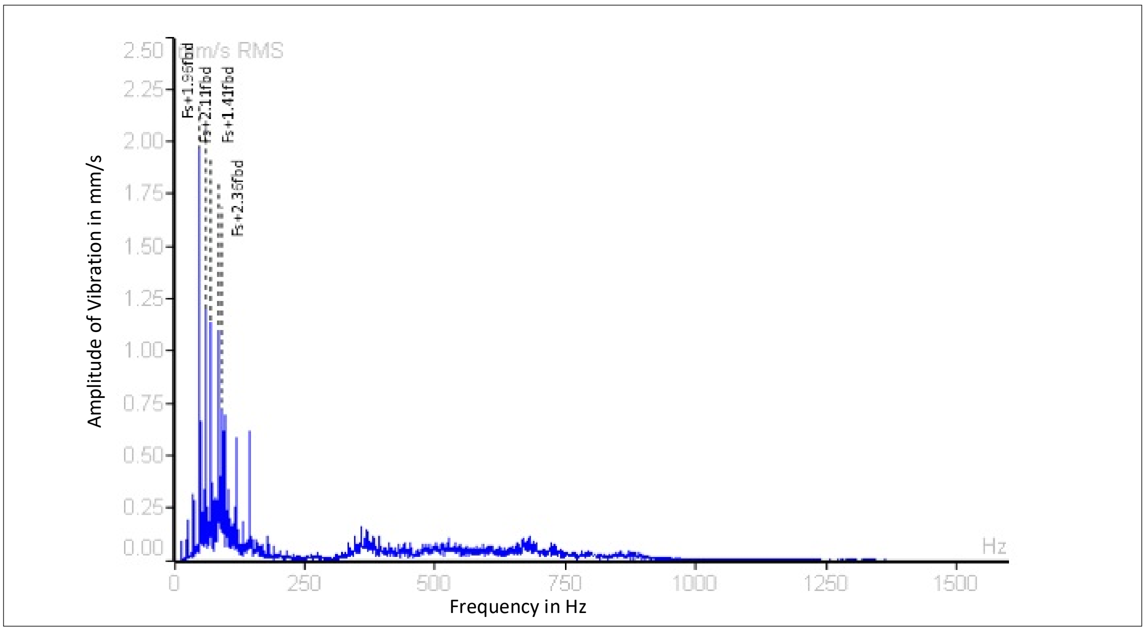

Fig.8 Frequency spectrum for faulty bearing at 700rpm

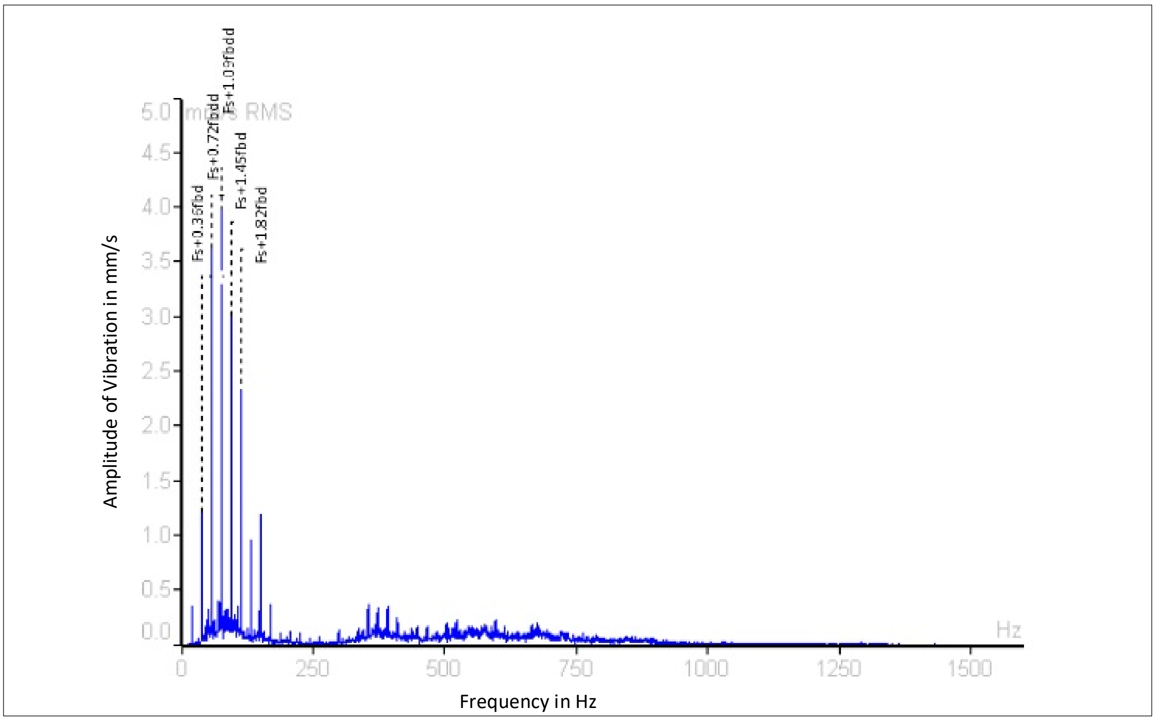

Fig.9 Frequency spectrum for faulty bearing at 1100rpm

E. Frequency response of faulty bearing with 2.5mm depth and 0.04mm clearance

FFT spectra is shown in Fig.10 and Fig.11.Consider for speed of 1100rpm or 18.34Hz shaft frequency at which ball defect frequency is 51.53Hz.At this fbd ,amplitude of vibration is 0.05mm/s. Frequency harmonics at this speed is fs+0.72fbd, fs+1.08fbd, fs+1.44fbd, fs+1.8fbd and fs+2.17fbd.. But with speed magnitude of vibration increases.

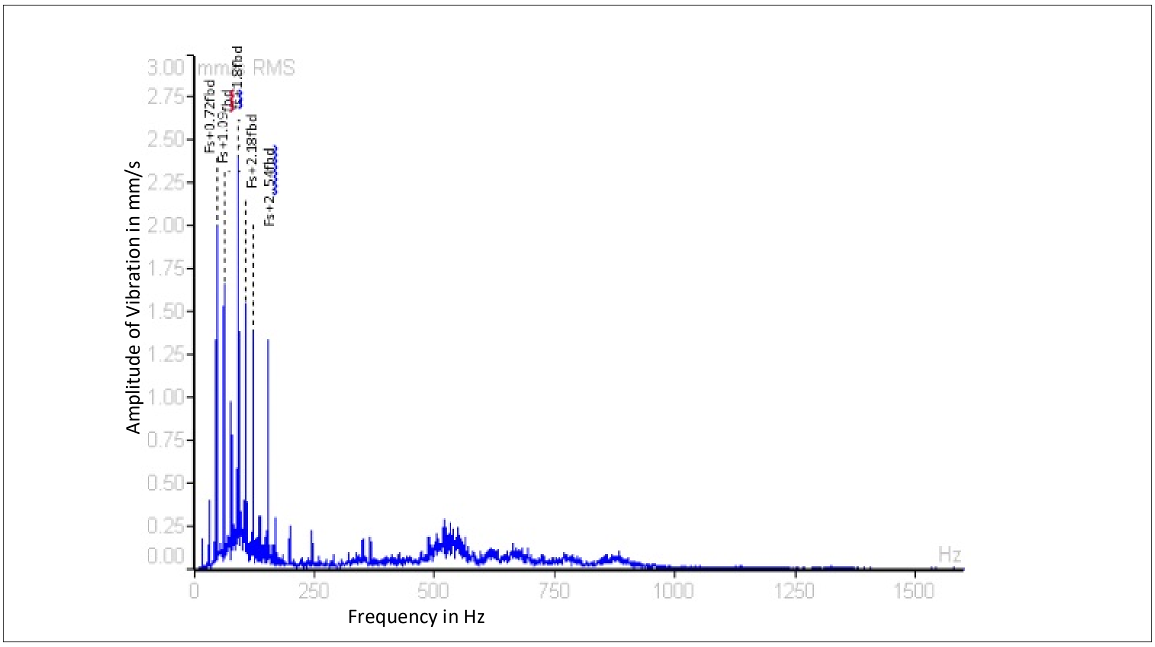

Fig.10 Frequency spectrum for faulty bearing at 900rpm

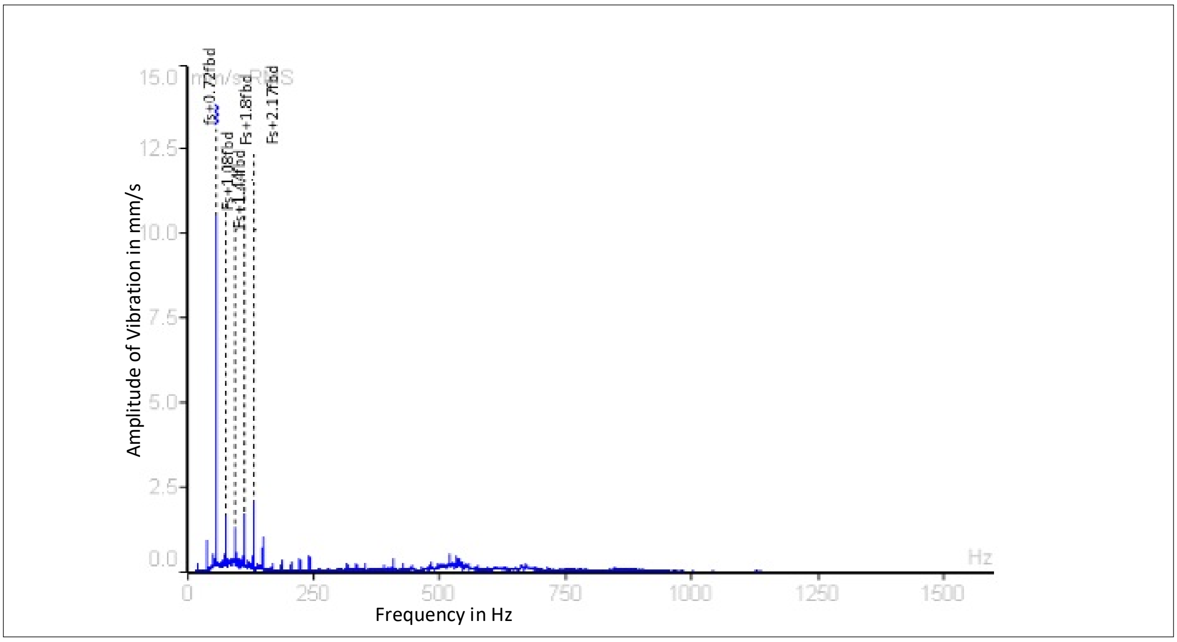

Fig.11 Frequency spectrum for faulty bearing at 1100rpm

IV. COMPARISON OF AMPLITUDE OF VIBRATION WITH SPEED FOR HEALTHY AND FAULTY BEARINGS

In Fig.12 and Fig.13 peak amplitude of vibration of healthy bearing and various faulty bearings are compared at different speeds. It can be observed that vibration level for healthy bearing is least and whatever magnitude seen is due to unbalances in the system. In all cases amplitude of vibrations increases with speed. Also with increase in depth of cut in ball causes vibrations to rise and different harmonics can be seen at different ball defect frequency.

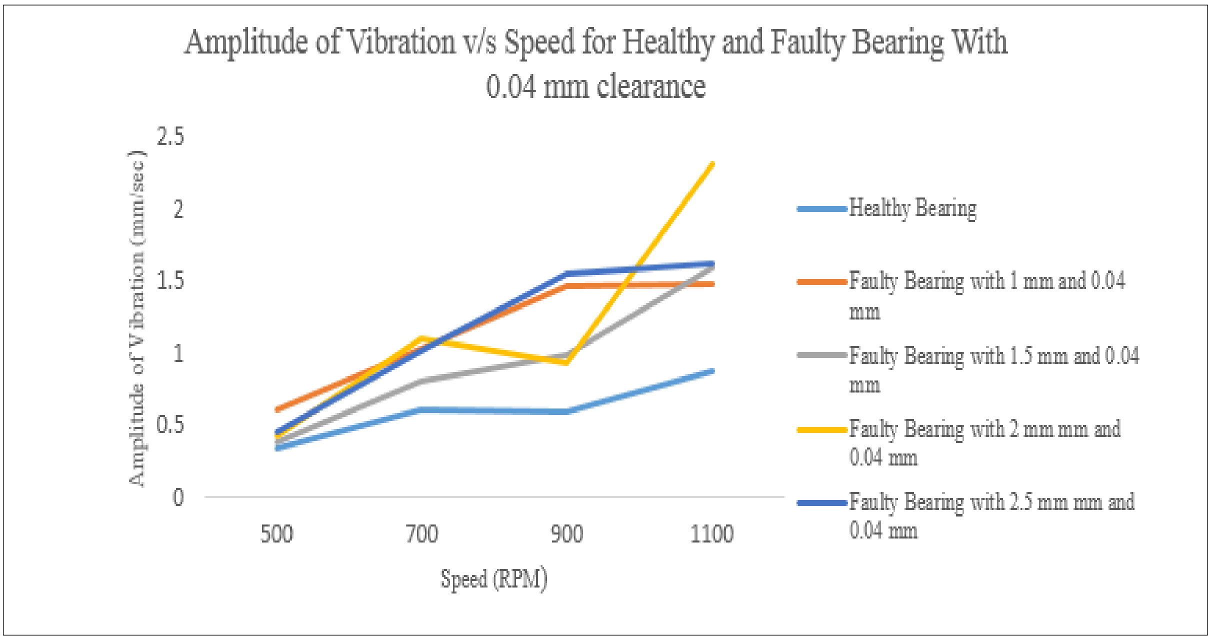

Fig.12 Amplitude of vibration Vs Speed

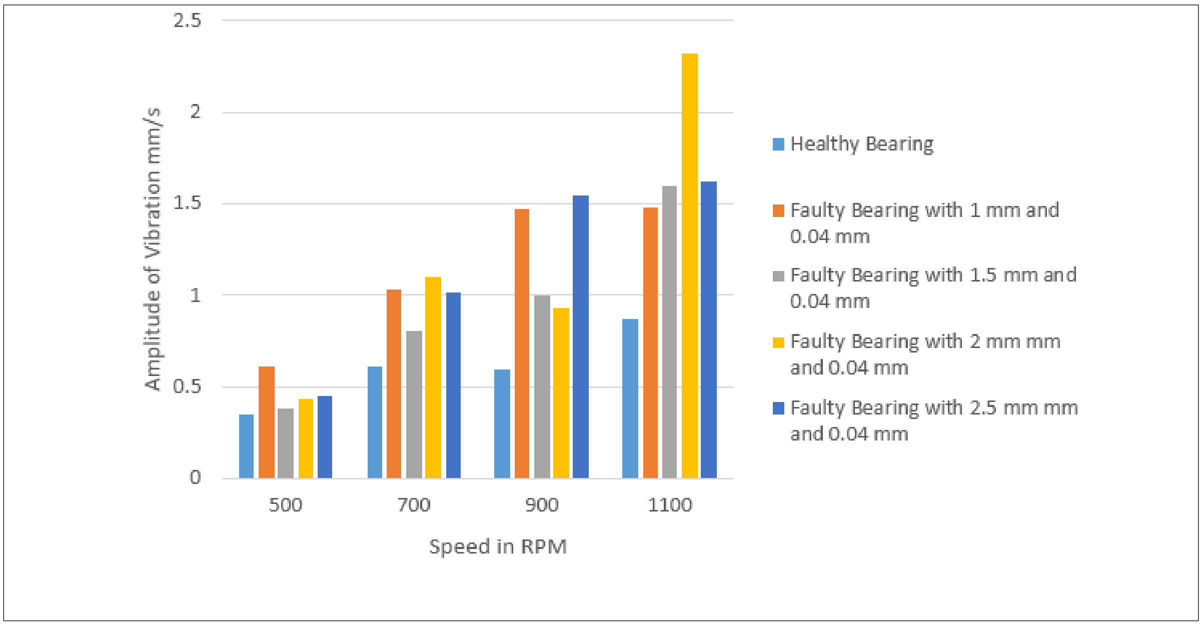

Fig.13 Variation of Amplitude of vibration with Speed

V. CONCLUSIONS

In this paper experimental vibrational analysis is done for healthy and faulty self-aligned ball bearing with clearance of 0.04mm between ball and outer race. Following conclusions are drawn-

- In healthy ball bearing amplitude of vibrations noted by FFT analyser are small in magnitude. It also accompanied by harmonics in terms of shaft frequency.
- Self-aligned faulty bearing with 1mm and 0.04 clearance is used there is rise in magnitude of peak vibrations as compared to healthy bearing. Also harmonics of vibration noted at ball spin or ball defect frequency.
- For depth of cut of 1.5mm, 2mm and 2.5mm on ball induced more vibration level as depth of cut increase.
- Ball bearing with depth of cut 2.5mm has highest amplitude of vibration at all speeds. Healthy bearing has least vibration.

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