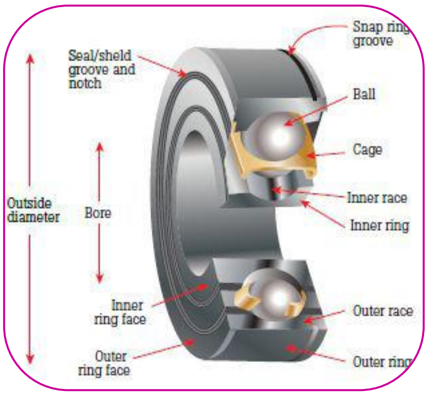
REVIEW OF RESEARCH
ISSN: 2249-894X
IMPACT FACTOR : 5.2331(UIF)
VOLUME - 7 | ISSUE - 4 | JANUARY - 2018

VIBRATION SIGNAL ANALYSIS AND FINITE ELEMENT ANALYSIS OF FAULTS IN ROLLER BEARING

Mr. Jagdale Vaibhav D.[1], Prof. P. H. Jain[2] and Prof. A. B. Ghalke[3]
Dept. of Mechanical Engg, College of Engineering, Osmanabad, Maharashtra, India.



ABSTRACT—
Rolling element bearings are one of the most widely used elements in machines and their failure one of the most frequent reasons for machine breakdown. Roller bearing failure is a major factor in failure of rotating machinery. When the defect arises in bearing there is possibility to shut down the machine. So it is necessary to find out the defects in bearing before they failure. The defect occurs on inner race, outer race, roller, casing here we consider defects on outer race. In this work we change the size of defects on outer race of bearing. We obtained the signal of vibration by changing Radial load and RPM. The FFT analyzer is used to get vibration signals. Here we validate the result of experimentation with results of finite element analysis by using ansys software. Here we compare the healthy and defective bearing and Results are plotted. It shows that there is continuously increase in amplitude of acceleration with increasing in RPM.

KEYWORDS— Defect on Outer race. BPFO, Load zone, Vibration signal analysis, Finite element Analysis, ANSYS

I.INRODUCTION

A cylindrical roller bearing N206 is used in different machinery. It is mainly used in precision machinery and auto accessories. In roller bearing have line contact between roller and outer race having very high radial load carrying capacity. Different vibration measurement techniques, signal processing technique are useful for condition monitoring of defective Cylindrical bearing system such as Time Domain Technique, Frequency Domain Technique. The comparative study of the good and defective bearing is necessary in condition monitoring of the bearing. By using this we can find out the probable life of bearing.

Amit R. Bhende, Dr. G. K. Awari and Dr. S.P. Untawale [1] in his paper they discuss the dynamic performance of bearing is highly influential on performance of any machine. The presence of bearing defects often results in reduced efficiency, or even severe damage of the machine under consideration. Rolling element bearing find widespread domestic and industrial application. Different methods are used for detection and diagnosis of the bearing defects. Shyam Patidar, Pradeep Kumar Soni [2] in his paper they discuss the vibration monitoring and analysis is useful tool in the field of predictive maintenance. Zhang Yongqi,Tan, Qingchangn, Zhang Kuo Li Jiangang [3] in his paper they discuss Taper roller bearings are important part of gear reducers, and their work property affects behavior of the reducers. TANG Zhaopinga, SUN Jianping [4] prepared A 3-D model of deep groove ball bearing was built by using APDL language embedded in the finite element software ANSYS. M. Kotb Ali, M. F. H. Youssef, M. A. Hamaad and Alaa A. El-Butch [5] in this paper they discuss that due to the progress made in engineering and science of materials, rotating machines are becoming faster and lightweight. They're also required to run at different loading and speed conditions. Detection, location and analysis of faults in such machines play a vital role in the quest for high reliable operations. In the present work the effect of working under different speeds at two loading conditions will be studied. For this reason, intentional faults have been introduced to a dynamometer testing machine, and the corresponding fast Fourier transform (FFT) spectrum has been recorded for each case study. Results have shown that the vibration amplitude affected by changing both load and/or speed, therefore, it is important to fix the measuring positions as well as speed and load as much as possible to implement a good maintenance vibration monitoring program.

Arnaz S. Malhi [6] discuss rolling element bearings are important to nearly all forms of machinery fault diagnosis for rolling element bearings has been done using vibration analysis by identifying the fault frequencies in the spectrum. This work has been done to complement the bearing fault diagnosis process. Xu Li-xin , Yang Yu-hu , Li Yong-gang, Li Chong-ning, Wang Shi-yu [7] in this paper A general methodology for dynamic modeling and analysis of planar multibody systems containing deep groove ball bearing with clearance is presented.Robert B.Randall , Jerome Antoni [8] in this paper they intended to guide the reader in the diagnostic analysis of acceleration signals from rolling element bearings. Yi Guo, Robert G. Parker [9] in his paper they discuss the Current theoretical bearing models differ in their stiffness estimates because of different model assumptions. In this work, a finite element/contact mechanics model is developed for rolling element bearings with the focus of obtaining accurate bearing stiffness for a wide range of bearing types and parameters. To solve for the contact mechanics between the rolling elements and races a combined surface integral and finite element method is used. Vatroslav Grubisic, Nenad Vulic, Samue [10] in his paper the aim is to present the state-of-the-art methodology for structural durability evaluation of marine Diesel engines bearing girders and to explain the responsibility of engine designers, manufacturers and system suppliers. Zeki Kıral, HiraKaraglle [11] in his paper they discuss the a method based on the finite element vibration analysis is presented for defect detection in rolling element bearings with single or multiple defects on different components of the bearing structure using the time and frequency domain parameters. Mr. Deshpande Hrishikesh S. Prof. S. S. Kulkarni[12] in his paper discuss that the Statistical method is most suitable for random signals which are collected from bearings. From the Stastical and Harmonic analysis of experimental result carried out in his work.

From the above literature survey it is found that number of researcher work on different types of bearing. So it is need to work on N type cylindrical roller bearing. Number of researcher used the ansys software for finite element analysis. The time domain and frequency domain technique is used for vibration signal analysis.

We develop mathematical model of bearing with simply supported arrangement for loading on test bearing. To measure the amplitudes of vibration of test bearing we use ansys software. We find out the amplitudes of vibration of test bearings experimentally with different speed range with the different defect size ranging from at the outer race of roller bearing the method used this work are Experimental and FEA.

DYNAMIC ANALYSIS USING ANSYS SOFTWARE

The finite element method is used to solve field problems in engineering and science. In this work consists of modeling and meshing of test bearing in catia and solution is get for number of defect sizes and at different speeds using LS-DYNA solver. During FEA analysis following processes carried out to reduce the number of element and nodes in FEA analysis author used cyclic symmetry for bearing analysis and focused his work on load zone

Bearing for study: Cylindrical roller bearing (N 206)
Calculation of Load Zone For selected Bearing.[12]
To calculate load zone we have following formula
$\Phi = \cos^{-1}(Pd / 2\, \delta r)$
Φ = Load Zone Angle

Pd =Diametral Clearance

δr = Ring Radial shift

$\Phi = \cos^{-1}(32.56 \times 10^{-6}) / (2 \times 3.292 \times 10^{-5})$

$\Phi = 60^0$

Therefore Considering load zone Angle=60^0

2.1 Model generation

The model is prepared in CATIA V5 R20.Part drawing of inner race outer race and cylindrical roller are made separately then all three parts are called in bearing assembly product. Model without defect and with defect is shown in Fig.1 and 2 respectively.

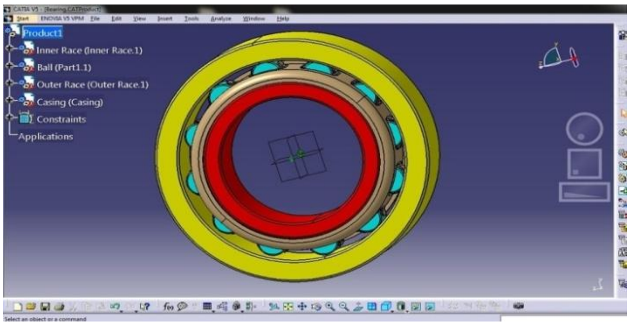


Fig.1 Model of Healthy bearing Catia

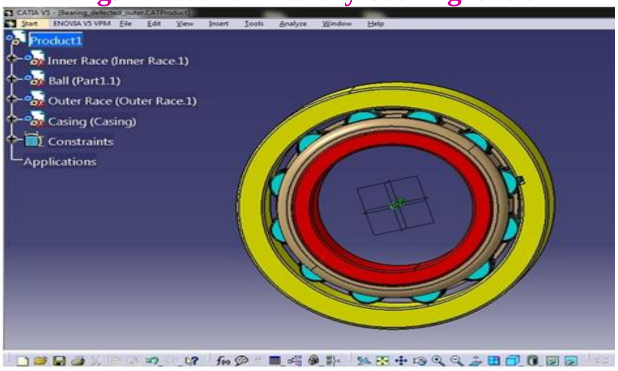
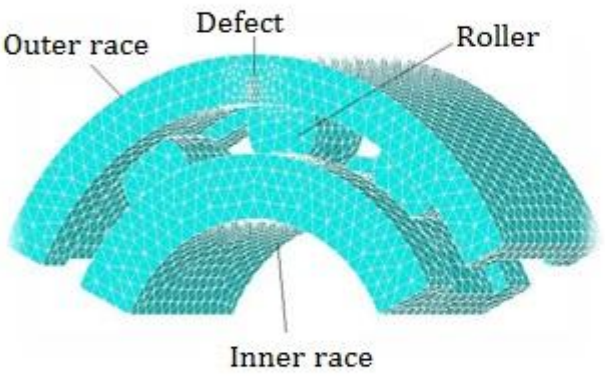


Fig.2 Model of defective bearing in Catia

The parameters considered in ansys software are outer race, inner race, casing, outer race diameter, thickness, depth of defect. The meshed model is created. The bearing material properties are considered. The important consideration during meshing was to ensure that the volume in the neighbourhood of the defect was suitably meshed and that a volume in the defect neighbourhood be identified that would be most finely meshed. Now the free mesh was used for the volume which contained the defect in bearing and meshing can be used for any kind of setting all these initial controls for the mesh. For the outer volumes the element size decided was 0.5mm, 1 mm, 1.5mm as a coarser mesh could be used the following Fig.3 shows meshed model of defective bearing. The three element types had been defined for the analysis is Shell 163. Because it is a transient analysis and study of vibration response of the bearing we selected the LS-DYNA Explicit mode of ansys and the after meshing total number of element 3224 and total number of nodes are 3222.



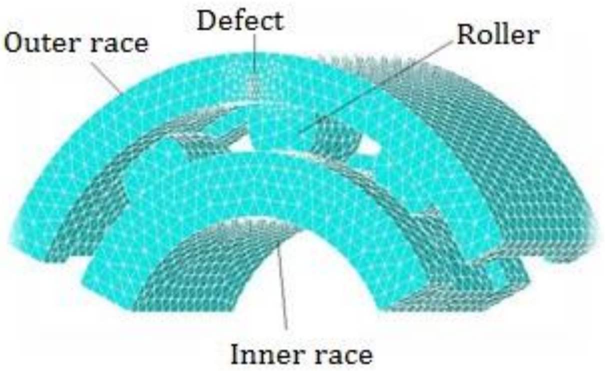


Fig3.Meshed Model

Three individual components are created for the contact pair Inner race, Outer race and Cylinder Taking separately the raceway's groove surface of inner and outer Race as target surface, considering corresponding half sphere surfaces of balls as target surface, two contact pairs can be built. There is important to make sure that the contact is rigid-flexible contact between rolling element and inner or outer race, to choose CONTA170 as contact element type it has 8 nodes and quadrilateral include middle node and to choose TARGE174 as target element type which has 3 nodes without middle-node, to set 0.1as normal penalty stiffness (FKN) value of every contact pair (if the value is excessive, it will cause some problems which contact analysis doesn't convergent), to set 0.01 as initial contact closure(ICONT) value and 0.003 as friction factor value.

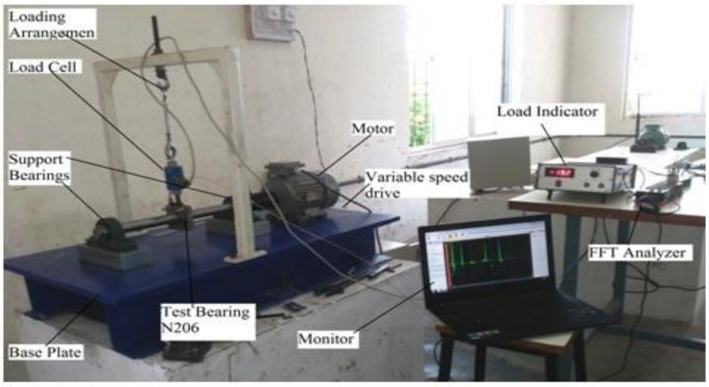
Appling boundary conditions and loads, which restrained the all degrees of freedom (DOF) of bearing outré surface of outer race, fixed the displacement of the axial direction（UZ in Cartesian coordinate system and circle direction(UY in cylindrical coordinate system) of groove surface and bore surface of outer ring, groove surface and cylinder surface of inner ring, Cylinder and cage's nodes in pitch diameter of ball set, added constraint of the axial direction and radial direction(UX in cylindrical coordinate system),The displacement of Cylinders in (UY in Cartesian coordinate system) is restrained and applied radial loads to the lower part's nodes of bore surface in inner race of 10Kg.

This analysis is belong LS-DYNA Explicit mode of ANSYS, little-displacement, little-sliding. Time step must be set enough small so as to capture appropriate signals, because if it is too big then analysis time increases tremendously, so time step i.e. up to 0.5sec is selected for analysis.

III.EXPERIMENTAL SETUP

The actual bearing experiment is performed to validate the model used in simulation study as shown in fig.4 it consists of a D.C motor, chain coupling, cylindrical bearings and two healthy supported bearing with pedestal. The rotor shaft has a length of 4.5m with a bearing span of 3.8m.The almost care is taken to avoid angular misalignment of shaft and bearing. The rotor shaft driven by 0.75 HP d.c. motor. The d.c./a.c.

voltage controller is used to vary the voltage and to adjust motor power supply and due to this, the motor speed can be continuously increased or decreased in the range of 0 to 1800 rpm. The defect to the outer race of a bearing is produced by Wire Cut EDM (Electro Discharge Machining). It consists of a through circular hole of 0.8 mm diameter to the outer race of a bearing.



Experimental Set up

The developed experimental set up is as shown in Fig-4.It is placed on C-channel frame of size length 48m and width 99m with height of 15. The mass of set up is1.5tonne and special care is taken while design and fabrication to reduce the shocks and vibrations produced due to electric motor and rotating components. It consists of 2.23kw/5000 rpm three-phase induction motor and output shaft which is placed on concrete basement. The vertical arrangement was created to apply radial load on the test bearing. The support bearings (6206) are good bearings and the test bearings (N206) are good as well as bad. The artificial defect was induced on outer race of cylindrical bearing by using wire cut. A defect size of 0.5mm to1.5mm width with depth of 1mm created on outer race cylindrical bearings. The acceleration sensor used is of piezoelectric type and used to sense the vibrations from test bearing having sensitivity 100 mV per m/s2 .The accelerometer is connected to FFT Analyzer having 8 Analog inputs and 2 can bus ports. The data acquired in computer. The shaft with test bearing was operated at different speeds ranging from 0 to1800rpm and with load varies from of 5kg to15kg.

IV.RESULTS AND DISCUSSION

We got the results from experimentally and by using finite element analysis, from the different defect sizes, speed, load and RMS. The results are shown in following cases. H.B=Healthy Bearing, D.B=Defective Bearing

4.1 Analytical results by Using ANSYS.

Using the ansys software we develop the model. The results are shown in following graph. The time domain plot for 1mm width and 1.5mm depth defect size on outer ring is considered. From Time Domain signals for Cases healthy bearing and defective in ANSYS is seen that for Defective bearing (Defect size =0.5mm,1mm,1.5mm) with radial load of 10kg speed from 600 to 1800 rpm the amplitude are considered.

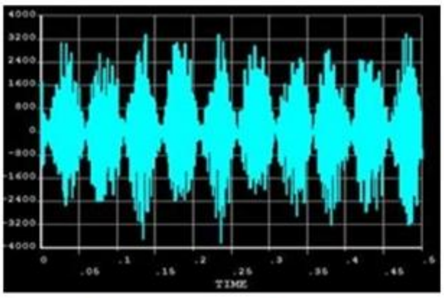


Fig.5 a) H. B. For 600 RPM (Peak Acceleration 2.9m/s^2)

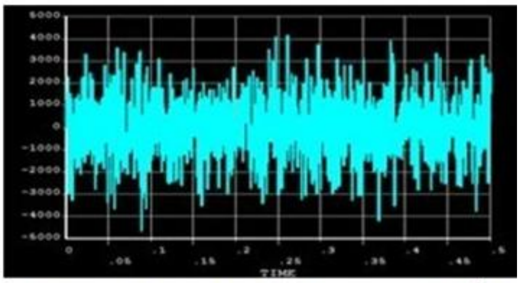


Fig.5 b) D.B. For 600 RPM (Peak Acceleration 3.8m/s^2)

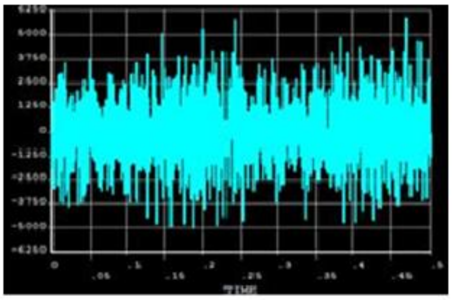


Fig.5 c) H.B. For 900 RPM (Peak Acceleration 4.6m/s^2)

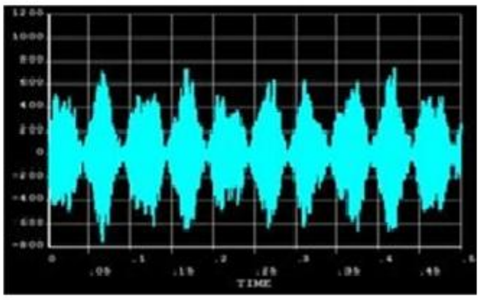


Fig.5 d) D.B. For 900 RPM (Peak Acceleration 5.9m/s^2)

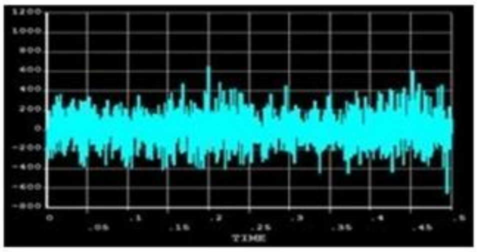


Fig.5 e) H.B. For 1200 RPM (Peak Acceleration 6.8m/s^2)

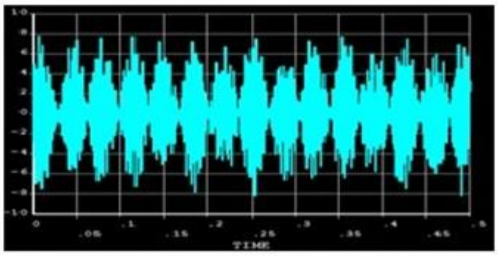


Fig.5 f) D.B. For 1200 RPM (Peak Acceleration 7.5m/s^2)

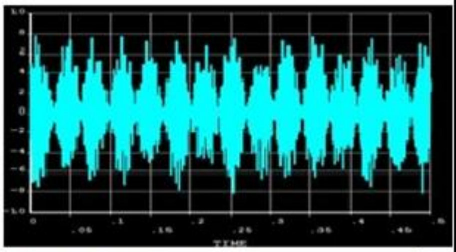


Fig.5g) H.B. For 1500 RPM (Peak Acceleration 6.1m/s^2)

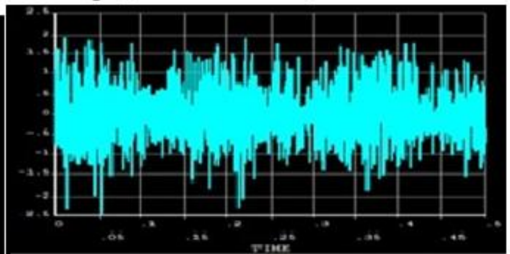


Fig.5h) D.B. For 1500 RPM (Peak Acceleration 7.6m/s^2)

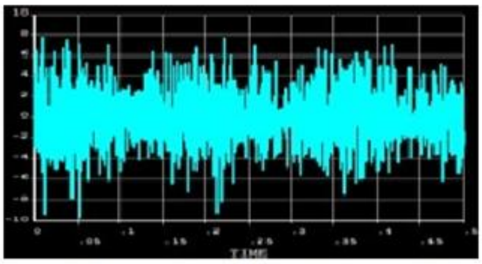


Fig.5i) H .B. For 1800 RPM (Peak Acceleration 6.1m/s^2)

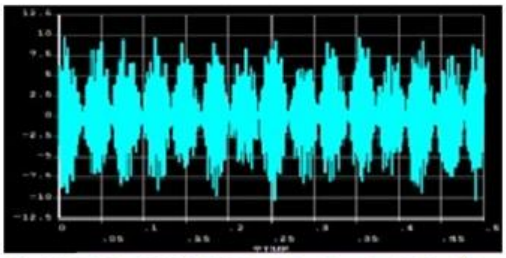


Fig.5j) D.B.For 1800 RPM (Peak Acceleration 10.3m/s^2)

From above Time Domain signals for Cases 5a,5b,5c,5d,5e,5f,5g,5h,5i,5j in ANSYS is seen that for Defective bearing (Defect size 0.5 mm,1mm,1.5mm) with radial load of 10kg and speed from 600 to 1800 rpm the amplitude of displacement increases for each cases as compared with healthy and defective bearing in respective rpm.

4.2 Experimental results.

The Experimental amplitudes of vibrations are measured at different speeds 600rpm to 1800rpm, loads from 5kg to 20kg and for different defect sizes0.5mm, 1mm and 1.5mm on outer race of bearings. The peak amplitudes are obtained at outer race defect frequency. The experimental graph in Time Domain signals for Cases from speed 600 to 1800 are shown in following graph.

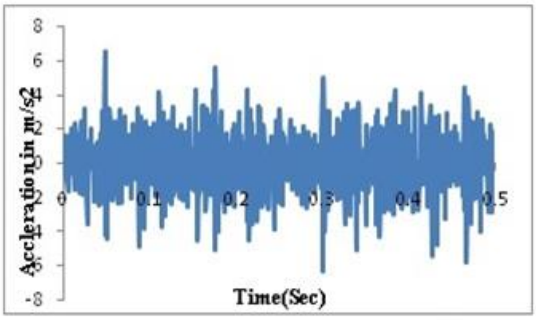


Fig.6a)H .B. For 600 RPM (Peak Acceleration 3.1m/s²)

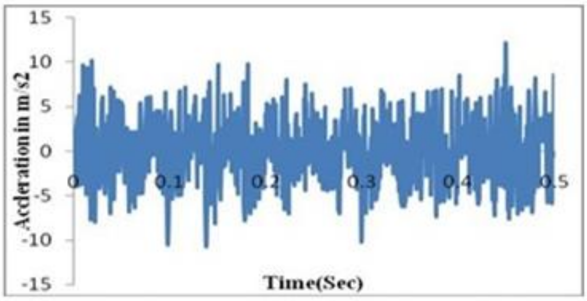


Fig.6b)D.B. For 600 RPM (Peak Acceleration 4.1m/s²)

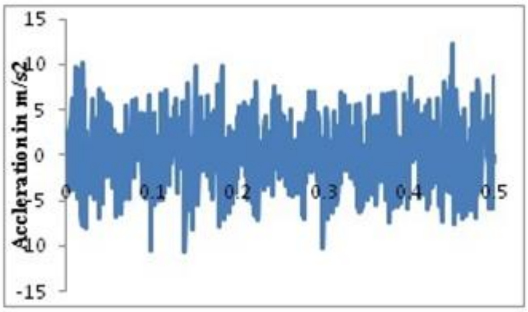


Fig6c) H.B. For 900 RPM (Peak Acceleration 4.8m/s²)

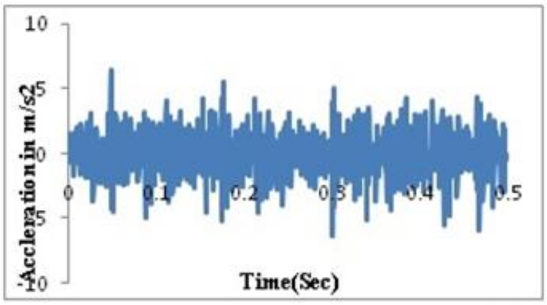


Fig.6d) D.B. For 900 RPM (Peak Acceleration 6.2m/s²)

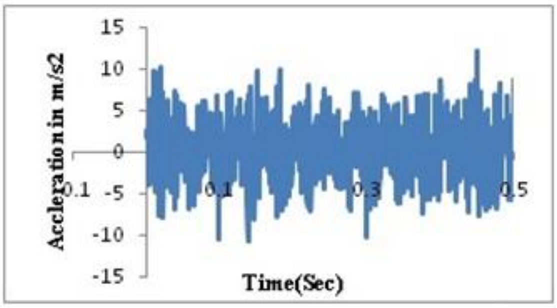


Fig.6e) H.B. For 1200 RPM (Peak Acceleration 7.2m/s²)

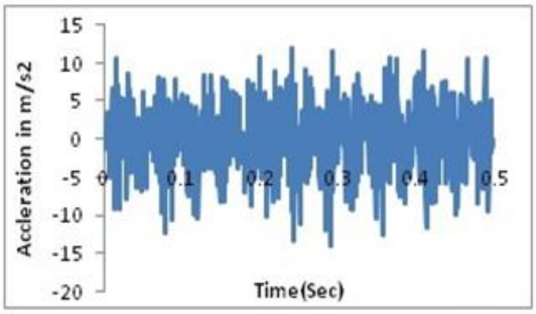


Fig.6f) D.B. For 1200 RPM (Peak Acceleration 7.8m/s²)

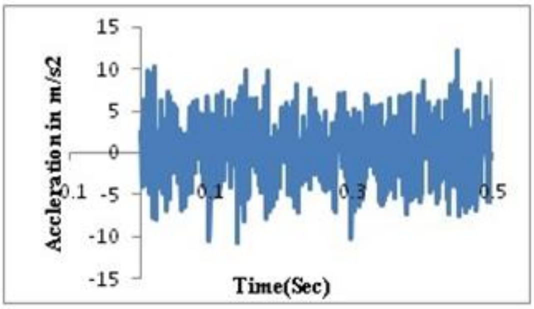


Fig.6g)H.B. For 1500 RPM (Peak Acceleration 6.3m/s^2)

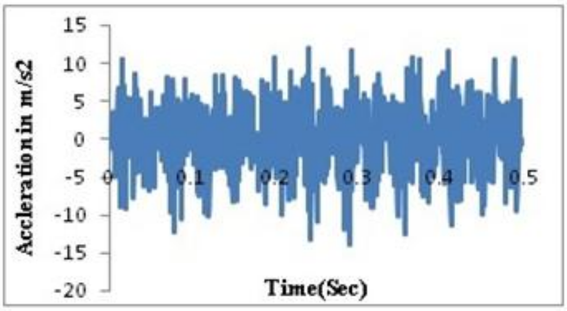


Fig.h)D.B. For 1500 RPM (Peak Acceleration 7.9m/s^2)

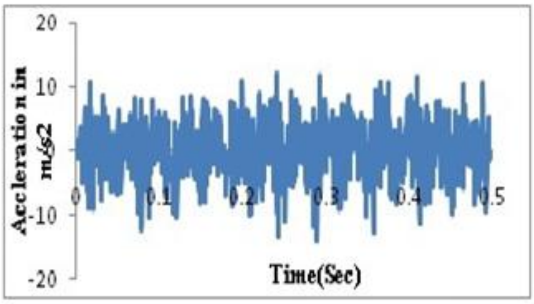


Fig.i)H.B. For 1800 RPM (Peak Acceleration 6.6m/s^2)

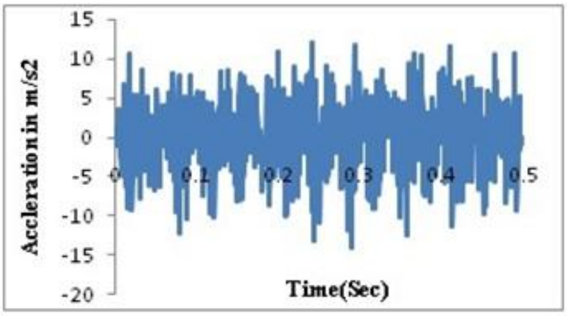
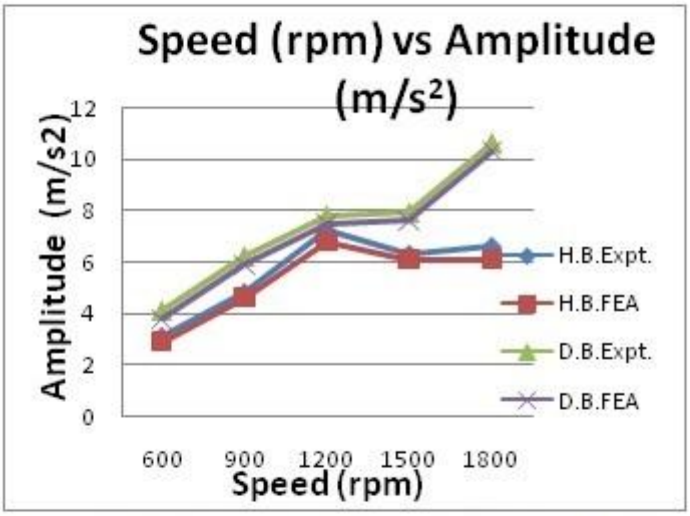


Fig.6j) D.B. For 1800 RPM (Peak Acceleration 10.6m/s^2)

From above Time Domain signals for Cases 6a,6b,6c,6d,6e,6f,6g,5h,6i,6j, in Experimental manner is seen that for Defective bearing (Defect size 0.5mm,1mm,1.5mm) with radial load of 10kg speed from 600 to 1800 rpm the amplitude of displacement increases for each cases as compared with healthy bearing. The comparison of FEA and Experimental results in Time Domain are shown in following table.

Cases	Type of Bearing	Radial Load (Kg)	R.P.M.	Peak Value in FEA(m/s²)	Peak Value in Exp.(m/s²)	Error %
1	Healthy	10	600	2.9	3.1	6.45
2	Defective	10	600	3.8	4.1	7.3
3	Healthy	10	900	4.6	4.8	4.16
4	Defective	10	900	5.9	6.2	4.8
5	Healthy	10	1200	6.8	7.2	5.5
6	Defective	10	1200	7.5	7.8	3.8
7	Healthy	10	1500	6.1	6.3	3.1
8	Defective	10	1500	7.6	7.9	3.7
9	Healthy	10	1800	6.1	6.6	7.5
10	Defective	10	1800	10.3	10.6	2.8

Comparison of FEA and Experimental result in Time Domain



Cmparison Graph of FEA and Experimental Work for Speed Vs Amplitude for H.B. and D.B.in Time Domain

The above graph shows the peak values of acceleration by FEA and Experimental readings. It found a good agreement in for both experimental and FEA approach.

V.CONCLUSION

The Bearing failure is one of the important reasons of interruption of machines. It causes to unscheduled shut down. It also increases the cost of operations. So to find the defects in bearing at earlier stages is necessary for condition monitoring of bearing.

The ability to get accurate bearing diagnostics is essential to the optimal maintenance of rotating machines with respect to cost and productivity.

The Statistical method is most suitable for random signals which are collected from bearings. From the statistical and Harmonic analysis of experimental result carried out in this work, following conclusions are fond out.

1. There was continuously increase of amplitude of acceleration with increasing RPM.
2. As the RPM of the bearing increases the maximum amplitude at the multiple of BPFO is increases.
3. We can easily understand which bearing element is defected by Vibration peaks generate in spectrum at the bearing characteristics frequencies.
4. Using finite element analysis software like ANSYS the different defects in the bearing are analyzed directly without actual deformation in bearing as seen in the vibration signal analysis.
5. Vibration Signal Analysis and Finite Element Analysis co-relates each other and deviation of percentage is less than 8.
6. Vibration analysis using FEA is a powerful tool for defect detection and with this method it is possible to predict the condition of bearing. It has been found that Finite Element modeling can be effectively used to get vibration signatures between healthy and defective bearing.

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Mr. Jagdale Vaibhav D.
Dept. of Mechanical Engg, College of Engineering, Osmanabad, Maharashtra, India.