To analyze the early Detection of Faults in Bearing at Inner and Outer race using Condition Monitoring

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ABSTRACT

Rolling element bearings find widespread domestic and industrial application as it is an important factor in failure of rotating machines and therefore bearings are the one which are exposed the most towards getting damaged and failure. In industrial applications, these bearings are considered as a critical mechanical components and a defect in such a bearing, unless detected in time, causes malfunction and may even lead to catastrophic failure of machinery which results in significant time and economic loss. These types of failures might take place during the manufacturing process and therefore it is important to review the problem and monitor the condition of roller bearings so that the details of failure would occur before any harsh consequences take place. Therefore an early detection and indication is necessary for the safety and reliability of machine. This project focuses on vibration monitoring technique suitable to analyze the defect in bearing. By performing this test, these techniques would reveal information about the progressing faults. From the different maintenance techniques, conditioning monitoring which is one of the techniques is highlighted. It uses the vibration having high frequencies which are generated from faulty bearing, is therefore investigated and compared. Vibration analysis methods are been elaborated and therefore utilised as a medium to fulfil the aim. An experimental set up is used to testify and investigate good bearing and faulty bearing by using different measurements. The vibration signatures caused due to damages at outer race of bearing are examined. The expected results will indicates that faulty bearing has a strong effect on vibration spectrum. This project therefore reveals comparison between frequencies and time domain signals from vibration analysis and it will be validate using suitable software. Overall this project has demonstrated that different techniques are useful in detecting the problems in roller bearings.

KEYWORDS: *Bearing fault diagnosis, outer race, MATLAB, Preventive maintenance*

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1. INTRODUCTION

The vibration analysis technique gives the precise and early information about the failure of bearing. Faults in bearing (inner race, outer race and cage fault) produce the particular defective frequencies which are calculated by using the following equations.

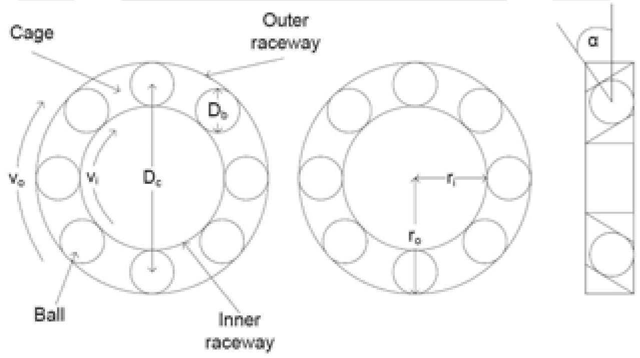

Fig-1: Standard rolling-element bearing

Ball Pass Frequency at inner race of bearing (BPFi)
BPFi=fr*(1+(d/D)*cos(A))*B/2..1

Ball Pass Frequency at inner race of bearing (BPFo)
BPFo=fr*(1-(d/D)*cos(A))*B/2..2

Cage malfunction frequency
FTF=fr/2*(1+(d/D)*cos(A))..3

Ball Spin Frequency
(BSF) =fr*(1-(d^2/D^2)*(cos(A))^2)*d/(D*2).........................4
Where,
fr=N/60=running frequency
n = no of balls
d = roller diameter
D = pitch diameter
A = contact angle
N = revolution/ minute

These equations are based on the good rolling races; nonetheless practically additional sliding motion might cause changes in characteristic frequencies. These frequencies indicate the fault status of the bearing. These may facilitate to find causes of the failure.

1.1 LITERATURE REVIEW

Beebe truly stated that providing the required capacity for production at lower cost is one of the vital purposes of maintenance in any industry. Therefore it should not be considered as repair function but it must be regarded as a reliability function. For any organization which exists, production is one of the major reasons.

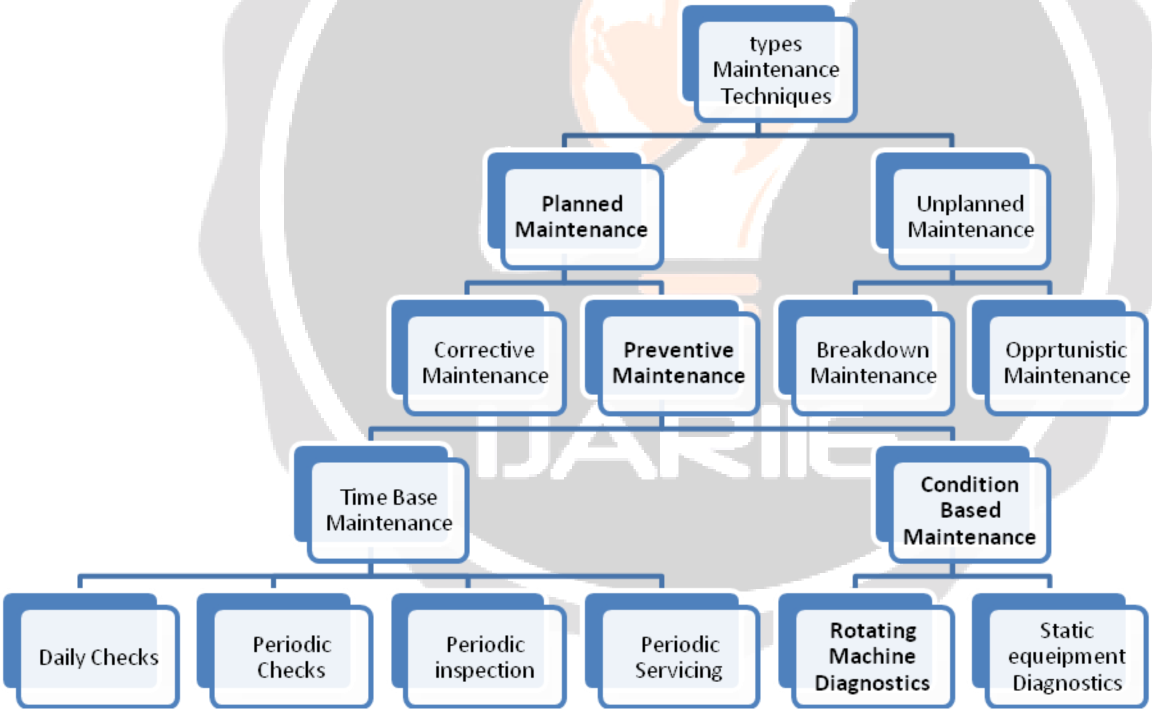

Fig-2: Different types of Maintenance Regimes

McFadden P. and Smith J stated that, Almost all the vibration analysis was done in the time domain before the spectral analyser was available. The time domain analysis is nothing but display or analysis of the vibration data as a function of time. To detect the fault, the time domain method analyzes phase information and amplitude of the vibration time signals.

Syam Patidar and Pradipkumar Soni said that Matlab is a fourth generation programming language and is kind of software programming or it is kind of a system which is usually used for numerical computation. It usually help in lowering down a routine tasks associated with numerical problem solving, which ultimately allows to spend more time in thinking and giving more time to discover the experiment. It's a kind of software which uses loads of procedure and therefore gives an accurate result which we can blindly rely on. It is so easy and functional that even big operations can be carried out using couple of commands. One can build its own set of functions for particular application. Matlab provides excellent graphic facilities and therefore it is widely used in vibration analysis.

2. METHODODLOGY AND EXPERIMENTAL SETUP

The characteristic defect frequencies for inner and outer race at speeds 2880 and 4866 rpm are calculated by using above equations. The bearing details necessary to find defect frequencies are as illustrated in table 1. also the values of different frequencies are as shown in table 2.

Bearing: DFM-85

Table-1: Rolling element details (DFM-85)

Parameters	**Values**
Outer Diameter, mm	84
Inner Diameter, mm	30
Number of Balls	7
Contact angle	0

Table-2: Estimated bearing characteristic defect frequencies.

Shaft Speed	Shaft Rotational Frequency	Defect Frequencies
N_1 = 2880 rpm	$(F_R)_{1=}$ 48.00 Hz	$(FTF)_1$ = 17.12 Hz
		$(BPFi)_1$ = 216.09 Hz
		$(BPFo)_1$ = 119.90 Hz
		$(BSF)_1$ = 153.92 Hz
N_2 = 4866 rpm	$(F_R)_2$=81.10 Hz	$(FTF)_2$ = 28.94 Hz
		$(BPFi)_2$ = 365.13 Hz
		$(BPFo)_2$ = 202.59 Hz
		$(BSF)_2$ = 260.07 Hz

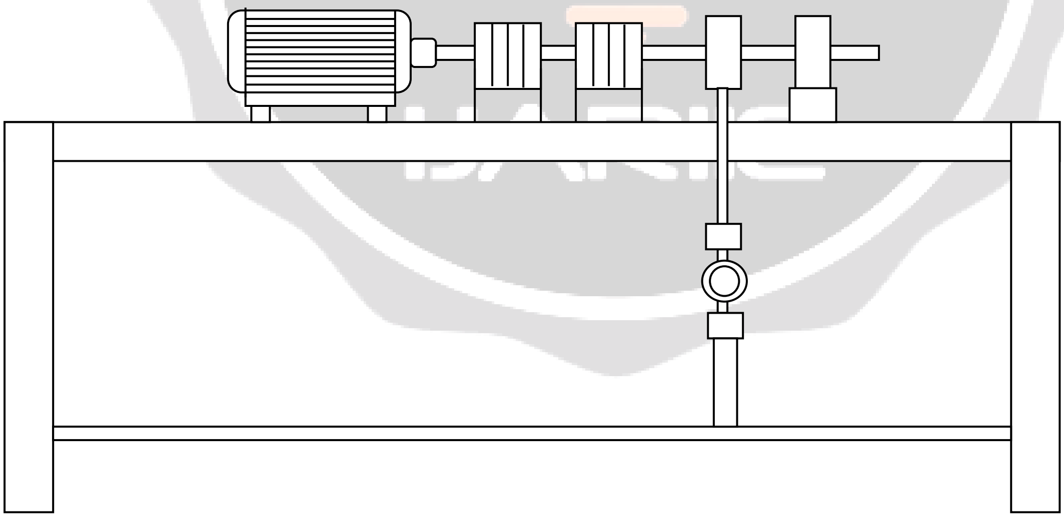

Fig-3: Experimental test rig

A pizo-electric accelerometer is mounted on the housing of the test bearing by using magnetic mount. The accelerometer is connected to charge amplifier, the output of which is connected to a computer. The computer contains relevant hardware and the software to acquire the data, store it and display the time domain and frequency domain signals.

2.2 Test Rig Specifications:

The specifications of the equipments used for the experiment are as follows:

2.3 Induction Motor:

Make	: Crompton Greaves
Power Supply	: 3 – phase A.C. 415 V
Power	: 3 H. P.

3. RESULT AND DISCUSSION

The MATLAB output of same defect shows this defect frequency (BPFo) at 108 Hz, which varies by 1.90 Hz from theoretical and by only 12 Hz from measured one. This output in time domain is shown in fig. 4 and its respective spectrum in fig. 5

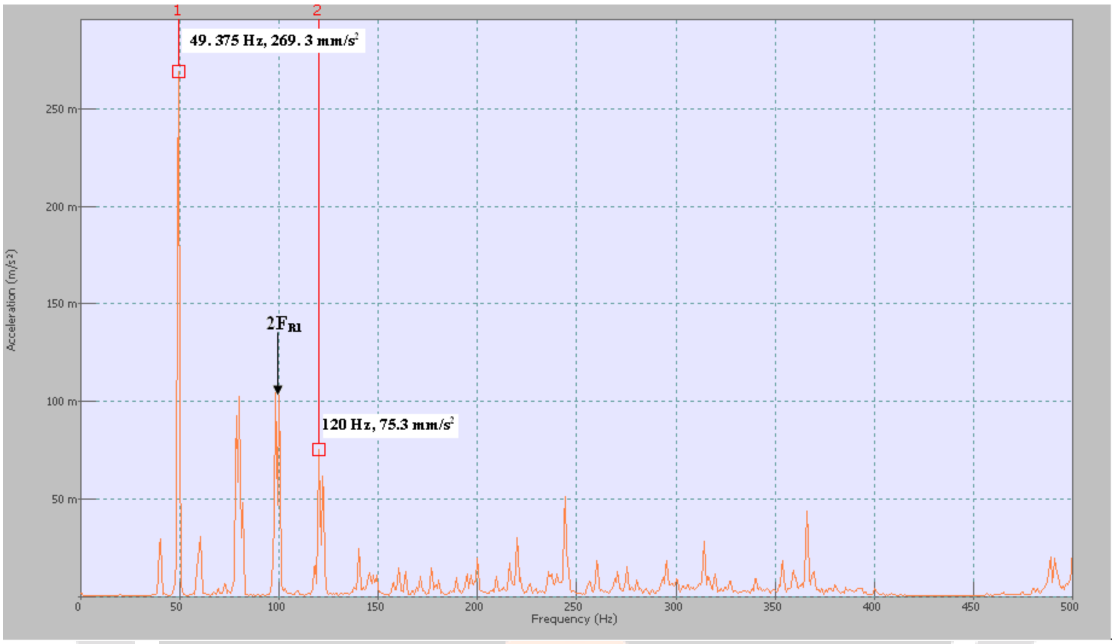

Fig-4: Spectrum of bearing with outer race defect with 20 kg load at 2880 rpm

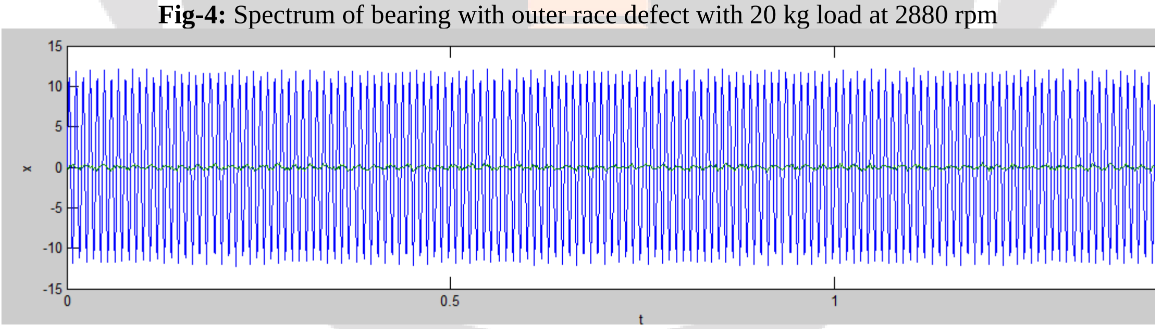

Fig-5: Time domain MATLAB output of bearing with outer race defect with 20 kg load at 2880 rpm

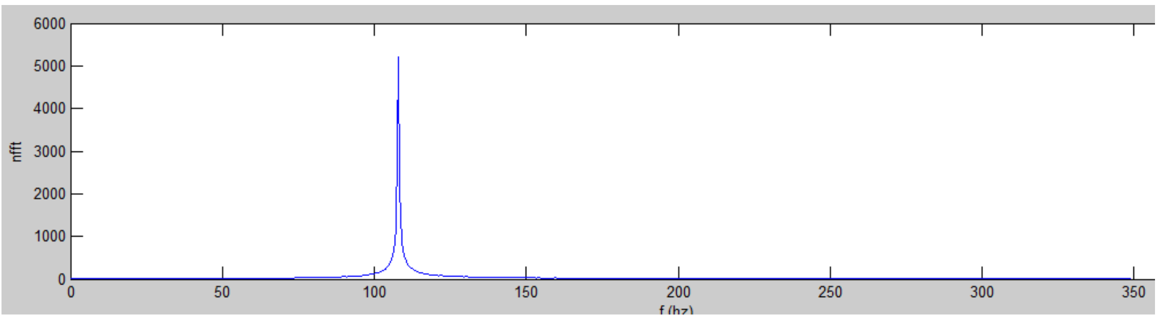

Fig-6: Spectrum of MATLAB output of bearing with outer race defect with 20 kg load at 2880 rpm

Also the frequency spectrum of the vibration signals from the bearing with inner race defect at speed 4866 rpm is shown in Fig.6.9.

It shows peaks, the peak at 80 Hz is of shaft rotational frequency (F_{R2}) with difference of 1.10 Hz only and also peak at 359.375 Hz is of inner race defect frequency (BPFi) with difference of 5.755 Hz only with estimated one.

F_{ORD} respectively. In similar way peaks are occurred in spectrum of bearing with outer race defect at 20 kg as shown in Fig.6.28. Those are at 81.25 Hz and 201.875 Hz for F_{R2} & BPFo respectively. The difference between estimated value & experimental value is 0.15 Hz & 0.765 Hz for F_R & BPFo respectively.

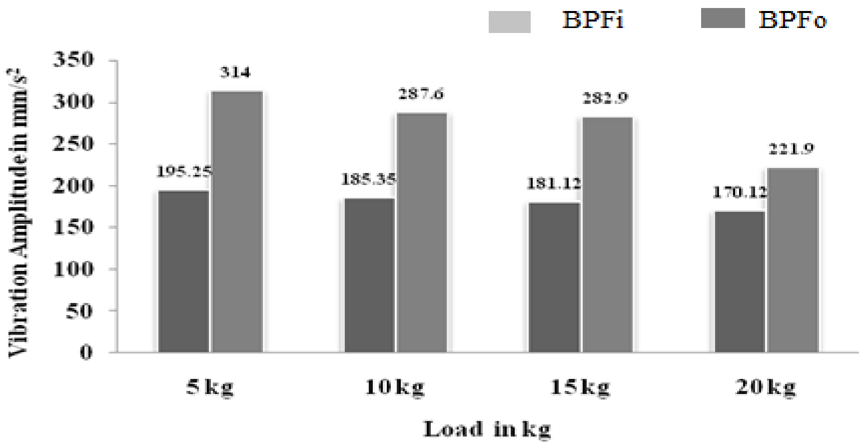

Fig-7: Load effect on vibration amplitude for the bearing with inner race defect & bearing with outer race defect

The agreement between the calculated frequencies and those obtained from the FFT analyzer is quiet excellent. It is seen that there is decrease in the vibration amplitude when the load on bearing is increased under constant speed as shown in Fig.7. The variation in amplitude has the same trend in both cases (i.e. bearing with inner race defect and bearing with outer race defect). The vibration amplitude decreases to 170.12 mm/s^2 for maximum load 20 kg for bearing with inner race defect. However the vibration amplitude decreases to 221.9 mm/s^2 for bearing with outer race defect at maximum load 20 kg. The study predicts the amplitude of vibration due to outer race defect to be much higher as compared to those due to inner race defect.

Early detection of faults has been one of the major issues in the manufacturing industries. In recent years, the industry has been evolved from the costly time based maintenance schedules to more efficient condition based maintenance. The use of vibration analysis is been widely used technique by the industries. Since then it has been an important to accurately determine the condition of bearing or to monitor components and its lifelong use. In case of rolling element bearing, the main aim of the vibration analysis is to detect the changes in vibration condition of object. Well this change takes place due to defects and faults present in the bearing. All the machine elements including the rolling element bearing has a characteristic natural frequency vibration. When the individual components like inner race, outer race or ball bearings are vibrating, different frequencies can be calculated. With help of Fast Fourier Transform and the calculation of spectrum of frequencies, the frequencies of element bearings can be differentiated and conceived. if there is any fault present in particular component so that the interruption of machine operation can take place on times. Vibration data available for the faulted system under realistic operating conditions is limited. Seeded fault tests are very costly, and it is often almost impossible to achieve realistic operating conditions. For these reasons, it is beneficial to develop the technology to accurately simulate fault vibrations. In this experiment, the vibrating signals were obtained by using the faulty bearings and some good bearings. These signals were captured through Fast Fourier Transform (FFT). Later these signals were analysed through nv gate software, which is developed by OROS as it is probably the most popular and widely used noise and vibration analysis software. The data obtained during the experiment from FFT analysis and theoretical data was used to compare with results in produced by simulation in MATLAB software as it is used for simulation and also it has good graphic and accurate facilities. Using all the analysis methods, the objectives and therefore the aim is fulfilled.

4. RESULT AND DISCUSSION

In this thesis, condition monitoring and its different techniques of determining defects and faults were highlighted. An overall review of study on vibration measurement technique for detection of faults in rolling bearing element was focused and therefore different vibration measurement methods were highlighted. Different researches on detection of faults are being done for ages. Although literature is available for detection of both localized and distributed faults, this thesis revealed the proper hopeful or alternative technique to detect the fault more precisely and experimentally. Vibrations in time domain and frequency domain were studied as it can be measured through parameters like skewness, Kurtosis, crest factor, RMS (root mean square value), probability density. To find more precise results in finding those faults, vibration analysis was merely focused experimentally and theoretically. Different signal data were obtained for good new bearings and faulty bearings with induced inner race faults at 2880 rpm and 4866 rpm. In the data analysis, plots obtained for each test conditions are compared i.e. different frequencies obtained from Fast Fourier Transform (FFT) analyzer. The theoretical Vibration fault signatures were also compared with the frequency determined from power spectrum graphs and frequency domain graphs.

The peaks acquired from the MATLAB programming were compared with the measured ones from both the analysis methods. It showed that the faulty frequencies obtained by vibration analysis were similar as applied on rolling element bearings. The similarity between measured and simulated signals focused to diagnostic techniques reveals that it can be used effectively to simulate faults of different sizes and locations therefore useful in development of analytical methods.

Through the experimental results, it can be seen that the calculated inner race and outer race frequencies of the bearings at operational speeds of 2880rpm, 4866rpm with constant load is applied are 228.25 Hz, 108 Hz, 385.225Hz and 182.475 Hz respectively. As per experimental results, it was observed that peaks were generated at the characteristic frequencies. It is been observed that from the acquired graphs there is increase in amplitude as the defect size level increases. Considering all the results and analysis, the thesis reveals that the defect in ball bearing exists at the inner race and outer race of a faulty bearing. Also it was proved that faulty frequencies obtained through the vibration analysis are similar to faulty frequencies obtained through MATLAB programming. An algorithm was generated to find the faulty frequencies. Looking at all the results and analysis, all the objectives like to discover graphical analysis by using nv gate software and investigate bearing vibrations which occurs at certain peak frequencies and designing an algorithm which helps in detecting the faulty frequencies by putting all the parameters were proved. Further at different load test and constant speed analysis is done on FFT it shows that as load increases there is more peaks occur at high frequencies generated. were taken Hence the thesis concludes that the vibrating signals created on inner race and outer race of the bearing are analysed evaluated and simulated respectively thus fulfilling the aim.

5. REFERENCES

[1] Wasimul Haque et.al, (2019), Bearing condition monitoring and diagnosis through vibration and Artificial intelligence techniques,IJARIIE, vol.5, Issue-5

[2] Bapat P.M. and Asati S.K, (2012), Vibration signature and fault diagnosis of machines using neutral networks, *International journal of research of in engineering and applied sciences,*ISSN 2249-3905, vol.2,issue 9, pp.60-68.

[3] Bearing condition monitoring using vibration signature, (2012). Vibration analysis proven techniques as a productions maintenance tool. *IEEE Transactions on Industry Applications*, Vol. 21(2). pp. 324–332.

[4] Beebe R.,(2004), Predictive maintenance of the pump using condition monitoring, Elsevier Ltd,pp1-13.

[5] Bhuiyan M.S.H.et al, (2012), Tool condition monitoring using acoustic emissionand vibration signature in turning, *Proceedings of the world congress on engineering,* ISSN 2078-0958,vol.3.

[6] Shayela Farheen Aziz, Arun kumar Sahu (2017), Condition Monitoring and Fault diagnosis of Rolling Element Bearing, IJIREEICE , Vol. 5, Issue 9, ISSN: 2321-5526

[7] Botsaris P.N. and Koulouriotis D.E., (2007), A Preliminary Estimation of Analysis Methods of Vibration Signals at Fault Diagnosis in Ball Bearings, *4th International Conference on NDT.*

[8] Carina Freitas, Paula Morais, Jacques Cuenca (2018),Condition Monitoring of bearing under medium and low rotational speed , Siemens Industry software NV, Belgium.

[9] Dube A.V.,et. al, (2013), Vibration based condition assessment of rolling element bearing with localized defects, *International journal of scientific and technology research,* vol. 2, issue 4,pp.149-155.

[10] Farrar C. and Sohn H., (2001), Damage diagnosis using time series analysis of vibration signals, *Journal of Smart Material and Structures Institute of Physics*, vol.10,pp. 446-451.

[11] McClintic R., Byington C., Lebold M. and Maynard K., (2000), Review of vibration analysis method for gearbox diagnostic and prognostic, *In Proceedings of the 54th Meeting of the Society for Machinery Failure Prevention Technology*,pp.623-634.

[12] Francesco Castellani et.al. , (2019), Condition monitoring techniques for machine bearings in non-stationary operation, Elsevier.

[13] McFadden P., (1990), Condition monitoring of rolling element bearings by vibration analysis, *IMechE Paper, Solid Mechanics and Machine Systems Group Seminar*, pp.49–53.

[14] Product information 40,(1994),Bearing failures and their causes, SKF publications [online]pp4-8.Availableat: http://www.alliedbearings.com/downloads/skf_bearing_failureandcauses.pdf.

[15] Qian S., (2002), Intruduction to Time,-Frequency and Wavelet Transforms, *Prentice Hall,New Jersey*.

[16] Rao B.K.N., (1996), Handbook of Condition Monitoring, Elsevier advanced technology,pp.1-34,ISBN:1 85617 234 1

[17] Ross D., (2008), Handbook: Total Productive Maintenance, Section 5, pp.1-5.
Shikari B. and Sadiwala S, (2004), Automation in Condition Based Maintenance using vibration analysis, MANIT Bhopal,pp.3-5.

[18] K.Jemielniak and O. Otman, (1998), Catastropic tool failure detection based on acoustic emission signal analysis, *Annals of the CIRP*, vol. 47/1, pp.31-34.

[19] Kannatey-Asibu E., (1982),A study of tool wear using statistical analysis of metal cutting acoustic emission. *Journal of Wear*, Vol.76(2),pp.31-37.

[20] Karimi M., (2006), Rolling Element Bearing Fault Diagnostic using the Blind deconvolution techniques, Queensland University of Technology, PhD Thesis, pp.20-24.

[21] Len Gelman et al, (2013), Rolling bearing diagnosis based on the higher order spectra, *International journal of prognostics and health management,*ISSN 21532648,vol.22,pp.1-8.

[22] Li C., Ma J. and Wang B.,(1996), Bearing condition monitoring by pattern recognition based bi-coherence analysis of vibrations. *Journal of Mechanical Engineering*, vol.210(4), pp.277–285.

[23] Loparo K. and Ocal H., (2004), Estimating the running speed and the bearing key frequencies of an instruction motor from vibration data, *Mechanical System and Signal Processing*,vol.18(3),pp.515-533.

[24] Mathew J. and Alfredson R., (1984), The condition monitoring of rolling element bearing using vibration analysis, *Journal of vibration, acoustic and stress reliability design*, vol.10(6),pp.47-53

[24] MATLAB – The Language of Technical Computing. [online] Available at: http://www.mathworks.com/products/matlab/ ,

[25] McClintic R., Byington C., Lebold M. and Maynard K., (2000), Review of vibration analysis method for gearbox diagnostic and prognostic, *In Proceedings of the 54th Meeting of the Society for Machinery Failure Prevention Technology*,pp.623-634.

[26] McFadden P. and Smith J., (1984), Information from the vibration of rolling bearings, *In Proceedings of International Condition Monitoring Conference*, pp.178–90.

[27] McFadden P., (1990), Condition monitoring of rolling element bearings by vibration analysis, *IMechE Paper, Solid Mechanics and Machine Systems Group Seminar*, pp.49–53.

[28] Product information 40,(1994),Bearing failures and their causes, SKF publications [online]pp4-8.Availableat: http://www.alliedbearings.com/downloads/skf_bearing_failureandcauses.pdf.

[29] Qian S., (2002), Intruduction to Time,-Frequency and Wavelet Transforms, *Prentice Hall,New Jersey*.

[30] Qu S., Shi D. and Wang W., (2004), Defect detection for bearing using envelope spectra of wavelet transform, *Journal of Vibration and Acoustics*, vol.126(4),pp.567-573.

[31] Rao B.K.N., (1996),Handbook of Condition Monitoring, Elsevier advanced technology,pp.1-34,ISBN:1 85617 234 1

[32] Ross D., (2008), Handbook: Total Productive Maintenance, Section 5, pp.1-5.
Shikari B. and Sadiwala S, (2004), Automation in Condition Based Maintenance using vibration analysis, MANIT Bhopal,pp.3-5.

[33] Sumitkumar Sar and Ramesh kumar ,(2015), Techniques of vibration signature analysis, *Interational journal of adavanced research in computer and communication engineering*, ISSN 2278-1021, vol.4, issue 3,pp.240-244.

[34] Syam Patidar and Pradipkumar Soni, (2013), An overview on vibration analysis technique for the diagnosis of rolling element bearing faults, *International journal of engineering trends and technology*,ISSN 2231-5381, vol4, issue 5,pp.1084-1809.

[35] Su Y. and Lin S., (1992), On initial fault detection of a tapered roller bearing: frequency domain analysis, *Journal Sound and Vibration*, vol.155(1),pp.75–84.

[36]Tandon N., (1992),Detection of Defects in Rolling Element Bearings by Vibration Probability Density and Cross-correlation Measurement, *International Journal of Quality and Reliability Management*, vol.9(4). pp. 53-57. ISSN: 0265-67LX

[37] Taylor J., (1980), Identification of the bearing defects by spectral analysis, *ASME Journal of mechanical Engineering*. vol.102 (2),pp.198-204.

[38] Tondon N. and Choudhury A., (1999), A review of vibration and acoustic measurement methods for the detection of defects in rolling element bearings, *International Journal of Tribology*, vol. 32 , pp.469–480.

[39] Tondon N. and Nakra B.,(1990).Defect detection in rolling element bearing by acoustic emission method, *Journal of Acoustic*

emission, vol.9,pp25-28.

[40] Venkatesh J., (2007), An Introduction to Total Productive Maintenance (TPM),pp.4-7.

[41] Verma S. and Balan A., (1998), Experimental investigation on the station of electrical machines in relation to vibration and noise problems, *IEEE Proceedings Electric Power Applications*, vol.145(5), pp.455-461.

[42] Wang Y., (1998), Modelling of low shaft speed bearing faults for condition monitoring, *Journal of Mechanical System Signal Processing*, pp.415–26.

[43] White M., (1984), Simulation and analysis of machinery fault signals. *Journal of Sound and Vibration*, pp.95–116.