ISSN(Online): 2319-8753
ISSN (Print): 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 6, June 2015

A Review on Bearing Fault Detection by Vibration Signature Analysis

Mr. K H Munde[1], Dr. S B Thakre[2]

Assist. Professor, Department of Mechanical Engineering, Dr. D. Y. Patil SOE, Pune, Maharashtra, India[1]

Professor, Department of Mechanical Engineering, PRMIT & R, Badnera, Amravati, Maharashtra, India[2]

ABSTRACT: Vibration analysis is one of the most usual methods utilized to evaluate the conditions of bearings in an operating machine. Such measurements may be used for machines with bearings in new condition as well as for machines whose bearings are deteriorating and approaching the end of their useful lifespans. If a machine's vibration response to known excitation forces has been determined through techniques such as finite element analysis and modal analysis, then vibration measurements during service can determine the dynamic characteristics of the forces working on the car. Vibration data can likewise be used to know forcing characteristics and the condition of machine parts, mainly bearings. The paper highlights the work done by various researchers for bearing fault detection.

KEYWORDS*:* Vibration analysis, Defect frequency, Condition monitoring, Review Defect analysis.

I. INTRODUCTION

The monitoring bearing vibrations and comparing the vibration signals against a baseline for satisfactory bearing operation may be given as a means to detect impending bearing failures. The occurrence of abnormal signals indicates initial spalling or pitting of rolling contact surfaces. On the other hand, the bearing, although running rough with increased friction, generally will continue to turn out later on the initial surface damage, permitting continued effective machinery use. In conclusion, the rolling contact surfaces will be completely destroyed and the machine will cease to run because of bearing failure or excessive vibratory loading and component fracture. These last conditions represent a potential catastrophe from the minimum standpoint of unscheduled machinery downtime and excessive cost, or worse, from the standpoint of loss of human life in life-critical applications. The latter would let in, for instance, air transport applications and applications that handle hazardous fluids. From the time at which excessive vibration signal is experienced in the time at which the machinery no longer functions represents a duration in which action may be taken to prevent catastrophic events. Historically, many applications have relied on preventive maintenance to minimize unscheduled downtime due to bearing failure. Based on calculations of bearing endurance, either from fatigue of rolling contact surfaces or other wear phenomena, or based on past experience of bearing failures, periodic stoppages of machinery are scheduled, during which bearings are inspected and replaced. Frequently, inspection does not occur and rolling bearings are simply replaced. The problem with this procedure, in addition to the cost of taking equipment out of service and losing production and revenue, is that the bearings that had been in operation were most likely not prone to failure; however, they might be replaced with bearings that could fail. Once a rolling bearing has experienced sustained operation, it has passed the period in which birth defects cause early failures, and under proper mounting, applied load, speed, and lubrication conditions, it will continue to operate without failure. Thus, presuming proper operation, it is usually best to allow the bearing to run without interruption once an initial operating period has been successfully achieved.

II. JOURNEY OF BEARING VIBRATION ANALYSIS

The first vibration meters were introduced in the 1950s, and they measured the overall, or "broad band" level of machine vibration, either in peak-to-peak mils (thousandths of an inch) of vibratory displacement, or in inches per

ISSN(Online): 2319-8753
ISSN (Print): 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 6, June 2015

second (IPS) of vibration velocity. A little later, tunable analog filters were added to the meters in order to discriminate between different frequency components, and thus to produce a sort of vibration spectrum.

The 1970s brought forth the personal computer and the advent of digital signal processing that led to the FFT analyzer, and it made quick work of calculating a frequency spectrum from a recorded vibration signal. The first such analyzers were quite bulky, weighing as much as 75 pounds, and this made them more suited as laboratory instruments than portable units for field use.

The 1980s saw the exploitation of the microprocessor on a single silicon chip, and the battery-powered truly portable digital signal analyzer quickly followed this. It is this device, coupled with a computer program that stores the data and takes care of the logistics of vibration data collection that has revolutionized the application of vibration analysis to machinery diagnostics.

Mathew J. & Alferdson R. J. [1] developed the technique of condition monitoring for rolling element bearings by using vibration analysis. The vibration data were analysed and several parameters [Peak Level, RMS Level, Matched Filter RMS, Kurtosis Factor] were assessed with regard to their effectiveness in the detection of bearing condition it was found that all the parameters were having some value depending on the type of bearing failure encountered. Frequency domain parameters were more consistent in the detection of damage than time domain parameters. They have suggested it would be unreliable to depend exclusively on any one technique to detect bearing damage.

McFadden P D and Smith J D [2] presented a model for the vibration created by a single point defect in a rolling element bearing. It indicates the vibration produced by a single point defect on the inner race of a rolling element bearing under constant radial load. The model integrates the shaft speed, effects of bearing geometry, bearing load distribution, transfer function and the exponential decay of vibration. The vibration is modeled as a product of a series of impulses at rolling element passing frequency with bearing the load distribution and the amplitude of a transfer function, convolved with the impulse response exponential decay function. The model is used only to a single point defect on bearing inner race under radial load. Extension of the model to include multiple point defects and outer race and rolling element defects under radial and axial load is required.

McFadden P D and Smith J D [3] showed that the vibration created by multiple point defects in a rolling element bearing. A model for the high frequency vibration formed by a single point defect on bearing inner race under radial load is extended to describe the vibration produced by multiple point defects. The phase angles were derived for defects at any position on the inner race and superposition was used to give the vibration spectrum. The performance of the model will be confirmed by experiments on a bearing with more defects on its inner race.

Sunnersjo C. S. [4] has given clarification about the relationship between geometrical imperfections of the bearing components and resulting pedestal vibrations during operation. A mixed theoretical and experimental impedance approach has been used to treat the bearing when fitted into a simple machine structure. Further, it shows how resulting vibrations of the bearing pedestal can be calculated. It highlights possible methods of condition monitoring and prediction of impending bearing failure. This method is useful for lightly loaded bearings operating at low and moderate speeds. This can be extended to the high speed bearing operating at various conditions.

Yhland E. [5] presented a linear theoretical model for the vibrations of a shaft bearing system produced by ball bearing geometrical imperfections. It is usable for low and medium speeds where ball centrifugal forces can be omitted. The excitation forces from each bearing are considered and can serve as input to suitable rotor dynamic programs. Imperfections shielded are radial and axial waviness of outer and inner rings, non-uniform cage pocket distribution, ball waviness and diameter distribution. Explicit rules are demonstrated in the bearing stiffness matrix, the influence matrix of form errors and the form error vector, the three central concepts of the mannequin. The answer to the non-linear equilibrium equations of the same shaft-bearing arrangement is expected to be recognized if the bearings are geometrically perfect. The example of rotating outer ring and stationary inner ring requires minor modifications. Minor variations in groove radii are readily brought out as an additional case of configuration error. The enlargement of the model to cover the centrifugal action of the balls. The incorporation of roller bearings into the mannequin is very much a question of how accurately the (non-Hertzian) contacts encountered have to be treated. Lightly loaded roller bearings with optimized roller profiles have non-Hertzian contacts, already at low load, and cause considerable complications. The extension of the model to work in a more general environment, like coupling to flexible pedestals. Modern computational methods developed in structural dynamics should be immediately applicable. The over rolling of local raceway defects and similar positions are essentially different from those encompassed by the present example and are not amenable to linearization.

Tandon N. and Choudhury A. [6] presented an analytical model for the vibration response of rolling element bearings due to a localized defect. The amplitudes of significant frequency components on inner race\ outer race or on one of the rolling elements under axial and radial loads. The model forecasts a discrete spectrum having peaks at the characteristic defect frequencies and their harmonics. And it predicts the effect of load and pulse shape on the vibration amplitude has been considered in the model. The example presented here predicts a frequency spectrum having peaks at characteristic defect frequencies with modulations in the shell of a rolling element defect and an inner race defect under a radial load. The amplitudes at these frequencies are also called for various defect locations. The amplitude of the outer race defect is found to be quite high in comparison to those for the inner race defect and the rolling element defect. The amplitude level is likewise set up to increase with an increase in load and it is represented by the configurations of the generated pulses. The analytical and experimental values agreement is limited to the elements at the inner race defect frequency and sidebands about this component at multiples of the beam frequency. The points at the multiples of the shaft frequency could not be foretold by this example.

Choudhury A. and Tandon N. [7] have been presented an analytical model to forecast the vibration response of rolling bearings due to distributed defects under radial load. For bearings without defect and with race defect, the model prophesies a discrete spectrum with components at outer and inner race characteristic defect frequencies for the response of the respective races. The amplitudes for race defects increase considerably in comparison to the amplitudes at corresponding frequencies for a bearing without defect. For a bearing with off-size rolling element, the response of the outer race is at cage frequency and its multiples. The response of inner race is create to be at the relative frequency of inner race with respect to cage along with sidebands at shaft frequency and its multiples. The results can be compared with FEM and experimentation. The model can be extended for radial and axial load.

Fawzi M. A. El-Saeidy [8] studied the effect of the outer ring ovality on the dynamic behaviour of rotating machinery under rotating unbalance with consideration of ball bearing nonlinearities, shaft elasticity, and speed of rotation. The equations of movement of a rotor–ball bearing system are formulated using finite-elements FE discretization and Lagrange’s equations. The analyses are specified to a rigid-rotor system, by retaining the rigid body modes only in the FE solution. The time domain and frequency domain techniques were used in a system with and without outer ring ovality. It is found that with ideal bearings, no ovality, the vibration spectrum is qualitatively and quantitatively the same in both the horizontal and vertical directions. When the ring ovality is introduced, however, the spectrum in both orthogonal planes is no longer similar. And the magnitude of the bearing load has improved in the form of repeated random impacts, between balls and rings, in the horizontal direction of maximum clearance compared to a continuous contact along the vertical direction of positive zero clearance. This underlines the importance of the vibration measuring probe’s direction, with respect to the outer ring axes, to capture impact-induced vibrations. When the harmonic excitation is increased in a system with ideal bearings, the spectral peaks above forcing frequency have shifted to a higher-frequency region, indicating some sort of a hard spring mechanism inherent in the system. Another observation is that for the same external excitation, vibration amplitude at forcing frequency in the bearing force spectrum is the same for systems with or without outer ring ovality. The adopted modelling approach, that is solved for a rigid shaft system using existing FE codes for rotor dynamics, can be used for inner ring also. It has to be validated by experimentation for outer and inner rings.

ISSN(Online): 2319-8753
ISSN (Print): 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 6, June 2015

AktuÈrk N. and Gohar R. [9] Shown the effect of ball size variation on vibrations associated with ball-bearings. The axial and radial vibrations of a rigid shaft obtained by a pair of angular contact ball-bearings are studied. The theoretical model model and a computer program were developed to simulate this effect and the results presented in frequency and time domains. All results show that off-sized balls in the bearing cause vibrations at cage speed and its harmonics, depending on their arrangement within the bearing. Symmetric combinations will produce vibrations at the multiples of the cage speed and all other combinations will produce vibrations at the cage speed. If only one ball is oversized when the diameter difference increases, the peak-to-peak amplitude of the vibrations will also increase. The effect due to more than one ball oversized is yet to study.

Brian T. Holm-Hansen Robert X. Gao [10] studied the vibrational behavior of a deep groove ball bearing with a structurally integrated force sensor. The miniaturized force sensor fitted within a slot on the bearing, provides real time condition monitoring of the bearing. Mathematical and FE models were developed to predict the sensor output due to bearing dynamic load and rotational speed variations. Experimentation was conducted on a ball bearing to validate the mathematical and FEA solutions. The results confirm the approach of integrated-sensing for bearing condition monitoring. Future research will emphasis on creating efficient and advanced signal processing techniques using neural-fuzzy networks and wavelet transform to relate signal features to specific bearing faults. Also, further experimental studies will be conducted on a better-quality bearing test bed that permits for a much wider range of operating conditions to be examined. The joint theoretical and experimental work will make a strong basis for the development of an integrated real time bearing condition monitoring. The model will provide early defect warning to a wide range of ball bearings and manufacturing equipment.

S. Prabhakar, A.R. Mohanty, A.S Sekhar [11] investigated faults in ball bearing by application of DWT. Vibration signals from rolling contact bearings having single and multiple point defects on outer race, inner race and the combination faults have been observed for analysis. In wavelet decompositions the impulses in vibration signals due to bearing faults are prominent. It is observed that according to characteristic defect frequencies impulses come out periodically with a time period. For detecting single and multiple faults in the ball bearings DWT can be used as an efficient instrument.

S. A. McInerny and Y. Day [12] presented a laboratory module for fault detection in rolling element bearings. The formulas given for the deliberation of the characteristic fault frequencies and backdrop on the basic operational features of ball bearings is presented. The defects of conventional vibration spectral analysis for the detection of bearing faults is observed in the setting of a synthetic vibration signal that students generate in MATLAB. The vibration signatures measured on bearing housings shares several key features Envelope analysis and the connection between bearing fault signatures and amplitude modulation /demodulation are explained. Lastly, a graphically driven software utility is inserted. This software helps to explore envelope analysis using measured data or the synthetic signal that they created. The software service program and the material introduced in this paper establish an instructional module on bearing fault detection. After surveying the basic performance of rolling element bearings and the characteristics of idealized bearing fault vibration signatures, the defects of conventional spectral analysis were illustrated with a synthetic signal generated in MATLAB.

M Amarnath, R Shrinidhi, A Ramachandra, S B Kandagal [13] established the technique to give early information about progressing malfunctions. To monitor the condition of antifriction bearings and to understand the details of severity of defects before they cause serious catastrophic failures. The vibration monitoring technique is worthy to analyze various defects in bearing. Frequency domain analysis, time domain analysis and spike energy analysis have been used to identify different defects in bearings. The outcomes have validated that each one of these techniques is useful to investigate problems in bearings. Frequency spectrum identifies the exact nature of defects in bearings and time waveform indicates severity of vibrations for defective bearings. The spike energy level, which is more comprehensive parameter to predict the severity of the defect in antifriction bearings in the bearings, was also recorded for all bearings.

ISSN(Online): 2319-8753
ISSN (Print): 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 6, June 2015

Xinsheng Lou, Kenneth A. Loparo [14] presented a technique to diagnosis bearing fault based on wavelet transform and fuzzy inference. The analysis of defects in ball bearings based on the wavelet transforms and Neuro-fuzzy classification. Vibration signals for healthy bearings, bearings with ball faults and race faults were captured from an experimental system. The wavelet transform was used to generate feature vectors by processing the accelerometer signals. An adaptive neural-fuzzy inference system (ANFIS) was used as a diagnostic classifier. For comparability purposes, the Euclidean vector distance method as well as the vector correlation coefficient method was also looked into. The developed diagnostic method can reliably separate different fault conditions under the presence of various loads.

V. Purushothama, S. Narayanana,, Suryanarayana A.N. Prasad [15] demonstrated a suitable condition monitoring process to prevent malfunctions and breakages during operation. The method for detecting localized bearing defects based on wavelet transform. Bearing race faults found by using discrete wavelet transform. Vibration signals from ball bearings having a single and multiple point defects on outer race, inner race, ball fault and combination of these faults considered for analysis. Wavelet transforms gives a variable resolution time–frequency distribution. It is shown that the impulses created periodically with a time period corresponding to characteristic defect frequencies. The diagnoses of ball bearing race faults have been found using wavelet transform. These results are compared with feature extraction, data and results from spectrum analysis. It also presents a novel method of pattern recognition for bearing condition monitoring using hidden Markov Models. Experimental results shows that successful bearing fault detection rates as high as 99% can be achieved with this plan of attack. It has been shown that DWT can be used as an efficient instrument for detecting single and multiple faults in rolling contact bearings.

R. K. PUROHIT and K. PUROHIT [16] the axial and radial vibrations of a rigid shaft supported bearings are considered. The effect of vibrations of varying the number of balls and preload in the bearings is studied for prefect bearings. In the mathematical formulation the contacts between the races and the balls are considered as nonlinear springs. The stiffness is obtained by using the Hertzian elastic contact deformation theory. The numerical integration technique Newmark-b with Newton-Raphson method is used to crack the nonlinear differential equations iteratively. For healthy bearings, vibrations occur at the ball passage frequency. The amplitudes of these oscillations are noted to be considerably scaled down if the preload and number of balls are correctly chosen. All results are obtained in the form of Fast Fourier Transformations.

A Choudhury And N Tandon [17] showed the vibration response of ball bearings in a rotor bearing system to a local defect under radial load. In the present research, a theoretical model has been established to generate the vibration response due to a localized defect in various bearing components in a rotor-bearing system under radial load conditions. The experimental setup on which the theoretical results have been validated has been modeled as a multi-DOF system. In this study poor agreement for the harmonics of shaft and cage frequencies in the case of an inner race defect and rolling element defect respectively. This was expected because the components at harmonics of shaft frequency primarily occur due to rotor malfunction such as residual unbalance, misalignment etc. which have not been considered in the theoretical model.

Abderrazek Djebala · Nouredine Ouelaa Nacer Hamzaoui [18] detected bearing faults so much desired objective remains the extraction of the defect vibratory signature from the measured signal in which immerses the random noise and other components of the machine. Established on the optimization of wavelet multi resolution analysis, it uses the courthouse as an optimization and evaluation criterion, several parameters were then taken. The experimental results demonstrate the robustness of this method within the detection of several defects simulated on ball bearings. The various configurations, in which the signals were measured, allow leading to optimum conditions of its application. The application of WMRA on filtered signals allows better results than its application on broad band signals or a simple band pass filtering. In reality this approach seems more consistent in the case of incipient defects, in particular if the detection by a simple band pass filtering or a wide band WMRA is not possible. In conclusion the association of a bond passes filtering carefully selected and an optimized WMRA allows having better outcomes than the diligence of one of these techniques alone.

ISSN(Online): 2319-8753
ISSN (Print): 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 6, June 2015

H. Mohamadi Monavar, H. Ahmadi and S.S. Mohtasebi [19] investigated a technique to forecaste defects in bal bearings using vibration signal analysis. The vibration monitoring technique is suitable to analyze various defects in bearing. This technique gives early information about progressing defects. Triaxial vibration measurement technique was used at each terminal of the pairing of the motor and rotor bearing housings. Time waveform specifies severity of vibrations for defective bearings and vibration spectrum indicates the precise nature of defects in bearings. The answers propose that bad bearing has a substantial force on the vibration spectra. Time domain analysis, vibration spectrum analysis has been utlised to identify different defects in bearings. The outcomes have verified that each one of these techniques is useful to find problems in bearings.

Arun Kr. Jalan and A. R. Mohanty [20] presented technique for error diagnosis of rotor-bearing system was considered. The residual generation technique was employed for detection of errors due to misalignment and imbalance. The residual powers are compared with the equivalent theoretical forces. The fault condition and position of flaws are successfully discovered by this proficiency. This method may be useful for large systems like turbine shafts and gear boxes.

G Feng Wang, Yu Bo Li, and Zhi Gao Luo [21] presented a novel method to realize classification of fault signal without extracting feature vector. By calculating the time delay and embedding dimension of time series, vibration, signal is reconstructed into phase space and Gaussian mixture model was made for every sort of fault signal in the reconstructed phase space. It was shown that this method is effective for classifying not only fault types but also fault severity. Information obtained by examining the time series only so it is very suitable for industrial application.

M S Patil Jose Mathew. P K Rajendra Kumar/ [22] investigated experimentally the influence of the defect size on ball bearing vibration using Wavelet Transform. An analytical model is presented for predicting the effect of a localized defect on the ball bearing vibrations. In the mathematical modeling, the contacts between the races and the ball are incorporated as non-linear springs. The contact force is found using the Hertzian contact deformation theory. A computer program is developed to simulate the defect on the raceways with the solutions given in the frequency domain and time domain. The model produces both the frequency and the acceleration of vibration components of the bearing. The consequence of the defect size and its placement has been studied. This investigation is centered towards the growth of a mathematical model to find the issue of defect size on bearing vibration. Instead of using periodically repeated impulse function for the impulse due to defect, defect itself is modeled as part of sinusoidal waves. The present model is fairly limited in treating the ball skidding effect. The present effort was targeted at a more elementary approach to obtain a theoretical model to analyze the issue of defect size, load and speed of the bearing vibration and predict the spectral components. Including the ball raceway interaction and the ball skidding phenomenon would make the model more rigorous. Nevertheless, this model will be promoted at a future time to contain the issue of ball skidding to predict the spectral components of giving birth with defects.

F. Cong J. Chen G. Dong M. Pecht [23] investigated bearing faults are among the main causes of breakdown in rotating machines. In this study, a bearing fault model is suggested based on the dynamic load analysis of a rotor-bearing organization. The rotor impact factor is taken into consideration in the rolling bearing fault signal model. The defect load on the airfoil of the bearing is divided into two sections: the determinate load and the alternate load. The vibration response of the proposed fault signal model is investigated and the fault signal calculating equation is derived through dynamic and kinematic analysis. Outer race and inner race fault simulations are seen in the composition. The simulation process includes consideration of various parameters, such as the gravitational force of the rotor-bearing system, the asymmetry of the rotor, and the position of the shortcoming on the airfoil. The simulation result shows that different amplitude combines the alternate load and determinate load will cause different envelope spectrum expressions. The rotating frequency sidebands will arise in the envelope spectrum in addition to the fault characteristic frequency. This appearance of sidebands will produce the difficulty of fault recognition in intelligent fault diagnosis. The proposed results of signal model simulation have successfully validated by experimentation.

S P Harsha K Sandeep R. Prakash [24] described an analytical model to forecast non-linear dynamic responses in a rotor bearing system due to surface waviness have been established. In the mathematical modeling the contacts between the races and the rolling elements are considered as non-linear springs, whose stiffness are got by using Hertzian elastic contact deformation theory. The governing differential equations of motion are developed by using Lagrange's equations. The numerical integration technique Newmark-b with Newton–Raphson method is used to solve the nonlinear differential equations iteratively. A computer program is developed to simulate surface waviness of the ingredients.

III. CONCLUSION

The short review of the various methods of the vibration analysis is for fault detection in the bearing is done. The theoretical approach is too considered by many researchers at earlier levels. The different mathematical tools are used for indicating the dynamic model and analysis the defects. The various new wavelet techniques are yielding answers in prompt time. The complete model will require incorporation of all the parameters to modeled in the for showing the exact phenomenon in the experiment. There is a need to face into the technique which will move over the real-time solution and precise prediction about the condition of bearing.

REFERENCES

[1] Alfredson RJ, Mathew J., Frequency domain methods for monitoring the condition of rolling element bearings, Mech Engg Trans, IE Australia 1985;ME10(2):108–12.
[2] P. D. McFadden, J. D. Smith, Model for the vibration produced by a single point defect in a rolling element bearing, Journal of Sound and Vibration 96 (1) (1984)69–82.
[3] P. D. McFadden, J.D. Smith, Vibration monitoring of rolling element bearings by the high-frequency resonance technique a review, Tribology International 17 (1)(1984)3–10.
[4] Sunnersjo C S, Rolling bearing vibrations — geometrical imperfections and wear, J Sound Vibr 1985;98(4):455–74.
[5] Yhland E. A linear theory of vibrations caused by ball bearings with form errors operating at moderate speed. Trans ASME, J Tribol 1992;114:348–59.
[6] N. Tandon, A. Choudhary, An analytical model for the prediction of the vibration response of rolling element bearings due to a localized defect, Journal of Sound and Vibration 205 (3) (1997) 275–292.
[7] Choudhary A., Tondon N., A theoretical model to predict vibration response rolling bearing to distributed defects under radial load, ASME J. Vibr. Acoust., 1998, **l20**, pp. 214–220.
[8] Fawzi M. A. El-Saeidy, Rotating machinery dynamics simulation. I. Rigid systems with ball bearing nonlinearities and outer ring ovality under rotating unbalance excitation, Journal Acoustical Society of America, 2000, 851-860
[9] Akturk N, R Gohar, The effect of ball size variation on vibrations associated with ball-bearings, Proc Instn Mech Engrs Vol 212 Part J, 1997, 101-110.
[10] Brian T. Holm-Hansen Robert X. Gao, Vibration analysis of a sensor integrated ball bearing , Transactions of the ASME, Vol. 122, OCTOBER 2000, 384-392.
[11] S. Prabhakar, A R Mohanty, A S Sekhar, Application of discrete wavelet transform for detection of ball bearing race faults, Tribology International 35 (2002) 793–800
[12] S. A. McInerny and Y. Dai, Basic vibration signal processing for bearing fault detection, IEEE Transactions on Education, Vol. 46, No. 1, February 2003, 149-156
[13] M. Amarnath, R. Shrinidhi, A Ramchandra, S B Kandagal, Prediction of defects in antifriction bearings using vibration signal analysis, 2004, IE(I) Journal-MC, 88-92.
[14] Xinsheng Lou, Kenneth A. Loparo, Bearing fault diagnosis based on wavelet transform and fuzzy inference, Mechanical System and Signal Prpocessing, 18,5, 2004, 1077-1095
[15] V. Purushothama, S. Narayanan, Suryanarayana A. N. Prasad, Multi-fault diagnosis of rolling beraing elements using wavelet analysis and hidden Markov model based fault recognition, NDT&E International 38 (2005) 654–664.
[16] R. K. Purohit, K. Purohit, Dynamic analysis of ball bearings with effect of preload and number of balls, Int. Journal of Applied Mechanics and Engineering 11(1) (2006)77–91.
[17] A. Choudhary, N. Tandon, Vibration response of rolling element bearings in a rotor bearing system to a local defect under radial load, Journal of Tribology 128 (2)(2006)252–261.
[18] Abderrazek Djebala Nouredine Ouelaa Nacer Hamzaoui, Detection of rolling bearing defects using discrete wavelet analysis,Meccanica, Springer.
[19] H. Mohamadi Monavar, H. Ahmadi and S. S. Mohtasebi, Prediction of defects in roller bearings using vibration signal analysis, World Applied Science Journal 4 (1): 150-154, 2008

ISSN(Online): 2319-8753
ISSN (Print): 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 6, June 2015

[20]Arun Kr. Jalan and A. R. Mohanty, Model based fault diagnosis of a rotor–bearing system for misalignment and unbalance under steady-state condition ,Journal of Sound and Vibration, 2009

[21] G Feng Wang, Yu Bo Li, and Zhi Gao Luo, Fault classification of rolling bearing based on reconstructed phase space and Gaussian mixture model, Journal of Sound and Vibration, Volume 323, Issue 3-5, p. 1077-1089.

[22] M. S. Patil, J. Mathew, P. K. Rajendrakumar, S. Desai, A therotical model to predict the effect of localized defect on vibrations associated with ball bearing, International Journal of Mechanical Sciences 52 (2010)1193–1201.

[23] F. Cong, J. Chen, G. Dong, M. Pecht, Vibration model of rolling element bearings in a rotor bearing system for fault diagnosis, Journal of Sound and Vibration 332 (2013)2081–2097.

[24] S. P. Harsha, K. Sandeep, R. Prakash, Non-linear dynamic behaviours of rolling element bearings due to surface waviness, Journal of Sound and Vibration, 272 (2004) 557–580