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REVIEW ON CONDITION MONITORING OF BEARINGS USING VIBRATIONS

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Abstract: ***A comprehensive review has been done on condition monitoring of bearings using vibration analysis in present study. Bearing is a machine element which is used to transform the motion and reduce the friction between the two rolling elements. It is very important to detect the defects of the bearing. It deals with the effectiveness in the detection of bearing condition and failure based on the analysis of lubricating oils and greases and their vibrational signals explained by frequency domain approach and time domain approach.***

Keywords: *Condition Monitoring, Vibration Analysis, Frequency Domain, Time Domain, Crest Factor.*

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I INTRODUCTION

The inevitable usage and necessity of bearings in industries had paved a way to keen observation and research in this area since 1950. Mathew et al have been studied about detection of bearing condition and its failure by using frequency domain approach and time domain approach [1]. Tandon et al have investigated on bearing by considering factors are overall RMS, Peak, Crest factor, Power and defect frequency (1/f) [2]. and defect of bearings in induction motors by using stator current monitoring by some experimental methods Chaudhary et. al has predicted bearing failures are common factor for motor failure using three different bearing of same geometry.

Gupta et. al had observed that the rolling element bearings are commonly used to support machine components and the compliance, geometrical imperfection, surface roughness are the factors for causing an vibrations [3] . the vibrational signals are examined with frequency analysis technique to detect bearing faults the main cause of vibrations are geometry of radial rolling bearing and elasticity of component.

II. LITERATURE REVIEW

Mathew et al. have been studied on condition monitoring of rolling element bearings using vibration analysis. The study describes the effectiveness in the detection of bearing condition and failure. The study was initially conducted based on the analysis of lubricating oils and greases and the vibration signals were measured. They have studied the vibrations in bearing by using the frequency domain approach and time domain approach. The equipment and instrumentation within the check rig along with a shaft supported with the aid of double row spherical roller bearings and matched to an electric motor. A load of 15KN is imposed at the take a look at bearing (A double row self-aligning ball bearing). An accelerometer used within the trying out was a Bruel and Kjaer type 4333 accelerometer. They have conducted tests on seven bearings which are allowed to run for a few hours under minimum load conditions. And then various types of conditions were observed by contaminating the lubricating oil and making a groove and small flats on the outer race. And some bearings were operated at overload condition and allowed to fail. The bearings were operated by draining out the lubricating oil led to the seizure. Finally, they have observed that it is unreliable to depend only on one parameter to detect bearing damage. And recommend for a number of tests by examining the RMS, Peak level, crest factor, geometric and arithmetic mean [1].

Tandon et al. have been studied on condition monitoring and vibrations in bearings are to identify the defects or faults in bearing elements. The early detection of defects in bearings to prevent the machinery from many mechanical failures by using vibrations produced in them. The vibration levels may

differ based on the size of the defects that are produced in a bearing. The factors that are observed during the testing are standard RMS, height, crest thing, electricity and disorder quefrency (1/f), and stage within the cepstrum of the vibration acceleration sign. Shock pulse measurements (SPM) have been also performed. The test was conducted on the test rig in which a shaft of required dimensions was supported by two supporting bearings lubricated on both ends. The bearing to be tested is fitted at the end of the shaft and a load of 50 kg is applied radially by a lever type arrangement. The shaft was rotated at 1500 rpm. The bearing to be tested is compared with a defect less bearing. The diameter of the contact area is reduced due to defect then the contact stresses are increased resulting in higher vibrations. The high resonant-frequency accelerometer and electronic industries. Voltmeter used to measure vibration signals and peak value [2].

Scheon et al. have been studied on motor bearing damage detection using stator current monitoring. The main aim of this study is to find the defect in bearings used in induction motors. The bearing failure is one of the main reason for many mechanical failures in The factor that affects the quality of a bearing mainly is brinelling. The brinelling and erosion of bearing materials is due to improper fitting and maintenance and by using improper lubricants contaminated with water, acid and other metal fragments especially in adverse conditions in industries. The current spectrum effect is used to detect the fault in a bearing element. The damaged or eroded surface produces an air gap which in return produces a number of vibrations with frequencies while functioning. The bearings are subjected to various heavy loads radially. These frequencies and a series of harmonics are used to detect the fault by stator current monitoring [4].

Chaudhari et al has studied about the vibration analysis for bearing fault detection in electrical motors. He has predicted that the bearing failures are the most common factor for motor failures. The vibrational analysis is most widely used technique to find the bearing failure. The bearing defects are classified into ways as local and distributed defects. The wavelet transform is used to extract the variety of signals at different frequencies and resolutions. The wavelet transform is obtained in two types. They are continuous and discrete wavelet transforms. The experimental test was conducted on three different bearing of same geometry. The first bearing was tested with no defects and the next two bearings are tested with some defects on outer race and ball of the bearings and a load of one kilogram applied radially on each bearing. The vibrational signals that are obtained by using accelerometer are examined with FFT and discrete wavelet transform(DWT). Based on the bearing size and geometry, the defects will generate vibrations at particular frequencies. The DWT has shown good performance than FFT in detecting the faults using wavelet analysis [5].

Mao Kunli et al had studied about the fault diagnosis of rolling element bearing based on vibration frequency analysis. In research they predicted that the bearings are most commonly used parts in the machines and rolling elements. The bearing failure leads to the ultimate failure of the machine operations. The vibrations produced by a bearing in a centrifugal machine. The accerolometer are used to observe the vibrational at particular points. This vibrational signals are examined along with time domain waveform by using frequency analysis to find the bearing fault. The bearing defect will generate and increase vibration levels more than normal. By employing condition monitoring method, the bearing faults can be identified instead of periodic replacement. The permanent monitoring cannot be applied each and everywhere due to its cost and maintenance. So, instead periodic monitoring is preferred mostly. The high frequency and low frequency band analysis is used to find extremity and location of bearing defect. By applying improper lubrication systems leads to increase in noise levels, wear and tear of bearing elements [6].

Gupta P et al(2017) had studied about fault detection analysis in rolling element bearing. He had observed that rolling element bearings are most commonly used to support machine components such as shaft, sleeve etc. These bearings are subjected to heavy loaded conditions during operation. So it is necessary to find the bearing defects before it completely fails. The vibrational analysis and condition monitoring are commonly employed to find the bearing defects due to its cost effectiveness. The defects in the bearings are classified into types. They are distributed and localized defects, such as manufacturing defects, improper installation, cracks and wear.

The bearing components contact each other during operation and generate different vibrational signals. The common factors for causing vibrations are variable compliance, geometrical imperfection (due to poor manufacturing process), surface roughness, waviness and any defects in the raceways increases the vibrational levels. And these sources of defects may also occurs due to improper lubrication system. The vibrational signals are collected and examined both in time domain approach and frequency domain approach. The time domain approach is more capable than frequency domain approach for detecting the bearing failure [3].

Boudiaf. A et al (2016) had studied about the vibrational analysis techniques for fault detection and diagnosis in bearings. He had realized that bearings are most commonly used parts to support components like shafts, sleeves, connecting rods etc. In this paper, he had explained about the

pros and cons in condition monitoring of bearing defects. The bearing failure leads to the shutdown of machine operation and breakage of machine components. In this experiment the test rig consist of an induction motor and dynamo connected with the help of a torque transducer. The vibration signals are collected from the bearing which contains defects at inner and outer raceways, ball defect at particular speeds(rpm) by using accelerometer.

The vibrational signals are examined with frequency analysis technique to detect the bearing faults. He also used envelope analysis which consists of many stages like filtration of signals and envelope extraction to locate the defects. The short-time Fourier transform(STFT) and empirical mode decomposition(EMD) techniques are used to observe non stationary and non linear vibration signals along with these many other techniques such as wavelet transform, Wigner-ville distribution(WVD) are also employed. So a greater care must be taken on condition monitoring of rolling element bearing [7].

R.B.W.Heng And M.J.M Nor Presents A Study On The Application Of Sound Pressures And Vibration Signals To Detect Presence Of Defects In Bearings Using Static Analysis Method. The Static Parameters Such As Crest Factor And Distribution Of Moments Including Kurtosis And Skew Are Utilized To Perform Calculations Of Statical Parameters A Programme Developed Using C++ Language. The Effect Of Shaft Speed Can Also Be Studied.

The Results Also Reveal That No Significant Advantages In Using An Beta Function Parameters. The Exception In Case Of Rolling Element Defect Where Results Obtained from Vibration Signals and Sound Pressure Signals are Different. Presence Of Rolling Element Line Defect Can Be Identifying By Both Sound And Vibration Signals. Detailed Study Indicates That Results Are Less Sensitive Therefore Leading To Poor Performance. When Shaft Speed Is Between 1500 Rpm (25HZ) And 2500 Rpm(416HZ).The Sensitivity Of Test Bearing Housing Components to a Longitudinal Vibrations that Excites Fixing Rings which Holds Test Bearings In Housing [8].

M.C.padden P.D et al studied about an a few utilities of synchronous average to vibration monitoring of rolling component bearings. The high-frequency vibration has demodulated the usage of a rectifier and LPF, to attain a low-frequency signal. The amplitude spectrum of this signal, called the envelope spectrum. However, damage causes due to some lines which are an increase in amplitude while others decrease, which makes a spectrum extra difficult to interpret. Those approaches of synchronous averaging offer this kind of functionality by way of providing vibration data for tracking of gears. By using the usage of these methods, the condition of different elements of inner or outer race needs to be in comparison. When a defect is found in inner race is less than angular separation between rolling elements. In this experimental investigation includes about a test rig and test bearing. The impulses obtained as stall strikes can clearly been seen on the rolling elements can visible clearly, so we can conclude that the spectrum of broadband calculated from time signal. Above experiment shows the synchronous average of envelope signal from an resonance at20.4 HZ up-to 475 averages synchronized by the shaft rotation. By employing an technique described in this paper for windowing of an envelope signal, the average synchronous can be obtained. It describes the information about distribution of defect around inner face. By increasing a bandwidth can be improved the resolution, giving an sharper peaks. It is possible by applying an radial load to remove this interpretation by windowing an vibration signal [9].

Ya Jiang et al studied about the fault detection of rolling bearings in different process. They chose that Empirical Wavelet Transform (EWT) and chaotic oscillators are the best methods to find out the fault detection of the bearings. The rolling bearing plays an important roll in any machines. So finding the fault detection to the rolling bearing is very important. In this method every fault are represented by differently. This method is very simple and it is very easy to the operator to operate. While compared with other methods the EWTDO (Empirical Wavelet Transform Duffing Oscillator) is more feasible to operate . In the process of fault detection the most difficult think is reliably decouple compound faults. The EWTDO will gives the best result and gives the accurate values and finds the fault differently without mixing. To work with EWTDO requires much knowledge to the operator. In this paper the wavelet analysis is most important think. In this paper they proposed a EWTDO for fault detection first time [10].

In the induction motor rolling bearing are the place a critical role so the monitoring there conditions is very important. The common mode of failures of an induction motor is the bearing failure followed by starter winding and rotter bar failures. For the condition monitoring on bearings there are many methods they are vibration measurements, temperature measurements, shock pulse method (SPM) and acoustic emission (AE). In this they are the test ring is used for the condition monitoring of the bearings. in this they find the defects by vibration velocity and by using the stator current signals , in this he explained the minimum and maximum defects sizes in the outer race of the bearing [11].

In this Brandon van hecke ,jaeyoon , david he presents the methodology for low speed bearing fault diagnosis using acoustic emission sensors . the study of various methodology of on monitoring of the bearings shows that the neural networks by using vibrational data of the bearing test ring .

The low speed has been referred to as in the range from 0.33Hz to 10Hz. The first methodology used in heterodyne based frequency reduction technique. We can by the spectral averaging of AE signals. The time synchronous averaging (TSA) is used for vibration in a gear fault diagnosis. For more efficiency in the test the vibration of bearings by quantifying AE signals [12].

Bellini et al studied about the conditional monitoring on bearings which is used in the induction machines by using vibration or current signals. In this paper they focused on the relation between the torque and amplitude of current components. In bearings the faults very from 40% to 90% mostly depends upon the type and size of machine. It includes a mechanical behavior of radial bearings.

In generally for healthy condition also there is a cause of vibration because of the geometry and elasticity of components . Vibration is a complex harmonic motion . In case of imbalance the vibration in radial detection via piezometric accelometer measures directly. The resulting defect can be a fluting with rough surfaces or shallow groove which is running perpendicular to outer race. In three phase stator circuits the failure will be occurred in symmetrical to the outer raceway. Only in specific operation condition the current signal are reliable to detect bearing faults [13].

F.K.choy and M.J.Braun studied about the examination of vibrations and damage occurred due to bearing balls. Normally, overall results are occurred due to experimental setup such as rotor test rig which includes specified measured damages mostly influence in bearings which has supported rolling elements. By experimental investigations shows not only modified Poincare but also an exact pinpointing of damage. Mostly results are detected by using variation of frequency in spectral analysis which uses time signal in Fourier.

G.In this we can use statical method, which is already develops for vibration analysis.by using values of phase and amplitude due to vibrations, the average of these two values can gives Poincare map. In this to develop the relationship between bearing damage to its amplitude and quality of vibration many experiments are conducted practically on ball bearings by increasing the area of damage the width of peak also increases. In this the overall study say the exact damage of ball bearings can be determined by using the Poincare map which is modified. Degree of damage can be noted by using the above information [14].

Frosiniet. alhad studied about the induction motors in which different types of faults in ball bearings are takes place, by using b reference as stator current and efficiency of motor. Induced stator current and efficiency of various indicated motors to be used in different uses are proposed in this paper. Over all this paper, we should assume that results are obtained experimentally by using four different types of defects occurred in ball bearings: like cracks obtained in outer race, outer race shell holes, change in seal and corrosion. By, using various studies and analysis, we can conclude that rolling bearings are main reasons for defects in induction motors. Bearings or motor cases of vibration monitoring is used for carrying mostly diagnostics of bearings. By, using various studies we found that effective fault detection in induction motors is analysis of stator current. The efficiency of motor is reduced by using an increasing in friction losses

By using this paper we can found difference in defects at any point defect and roughness produced generally to be found out easily .Over all this paper suggests that when this type of faults are produced an undetermined conditions in current spectra and vibration signals takes place. the considered faults have produced a decrease in motor efficiency. When we observe outer race the cyclic faults obtained gives the effects on current spectrum which is already noticed. By, this we conclude that for this type of faults usage of stator current analysis is to be very difficult. The stator current can be used as Indication of efficiency by considering load as constant [15].

S.A.Mcinerny and Y.Dai explained about the usage of basic signals obtained due to vibrations which is used for detection of faults in ball bearings. In this paper it is focused and studied about the operational characteristics of ball bearings, and also fault frequencies are to be calculated by using required formulas and calculations which are mentioned. No signal processing or Fourier analysis background is assumed. In this paper they made bearing diagnostics as alternate for usage of applications in spectral analysis. By using Matlab they combined the graphs together for using development to start and assume signals processing techniques which are used in ball bearings.by this experiment we conclude that Load carrying capacity of roller in which it transfer the load is higher than that of ball bearings which do not carry load.

In this paper they discussed about to reduce a poor lubrication in many required cases. During usage ball bearings are hold together. Mostly, in the usage of carrying high amount of loads are the general applications by, using above analysis they conclude that this study of spectral analysis is developed for usage of further courses. The short comings of useful spectral analysis are used by using normal signals under matlab environment. Finally to assume bearing faults a set of graphs are driven together as a procedure. Main aim is to useful for preparation of spectral analysis [16].

Tabel1: The investigation on various bearing system using Vibrations - Condition Monitoring system.

Studied on	Methods used	Major Find out	Ref
Electric motor	Discrete wavelet transform (DWT) and using wavelet analysis	Classified into two ways local and distributed defects	[5]
Electric motor using stator current	Spectrum effect		[4]
Centrifugal machine	Time domain	Vibrational signals are examined along with time domain waveform by using frequency analysis	[6]
Rolling elements in machines	Time domain and frequency domain		[3]
Electric motor	The Short-Time Fourier Transform (STFT), empirical mode decomposition(EMD),Wigner-ville distribution(WVD)	Explained about pros and cons	[7]
Bearing in machines	Sound pressure and vibration signals	They studied for effect of shaft speed	[8]
Application of synchronous averaging to vibration monitoring of rolling bearing	Envelope spectrum	It describes the information about distribution of damage around inner face	[9]
Rolling bearing	Empirical wavelet transform(EWT) and duffing oscillator(EWTDO)		[10]
Induction motor	Shock pulse method(SPM) and acoustic emission (AE)	They find out defects by vibration velocity and by using the stator current signals	[11]
Low speedbearing fault diagnosis	Acoustic emission sensors	Neural networks by using vibrational data of the bearing test ring	[12]
Bearing faults in induction machines	Vibrational and current signals	theoretical development of correlation between torque disturbances and amplitude of current components	[13]

III .CONCLUSION

The study on condition monitoring of bearings using vibrations describes the bearing performance and failure. This type of vibrational analysis mainly done to find the defects and faults in bearing .the bearings are the crucial component in many machines and failure of the machine. The bearing faults are classified into two type's local and distributed defects. The manufacturing defects, improper installation, cracks and wear contribute to the bearing failure. The condition monitoring of bearing is a cost effective method to find the bearing defect instead of periodic replacement.

IV. FUTURE WORKS:

Future research will focus on developing advanced and efficient signal processing techniques using wavelet transformation and Matlab programming to relate signal features to specific bearing faults. Also, further experimental investigations will be conducted on an improved bearing test bed study. Our future research is focused on the analysis of the bearing system and to enhance and inspect the condition monitoring system to provide early defect warning capabilities to a wide range of rolling element bearings and manufacturing equipment.

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REFERENCE: -

[1] Mathew, J. and Alfred son, R.J., 1984. The condition monitoring of rolling element bearings using vibration analysis. Journal of vibration, acoustics, stress, and reliability in design, 106(3), pp.447-45

[2] Tandon, N., 1994. A comparison of some vibration parameters for the condition monitoring of rolling element bearings.

[3] Gupta, P., & Pradhan, M. (2017). Fault detection analysis in rolling element bearing: A review. Materials Today: Proceedings,4(2),2085–2094. doi:10.1016/j.matpr.2017.02.054

[4] Schoen, R.R., Habetler, T.G., Kamran, F. and Bartfield, R.G., 1995. Motor bearing damage detection using stator current monitoring. IEEE transactions on industry applications, 31(6), pp.1274-1279.

[5] Chaudhari, Y. K., Gaikwad, J. A., & Kulkarni, J. V. (2014). Vibration analysis for bearing fault detection in electrical motors. 2014 First International Conference on Networks & Soft Computing (ICNSC2014). doi:10.1109/cnsc.2014.690668

[6] Mao Kunli, & Wu Yunxin. (2011). Fault Diagnosis of Rolling Element Bearing Based on Vibration Frequency Analysis. 2011 Third International Conference on Measuring Technology and Mechatronics Automation. doi:10.1109/icmtma.2011.337

[7] Boudiaf, A., Djebala, A., Bendjma, H., Balaska, A., &Dahane, A. (2016). A summary of vibration analysis techniques for fault detection and diagnosis in bearing. 2016 8th International Conference on Modelling, Identification and Control (ICMIC). doi:10.1109/icmic.2016.7804187

[8] Heng, R.B.W. and Nor, M.J.M., 1998. Statistical analysis of sound and vibration signals for monitoring rolling element bearing condition. Applied Acoustics, 53(1-3), pp.211-226.

[9] McFadden, P.D. and Toozhy, M.M., 2000. Application of synchronous averaging to vibration monitoring of rolling element bearings. Mechanical Systems and Signal Processing, 14(6), pp.891-906. [10]. Jiang, Y., Zhu, H. and Li, Z., 2016. A new compound faults detection method for rolling bearings based on empirical wavelet transform and chaotic oscillator. Chaos, Solitons & Fractals, 89, pp.8-19.

[11] Tandon, N., Yadava, G.S. and Ramakrishna, K.M., 2007. A comparison of some condition monitoring techniques for the detection of defect in induction motor ball bearings. Mechanical systems and signal processing, 21(1), pp.244-256.

[12] Van Hecke, B., Yoon, J. and He, D., 2016. Low speed bearing fault diagnosis using acoustic emission sensors. Applied Acoustics, 105, pp.35-44

[13] Immovilli, F., Bellini, A., Rubini, R. and Tassoni, C., 2010. Diagnosis of bearing faults in induction machines by vibration or current signals: A critical comparison. IEEE Transactions on Industry Applications, 46(4), pp.1350-1359.

[14] Choy, F.K., Zhou, J., Braun, M.J. and Wang, L., 2005. Vibration monitoring and damage quantification of faulty ball bearings. Journal of Tribology, 127(4), pp.776-783

[15] Frosini, L. and Bassi, E., 2010. Stator current and motor efficiency as indicators for different types of bearing faults in induction motors. IEEE Transactions on Industrial electronics, 57(1), pp.244-251.

[16] Kankar, P.K., Sharma, S.C. and Harsha, S.P., 2011. Fault diagnosis of ball bearings using continuous wavelet transform. Applied Soft Computing, 11(2), pp.2300-2312.