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Excitation forcing function in rotating machinery experimentally investigated

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Abstract

One of the main defects in the rotating machine's crystallographic failure is bearing fault. These rotating machine flaws will cause an excitation force, also known as a dynamic imbalance force, which is what excitation forcing functions are. Also, a variety of parameters influence the size of these excitation forcing functions that are induced in the rolling element bearings. And the causes include problems with the bearings, belt deterioration, misalignments, leaks, etc. The failure of rotating machinery is mostly caused by the unbalance excitation forcing function brought on by bearing failures. It is possible to study in depth the vibration spectrum analysis for each of these defects in particular for the excitation forcing function. The excitation forcing function in the rolling element ball bearing is investigated using a novel experimental method in this research. And from the vibration spectrum obtained based on the frequency domain, the excitation forcing function is formulated. These actions are taken in consideration of two different forms of ball bearing failures, including faults in the inner race and the outer race when compared to healthy bearings. And this experimental investigation will provide a precise evaluation of the imbalance excitation force that causes rolling bearing defects to fail in rotating machinery.

*Keywords:*Excitation forcing functions, Rotating machinery, Bearing faults

1. Introduction

Many approaches and hypotheses are being examined by several studies in order to explore and pinpoint the excitation forcing function that bearing problems in rolling element bearings cause. A fairly frequent form of issue is the imbalance excitation force brought on by bearing problems in rotating machinery.

The vibration condition monitoring approach, which is frequently used to assess this issue of imbalance force, can precisely pinpoint the primary cause of bearing failures in rotating machinery. The cost of maintenance may be cut based on the industry's adoption of vibration condition monitoring. Preventing and managing the early failure of rotating machinery due to bearing defects is a crucial and important component of the maintenance programme. Several wavelet theories, including continuous, discrete, and wavelet packet transforms, have recently been examined, along with their application to bearing failures, using both analytical and experimental methods [1–7]. And in relation to the time domain, these crucial frequency domains will display various speed ranges and ways of deformation. This time-frequency vibration spectrum does more than just amplify the machine signal. It will be possible to extract the numerous imbalance excitation forces and their impact on the machine's health status by magnifying the signal from the time to frequency domain. It is possible to determine the machine's health accurately. Moreover, both the numerical and finite element methods can be used to carry out the frequency-time spectrum decomposition. A non-linear dynamic mathematical investigation of rolling bearing element for the various localized defects that is outer, inner race studied subject to stability of the bearing element and the rotating machinery for layout a framework of monitoring the health of the machine [9-10]. In this work, experimental approach for investigation of the impulse excitation forcing functions in ball bearings subjected to the defects for the case of outer and inner race. This is done with effect radial load on the faults for amplitude variations of impulse force over the time span. The impulse force generated due to radial load acting the defect zone will have wide range of frequency spectrum and respective harmonics value. And also the BPFI and BPFO are calculated in this frequency spectrum side band.

2. Experimental test rig

In this experimental test rig as shown in the figure 1, the rotating machinery used in the electric motor with speed range up to 3000rpm.Speed of electric motor coupled shaft between the motor and ball bearings is measured using the laser tachometer to see the effect of speed on the faults in rolling element ball bearings and the vibration spectrum obtained from the machines. The electric motor shaft is connected to the rolling element ball bearings in the bearing housing. And the external load is applied to the rolling element bearing using the dead weights on the other end shaft connected to the electric motor. The bearing housing is provided with option to replace the bearings with the different types of bearing condition sets to analysis the faults in the rotating machinery due to the rolling elements. The bearing conditions sets are three types that are without any defects that are healthy bearing, outer race defect bearing and also inner race defect bearings. For the rolling element ball bearings the defects are created artificial using the electric discharge machine.

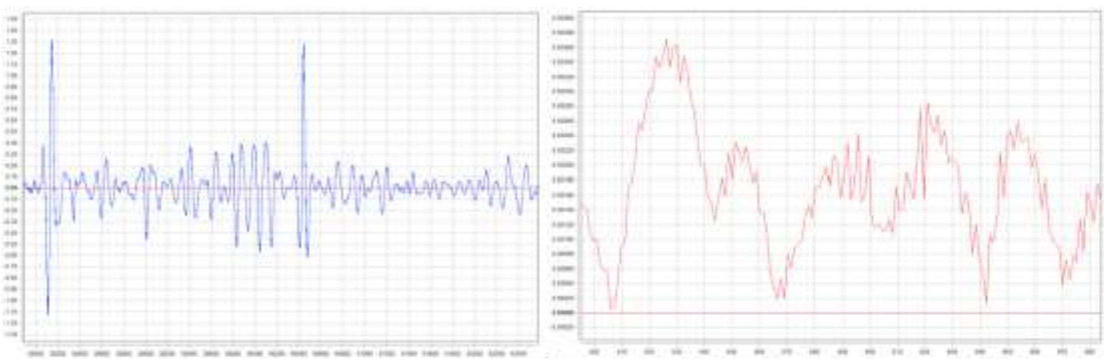
Figure 1 Experimental test rig and rolling element ball bearings

Ball bearing model UCP204 and the parameters for outer and inner diameter is 48 mm and 18 mm, pitch diameter is 38 mm.The ball bearings used in the test rig, with artificial faults that is outer and inner race is shown in the figure 1. Piezoelectric usb accelerometer 330 mV/g sensitivity as shown in figure 2 .To measure vibration spectrum from the rolling element ball bearings are obtained along the two x and y axis. This accelerometer is interfaced with DAQ through the usb port, in turn the data are recorded using an application Ei-calc algorthim.This algorithm covers the wide range of points in vibration signal recorded in a cycle, allowing to include the various range of harmonics and spectral values.

Figure 2: Piezoelectric usb accelerometer

3. Results and Discussion

The test rolling element ball bearings used in experimental test rig is subjected to the dynamic load on other end of the shaft electric motor. These dynamic load acting on the shaft and ball bearings enable to induce the radial load of 500N, due to these radial load acting on the bearings will involve the two components of force along the x and y-axis with function of time. The forcing function will have cosine and sine angle components in the resolving forces of the radial load. Radial load effect on the outer and inner race defect are recorded in term of time and frequency domain obtained for rolling element bearings. The balls pass frequency inner and outer are important parameters to define the impact of the forcing function over the defects locations. The excitation forcing functions f(t) analysis with respect faults in rolling elements ball bearings that is outer and inner race are characterized by the time and nature of signal obtained like triangular, impulse, which is interaction to the time. And these ball pass frequency inner and outer (BPFI & BPFO) are correlation to the amplitude of force. The amplitudes of excitation forcing function is depend on the defect position and location, subjected to the radial load the amplitudes of force varies with a angle of defect position in the rolling element ball bearings.



Healthy Bearings time-frequency spectrum

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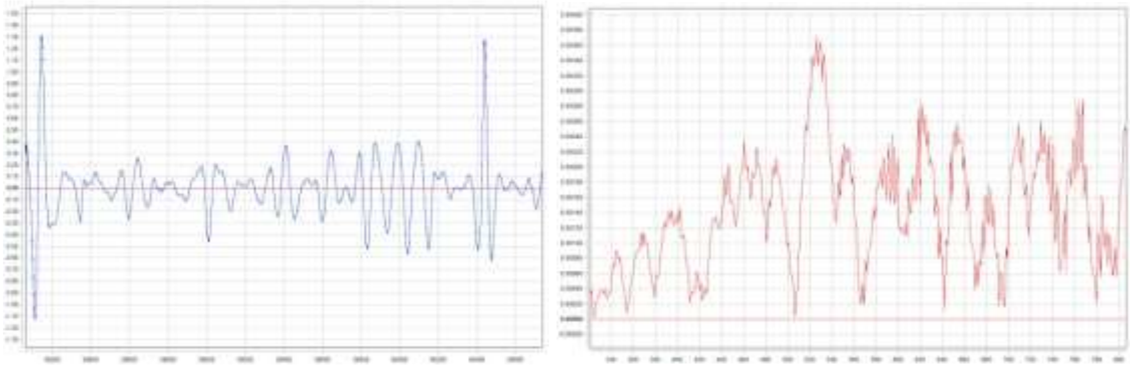
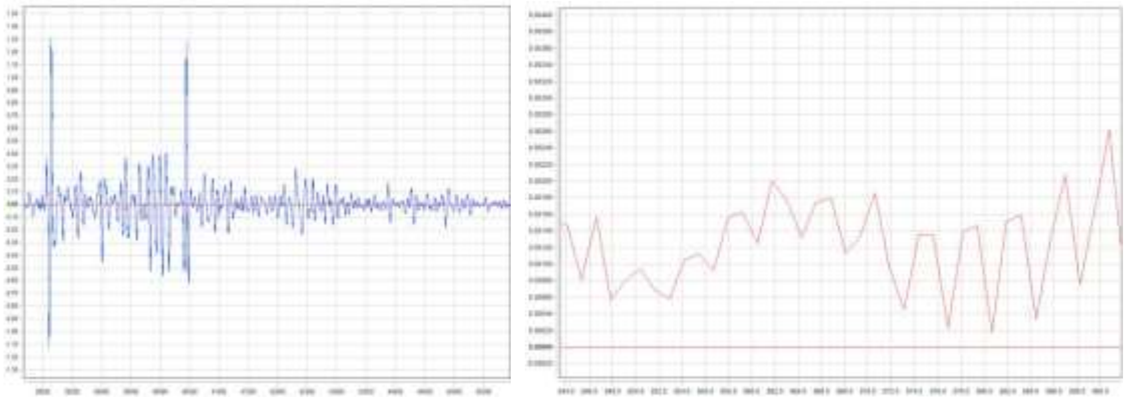


Outer race time-frequency spectrum



Inner race time-frequency spectrum

Figure 3: Time-frequency spectrum for the healthy, inner and outer defects

The speed of the rotating machine electric motor is varied speed from range of 400,800 and 1200 rpm respectively. Variation in speed change the harmonic and amplitude of excitation force along the time-frequency spectrum as shown in figure 3.The harmonics values of the healthy, inner and outer race with speed will affect the amplitude of impulse force and also BPFI and BPFO frequency is represented in the spectrum is 65, 76.5 and 98 Hz. And also the inner and outer race defects size will affect the impulse force over the time period and increase the amplitude of frequency.

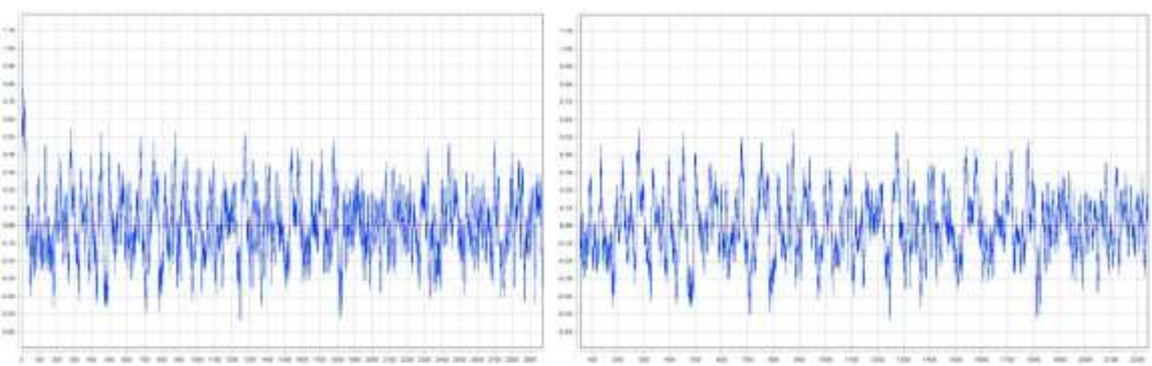


Figure 4: Size effect in frequency spectrum for inner and outer defect region

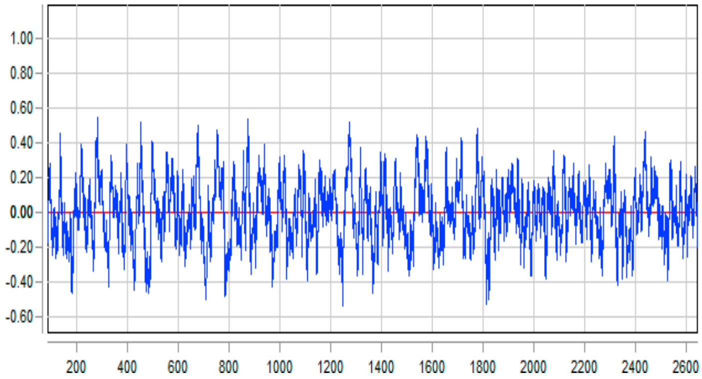


Figure 5: Frequency spectrum for outer defect region

The rate of impulse excitation force is function of time that impact the radial load in the region of defect region varies with time for inner race is 0.0012 sec and outer race region is 0.013 sec, were as in healthy bearing rate of impulse force amplitude is zero. The variation of frequency spectrum and impulse force for the rolling element ball bearings with time rate over the defect faults increase with size of defects, and this variation of frequency spectrum as shown in above figure 4 and 5.

4. Conclusions

To determine the peak value of the impulse excitation force, the experimental investigation excitation forcing function for rolling element ball bearing defects that are outer and inner races subjected to radial load involving the force components along x-y axis direction decomposition is carried out. According to the location of the defect subjected to radial load, the frequency spectrum recorded from the ball bearings in this investigation includes a wide range of peak values of impulsive force. And together with frequency sidebands, this peak value of excitation force in the frequency spectrum also represented the BPFI and BPFO values. With increasing defect size, the excitation forcing function value is shown to grow in the spectrum analysis.

5. Reference

[1] Ruqiang Yan, Robert X.Gao, Xuefeng Chen. "An Wavelets for fault diagnosis of rotary Machines: A review with applications", Journal of Signal Processing 96(2014)1–15, Elsevier

[2] Khadersab A , Dr.Shivakumar S "Parametric vibration Analysis of Rotating Machinery", Journal of Tribology IConAMMA , Materials Today: Proceedings Elsevier

[3] Erik Swanson. "A Practical Review of Rotating Machinery Critical Speeds and Modes", Journal of Sound and Vibration, May 2005, Elsevier

[4] Agnes Muszynska. "Vibrational Diagnostics of Rotating Machinery Malfunctions", International Journal of Rotating Machinery 1995, Vol. 1, No. 3-4, pp. 237-266

[5] P.Borghesani, R.Ricci, S.Chatterton, P.Pennacchi. "A new procedure for using envelope analysis for rolling element bearing diagnostics invariable operating conditions", Mechanical Systems and Signal Processing,38 (2013)23–35, Elsevier

[6] N. Harish Chandra, A.S.Sekhar. "Fault detection in rotor bearing systems using time frequency techniques", Mechanical Systems and Signal Processing, Elsevier

[7] Jinglong Chen, YanyangZi, Zhengjia He, Jing Yuan. "Compound faults detection of rotating machinery using improved adaptive redundant lifting multi wavelet", Mechanical Systems and Signal Processing,Volume 38, Issue 1, 5 July 2013, Pages 36-54, Elsevier.

[8] Jinglong Chen, ZipengLi ,JunPan , GaigeChen , YanyangZi, JingYuan , Binqiang Chen , Zhengjia He . "Wavelet transform based on inner product in fault diagnosis of rotating machinery: A review", Mechanical Systems and Signal Processing Volumes 70–71, March 2016, Pages 1-35, Elsevier

[9] W. Cioch, O.Knapik, J.Les´kowa. "Finding a frequency signature for a cyclostationary signal with applications to wheel bearing diagnostics", Mechanical Systems and Signal Processing 38(2013)55–64, Elsevier

[10] Zhipeng Feng, MingLiang, Fulei Chu. "Recent advances in time–frequency analysis methods for machinery fault diagnosis: review with application examples", Mechanical Systems and Signal Processing 38(2013)165–205, Elsevier.

[11] Junhong Zhang, Wenpeng Ma, Jiewei Lin, Liang Ma, XiaojieJia "Fault diagnosis approach for rotating machinery based on dynamic model and computational intelligence", S0263-2241(14)00425-4, Elsevier

[12] Christ of Sihler, "A novel torsional exciter for modal vibration testing of large rotating machinery", Mechanical Systems and Signal Processing 20 (2006) 1725–1740, Elsevier

[13] I.A. Kougioumtzoglou, V.C. Fragkoulis, A.A. Pantelous, A. Pirrotta, "Random vibration of linear and nonlinear structural systems with singular matrices: A frequency domain approach," Journal of Sound and Vibration 404 (2017) 84–101, Elsevier

[14] Genfeng Lang , Jing Lin , Yuhe Liao, Ming Zhao "Impact of system anisotropy on vibration reduction of rotating machinery and its evaluation method", Mechanical Systems and Signal Processing 93 (2017) 299–311, Elsevier

[15] Yaguo Lei, JingLin ,Zhengjia He, Ming J .Zuo. "A review on empirical mode decomposition in fault diagnosis of rotating machinery", Mechanical Systems and Signal Processing 35(2013)108–126, Elsevier

[16] S. Khanam, N. Tandon, J. K. Dutt. "Fault size estimation in the outer race of ball bearing using discrete wavelet transform of the vibration signal", Procedia Technology 14 (2014) 12 – 19, Elsevier

[17] Renata Klein. "Comparison of methods for separating vibration sources in rotating machinery", Mechanical Systems and Signal Processing, 29 March 2017, Elsevier

[18] R.B. Randall, J. Antoni, S. Chobsaard. A "The relationship between spectral Correlation and envelope analysis in the diagnostics of bearing faults and other cyclo stationary machine Signals", Mechanical Systems and Signal Processing (2001) 15(5), 945}962, Elsevier

[19] Linfeng Deng, Rongzhen Zhao. "A vibration analysis method based on hybrid techniques and its application to rotating machinery", Measurement 46 (2013) 3671–3682, Elsevier

[20] Binqiang Chen, Zhou Suo Zhang, Yan Yang Zi, Zheng Jia He, Chuang Sun. "Detecting of transient vibration signatures using an improved fast spatial–spectral ensemble kurtosis kurtogram and its applications to mechanical signature analysis of short duration data from rotating machinery", Mechanical Systems and Signal Processing 40(2013)1–37, Elsevier

[21] Dongyang Doua, Shishuai Zhoua, "Comparison of four direct classification methods for intelligent fault diagnosis of rotating machinery", applied Soft Computing Volume 46, September 2016, Pages 459–468, and Elsevier