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Experimental Investigation of Defective Ball Bearings with Vibration Analyzer

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Abstract

Ball bearings provide rotational freedom and support for transmitting the load between two ends of machine. Roller bearing defect is a major factor of failure in rotating machinery that affects its proper functioning which results in substantial time and economic losses. Therefore, condition monitoring of roller bearing is important and the study of severity of defects are necessarily required in order to avoid catastrophic consequences. The analysis of signal resulting from measurements taken from outer machineries has proven to be effective, by detection of failure in bearings over rotating shaft. The authors have used a method based on the vibration analysis for detection of defects in rolling element bearings with single or multiple defects on different components of the bearing structure using the time and frequency domain parameters. A dynamic loading model is used in order to create the rotary motion of bearings. A vibration analyser is used for vibration diagnosis and on-site measurements of the model. Vibration analysis has been done at the free end of shaft .In non-defective bearings the variation of velocity was found to be smooth and decreasing with respect to time, whereas an interruptive upward trend was there in defective ball bearing which is very useful in detecting defects in rolling ball bearings.

1. Introduction

Roller element bearing condition monitoring has received considerable attention for many years because the majority of problems in rotating machines are caused by faulty ball/ roller bearings. The typical failure mode of rolling element bearing is localized defects, which occur when a sizable piece of material on the contact surface is dislodged. Elasto-hydrodynamic pressure is developed between rolling element. Faulty bearings produce unwanted vibrations and noise. If not detected can lead to critical damage. According to Feiyun [1] and many others, different amplitude contributions of the alternate load and determinate load will cause different envelope spectrum expressions. Zhenhuan [2] provided a comprehensive overview of tilted misalignment on loading characteristics of cylindrical roller bearing. Jing-Shan [3] , successfully provided that gyroscopic moment could not bring any direct damage to the rollers and raceways and also concluded that it provided the boundary conditions to induce the side damage of rollers and raceways when the parameters of a bearing are not properly designed. De Zhu[4] , used null space pursuit and S transform to detect the faults of the bearing vibration signal. Patricia [5] applied the Teager-Kaiser energy operator in order to detect faults in bearings. The diagnosis was performed with two classifiers; a neural network classifier and a LS-SVM classifier. Min-Chun Pan [6] presented a new concept based on the empirical mode decomposition (EMD) to choose an appropriate intrinsic mode function (IMF) for the subsequent envelope analysis of ball bearings. This method ameliorated the need to examine all resonant frequency bands during diagnosis P. Borghsani [7], provided and tested a procedure for the application of envelope analysis to speed transients. The effect of load variations was also studied Generalised empirical mode decomposition method was used by Jinde [8] for rolling element fault diagnosis. Peter [9], enhanced the fault signatures from weak bearings by using a sparsity measurement based optimal wavelet

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filter that provided more flexible centre frequency and bandwidth for covering a bearing resonant frequency band Amarnath [10], used acoustic signals acquired from near field area of bearings in good and simulated faulty conditions for the purpose of fault diagnosis in bearings Bubathi [11] proposed a simple time series method for bearing fault feature extraction using singular spectrum analysis (SSA) of the vibration signal by decomposing the acquired signals into an additive set of principal components Jinshan [12] introduced multifractalde trended fluctuation analysis (MF-DFA) to analyze bearing vibration data and did fault diagnosis of rolling bearing based on MF-DFA and Mahalanobis Distance Criterion (MDC Choon-Su[13] used Minimum Variance Cepstrum (MVC) for observation of periodic impulse signal from faulty bearings in automotives under noisy environment A quantitative diagnosis of a spall like fault of a rolling element bearing was done by Shuan Feng [14] by using empirical mode decomposition and the approximate entropy method, whereas, Kankar[15] used cyclic autocorrelation and wavelet transform for diagnosis and Pandya[16] presented intrinsic mode function of acoustic emission data using APF-KNN for bearing fault analysis. Another researcher Luan[17] used a new strategy based on fusion of different Support Vector Machine(SVM) in order to reduce noise effect in bearing fault diagnosis. Edurado[18] conducted a series of in-situ test with defective and healthy wheel hub bearings to find that most of the methods used in this test are well suited for analysis Upadhyay [19] addressed Rolling Contact Fatigue (RCF) that occurred due to the result of cyclic stress developed during operation and mechanism that involves in fretting failure of rolling element bearing Similarly ,Gurumoorthy [20] investigated failure of tapered roller bearings Monavar[21], used an experimental setup and analysed vibration signals and predicted defects in roller bearings. According to HimanshuSaxena [22] Ball bearings of suitable low starting and good operating friction are used. They should have ability to bear radial and axial load. Bearings should be sensitive to interruptions in lubrications and should not have starting problems at low temperatures.

2. Experimental Setup

An experimental test model is used to predict defects in roller bearings as shown. The test model consists of a shaft with motor attached to its end. Shafts having radial loading are provided the positioning with accuracy and stability. The design incorporated two coupling discs and two roller bearing attachments over rotating shaft. The whole system is placed on base frame which has shock absorbing springs attached on its legs .The unique feature of the model is that independent motor drives the system. This permits the damaged and undamaged bearing signals to be observed simultaneously. Essential parts of ball bearings are inner race, outer race, the balls, and the separator. The inner (or ring) is fitted on a shaft and has a groove in which the balls ride. The inner race rotates with the same speed as that of the shaft. The outer race is usually a non-rotating member and also has a groove to guide and support the balls. The separator prevents the contact between the balls and thus reduces friction, wear and noise.

The roller bearing is tested at constant speed of 1500 rpm with cylindrical roller bearing of type SKF 1205 EKTN9. The details of the bearings used in present analysis are given in table.

Two types of bearing defects, namely, ball defect and outer race defects were studied. Experimental tests were carried out on two sets of bearings. Initially new bearing (good bearing) was fixed in the test rig and signals were recorded using VibeXpert II. The good bearing was replaced by defective bearing and signals were recorded for each one of the case separately under the same standard condition. Time domain analysis and vibration spectrum analysis were carried out. Time waveform indicates severity of vibrations for defective bearings and vibration spectrum identifies exact nature of defects in bearings.

2.1 Figure and Table

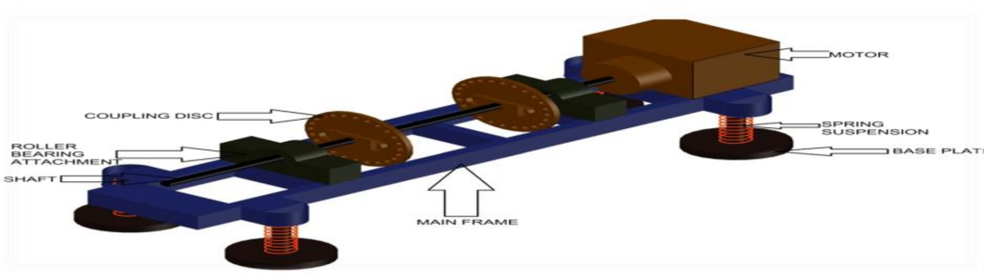

Fig: 1. CAD model of experimental setup. A vibration analyzer is attached on the roller bearing attachment on the free end of the rotating shaft

Table: 1. Roller Bearing Specifications

Bearing Model	SKF 1205 EKTN9
Clearance	Standard
Brand	SKF
Limiting Speed	18000 rpm
Width	15 mm
Outside Diameter	52 mm
Inside Diameter	25 mm
Bore Type	Taper
Mass	0.14 Kg

2.2 Results and discussions

The overall vibrations signals of the free end bearing in good bearing position and defective bearing position are shown in Fig. 2, 3 and 4.

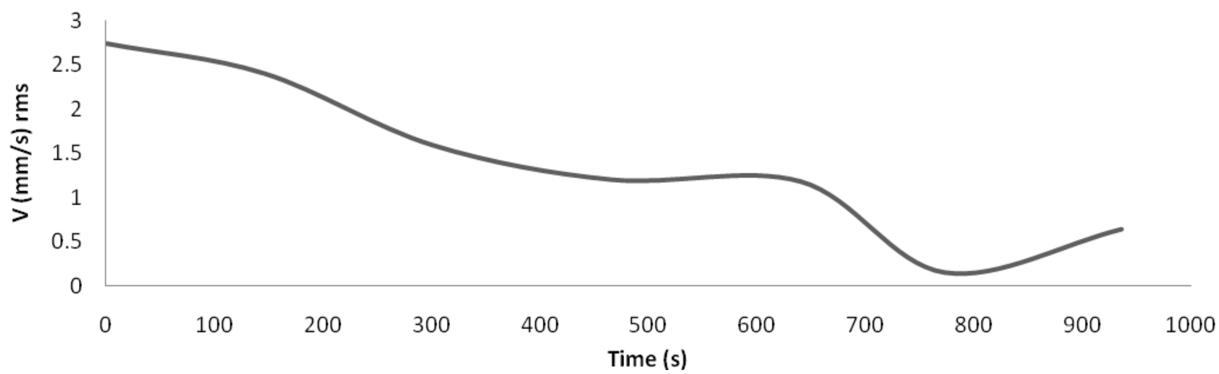

Fig: 2. Overall vibrations of the free end bearing in good bearing position

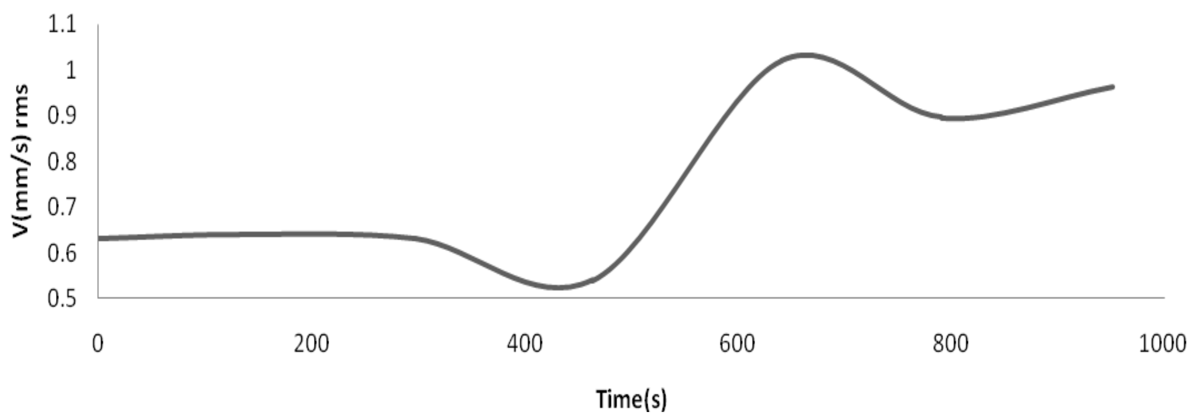

Fig: 3. Overall vibration of the free end bearing in bad bearing position with Outer Race defect

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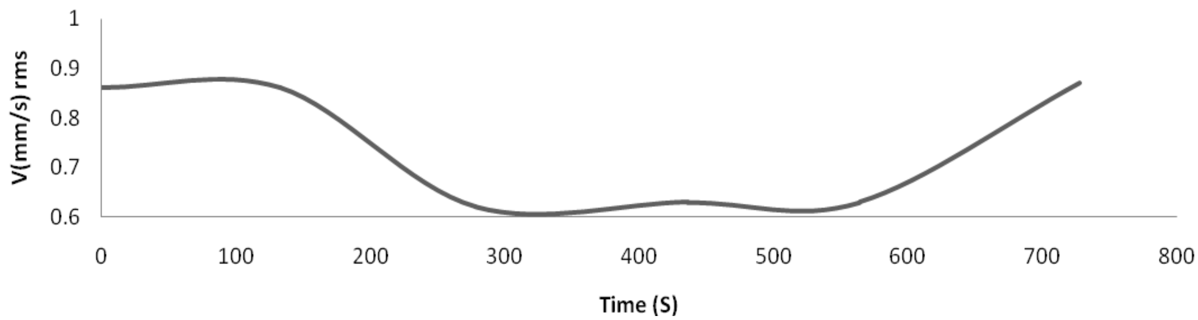

Fig: 4. Overall vibrations of the free end bearing in bad bearing position with ball defect

The magnitude of signals in form of V (mm/s) RMS for Good Bearing is significantly different from that of Defective Bearing. V rms for good bearing is around 2 mm/s while for bearing with Outer Race defect it is around 0.64 mm/s and for bearing with Ball Defect it is around 0.7 mm/s at around 220 seconds at 1500 rpm

The peak to peak values values of velocity at different frequencies are plotted for the three types of bearings in Fig. 5,6 and 7:

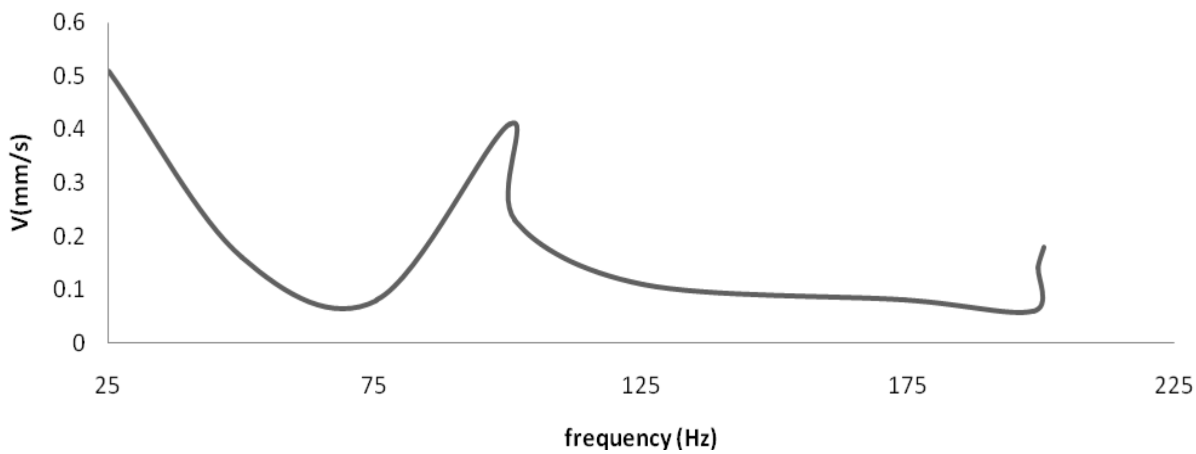

Fig: 5. Peak values of velocity in a Bearing with Ball Defect

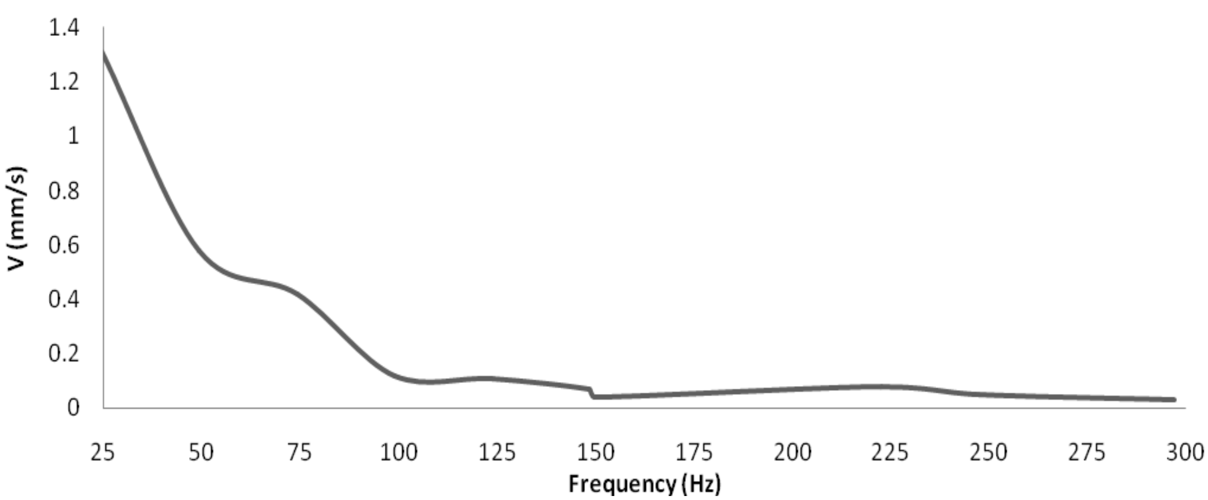

Fig: 6. Peak values of velocity in a Defect-Free Bearing

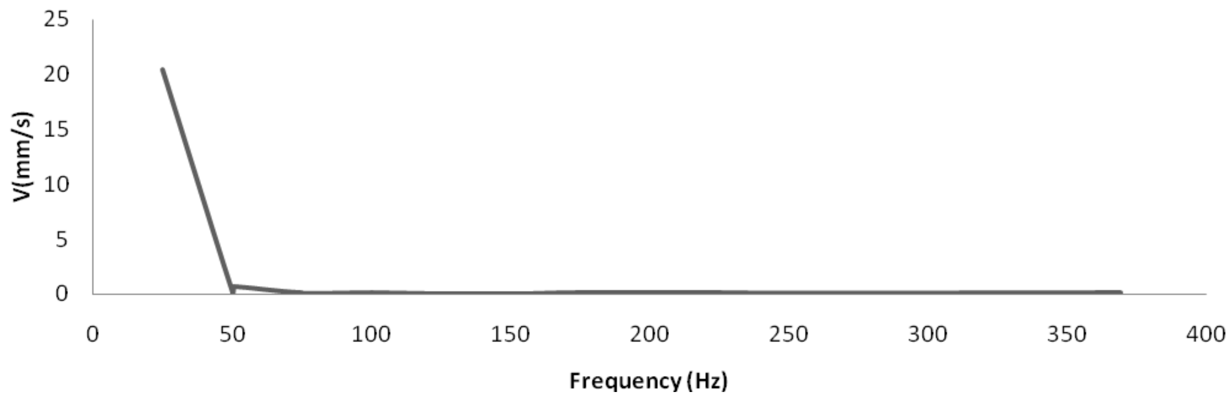

Fig: 7. Peak value of velocity in a bearing with Outer-Race Defect

In order to asses the clarity in different defects in bearings the peak values of spectrum have been shown in Fig. 5,6 and 7 for good bearing , bearing with Ball defect and bearing with Outer Race defect at 1500 rpm. The magnitude of spectrum at various harmonic frequencies for defective bearing is found to be quiet distinct in comparison to good bearings.

3. Conclusion

Trend of overall frequencies and vibration spectrum provide useful information to analyze defects in roller bearings. Trend indicates severity of vibration in defective bearings. Vibration domain spectrum identifies amplitudes corresponding to defect frequencies and enables to predict presence of defects, i.e, ball defect and outer race defect. The distinct and different behavior of vibration signals from bearings with ball defect and outer race defect helps in identifying the defects in roller bearings.

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