American Journal of Mechanical Engineering, 2019, Vol. 7, No. 3, 146-150
Available online at http://pubs.sciepub.com/ajme/7/3/5
Published by Science and Education Publishing
DOI:10.12691/ajme-7-3-5

Study Various Defects of Ball Bearings through Different Vibration Techniques

Nouby M. Ghazaly[1,*], G. T. Abd el- Jaber[1], Nadica Stojanovic[2]

[1]Mechanical Engineering Department, Faculty of Engineering, South Valley University, Qena-83521, Egypt
[2]University of Kragujevac, Faculty of Engineering, 6 Sestre Janjić STR., 34000 Kragujevac, Serbia
*Corresponding author: noubyluxor@gmail.com

Received July 28, 2019; Revised August 30, 2019; Accepted September 22, 2019

Abstract The main objective of this study is to evaluate ball bearing defects under different operation conditions through vibration measurements. There are several tests conducted for healthy and defective bearing under variable speeds and load conditions. Experimental tests are conducted for six sets of ball bearings. Initially, a good bearing is fastened in the test rig and vibration signals are measured using the FFT analyzer to show the base-line performance of a healthy bearing. Then, the good bearing is exchanged by defective bearing and vibration signals are measured for each case separately under the same operation condition. Frequency domain, time domain and root-mean-square are used to describe various bearing defects. The experimental results are showed that each one of these methods is useful to identify the bearing problems. Also, the results proved that the significant variation in the root-mean-square at different rotational speed.

Keywords: *condition monitoring, defective bearing, time domain, frequency domain analysis, root-mean-square*

Cite This Article: Nouby M. Ghazaly, G. T. Abd El-jaber, and Nadica Stojanovic, "Study Various Defects of Ball Bearings through Different Vibration Techniques." *American Journal of Mechanical Engineering*, vol. 7, no. 3 (2019): 146-150. doi: 10.12691/ajme-7-3-5.

1. Introduction

In the past years, vibration-based condition monitoring of rotating machinery has been mostly considered from a signal processing point of view. But very little attention has been paid to the effect of the fault on the bearing's vibration behavior [1]. Recently, detection of a rolling element fault is one of the most challenging tasks in bearing health condition monitoring, especially when the fault is at its initial stage. The defects in bearing unless detected in time may lead to malfunctioning of the machinery. The defects in the rolling element bearings may come up mainly due to the following reasons; improper design of the bearing or improper manufacturing or mounting, misalignment of bearing races, unequal diameter of rolling elements, improper lubrication, overloading, fatigue and uneven wear [2]. Therefore, the detection of these defects at an early stage without machine disassembly is important for condition monitoring, quality inspection, and predictive maintenance. Various methods are used for the diagnosis of bearing defects. The methods are broadly classified as acoustic measurements, current and temperature monitoring, wear debris detection, and vibration analysis [3,4].

The bearing defects may be classified into localized and distributed defects. Waviness, Surface roughness, and misaligned races are considered the distributed defects. The localized defects are pits, cracks, and spall induced by fracture on the rolling surface. The main reasons of these defects may result from abrasive wear or manufacturing error [5,6,7,8].

Recently, vibration analysis is utilized for condition monitoring and quality inspection in the industry fields. Since the vibration of rotary machines is considered as the first indicant for parts failure [9]. The most common defect signal is generated between the interaction of a damaged area and a rolling surface regardless of the fault type. Accordingly, the vibration analysis can be employed for the diagnosis of the localized or distributed faults. Moreover, low-cost sensors, simple set ups, accurate results, particular data on the damage location and corresponding rates of damage are the other gains of the vibration analysis [10].

From literature, one can find various techniques which have been implemented on vibration responses from bearing systems for fault identification namely; time domain analysis, frequency domain analysis and time frequency domain analysis. A brief review on the vibration approaches in time and in frequency domain can be found in Ref. [11].

The aim of this research work is the early detection of bearing faults in rotating machines under different operation conditions through vibration measurements. There are five types of bearing defects namely; bearing with outer race defect, bearing with inner race defect, bearings with rolling element defect, bearing with outer race, inner race and rolling element defect and bearing fully damage are experimentally studied. Initially, the good bearing is fixed in the test rig and signals are recorded using FFT analyzer. The good bearing is replaced by defective bearing and signals are measured for each one under the same condition. Time domain analysis, frequency domain analysis and root-mean-square are employed to describe the bearings defects.

2. Development of Bearing Test Rig

Bearing test rig is developed to provide the necessary rotation speed and applied load for evaluate different bearing defects under operational conditions. The driving unit consists of a 7.5 kW dc motor that has a maximum speed of 1500 rpm with a variable speed controller to rotate the driving shaft at different rotating speeds. Disc brake assembly is connected directly with the motor through coupling and A mild steel solid shaft of 40 mm diameter and 800 mm length, which fixed on the base by two bearing located in between motor and the brake assembly. The braking unit is used to apply the required load to disc brake system by hydraulic system and controlled by hydraulic valve to a certain value, which can be displayed in pressure gauge.

A piezoelectric accelerometer with sensitivity of 100 mV/g, which is directly mounted over the bearing through a magnetic base is used to acquire the vibration signals. The accelerometer output signal is directly fed into the dual channel vibration analyzer and is stored as vibration signatures. Time domain and frequency domain signals are acquired at different speeds and loads. The stored data in the vibration analyzer is retrieved through cable connected to the computer for further analysis using PULSE software. The bearings are tested under no load condition to obtain reference signatures. Before conducting the experiment, the test rig vibrations are measured and verified to check the misalignment. One end of the shaft is firmly fixed in the test rig and the bearings are rigidly supported on the two steady rests shown in Figure 1. The setup is run for 15 minutes to stabilize the vibration. Most ball bearings have four basic elements: inner race, outer race, rolling elements, and cage or separator has shown in Figure 2. The inner race, outer race, and rolling elements support the bearing load, while the cage separates adjacent rolling elements to avoid friction between them.

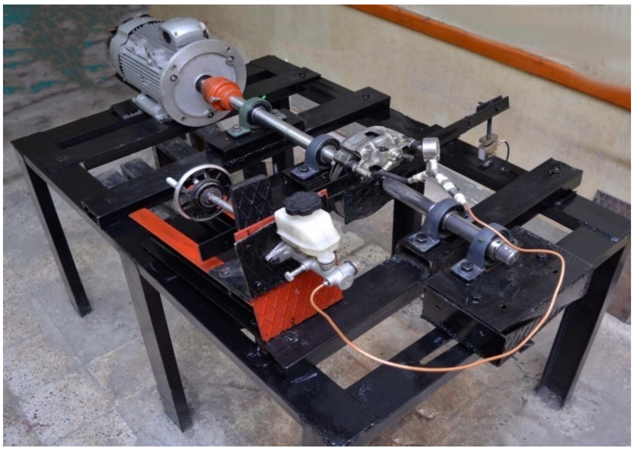


Figure 1. Ball bearing vibration test rig

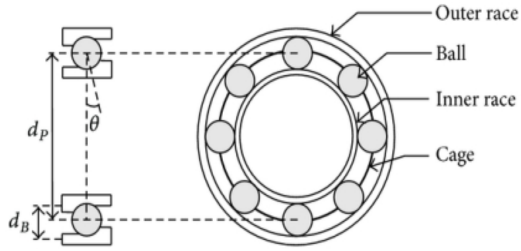


Figure 2. Schematic representation of single row ball bearing

3. Results and Discussion

3.1. Results of Time Domain and Frequency Domain

In this section, time domain and frequency domain are assessed with regard to their effectiveness in the detection of bearing condition, the procedures of the experimental methodology research are depicted in Figure 3. Initially healthy bearing (A) is fastened in the test rig and signals are recorded using FFT analyzer. Table 1 illustrate the typical waveform of the healthy bearing (A) in time domain and frequency spectrum. The vibration data are carried out under a shaft rotational speed of 800 rpm (14 Hz). It can observed that, the time domain signals displays a clear regular waveform with small peak less than 0.7 m/sec^2 in acceleration amplitude. In the frequency spectrum analysis, the largest amplitude is at the shaft running speed (14 Hz) and the spectrum of healthy bearing (A) displays no frequencies other than shaft rotational frequency.

Five types of bearing defects, namely bearing with outer race defect "B", bearing with inner race defect "C", bearings with rolling element defect "D", bearing with outer race defect, inner race defect, and rolling element defect "E" and bearing fully damage "F" are examined. Experimental tests are conducted on five sets of bearings. The healthy bearing (A) is exchanged by defective bearing. Time domain analysis and frequency domain analysis are collected through accelerometers and data acquisition system. It is found that the values of spectrum at various harmonic frequencies for defective bearing are found to be quite distinct in comparison to healthy bearing. Table 1 represents the amplitude of vibrations obtained with time, in the time domain mode and various frequencies during the frequency mode. The data shown are obtained at 800 rpm and 6 bar as applied load. It is found that each case of the ball bearing defects has a private characteristic of vibration profiles which it can be used to detect the defect types. Salem et al [12], they came to the same conclusions.

3.2. Results of Root Mean Square

For making the comparison between different defects at different rotational speed, root mean square (RMS) is used, as shown in Figure 3. It will serve as indicator of average amplitude of frequency analysis signals. Root mean square can also be regarded as a damage index. The RMS is defined as:

$$RMS = \sqrt{\frac{1}{N_s}\sum_{i=1}^{N_s} x_i^2}. \quad (1)$$

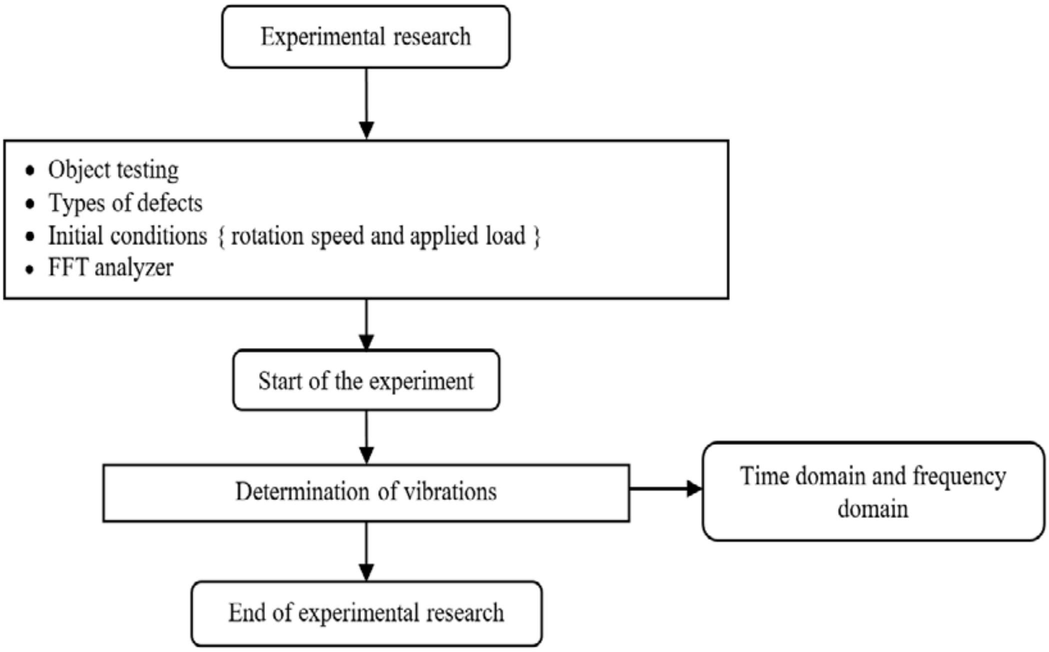
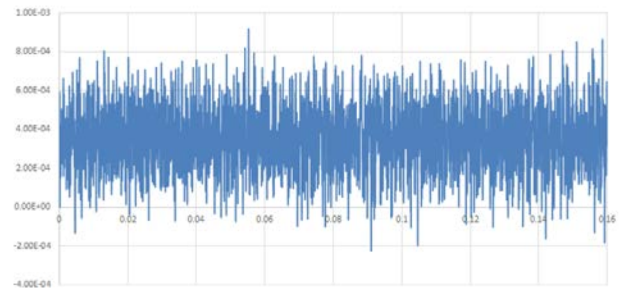
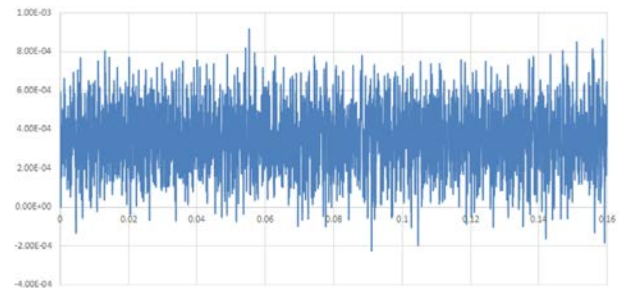
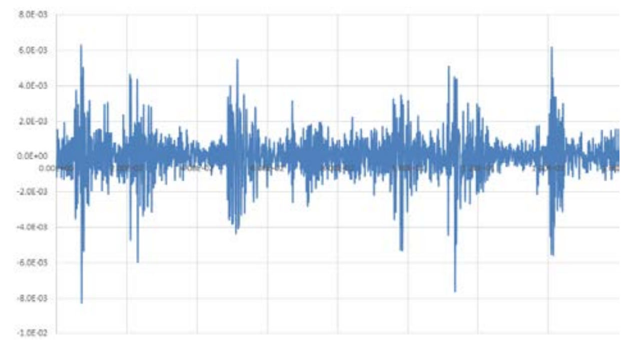
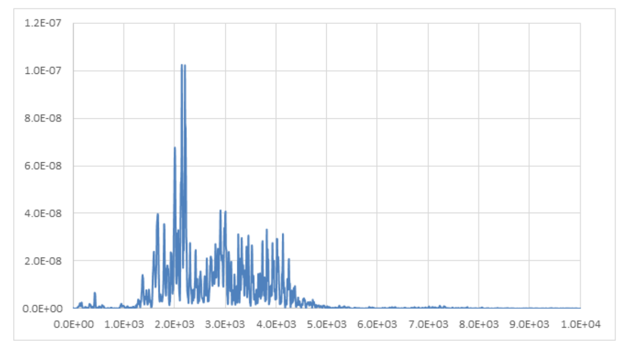
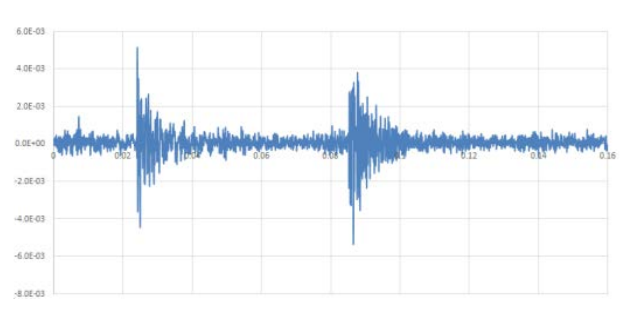
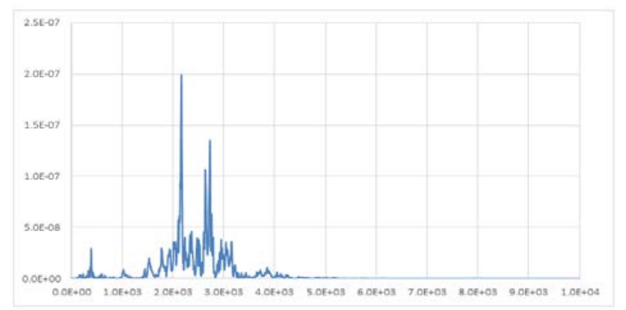
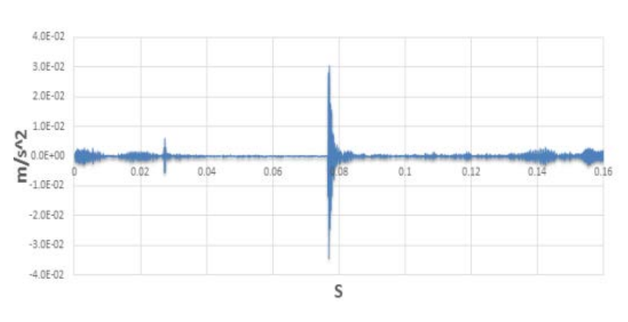
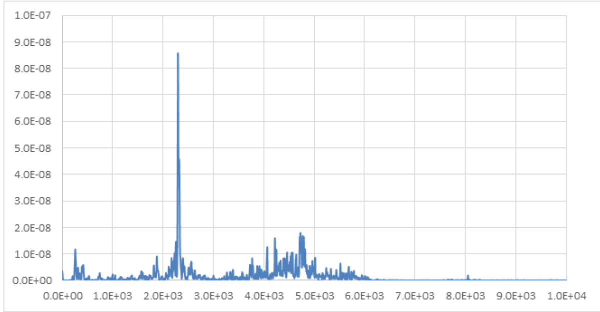
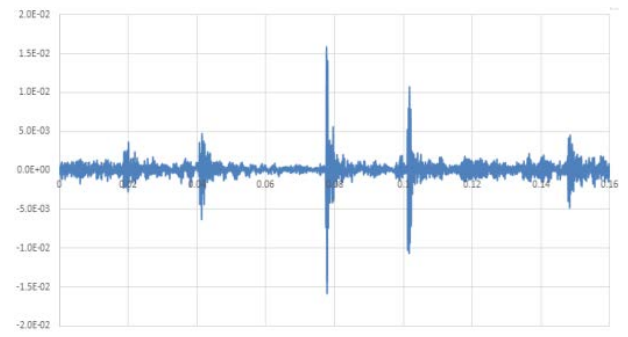
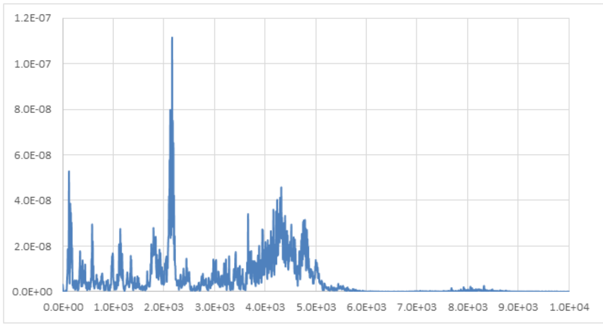
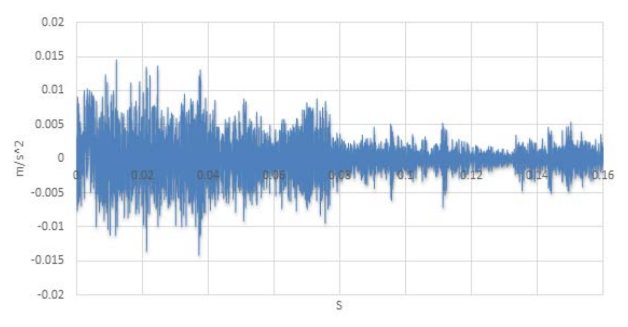
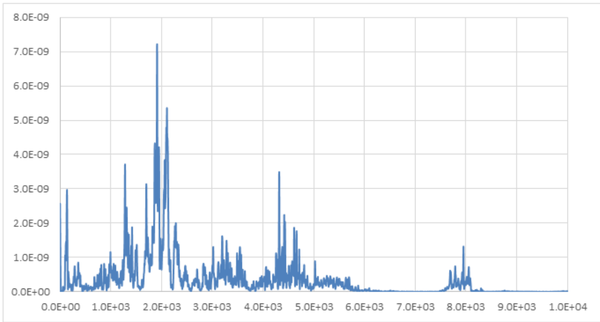


Figure 3. Flowchart of the experimental research

Table 1. Time domain and frequency domain for six bearings with different health conditions

No	Time domain	Frequency spectrum
	HEALTHY BEARING (A)	
1		
	OUTER RACE DEFECT (B)	
2		
	INNER RACE DEFECT (C)	
3		

No	Time domain	Frequency spectrum
	ROLLING ELEMENT DEFECT (D)	
4		
	OUTER RACE DEFECT, INNER RACE DEFECT, AND ROLLING ELEMENT DEFECT (E)	
5		
	FULLY DAMAGE (F)	
6		

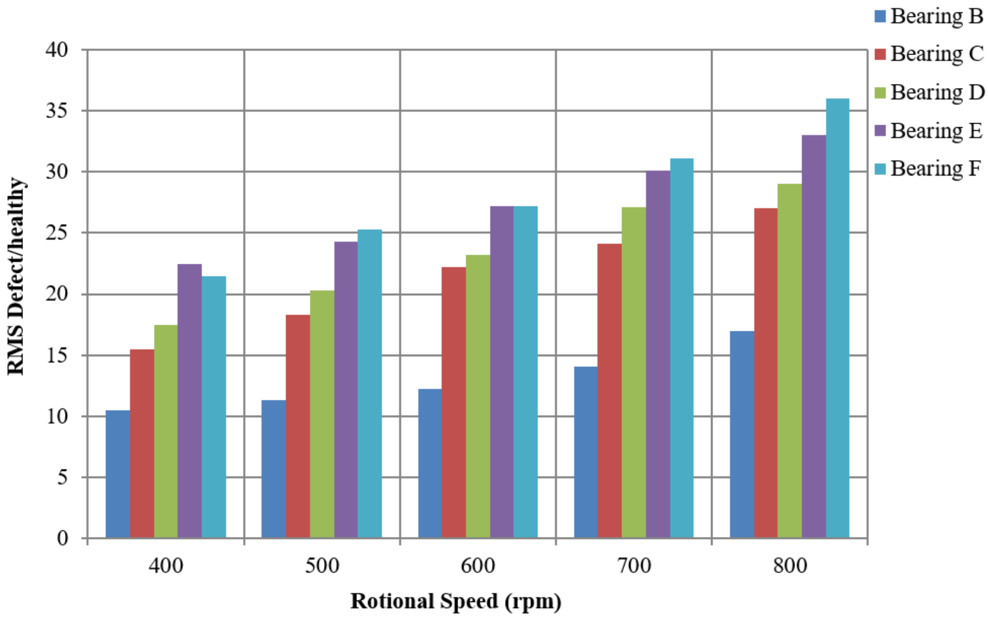


Figure 4 RMS defects at different rotational speed

3.2. Results of Root Mean Square

Each six bearings are tested under five different shaft speeds 400, 500, 600, 700, and 800 rpm. When a bearing is running at a specific shaft speed and load level, the vibration signals are collected. The vibration data are collected of all bearing conditions. The effect of various shaft rotational speeds is investigated under applied pressure of 6 bars. The *RMS* magnitude for acceleration responses for both healthy and defected bearings tends to be higher for faster shaft speed. The ratios between the statistical parameters of the acceleration responses calculated for different types of the defected bearings are shown in Figure 4 It can be found that, the "*RMS*" ratio value of the inner race defect is lower than the outer race defect and it may be due to a defect size on the inner race is less than the outer race. The *RMS* value of the bearing (*F*) is feed the highest result. It can be concluded that the increases of the vibration responses may be due to the bearing (*F*) have fully damage surfaces. Furthermore, the defect detection at low speeds may be due to the decreasing duration of the impacts and therefore invalidity of the time domain parameters at high speeds is meaningful.

4. Conclusion

Time domain analysis, frequency domain analysis and RMS have been employed to identify different defects in the ball bearings. Based on the results from the experimental work time domain and frequency spectrum provide useful information to analyze defects of ball bearings. Time domain indicates severity of vibration in defective bearings. Frequency domain spectrum identifies amplitudes corresponding to defect frequencies and enables to predict presence of many defects. The results have demonstrated that each one of these techniques is useful to detect problems in ball bearings. It is found that the magnitude of spectrum at various harmonic frequencies for defective bearing is found to be quite distinct in comparison to good bearings. The results of this paper can be used to determine the type and size of the damage that can occur in the bearing.

References

[1] Devendiran S., Manivannan K., 2016, Vibration based condition monitoring and fault diagnosis technologies for bearing and gear components-a review, International Journal of Applied Engineering Research, 11(6), pp. 3966-3975.

[2] Nabhan, A., Nouby, M., Sami, A. M., Mousa, M. O., 2015, Bearing fault detection techniques - a review, Turkish Journal of Engineering, Sciences and Technology, 3(2).

[3] Tandon, N., Choudhury, A., 1999, A review of vibration and acoustic measurement methods for the detection of defects in rolling element bearings, Tribology International, 32(8), pp. 469-480.

[4] Tandon, N., Yadava, G. S., 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.

[5] Liu, J, Shao, Y. M, Zuo, M. J, 2013, The effects of the shape of localized defect in ball bearings on the vibration waveform, Proceedings of the Institution of Mechanical Engineers, Part K: Journal of Multi-body Dynamics, 227(3), pp. 261-274.

[6] Sopanen, J, Mikkola, A, 2003, Dynamic model of a deep-groove ball bearing including localized and distributed defects, Part 1: Theory, Proceedings of the Institution of Mechanical Engineers, Part K: Journal of Multi-body Dynamics, 217(3), pp. 201-211.

[7] Sopanen, J, Mikkola, A., 2003, Dynamic model of a deep- groove ball bearing including localized and distributed defects, Part 2: implementation and results. Proceedings of the Institution of Mechanical Engineers, Part K: Journal of Multi-body Dynamics, 217(3), pp. 213-223.

[8] Abhinay, V., Dube, L.S., Dhamande, P.G., Kulkarni, Vibration based condition assessment of rolling element bearings with localized defects, International Journal of Scientific & Technology Research, 2(4), pp. 149-155.

[9] Randall, R. B., 2011, Vibration-based condition monitoring: industrial, aerospace and automotive applications, Wiley.

[10] Slavic, J., Brkovic, A., Boltezar, M., 2011, Typical bearing-fault rating using force measurements-application to real data, Journal of Vibration and Control, 17(14), pp. 2164-2174.

[11] Mathew, J., Alfredson, 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. 447-453.

[12] Salem, A., Aly, A., Sassi, S., Renno, J., 2018, Time-domain based quantification of surface degradation for better monitoring of the health condition of ball bearings, Vibration, 1(1), pp. 172-191.