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Investigations of Wear in Journal Bearings Due to Lubricant Contamination

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Abstract. Journal bearings should ideally function under a hydrodynamic lubrication regime to reduce wear and friction via sliding.Lubricant contamination by particles and moisture is the most prevalent cause of machine wear and failure. Now a day's machines are required to operate under more challenging conditions like very high temperatures or in a dust polluted environment. These conditions can adversely affect the proper functioning of rotating machine components and could impact the service life in particular journal bearings are prone to the contaminated environment and their performance can be reduced significantly due to moisture, dust particle, wear debris, or due to corrosion caused by water contamination. The present study was carried out to evaluate the cases of foreign ingested particle pollutants and water contamination using vibration monitoring techniques in the journal bearing lubrication system and aims to establish a relationship between contamination and the journal bearing vibration response to achieve an online condition monitoring of the tribological conduct of journal bearing. Besides, cases involving varying sizes and amount of particles and water contamination have been carefully investigated and demonstrated. The vibration responses of the journal bearing are obtained under various working conditions by connecting the accelerometer to the bearing housing. The results showed that in lubricating oil particle size, concentration, and water volume ratios have different degrees of impact on journal bearing performance.
Keywords:*Wear, Moisture, Lubricant contamination, Journal bearing, Vibration analysis.*

1 Introduction

Contaminations in industrial lubricating systems are common, and they can be exceedingly destructive and even fatal to particular components like bearings and pumps.Foreign objects that enter the clearance space endanger the reliability of hydrodynamic bearings. Shaft and bearing wear, as well as scoring, are common operational issues. overheating, degraded load capacity, shortened machine life, and even premature failure [1].

Journal slides within the bearing, trails lubricant, and generates hydrodynamic lift force by creating wedge flow motion. Oil film formed between the journal and bearing separates them. The clearance in between the journal and bearing is in order of microns.it is in the clearance space that contaminants get entrapped and result in bearing surface wear [2]. The rise in friction due to the interaction of the bearing-particle will cause localized heating which may lead to wiping and brushing of the surface [3]. Added to this, the absorbed contaminating particles increase the generation of internal particles, thus obstructing the lubrication system and generating starvation leading to failure [4]. The particle contaminant in a bearing is of two types external ingested particles which are sand, dust, grit and internal ingested particle which is generated due to wear and corrosion [5]. Previous research showed that, by attacking the bearing base metal and other elements of the circuit, or by mixing with the lubricant itself, water contamination can lead to lubrication failure [6]. In both situations, oil contamination with polluted water is inherently unsafe and strategies need to be sought to ensure better working conditions and longer life of bearings [7].

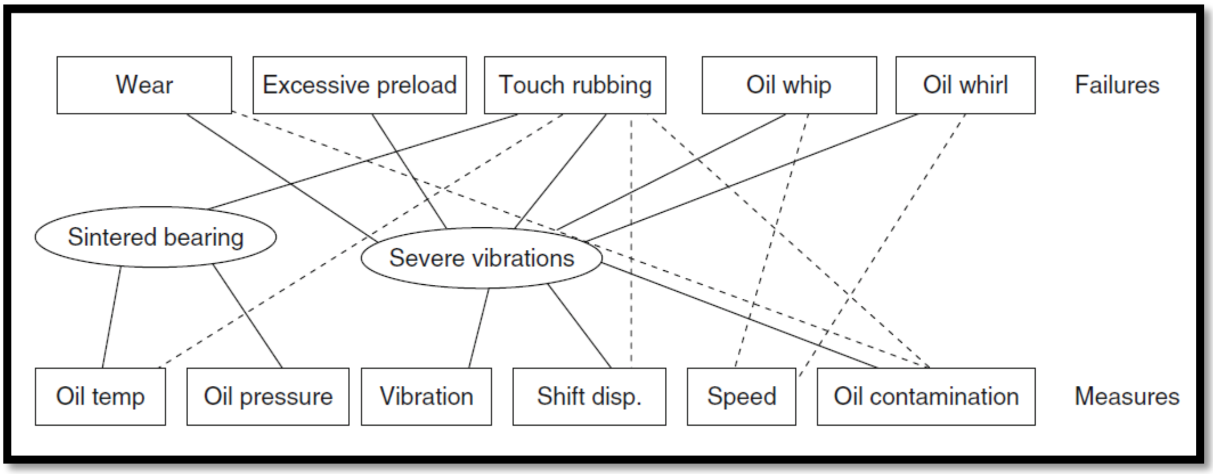


Fig.1.Schematic diagram of journal bearing

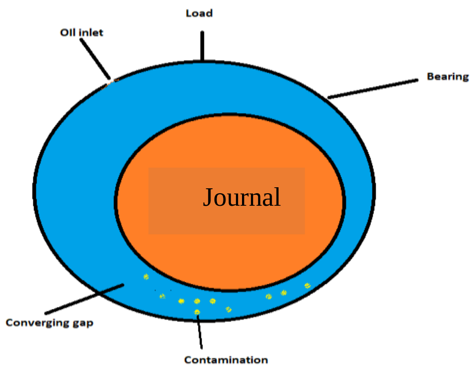


Fig. 2. Failure modes of journal bearing

Among the major detrimental effects of water, water mainly causes the lubricant to degrade itself, to resurface in a rust environment, and to reduce the boundary layer and hydrodynamic shielding [9][10]. Water may also lead to different types of damage to the journal bearing surfaces from corrosion to cavitation [11]. In the presence of hydrogen and oxygen, the Babbitt bearings, which consist mainly of lead and tin, and can easily be oxidized. Vapor cavitation is linked to the implosion of water vapor and can cause comb-like pitting on bearing surfaces [12]. Vibration analysis is a popular technique in the field of condition monitoring of machines. Monitoring of vibration signature has been widely used to gather information regarding the performance of bearings. Some fault detection analyses of bearings, such as oil whirl instability, oil whip, rubbing, and excessive preload, can be gathered from vibration signals [13]. Wear can also be predicted in the bearing surface by the use of the vibration signal. The existence of the 1X component is a significant feature of bearing wear [14]. The purpose of this article is to examine particulate contamination and water contamination in a journal-bearing lubricant (common sand particles of various sizes and weights as contaminants) by vibration techniques. Change in vibration signature level for cases involving various particle sizes concerning and the change in concentration. Features of the vibration signals such as peaks in terms of amplitude vs. frequency and spectrum gave results for the condition monitoring of bearing [15].

2 Methodology and Sample Preparation

2.1 Methodology

Vibration data of healthy bearing without contamination was first measured and after that vibration data of contaminated bearings were taken using an accelerometer which was mounted on the housing of the bearing, two oil grooves were there at an angle of 30 degrees to each other. Vibration data were obtained in the form of amplitude vs frequency graphs. The intensity of the vibrations relies on the tally of these faults and their concentrations, sizes. It should be in mind that multiple defects in various areas of the bearing surface generate the same frequency but different phases of vibration [16].

To scrutinize how the particles of various sizes and different concentrations interact with the bearing surfaces and produce vibration signals, sand particles of various sizes 10 µm, 15 µm, 20 µm,25 µm, and 40 µm and water contamination with soap, mineral, and saltwater was selected. The size of the biggest particle was not greater than 40 microns due to the clearance of the bearing otherwise the particle would accumulate in the oil grooves at the entry point of the bearing.

2.2 Sample Preparation

Sand particles of various sizes and concentrations and water of three types were mixed with the lubricant in the stirrer in a variable volume percentage of grease, the stirrer speed was 1000 RPM for 10 minutes to make it a homogeneous mixture, the dissolved air was removed by rotating mixer at 1500 for 2 minutes before any sample preparation, from different solid and liquid contamination variations [17].

Following is the table for samples:

Table 1. Sample preparation

<table>
<tr><th>Particle size (micron)</th><th>Weight of sand (grams)</th><th>Type of water</th><th>% of water (ml per ml of lubricant)</th></tr>
<tr><td>10</td><td rowspan="2">0.75</td><td>Salt</td><td rowspan="3">10</td></tr>
<tr><td>15</td><td rowspan="2">Soap</td></tr>
<tr><td>20</td><td rowspan="2">1</td></tr>
<tr><td>25</td><td>Rain</td><td rowspan="2">15</td></tr>
<tr><td>40</td><td>1.25</td><td>Mineral</td></tr>
</table>

Tests were performed for clean oil without contamination and for five separate contamination cases.

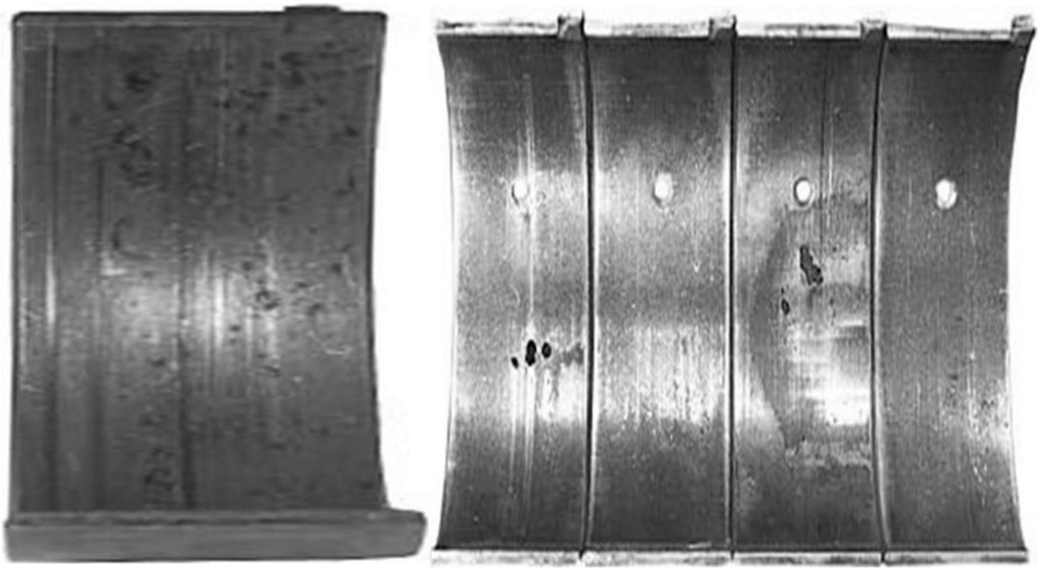
Case 1- Lubricant oil with particulate contaminant (sand) concentration of 0.75gm and size 10 μm .

Case 2- Lubricant oil with 20 μm particle size contaminant at 1 gm concentration.

Case 3- Oil with 40 μm particulate contaminant at a concentration of 1.25 gm.

Case 4- Water contamination by mineral water mixing 10% by volume in oil.

Case 5- Water contamination by mixing saltwater 10% by volume in oil.



(a) (b)

Fig. 3. (a) Solid contaminants (b) corrosive damage

3 Experimental Setup

The test rig was a machine fault simulator-rotor dynamics simulator, it has been extensively used for fault detection in machines like misalignment, unbalance, oil whirl [18]. The setup consists of two journal bearings, shaft, coupling,0.5kw motor, and accelerometer. Other accessories include an RPM calculation tachometer, a bearing oil temperature sensor, and a speed controller for the motor. To mitigate the addition of external noise in the measuring signal, rubber insulation pads were mounted under the motor, support bearing blocks, and loading lever. The photo of the test setup is shown in Fig. 2 (a).

The accelerometer is connected to the SO analyzer which analyzed the data and transfer to the computer, the computer processed the data in smart office software and gave a result in the form of amplitude vs frequency graphs.

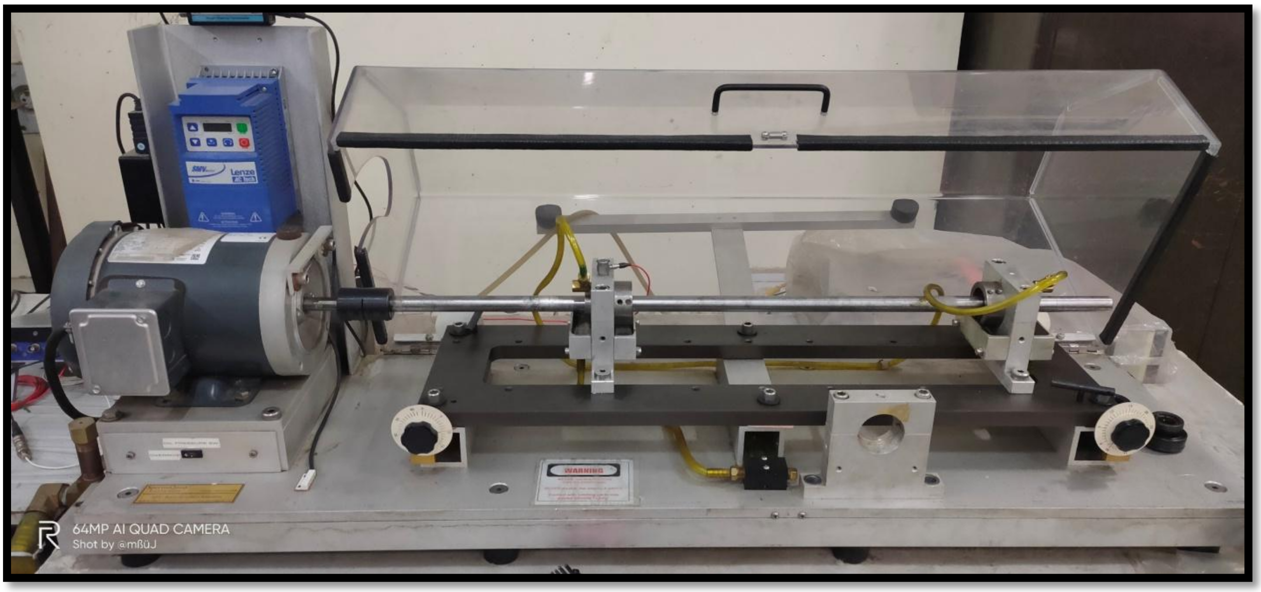


Fig. 4. MFS RDS Setup

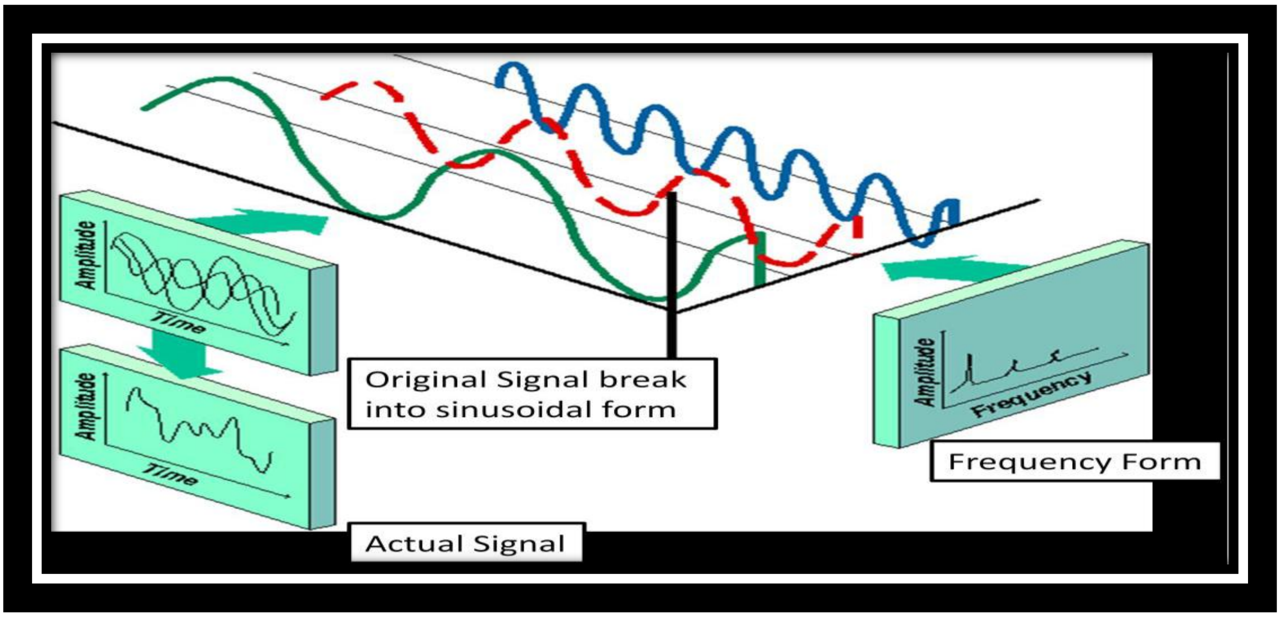


Fig. 5. FFT graph concept

4 Result and discussion

4.1 Particle size effect

The Peak of vibration in the normal operation without contamination is due to the friction of the fluid as shown in figure 4 but with the particle contamination in the oil amplitude of vibration tends to increase because the friction of oil and abrasion of particle plays a significant role as shown in figure 5.

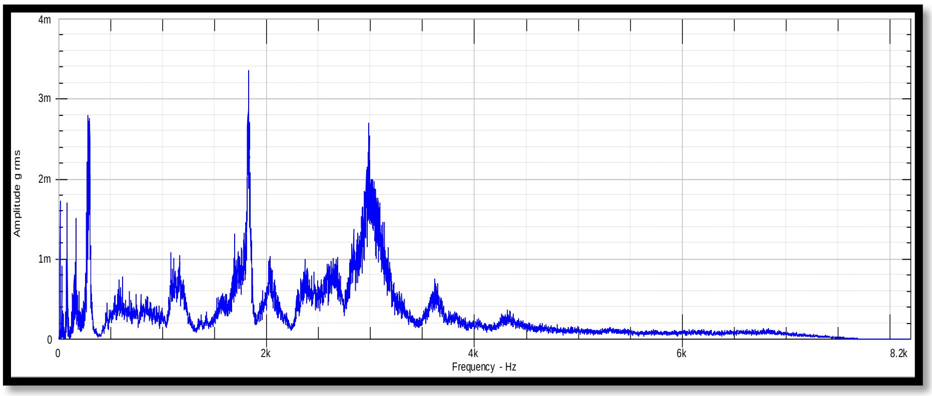


Fig. 6. Graph of amplitude vs frequency for clean oil

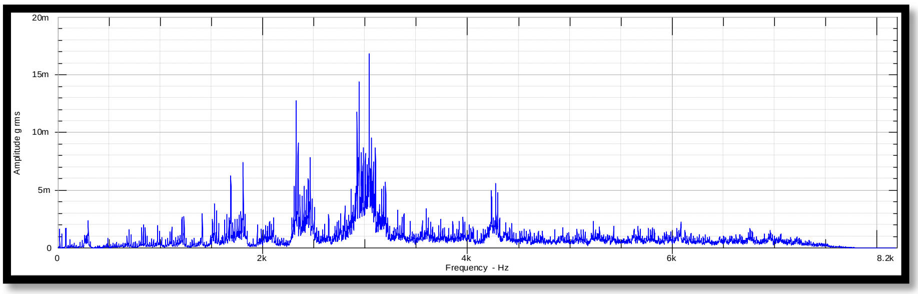


Fig. 7. Graph of amplitude vs frequency for case 1

The amplitude of vibration in case 1 is high as compared to the healthy bearing as shown in figure 4 and figure 5, vibration levels are twice as in case 1 as compared to the clean oil case which depicts particle contamination causes abrasion.

Case 2. By going with the same logic in case 2 where contaminant of 20 microns and 1 gm concentration has been used. particle size 20 micron and 1 gm concentration being smaller than clearance so it can be easily accumulated inside bearing, however it increases the viscosity of oil which further increase the friction of oil and it is clearly shown in figure 6.

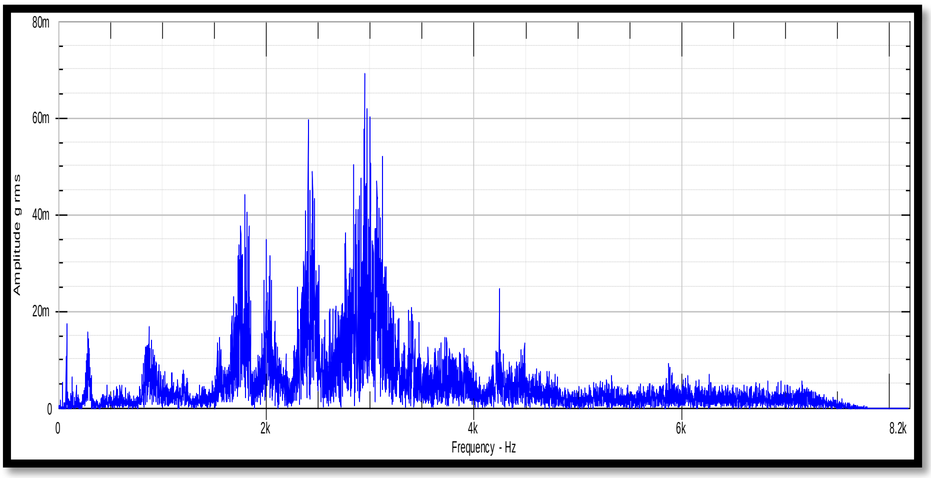


Fig. 8. Graph of amplitude vs frequency for case 2

Case 3. The effect of the contaminant concentration on vibration was different from that of the particle size in case 3 particle sizes of 40 microns and concentrations of 1.25 gm were used. The degree of vibration increased with concentration, as shown in Figure 7, which tends to stabilize to a maximum. On the other side, the vibration frequency first increased and then decreased as the particle size increased. The probable factor for vibration level reduction was the particle settling effect.

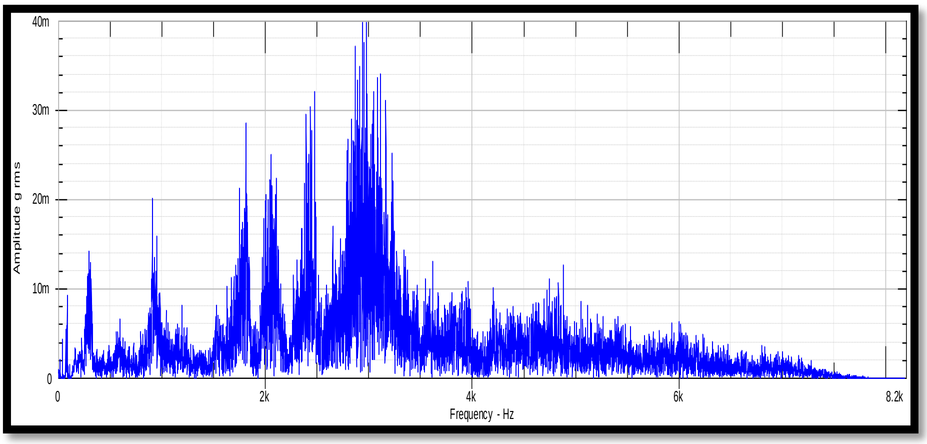


Fig. 9. Graph of amplitude vs frequency for case

4.2 Water contamination effect

In journal bearing hydrodynamic oil, the film is weakened by water in oil, which in turn contributes to excessive wear. As little as 1% of the water will decrease bearing output. significantly. under certain conditions, water is converted into its constituent element i.e., hydrogen and oxygen [19]. hydrogen being the small ion can absorb on the bearing surface resulting in a phenomenon called hydrogen embrittlement [20]. Water causes damage to the bearing surface by corrosion in very little time. In cases 4 and case 5 mineral water and saltwater have been used, from the experimental data and graph, it is found out that extreme bearing damage is caused by saltwater than mineral water.

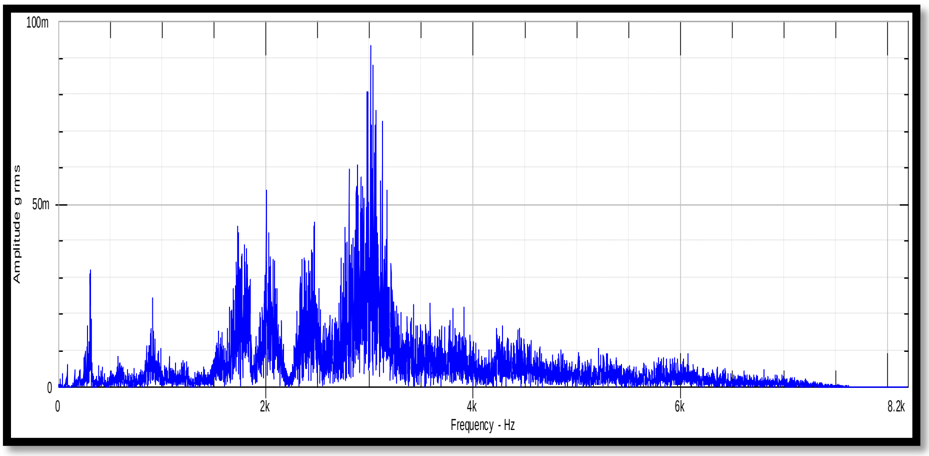


Fig. 10. Graph of amplitude vs frequency case 4

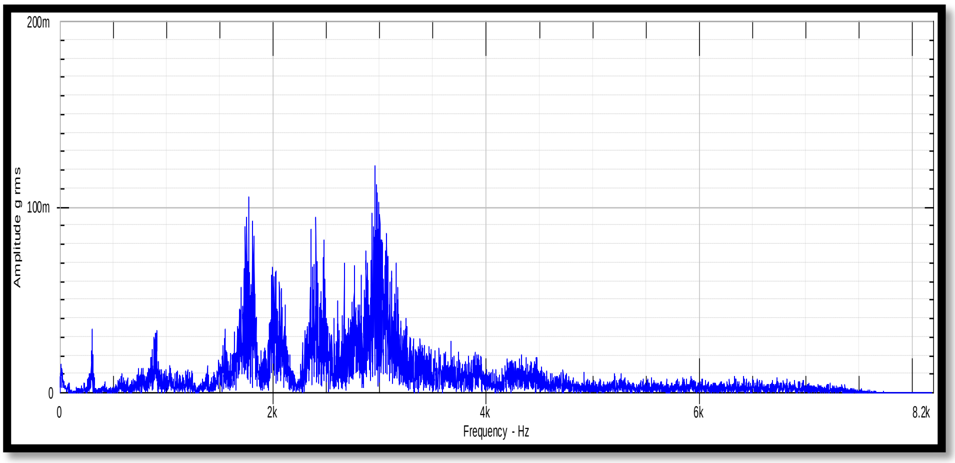


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Fig. 11. Graph of amplitude vs frequency of case 5

5 Conclusions

The data obtained are preliminary in nature, but they clearly illustrate that the presence of pollutants increases bearing part wear. The data gathered at this point demonstrates that the methodology used in the experimental investigation is satisfactory.

As particle concentration increased, the vibration caused by particles was proportionate to the vibration of the worn bearing. Particles smaller than H(min) pass through the bearing clearance at first, but when particle concentration increases in the H(min) zone, they begin to contact with the surface, and the wear phenomenon starts.

Moisture contamination lowers lubricant quality and causes the separation of machine surfaces that a healthy, dry lubricant provides to be lost.Water has several negative impacts, including causing the lubricant to degrade, resulting in a corrosive environment and reduced boundary layer and hydrodynamic protection. Water also adds to corrosive and cavitation damage to journal-bearing surfaces in many ways.

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