VIBRATON SIGNATURE ANALYSIS OF TAPER ROLLER BEARING WITH DIFFERENT HOUSING MATERIALS

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Abstract: Rolling element bearings are indispensable mechanical components. There are different types of housing material which can be used according to the purpose. This study has been undertaken to analyze the vibration of different housing materials i.e. Mild steel and Bakelite. For this study frequency and time domain approach is used. The bearings are tested under different speeds for better results. The resulting vibration signals are then processed using considered vibration-based techniques in frequency domain. The vibration signals were taken by FFT analyzer. In this study healthy taper roller bearing (30205) is used for analysis. In this study we investigate vibration analysis of bearing using different materials at different rotating speed.

***Index Terms* - Taper roller bearing, vibration, vibration analysis, FFT analyzer, Varying Compliance(VC), Fundamental Train Frequency(FTF)**

I. INTRODUCTION

A bearing is a mechanical element to reduce the friction between two rotating parts and constrains relative movement to the desired motion. Generally, Ceramics, Chrome steel, Stainless steel and plastics are used for bearing materials. Generally, Grey cast iron, spheroidal graphite cast iron and cast steel are used as housing material. Rolling bearings have major four elements and a very simple basic structure.

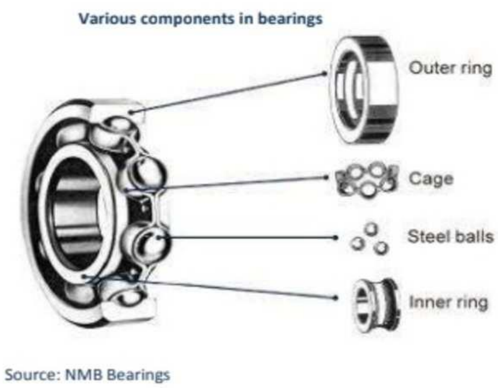


Figure 1: Components of Bearing

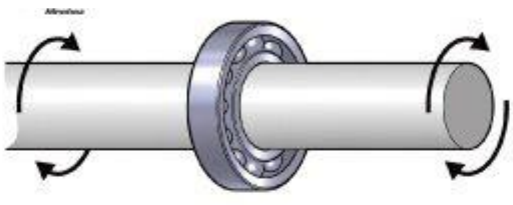


Figure 2:Working of bearing

(1) Outer Ring (2) Inner Ring (3) Rolling Elements (4) Cage

- Outer ring: This fits tightly inside the outer structure which is not moving e.g. Pump/Motor Casing
- Inner ring: This ring fits tightly on the shaft and rotates with it.
- Balls: These are the components which fill the gap between inner and outer ring and provide 'point contact' to simplify relative motion between inner and outer ring.
- Cage: This holds all the rolling element fixed at their relative positions while allowing them to rotate freely. It is generally made up of metal or ceramic.

From Figure 2, working of bearing can be understood easily. As the shaft rotates, along with the inner ring, balls start spinning inside the cage and a relative motion between the inner ring and outer ring is established with minimal contact area.

II. LITERATURE REVIEW

Abdusslam, S.A., Gu, Fengshou and Ball and Andrew presented a paper on bearing fault diagnosis based on vibration signals. They found that the information found from time domain technique is very limited. These signals made up of a large number of sinusoidal waveforms of overlapped dissimilar frequencies. Interference between these signals make it difficult to figure out useful information related to bearing conditions. In conventional spectrum analysis, the same problem preserves. But, envelope analysis is more effective reliable approach for detecting the faults because it is based on high-frequency signals. Once the type of fault is detected, the severity of fault can be calculated based on the envelope spectrum. This system has a high performance with overall reliability of 97%. (1)

Dr. S.V. Kshirsagar and G.R. Chaudhary presented a paper on fault detection of thrust bearing groove race defect using vibration signal and wavelet transform. In heavy load conditions, bearings defects are gradually induced. For finding these defects vibration signals are analysed. The bearing generates different vibration due to defects. For finding these faults, vibration analysis technique is used. FFT (Fast Fourier Transform) detects the frequencies of faults in the bearings. To overcome this difficulty, the pre-processing of the signal is done. In pre-processing the amplitude of signal is multiplied by its own absolute value, which gives large peak in the burst as compared to no burst region. This pre-processed signal is then analyzed and decomposed in wavelet 1D which gives burst at equal interval of the period. For finding the width of the defect, one of the burst is zoomed in wavelet for getting exact data points of entry and exit of the outer race groove defect. Five such bursts are used to find average burst data points of outer race groove defect. After calculating the width of the defect the deviation in the width of defect has been found to be 12% that of the actual width of outer race defect. (2)

Paula J. Dempsey, Gary Kreider and Thomas Fichter presented paper on Tapered Roller Bearing Damage Detection Using Decision Fusion Analysis. Failure progression tests were executed with tapered roller bearings. Tests were accomplished on one healthy bearing and three faulty bearings. The data was collected during the testing of four tapered roller beatings, one healthy and three pre-damaged bearings. The principle focus of this research was detection of damage progression on bearings. Spalling, peeling and damage from foreign material observed in this research. Data fusion utilizing fuzzy logic analysis techniques can be used to establish thresholds on the state of the bearings. (3)

N. Tandon and A. Choudhary presented a paper on analytical model for the prediction of the vibration response of rolling element bearings due to a localized defect. The model predicts a frequency spectrum having peaks at characteristic defect frequencies with modulation in the case of a rolling element defect and an inner race defect under a radial load. The amplitudes at these frequencies are also expected for different defect locations. The amplitude for the outer race defect is found to be quite high with compare to the inner race defect and the rolling element defect. The amplitude level is also found to increase with an increase in load; and it is affected by the shapes of the generated pulses. (4)

Shyam Patidar and Pradeep kumar soni presented a paper on vibration analysis techniques for the diagnosis of rolling element bearing faults. vibration signature discloses important information about the fault growth within them. This paper shows the recent research and developments in rolling bearing vibration analysis techniques. Frequency domain techniques have ability to find the location of fault(s) in bearing. Vibration peaks produces in spectrum at the bearing characteristics frequencies, from that we can easily recognize which bearing element is faulty. Time-frequency techniques can detect the bearing faults effectively due to its high resolution capability. Many researchers have proved that the wavelet analysis is a better tool for fault diagnosis. (5)

D.P. Jena and S.N. Panigrahi presented a paper on Precise Measurement of Defect Width in Tapered Roller Bearing using Vibration Signal. The aim of this experimental investigation is to establish a robust signal processing technique to measure the width of the defect present on the outer and inner race of taper roller bearing. It is difficult and ambiguous to detect the entry and exit points of the defect. The ambiguity gets reduced by using Symlet wavelet due to its linear phase nature which maintains sharpness in the signal even when there is a sudden change in signal. This method can be reckoned suitable and reliable in measuring bearing defect width in real-time from vibration signal. Undecimated wavelet transform denoise the signal and retain the defect signature. The time duration of roller to roll over the defect is observed from scalogram. Finest defect measurement is possible from ridge spectrum generated from scalogram. The average deviation in measured width from actual using CWT spectrum is 4.26% and that using wavelet ridge technique is 2.38%. Experimental analysis revels that measurement from ridge spectrum is more suitable and reliable method over CWT spectrum. (6)

III. Theoretical framework

The number of elements and their position in the load zone change with bearing rotation giving rise to periodic vibration of the total stiffness of the bearing assembly. The variation of stiffness generates vibrations commonly known as Varying Compliance Frequency. These parametrically excited vibrations are not related to the quality and accuracy of the bearing. The rise of radial and axial displacements of a shaft supported by rolling bearings are affected by VC of bearing.

$FTF = \frac{1}{2}S(1 - \frac{Bd}{Pd}\cos\theta)\frac{rpm}{60}$

VC = Number of rolling elements x FTF

Where,

FTF = Fundamental Train Frequency in Hz

S = Rotational speed of shaft in rpm

B_d = Roller diameter in mm (For this bearing - 6.5mm)

P_d = Bearing pitch diameter in mm (For this bearing - 39.1 mm)

Θ = Taper angle (15°)

VC = Varying Compliance

Number of rolling elements = 17

This VC is depending on speed of shaft and bearing parameters. As the speed of shaft increases, the VC increases. Here, we have used 30205 taper roller bearing. The experiments have been done from 400 RPM to 2500 RPM. The different values of FTF and VC are as below.

Table 1: Values of FTF and VC at Different RPM

Sr No	RPM	FTF	VC (FTF*Z)
1	500	3.5	59.5
2	600	4.2	71.4
3	700	4.9	83.3
4	800	5.6	95.2
5	1000	7	119
6	1200	8.4	142.8
7	1500	10.5	178.5
8	1800	12.6	214.2
9	2000	14	238
10	2200	15.4	261.8

11	2500	17.5	297.5

Bearing specifications are as follows.
Bearing Type – Taper roller bearing (30205)
d (Inside diameter) – 25mm
D(Outside diameter) – 52mT (Outer width) – 16.25mm
Dynamic load – 33.8kN
Static load – 37kN
Operating Temperature – (-40 °C to 120 °C)

IV. Experimental Setup

The experimental work for this research is done at LDRP-ITR college. The below photo shows the setup. The sensors are attached with the housing surface. They sense the vibration and transmit to the FFT analyzer. The shaft runs between 500 to 1800 rpm. The bearings are fitted on the shaft with the bearing housing. The motor speed is ±30 rpm. Mild steel and Bakelite are used as housing materials. Here, the output shaft of motor is attached with bearing shaft by the use of coupling. The sensors are attached at the opposite side of motor. These results are taken out from FFT analyzer and run in EDM software for vibration analysis.

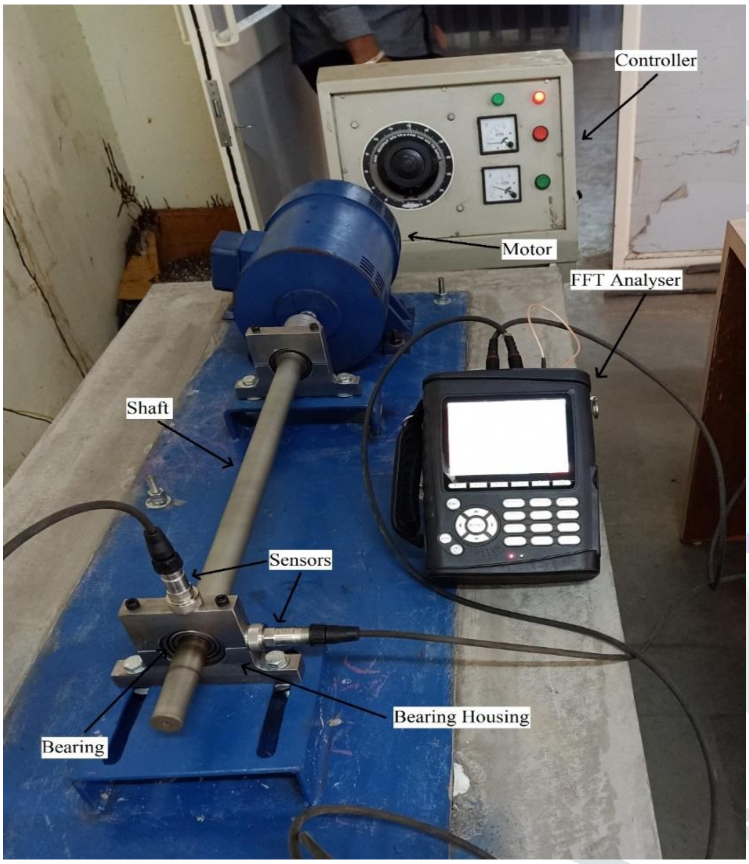
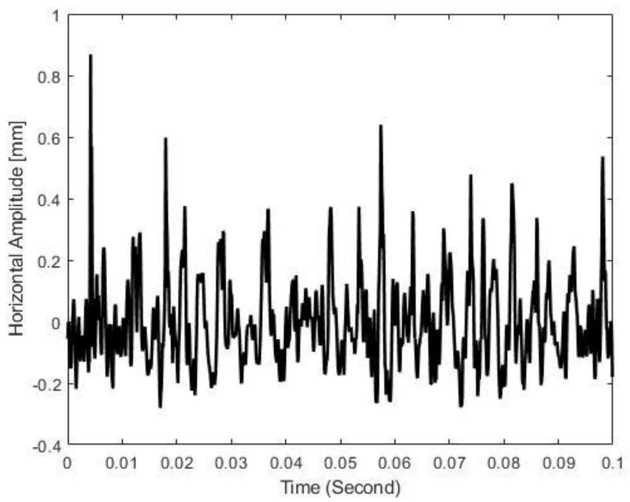
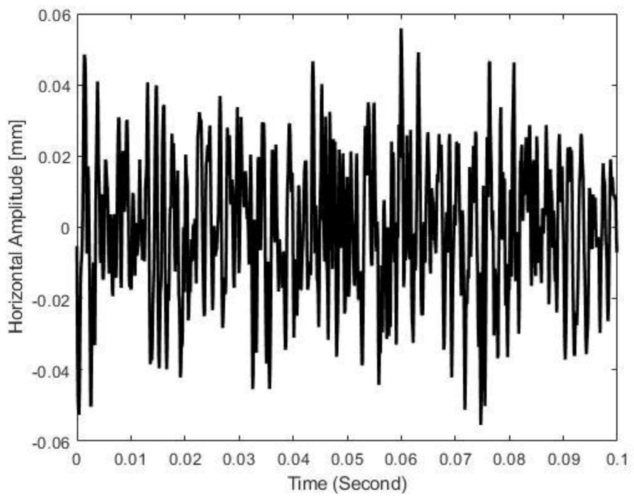


Figure 3: Experimental Setup

V. Results and Discussion

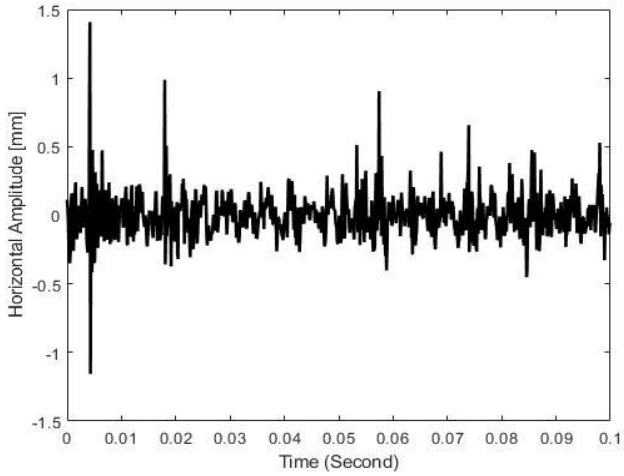
Orbit plots, time blocks and frequency responses at 1000 rpm are shown below.

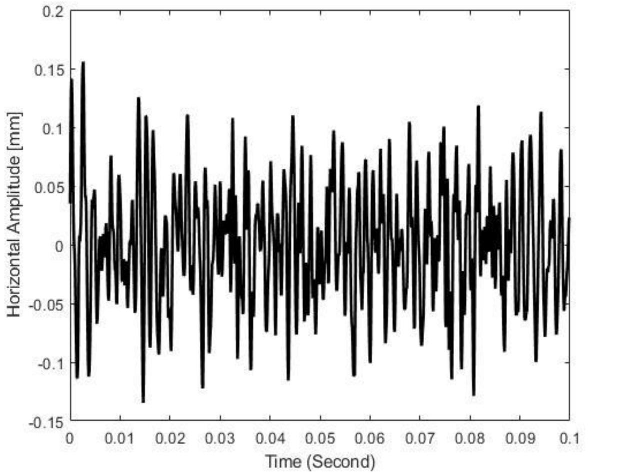




(b) Time block for radial horizontal for Bakelite @1000 RPM

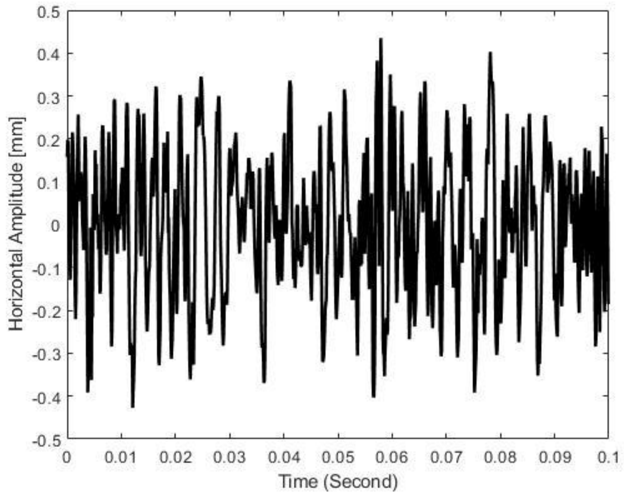
(a) Time block for radial horizontal for MS @1000 RPM

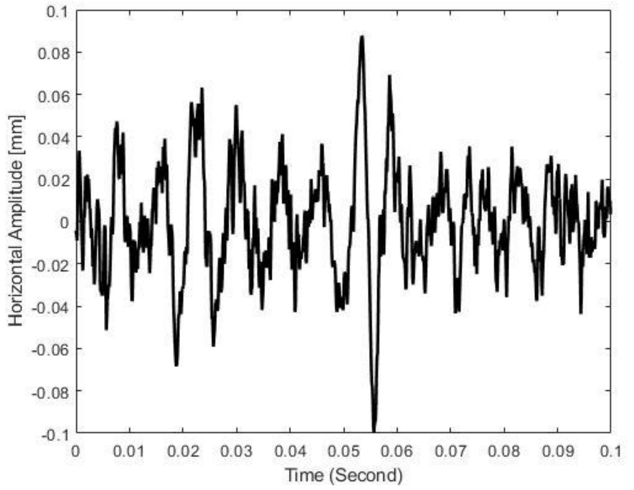




(c) Time block for radial vertical for MS @1000 RPM

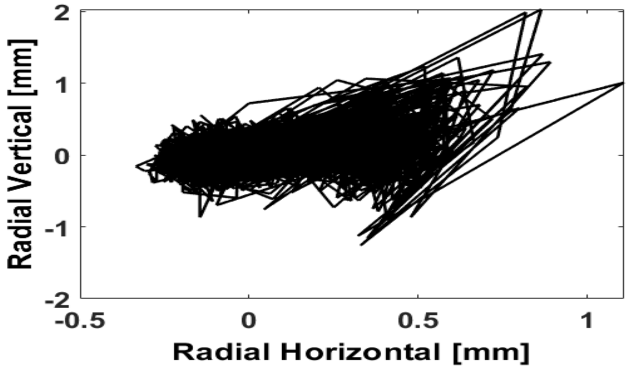
(d) Time block for radial vertical for Bakelite @1000 RPM



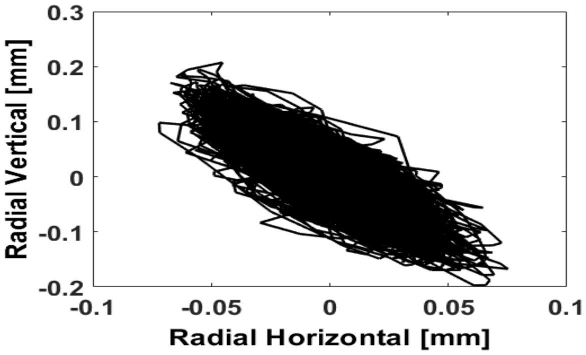


(e) Time block for axial for MS @1000 RPM

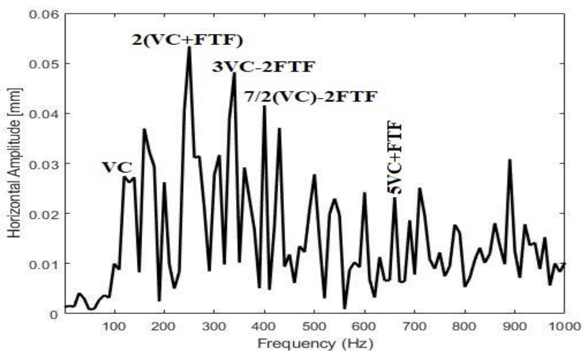
(f) Time block for axial for Bakelite @ 1000 RPM



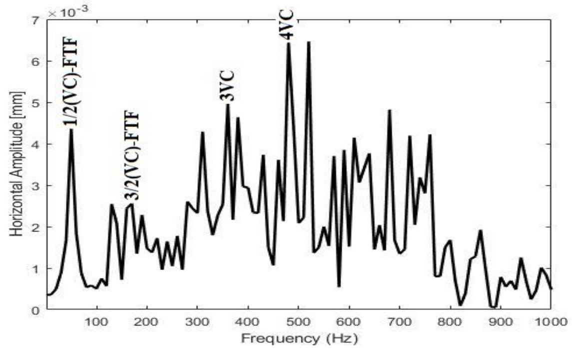
(g) Orbit plot for MS @ 1000 rpm



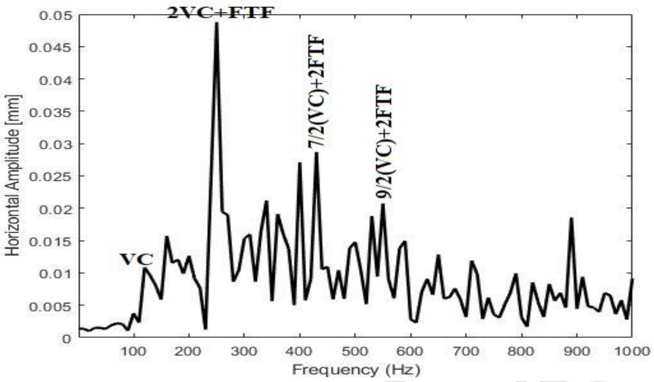
(h) Orbit plot for Bakelite @1000 rpm



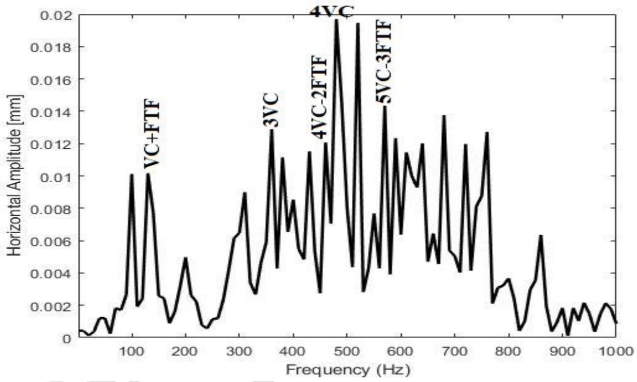
(i) FFT for radial horizontal for MS @1000 RPM



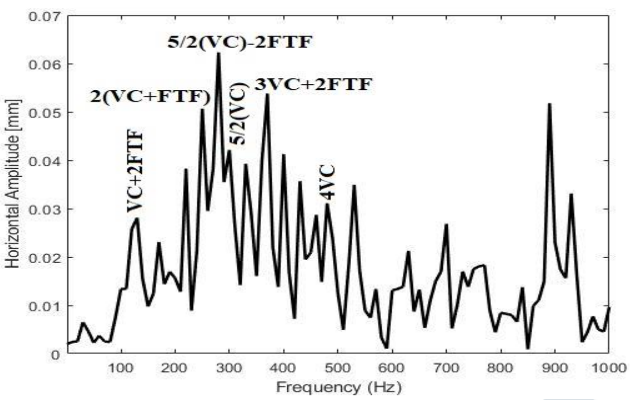
(j) FFT for radial horizontal for Bakelite @1000 RPM



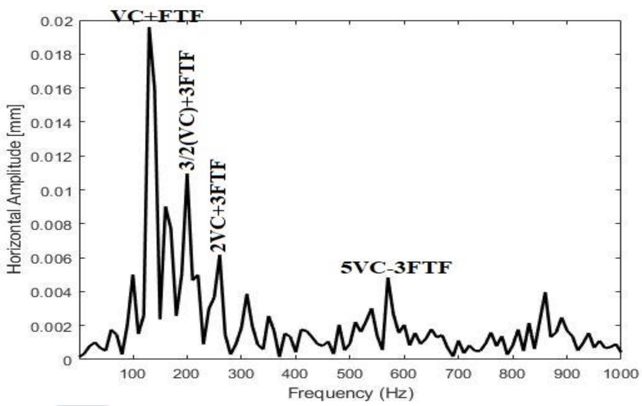
(k) FFT for radial vertical for MS @1000 RPM



(l) FFT for radial vertical for Bakelite @1000 RPM



(m) FFT for axial for MS @1000 rpm



(n) FFT for axial for Bakelite @1000 RPM

Figure 4: Vibration motion Analysis of MS and Bakelite @ 1000 RPM

From orbit plot in Bakelite, there is proximity route to chaos observed up to 2200 RPM and only at 2500 RPM, the system shows variation in route to chaos. In MS material, there are different types of chaos observed. In MS, at 400 and 500 RPM there is route to chaos, at 800 and 1000 RPM, there is a mixture of route to chaos and bifurcation chaos. At 1500 RPM, there is intermittent chaos. At 1800 and 2000 RPM, there is bifurcation chaos. At 2200 and 2500 RPM, there is again mixture of route to chaos and bifurcation chaos. In Bakelite housing the vibration in radial vertical and radial horizontal axis are in a fixed boundary with compare to MS housing. In short, there is chaos in both materials but, Bakelite is more reliable than MS according to orbit plots. From Frequency response chart, Bakelite shows all modulated frequencies, while in MS some modulated frequencies obsolete. From time blocks, MS material have denser part and sudden change in amplitudes and in Bakelite material, there is gradual change in amplitudes. In Bakelite, amplitude of vibration is lesser than MS in all three axes. Bakelite has more ability to damp the vibrations.

Table 2: Maximum positive amplitude in radial horizontal and radial vertical direction in MS and Bakelite in mm

RPM	RADIAL HORIZONTAL (mm)		% OF COMAPARISION	RPM	RADIAL VERTICAL (mm)		% OF COMAPARISION
	MS	BAK			MS	BAK	
500	0.19109	0.056595	70.38	**500**	0.14642	0.13611	7.04

800	0.74886	0.050581	93.25	**800**	1.1762	0.12359	89.49
1000	0.86821	0.055882	93.56	**1000**	1.408	0.15579	88.94
1200	0.52375	0.089747	82.86	**1200**	0.61349	0.23276	62.06
1500	0.60478	0.10278	83.01	**1500**	1.0073	0.24472	75.71
1800	1.0161	0.11807	88.38	**1800**	1.9549	0.30371	84.46
2000	1.4449	0.11616	91.96	**2000**	4.1022	0.29808	92.73
2200	1.6842	0.13096	92.22	**2200**	2.559	0.30708	88.00
2500	1.0597	0.1508	85.77	**2500**	2.3854	0.36636	84.64

Table 3: Maximum positive amplitude in axial direction in MS and Bakelite in mm

RPM	**AXIAL (mm)**		**% OF COMAPARISION**
	MS	**BAK**	
500	0.30349	0.073751	75.70
800	0.35521	0.055658	84.33
1000	0.43514	0.087671	79.85
1200	0.56768	0.1095	80.71
1500	0.44129	0.11197	74.63
1800	0.48181	0.12701	73.64
2000	0.76557	0.1852	75.81
2200	0.7026	0.15707	77.64
2500	0.83882	0.2044	75.63

Maximum positive amplitude of MS and Bakelite material in all three axes are shown above for different RPM. From this table, there is above 60% reduction of amplitude in Bakelite in all three axes.

VI. CONCLUSION

According to above results, Bakelite is more reliable between 500 RPM to 2500 RPM for application in hazardous pumps and off shore areas where MS material reacts with surroundings. Vibration absorption capacity of Bakelite is higher than mild steel.

VII. ACKNOWLEDGMENT

I would also like to show my deep gratitude to my supervisors who helped me to complete my project.

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