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Vibration Analysis Technique for the Diagnosis of Bearing Housing Vibrations with Different Housing Materials

Tirthak Shah[1], Ankit Darji[2], Divyang H Pandya[3]

[1]*PG scholar, Dept. of Mechanical Engineering, LDRP-ITR College, Gujarat, INDIA*
[2]*Assistant Professor, Dept. of Mechanical Engineering, LDRP-ITR College, Gujarat, INDIA*
[3]*Professor, Dept. of Mechanical Engineering, LDRP-ITR College, Gujarat, INDIA*

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Abstract - *Rolling element bearings are the most common component in all rotating machineries. There are different types of materials are used for bearing component manufacturing as well as bearing housing manufacturing. This research is undertaken to study the vibrations at bearing housing due to rotation of bearing. In this research two different materials are taken to study the vibrations on housing. For this research, Mild steel and Bakelite Hylam sheet are used as housing material. This study is done at different speeds of bearing. For this study FFT analyzer is used and 30205 healthy taper roller bearing is used. The resulting vibration signals from FFT analyzer are processed by vibration based techniques.*

***Key Words*: Taper roller bearing, Vibration signature analysis, Varying Compliance (VC), Fundamental Train Frequency (FTF)**

1. INTRODUCTION

Bearing is used to reduce the mechanical friction between two rotating parts. There are different types of materials are used for bearings e.g. Ceramics, Chrome steel, Plastics, stainless steel etc. As well as, grey cast iron, cast steel, spheroidal graphite cast iron are used for housing materials. There are total four elements in bearing construction. 1) Outer ring, 2) Inner ring, 3) Rolling elements, 4) cage. Outer ring fits tightly inside bearing housing and it is not moving part. Inner ring fits tightly on shaft, which rotates with shaft. Rolling elements fill the gap between outer and inner ring, which may be ball shape, needle shape, cylindrical shape according to the type of the bearing. Cage is used to hold the rolling elements between outer ring and inner ring and allowing them to rotate freely. As shaft rotates, the inner ring rotates with the shaft and the outer ring is fixed. So, the balls start spinning inside the cage and the relative motion between inner and outer ring is done. The contact area is very less.

Tuncay Karacay presented a paper on Experimental diagnostics of ball bearings using statistical and spectral methods. In this research, brand new bearing is installed and run throughout its lifespan under constant speed. Vibration signatures are produced and recorded. Vibration spectra are obtained and analyzed for defects. When the defect size increases, vibration magnitude increases. There is no general correlation between vibration magnitude and vibration amplitude. (1)

Manoranjan Mahanta presented a paper on Vibration Signature Analysis & condition monitoring of Tapered Roller Bearing. There is a variation in the signature of the Natural frequencies of the roller bearing with a rise in depth of defects. By this signal, the fault frequencies can be matched with the healthy bearing frequencies and initial faults can be avoided by taking necessary actions before it becomes a major defect. (2)

P.D. McFadden and J.D. Smith presented a paper on Vibration monitoring of rolling element bearings by the high frequency resonance technique. It is usually not useful calculating the bearing race and structural resonant frequencies, as calculations of the frequencies can give no level of the relative magnitudes of the resonances which are likely to be observed in practice. It is not possible even to be sure which frequencies correspond to which mode of vibration. (3)

M. F. While presented a paper on Rolling Element Bearing Vibration Transfer Characteristics: Effect of Stiffness. Roller bearing stiffness is very nonlinear when the applied load is small and a slight increase in load will produce a large change in stiffness. At higher loads, the effect of the nonlinearity is less than that for ball bearings. For a typical configuration of bearing with relatively small clearance the number of rolling elements present in the load zone at any instant has an insignificant effect on the bearing nonlinear stiffness characteristics. (4)

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. (5)

Yuan Gao presented a paper on Influences of bearing housing deflection on vibration performance of cylinder roller bearing–rotor system. In this article, a rotor supported by two cylindrical roller bearings is investigated. The influences of the housing deflection angles on the vibration performance of the bearing–rotor system are studied numerically and a series of conclusions are obtained and explained. (6)

2. THEORETICAL FRAMEWORK

The most fundamental cause of noise and unsteady running of rolling bearings is the so-called varying compliance (VC) vibrations. VC is parametrically excited vibrations that happen regardless of the quality and accuracy of the bearing. The fundamental train frequency (FTF) is the frequency at which the roller cage entering and exits the load zone. The VC and FTF can be find out by following equations.

VC = Number of Rolling elements x FTF

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

Where,

S = Rotational speed of shaft in rpm
Bd = Roller diameter in mm (For this bearing - 6.5mm)
Pd = 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. In this research we have used 30205 taper roller bearing. The vibrations are measured from 500 RPM to 2500 RPM. The different values of VC and FTF are shown in table 1.

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) – 52mm

T (Outer width) – 16.25mm

Dynamic load – 33.8kN

Static load – 37kN

Operating Temperature – (-40 °C to 120 °C)

3. 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

Fig 1: Experimental Setup

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.

4. RESULTS AND DISCUSSION

Orbit plots, time blocks and frequency responses at 1000 rpm are shown below. (From Fig 2 to Fig 15)

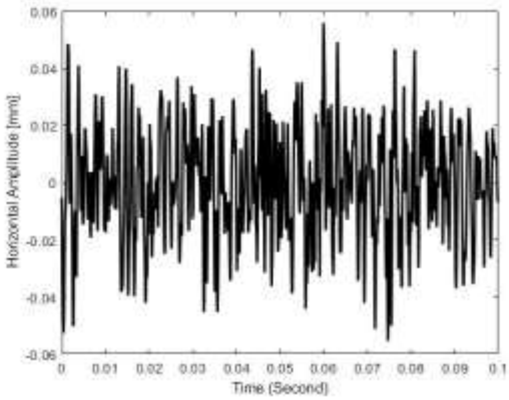

Fig 2: Time block for radial horizontal for MS @1000 RPM

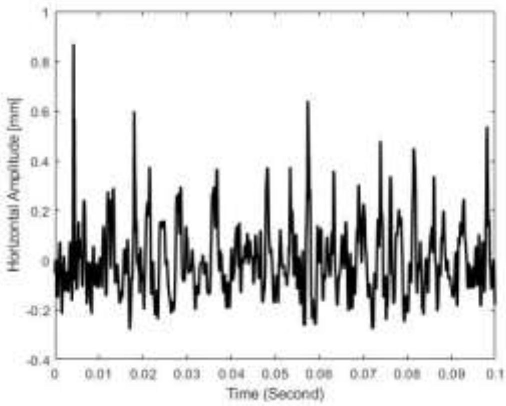

Fig 3: Time block for radial horizontal for Bakelite Hylam @1000 RPM

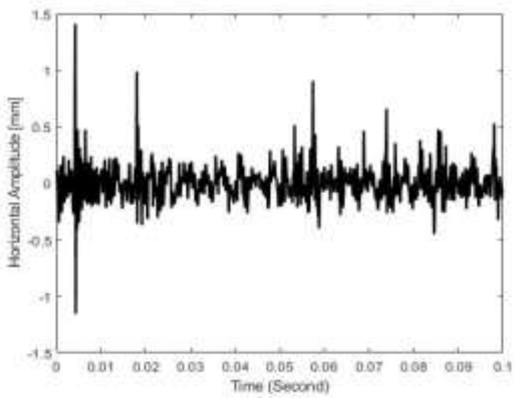

Fig 4: Time block for radial vertical for MS @1000 RPM

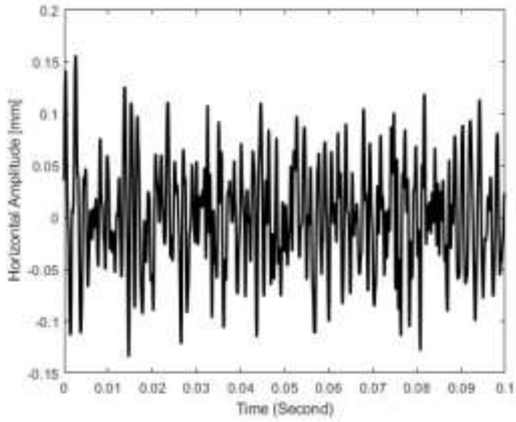

Fig 5: Time block for radial vertical for Bakelite Hylam @1000 RPM

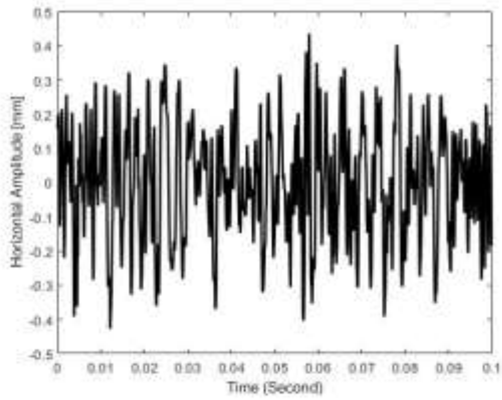

Fig 6: Time block for axial for MS @1000 RPM

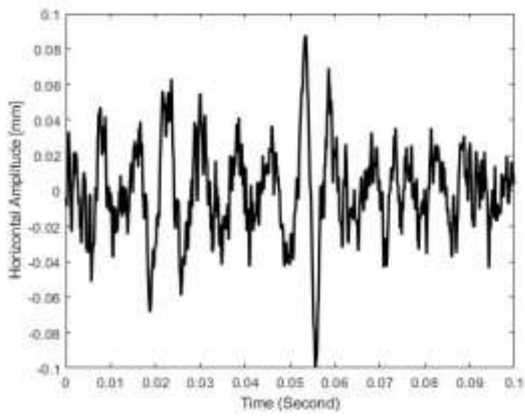

Fig 7: Time block for axial for Bakelite Hylam @ 1000 RPM

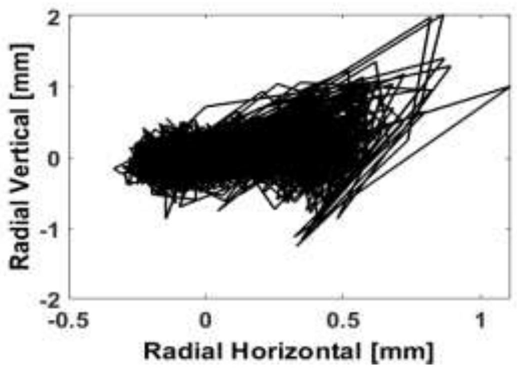

Fig 8: Orbit plot for MS @ 1000 RPM

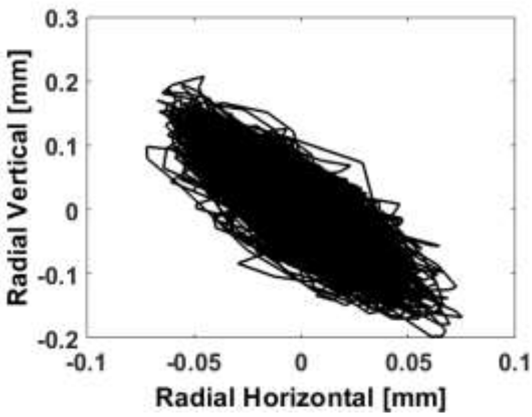

Fig 9: Orbit plot for Bakelite Hylam @1000 RPM

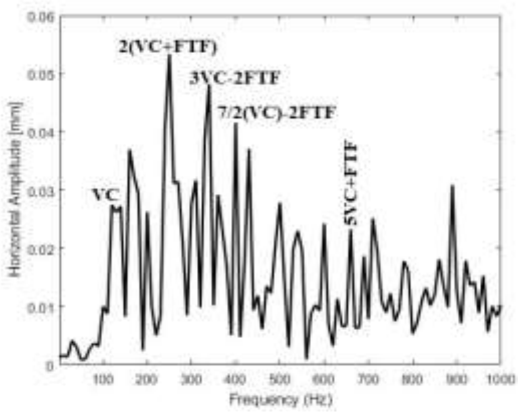

Fig 10: FFT for radial horizontal for MS @1000 RPM

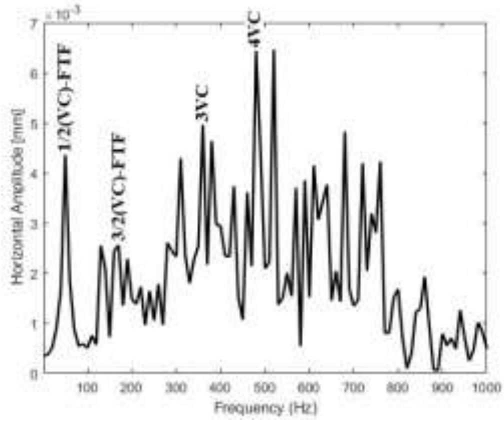

Fig 11: FFT for radial horizontal for Bakelite Hylam @1000 RPM

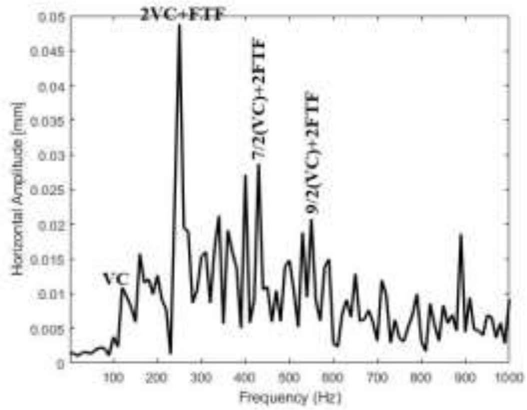

Fig 12: FFT for radial vertical for MS @1000 RPM

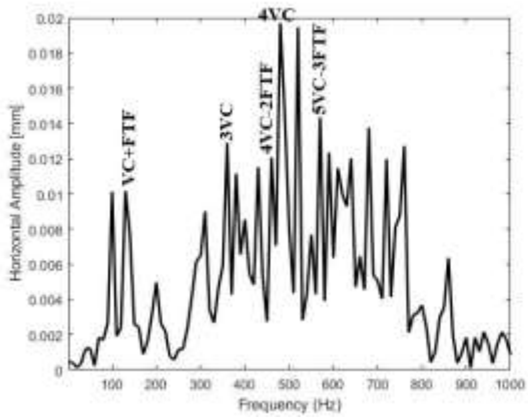

Fig 13: FFT for radial vertical for Bakelite Hylam @1000 RPM

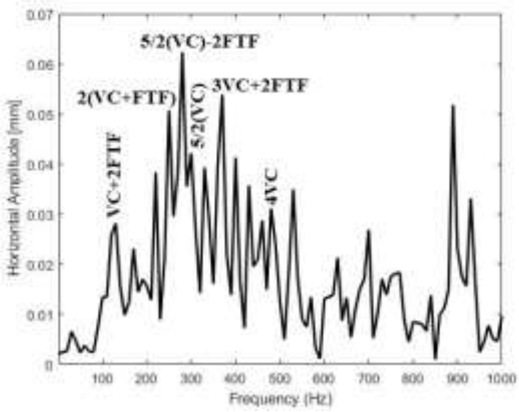

Fig 14: FFT for axial for MS @1000 rpm

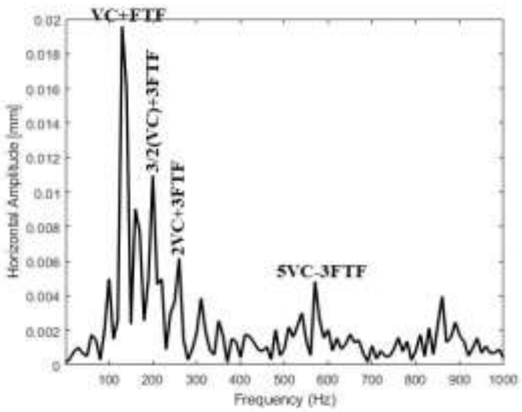

Fig 15: FFT for axial for Bakelite Hylam @1000 RPM

From orbit plot in Bakelite Hylam, 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 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 short, Bakelite Hylam has more uniform vibration pattern than MS Housing. In Bakelite Hylam housing the vibration in radial vertical and radial horizontal axis are in a fixed boundary with compare to MS housing. From Frequency response chart, Bakelite Hylam 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 Hylam material, there is gradual change in amplitudes. In Bakelite Hylam, amplitude of vibration is lesser than MS in all three axes. Bakelite Hylam has more ability to damp the vibrations. Amplitude of vibration in MS and Bakelite Hylam in different axes at different speeds are shown in table 2, table3 and table 4.

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

RPM	RADIAL HORIZONTAL (mm)		% OF COMAPARISION
	MS	BAK	
500	0.19109	0.056595	70.38
800	0.74886	0.050581	93.25
1000	0.86821	0.055882	93.56
1200	0.52375	0.089747	82.86
1500	0.60478	0.10278	83.01
1800	1.0161	0.11807	88.38
2000	1.4449	0.11616	91.96
2200	1.6842	0.13096	92.22
2500	1.0597	0.1508	85.77

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

RPM	RADIAL VERTICAL (mm)		% OF COMAPARISION
	MS	BAK	
500	0.14642	0.13611	7.04
800	1.1762	0.12359	89.49
1000	1.408	0.15579	88.94
1200	0.61349	0.23276	62.06
1500	1.0073	0.24472	75.71
1800	1.9549	0.30371	84.46
2000	4.1022	0.29808	92.73
2200	2.559	0.30708	88.00
2500	2.3854	0.36636	84.64

Table 4: 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 Hylam 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.

5. CONCLUSION

According to experimental results, Bakelite Hylam has more capacity to absorb the vibrations than MS during the rotation of bearings. Besides, Bakelite Hylam has very good chemical resistivity property. So, this material is more reliable in off shore areas and hazardous pump applications, where Metals reacts with surroundings. So, Bakelite Hylam is more reliable than MS material.

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