Experimental Dynamic Analysis of Rotating Shaft Subjects to Slant Crack

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***Abstract*— This paper presents the dynamic analysis of the rotating shaft which subjects to slant crack on its surface. Slant crack is created by artificially on various locations. At this various locations analysis is done with the help of FFT. Two types of materials EN8 and EN24 is taken for manufacturing of shaft which has slant crack.**

Keywords— Healthy shaft; Cracked shaft; Crack depth; Crack location; Slant crack; FFT.

I. INTRODUCTION

The issue of crack detection and diagnosis has wide industrial interest. The damage in the shaft element occurs due to accidents, normal operations and deteriorations. Damage can be analyzed through visual inspection or by the method of measuring frequency, mode shape and structural damping. Damage detection by visual inspection is a time consuming method and measuring of mode shape as well as structural deflection is difficult rather than measuring frequency. In this, study will be done on cracks on solid shaft such as slant cracks. In the current analysis, methodologies have been developed for damage detection of a cracked shaft using experimentation. In experimental analysis using FFT analyzer results will be calculated. For experimentation, shafts are manufactured with three different types of materials as EN8 and EN24. Slant cracks are developed artificially on surface on shafts with considerations of different crack locations. Also, for loading condition one disc is attached at centre of the shaft. Readings are taken with FFT analyzer at various speed conditions.

II. LITERATURE REVIEW

Qinkai Hann et. al. [1] have analyzed a geared rotor bearing system with slant breathing crack. The vibration problems associated with geared systems have been the focus of research in recent years. As the torque is mainly transmitted by the geared system, a slant crack is more likely to appear on the gear shaft. Due to the slant crack and its breathing mechanism, the dynamic behavior of cracked geared system would differ distinctly with that of uncracked system.

Yanli Lin et. al. [2] have done work for a Jeffcott rotor system with a 45^0 slant crack on the shaft, the motion equations are established with four directions, i.e. two transversal directions, one torsional direction and one longitudinal direction. It can be seen from the deducing process of the stiffness with the strain energy release approach that there are coupling stiffnesses of bending-torsion, bending–tension and torsion–tension for the slant cracked shaft and only bending-tension for the transverse cracked one. The paper shows that besides the coupling stiffnesses, there is bending–torsion coupling caused by the eccentricity.

Ashish K. Darpe [3] have presented finite element model of a rotor with slant crack. Based on fracture mechanics, a new flexibility matrix for the slant crack is derived that accounts for the additional stress intensity factors due to orientation of the crack compared to the transverse crack. Comparison between rotor with slant and transverse crack is made with regard to the stiffness coefficients and coupled vibration response characteristics.

A. S. Sekhar [4] have done the detection and monitoring of slant crack in the rotor system using mechanical impedance. The modeling of slant crack is discussed briefly in this paper.

A. S. Sekhar [5] have analyzed the dynamic behavior of structures in particular rotors containing cracks is a subject of considerable current interest. Finite element analysis of a rotor bearing system for flexural vibrations has been considered by including a shaft having a slant crack that has resulted from the fatigue of the shaft due to the torsional moment.

III. EXPERIMENTATION AND PROCEDURE

The Experimentation done for analysis of rotating shaft is as below. For this experimental set up is as:

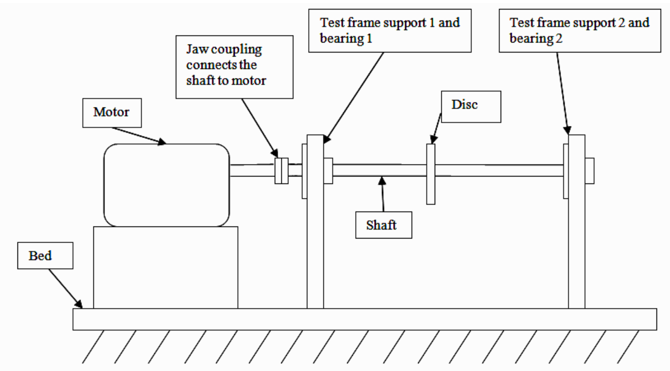

Fig. 1 Block diagram of Experimental setup

Motor Specifications: 1 HP motor with max 2880 rpm speed.

Bearing: Two bearing SKF 6204 with I. D 20mm O. D. 25 mm containing 8 balls inside.

Coupling is used to join the motor shaft and shaft to be analyzed.

Shafts: 10 shafts are manufactured with diameter of 20 mm and 700 mm length. Out of which 2 shafts are intact and remaining are defected. 4 shafts of one material are manufactured with slant crack on surface at location of 150mm, 300mm, 400mm and 550mm. With these locations 8 defected shafts for two materials are manufactured. Weight of one shaft is 3.5 kg.

Crack dimensions: angle of crack is 45^0 i. e. slant crack with 4.2 mm length and 0.5 mm width.

Disc: For loading condition disc is manufactured with EN8 material of 0.5 kg weight and O. D 90mm.

Experimental Procedure: For experimentation shafts are mounted on experimental setup for readings. For this paper work healthy shaft of EN8 and EN24 material is taken. Also, of same material and slant crack location at 150 mm from bearing 1 is taken. With the help of 1 H. P. motor these healthy and slant cracked shafts are controlled over speed and readings are taken at 500 rpm, 1000 rpm, 1500 rpm and 2000 rpm with the help of FFT (Fast Fourier Transform).

IV. Results and Discussion

Below figures 2 to 17 are graphs of Amplitude (m/s^2) Vs. Frequency (Hz). The peaks are shown for healthy shafts and slant cracked shafts at 150 mm of materials EN8 and EN24 for speeds of 500 rpm, 1000 rpm, 1500 rpm and 2000 rpm.

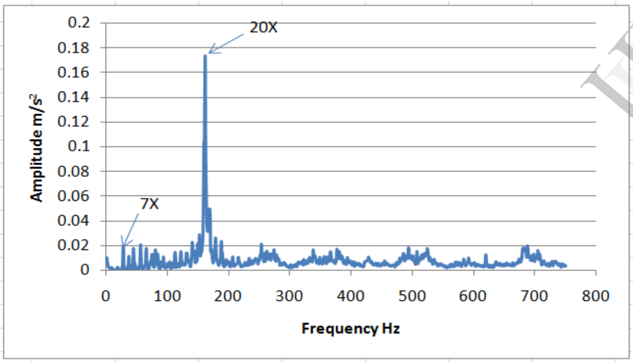

Fig.2 Amplitude Vs Frequency for EN8 healthy shaft at 500 rpm

Above fig.2 shows that peaks are observed at 7X and 20 X which are the harmonics of shaft speed at 500 rpm.

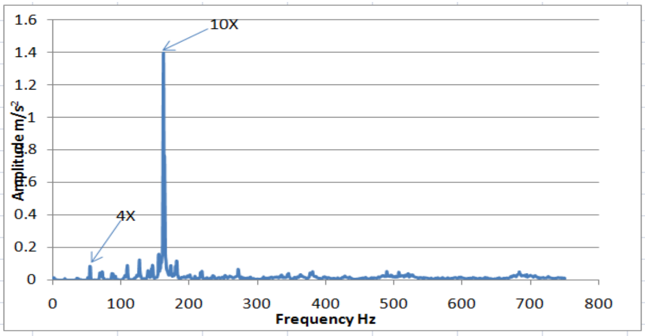

Fig.3 Amplitude Vs Frequency for EN8 healthy shaft at 1000 rpm

Above fig.3 shows that peaks are observed at 4X and 10 X which are the harmonics of shaft speed at 1000 rpm.

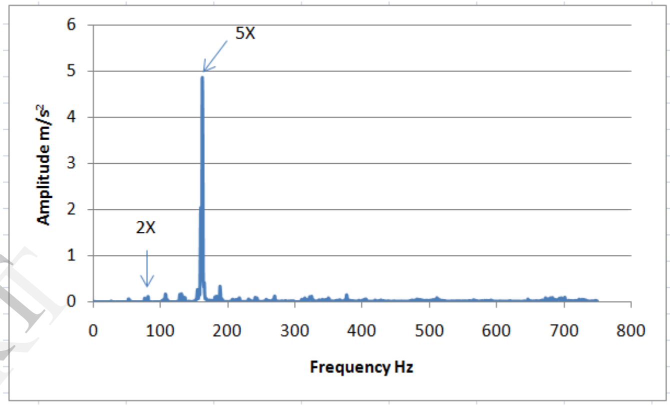

Fig.4 Amplitude Vs. Frequency for EN8 healthy shaft at 1500 rpm

Above fig.4 shows that peaks are observed at 2X and 5 X which are the harmonics of shaft speed at 1500 rpm.

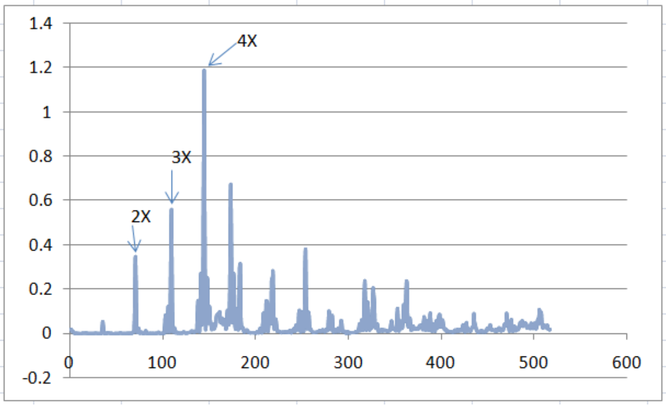

Fig.5 Amplitude Vs. Frequency for EN8 healthy shaft at 2000 rpm

Above fig.5 shows that peaks are observed at 2X and 3X and 4X which are the harmonics of shaft speed at 2000 rpm.

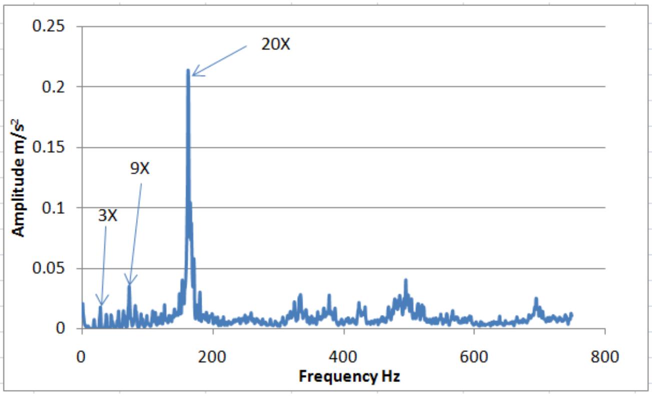

Fig.6 Amplitude Vs Frequency EN8 shaft slant crack at 150mm at 500 rpm

Above fig.6 shows that peaks are observed at 3X and 9X and 20X which are the harmonics of shaft speed at 500 rpm.

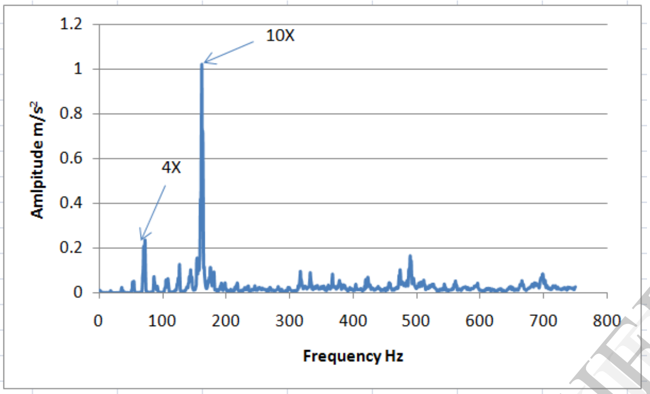

Fig.7 Amplitude Vs. Frequency EN8 shaft slant crack at 150 mm at 1000 rpm

Above fig.7 shows that peaks are observed at 4X and 10 X which are the harmonics of shaft speed at 1000 rpm.

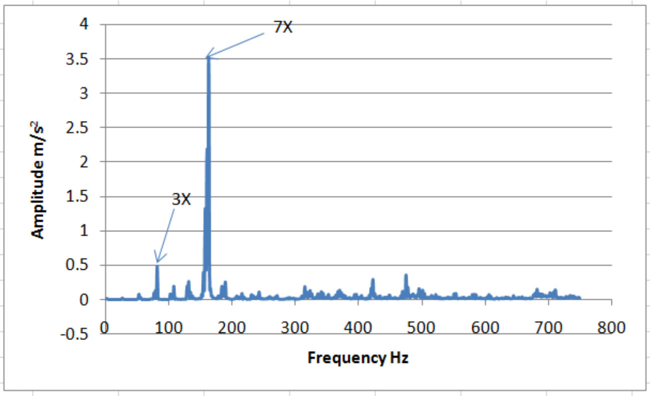

Fig.8 Amplitude Vs. Frequency EN8 shaft slant crack at 150 mm at 1500 rpm

Above fig.8 shows that peaks are observed at34X and 7X which are the harmonics of shaft speed at 1500 rpm.

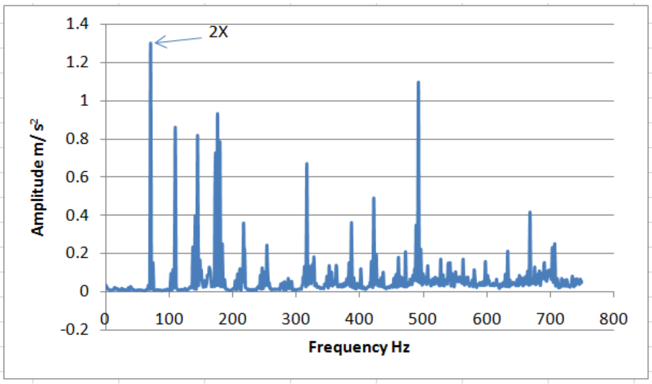

Fig. 9 Amplitude Vs. Frequency EN8 shaft slant crack at 150 mm at 2000 rpm

Above fig.9 shows that peaks are observed at 2X which are the harmonics of shaft speed at 2000 rpm.

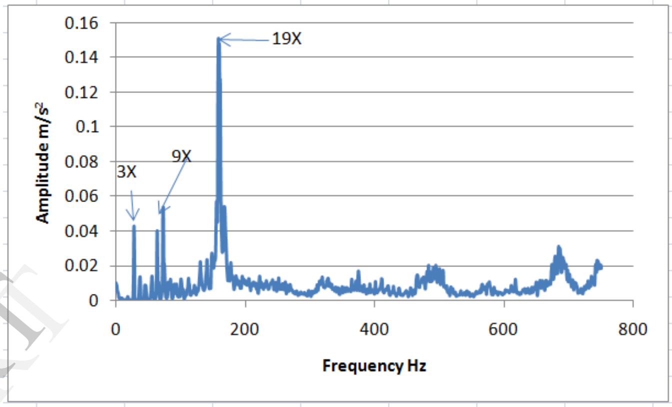

Fig.10 Amplitude Vs. Frequency EN24 healthy shaft at 500 rpm

Above fig.10 shows that peaks are observed at 3X and 9X and 19X which are the harmonics of shaft speed at 500 rpm.

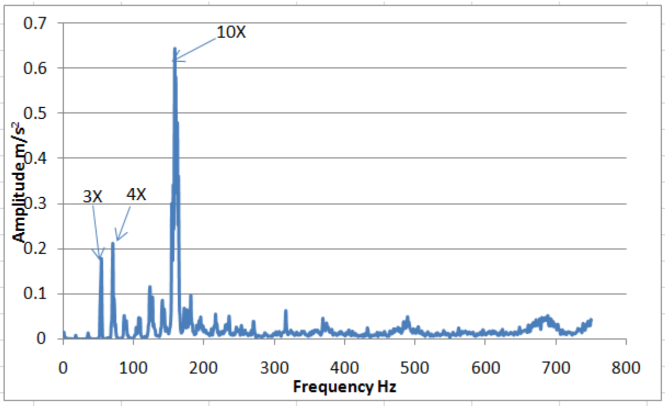

Fig.11 Amplitude Vs. Frequency EN24 Healthy shaft at 1000 rpm

Above fig.11 shows that peaks are observed at 3X and 4X and 10X which are the harmonics of shaft speed at 1000 rpm.

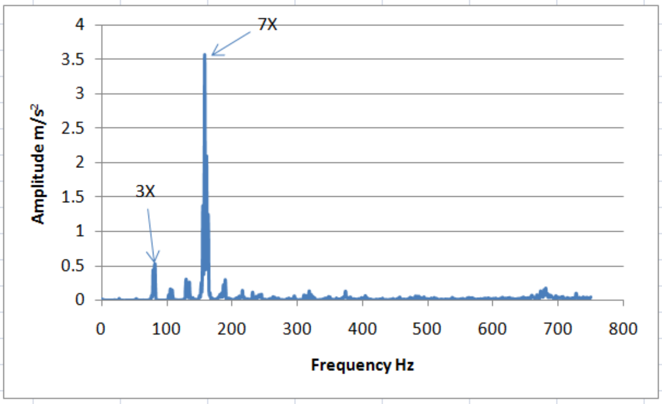

Fig.12 Amplitude Vs. Frequency EN24 healthy shaft at 1500 rpm

Above fig.12 shows that peaks are observed at 3X and 7X which are the harmonics of shaft speed at 1500 rpm.

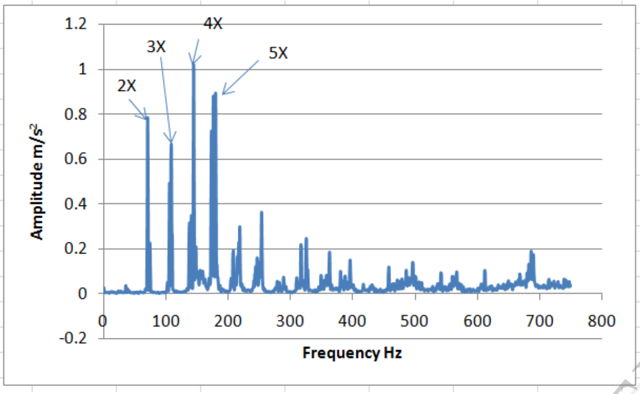

Fig.13 Amplitude Vs. Frequency EN24 healthy shaft at 2000 rpm

Above fig.13 shows that peaks are observed at 2X and 3X and 4X and 5X which are the harmonics of shaft speed at 2000 rpm.

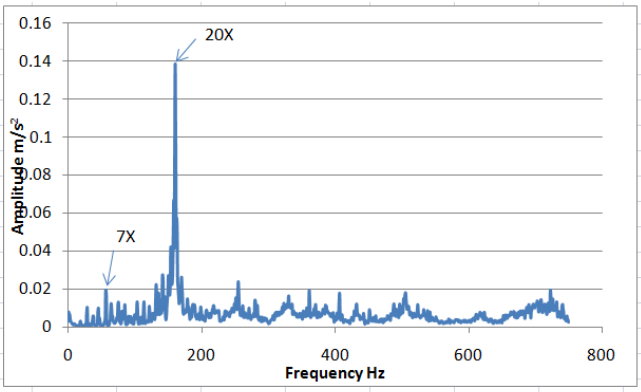

Fig.14 Amplitude Vs. Frequency EN24 shaft slant crack at 150 mm at 500 rpm

Above fig.14 shows that peaks are observed at 7X and 20X which are the harmonics of shaft speed at 500 rpm.

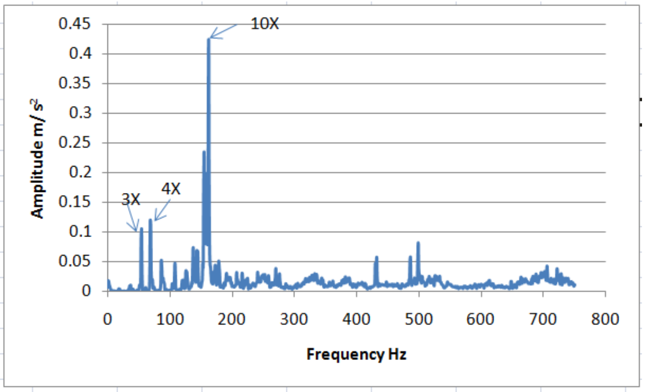

Fig.15 Amplitude Vs. Frequency EN24 shaft slant crack at 150mm at 1000rpm

Above fig.15 shows that peaks are observed at 3X and 4X and 10X which are the harmonics of shaft speed at 1000 rpm.

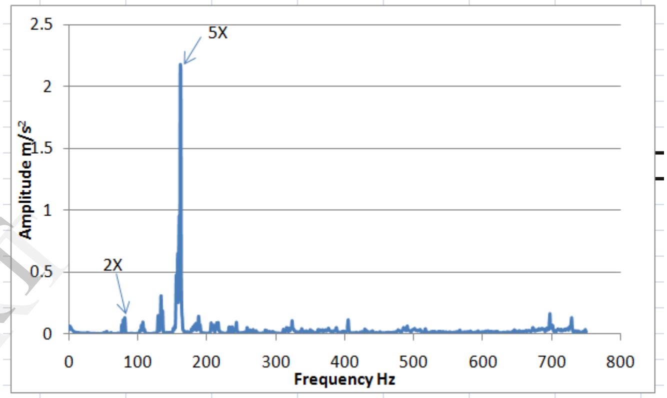

Fig.16 Amplitude Vs. Frequency EN24 shaft slant crack at 150 mm at 1500 rpm

Above fig.16 shows that peaks are observed at 2X and 5X which are the harmonics of shaft speed at 1500 rpm.

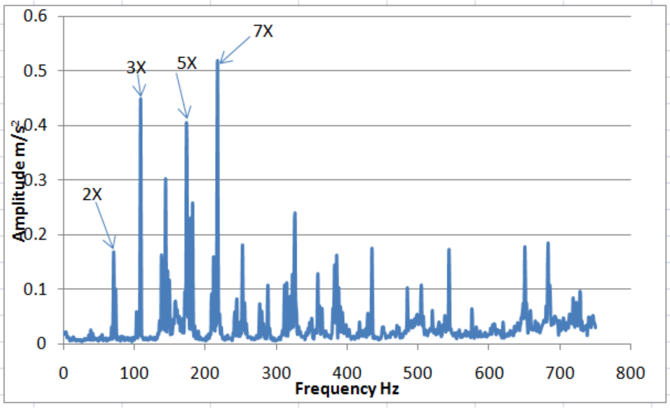

Fig.17 Amplitude Vs. Frequency EN24 shaft slant crack at 150mm at 2000 rpm

Above fig.17 shows that peaks are observed at 2X and 3X and 5X and 7X which are the harmonics of shaft speed at 2000 rpm.

TABLE I. SUMMARY OF RESULTS

Amplitude m/s2				Speed rpm
EN8		EN24		
Healthy	Slant Crack at 150 mm	Healthy	Slant Crack at 150 mm	
0.17	0.213	0.1215	0.1384	500
1.02	1.39	0.4264	0.488	1000
3.51	4.81	1.743	2.13	1500
1.18	1.3	0.3525	0.5341	2000

From above Table I, it is observed that for EN8 and EN24 material the slant crack located at 150 mm distance causes increase in amplitude than that of healthy shaft.

V. CONCLUSION

In the present study, the dynamic behavior of a rigid healthy and defective rotor supported on healthy ball bearings is investigated experimentally.

Experimentation in the case of slant crack is done at crack depth 4.2 mm at the angle of 45°. The response shows that the main peak amplitude occurs at harmonics of rotational frequency i. e. 3X. The neighboring frequencies are on multiple of rotational frequency X. Slant crack causes increase in amplitude which can be used as an indication of presence of crack in a shaft. The rate of increase in amplitude is lower for 500 rpm and 1000 rpm and this rate is higher for speed of 1500 rpm.

The amplitude of healthy shaft made up of EN8 material is greater than that of healthy shaft made up of EN24 material for all the speeds. Also, the amplitude of cracked shaft made up of EN8 material is greater than that of cracked shaft made up of EN24 material for all the speeds.

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