Vibration Analysis of Rotating Shaft with Transverse Crack

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Abstract: Shafts are the components which are subjected to the hardest conditions in high performance rotating equipments used in the process and utility plants like high speed compressors, steam and gas turbines, generators and pumps etc. Although when shafts are operated in different type of conditions then serious defects can appear, but these are much suspected to cracks because of the rapidly fluctuating nature of stresses. The development of crack changes dynamic behavior of rotor system. It decreases the strength of object or material. When shaft rotates then due to defect the vibration response of the rotating shaft will more or less change. By using the additional vibration extracted from the shaft due to defect, an on-line condition monitoring system for crack detection might be developed for rotor systems. Even for smaller crack, rotating shaft creates the vibrations. So, the vibration monitoring is more useful for detecting crack in rotating shaft .This paper gives the vibration analysis of rotating shaft with different crack location & with different shaft speeds.

Keywords – ***Dynamic behavior, condition monitoring, vibration monitoring ,vibration analysis.***

I. INTRODUCTION

For studying the vibration response of rotating shaft an experimental set up can be made as follows:

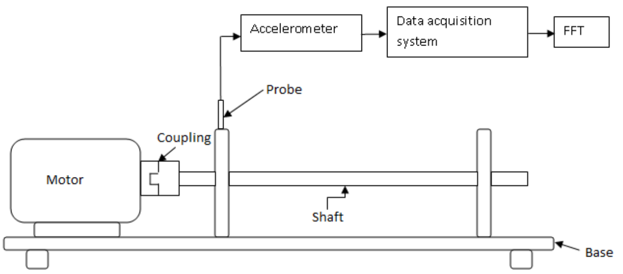


Fig. Schematic representation of proposed experimental setup

Experimental setup consist of a shaft with two test frame support bearing & driven by a variable speed motor. One end of the continuous shaft will connect to a variable speed electric motor. The artificial crack will be developed on shaft by using any convenient method. A piezoelectric accelerometer will be placed on the test rotor system to measure the vibration. The Fast Fourier Transform (FFT) analyzer will be used to acquire the vibration data. For our experiment we choose the shaft of working length 700mm, diameter 21mm & material EN24. The crack is of width 0.5mm, depth 21mm & the length as generated by these dimensions. The bearing of SKF 6204 is used. For our study we take five shafts, one healthy & other with different crack location.

For studying the vibration response of shaft, some terms like fundamental train frequency, varying compliance frequency are important.

Fundamental Train Frequency (FTF):

It is the rotation rate of the cage supporting the rollers in a rolling element bearing.

It is given by the formula:

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

Where,
S = Revolutions per second
Bd = Ball or roller diameter
Pd = Pitch diameter
Φ = Contact angle

Varying compliance frequency (V_C):

When the rolling element set and the cage rotates with a constant angular velocity, a parametrically excited vibration is generated and transmitted through the outer race. These vibrations are produced due to finite number of balls carrying load. The characteristic frequency of this vibration is called the varying compliance frequency (V_C) and is given as:

$$V_C = N \times FTF$$

Where,
N= No. of balls in bearing
FTF = Fundamental Train Frequency

II. VIBRATION ANALYSIS

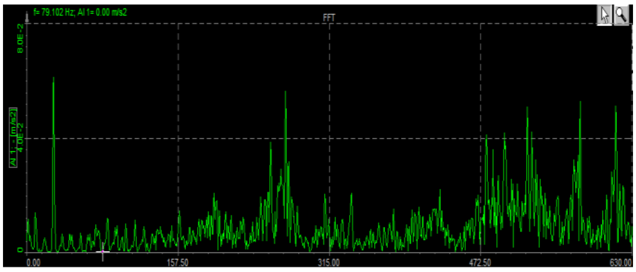
We take the readings of shaft at 500, 1000, 1500, 2000 & 2500rpm. One shaft is healthy & other containing the transverse crack at location 150mm, 300mm, 400mm, and 550mm from bearing 1 respectively. The rotational frequency & varying compliance frequency for above speeds is tabulated as follows:

Table 1: Ratational frequency & varying compliance frequency for different speed

Speed(rpm)	Rotational Frequency (Hz)	Varying Compliance frequency (Hz)
500	8.33	25.68
1000	16.67	51.36
1500	25	77.04
2000	33.33	102.72
2500	41.67	128.4

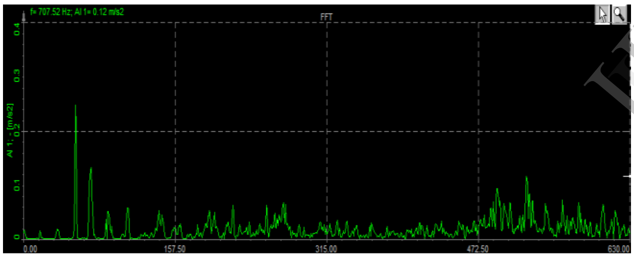
Case-I: Healthy shaft

1) The graph obtained at 500rpm is as follows :



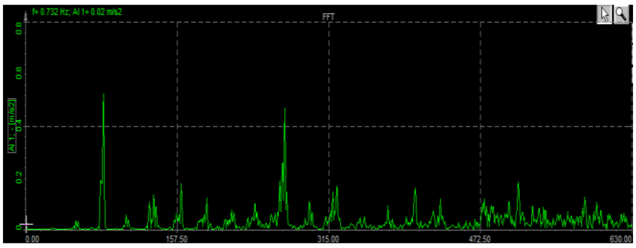
Here we get the max. peak at Vc =0.0614 m/s^2.

2) The graph obtained at 1000rpm is as follows :



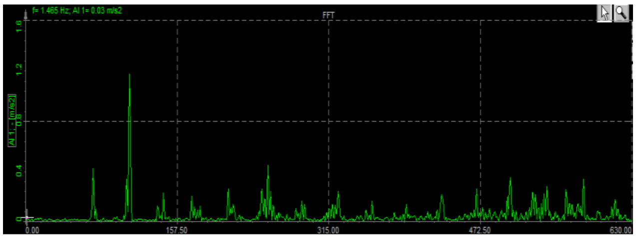
Here we get the max. peak at Vc =0.247 m/s^2.

3) The graph obtained at 1500rpm is as follows :



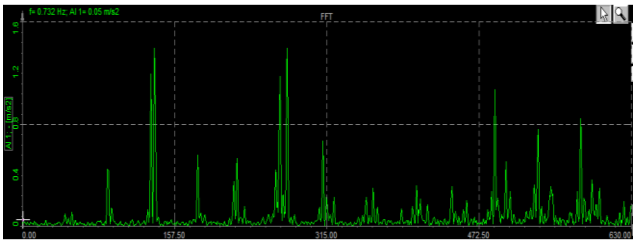
Here we get the max. peak at Vc =0.525 m/s^2.

4) The graph obtained at 2000rpm is as follows :



Here we get the max. peak at Vc =1.17 m/s^2.

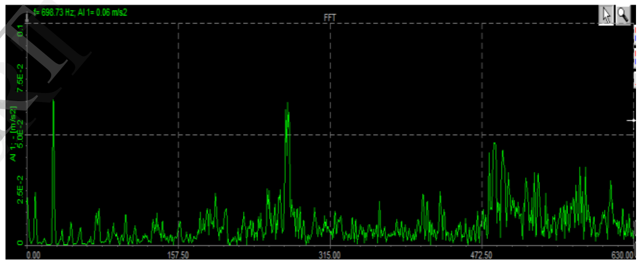
5) The graph obtained at 2500rpm is as follows :



Here we get the max. peak at Vc =1.39 m/s^2.

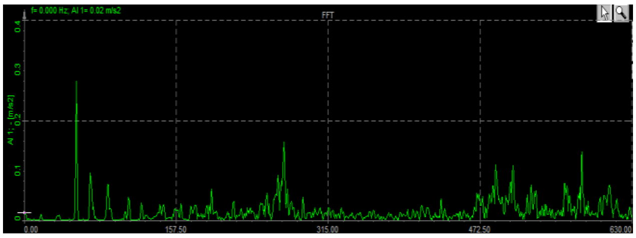
Case-II: Shaft with crack at 150mm:

1) The graph obtained at 500rpm is as follows :



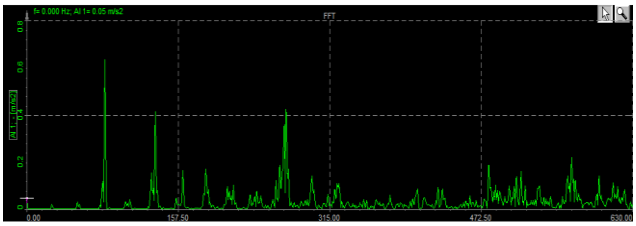
Here we get the max. peak at Vc =0.065 m/s^2.

The graph obtained at 1000rpm is as follows :



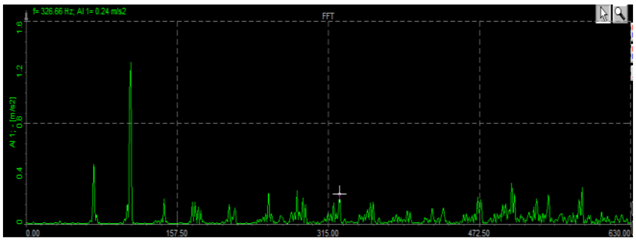
Here we get the max. peak at Vc =0.278 m/s^2.

2) The graph obtained at 1500rpm is as follows :



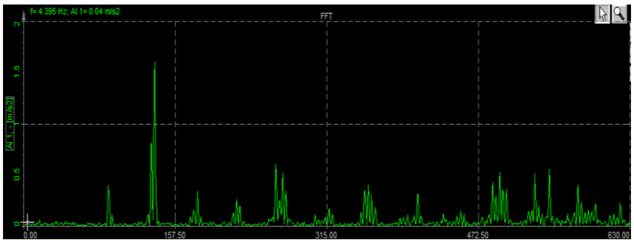
Here we get the max. peak at Vc =0.634 m/s^2.

3) The graph obtained at 2000rpm is as follows :



Here we get the max. peak at Vc =1.27 m/s^2.

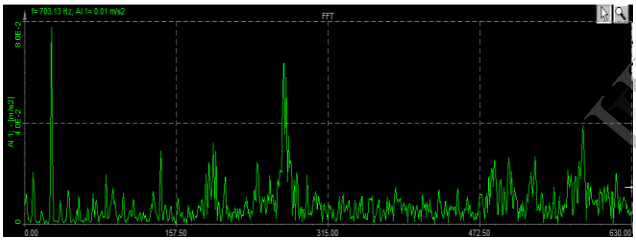
4) The graph obtained at 2500rpm is as follows :



Here we get the max. peak at Vc =1.61 m/s^2.

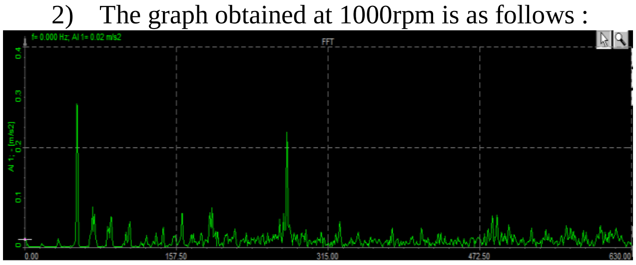
Case-III: Shaft with crack at 300mm:

1) The graph obtained at 500rpm is as follows :



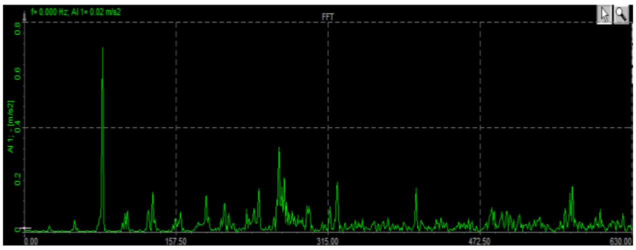
Here we get the max. peak at Vc =0.0776 m/s^2.

2) The graph obtained at 1000rpm is as follows :



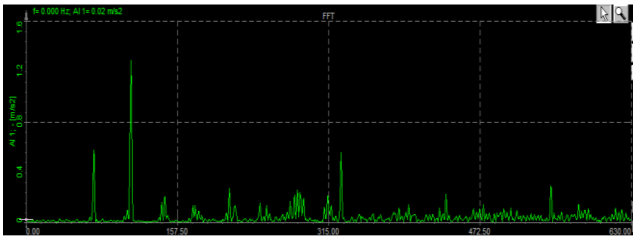
Here we get the max. peak at Vc =0.286 m/s^2.

3) The graph obtained at 1500rpm is as follows :



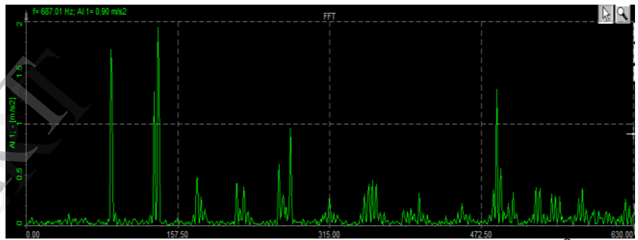
Here we get the max. peak at Vc =0.703 m/s^2.

4) The graph obtained at 2000rpm is as follows :



Here we get the max. peak at Vc =1.29 m/s^2.

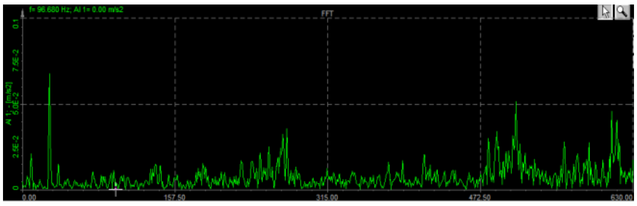
5) The graph obtained at 2500rpm is as follows :



Here we get the max. peak at Vc =1.94 m/s^2.

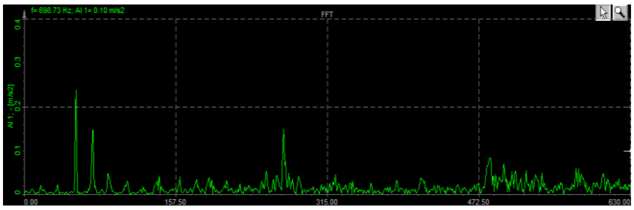
Case-IV: Shaft with crack at 400mm:

1) The graph obtained at 500rpm is as follows :



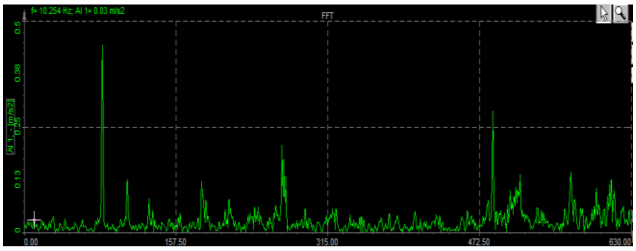
Here we get the max. peak at Vc =0.069 m/s^2.

2) The graph obtained at 1000rpm is as follows :



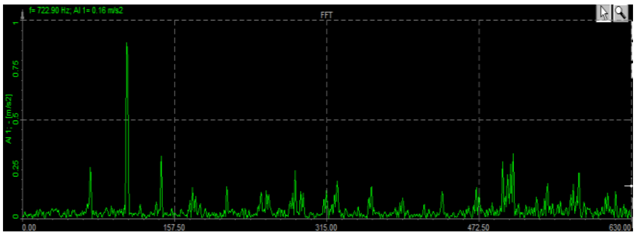
Here we get the max. peak at Vc =0.238 m/s^2.

3) The graph obtained at 1500rpm is as follows :



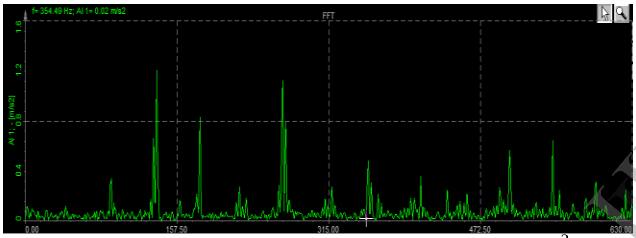
Here we get the max. peak at Vc =0.444 m/s^2.

4) The graph obtained at 2000rpm is as follows :



Here we get the max. peak at Vc =0.885 m/s^2.

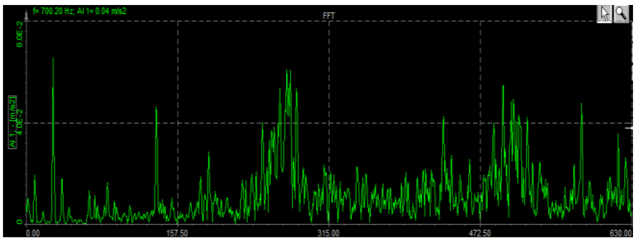
5) The graph obtained at 2500rpm is as follows :



Here we get the max. peak at Vc =1.21 m/s^2.

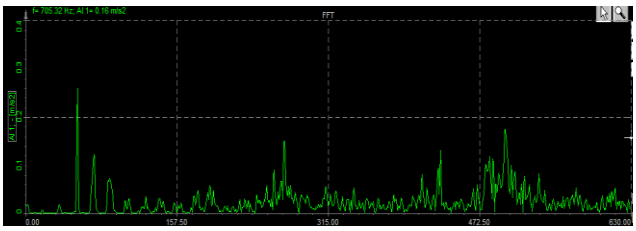
Case-V: Shaft with crack at 550mm:

1) The graph obtained at 500rpm is as follows :



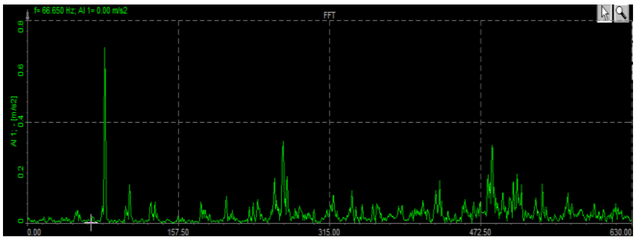
Here we get the max. peak at Vc =0.0654 m/s^2.

2) The graph obtained at 1000rpm is as follows :



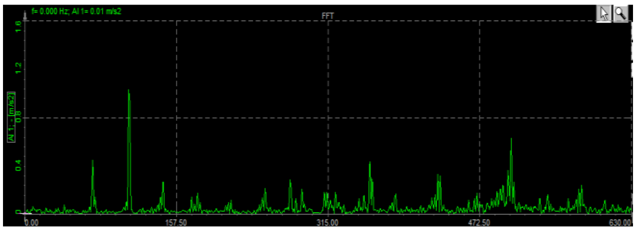
Here we get the max. peak at Vc =0.259 m/s^2.

3) The graph obtained at 1500rpm is as follows :



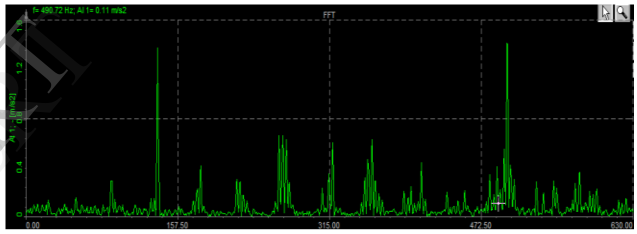
Here we get the max. peak at Vc =0.693 m/s^2.

4) The graph obtained at 2000rpm is as follows :



Here we get the max. peak at Vc =1.03 m/s^2.

5) The graph obtained at 2500rpm is as follows :



Here we get the max. peak at Vc =1.37 m/s^2.

From the above graphs it is clear that maximum peak is obtained nearly at the varying compliance frequency.

The maximum amplitudes from all the above graphs can be tabulated as follows:

Table 2: Maximum amplitude for different crack location

Crack location from bearing 1	Rotation speed in rpm				
	500	1000	1500	2000	2500
Healthy	Vc=0.0614 m/s^2	Vc=0.247 m/s^2	Vc=0.525 m/s^2	Vc=1.17 m/s^2	Vc=1.39 m/s^2
150mm	Vc=0.065 m/s^2	Vc=0.278 m/s^2	Vc=0.634 m/s^2	Vc=1.27 m/s^2	Vc=1.61 m/s^2
300mm	Vc=0.0776 m/s^2	Vc=0.286 m/s^2	Vc=0.703 m/s^2	Vc=1.29 m/s^2	Vc=1.94 m/s^2
400mm	Vc=0.069 m/s^2	Vc=0.238 m/s^2	Vc=0.444 m/s^2	Vc=0.885 m/s^2	Vc=1.21 m/s^2
550mm	Vc=0.0654 m/s^2	Vc=0.259 m/s^2	Vc=0.693 m/s^2	Vc=1.03 m/s^2	Vc=1.37 m/s^2

III. CONCLUSION

1) As speed of shaft increases, amplitude of vibration also increases.
2) Maximum peak obtained nearly at varying compliance frequency.
3) Amplitude of frequency depends on crack location; it is different for different crack location.
4) In above case study 300mm crack location gives nearly high amplitude as compared to other crack location for the respective speed.

IV. REFERENCES

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