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Study of Vibration Analysis of Rotating Shaft with Transverse Crack

Miss. Supriya S. Dixit[1], Miss.Manisha B.Narale[2], Miss. Firdos I.Pirjade, Miss. Jyoti G.Chavan

[1,2]*Department Of Mechanical Engineering, F.T.C.Sangola (Maharashtra)*

ABSTRACT: *In this paper, the influence of transverse cracks in a rotating shaft is analyses. 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. It's easy to find out the defects in stationary shaft than find out the defects in rotating shaft. During working, because of the cyclic loading or manufacturing flaws cracks frequently appears in rotating shaft. Although when shafts are operated in different type of conditions various types of cracks occurred due to of the rapidly fluctuating nature of stresses. The development of crack changes dynamicbehavior 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 vibrationmonitoring 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:-*Transverse crack, condition monitoring, vibration analysis*

I. INTRODUCTION

Shaft is a long piece of metal that turns and passes the power and movement from one part to another. It found the applications in plants like steam turbine, gas turbine, generator, compressors, pumps etc. in some applications much more speed is required. As there is more speed, there may be possibility of failure, or besides it there may bedefects in shaft like crack, bend in shaft.

It's easy to find out the defects in stationary shaft than find the defects in rotating shaft. During working, because of the cyclic loading or manufacturing flaws cracks frequently appears in rotating shaft. These defects in shaft can be diagnosed by many methods like ultrasonic detection, vibration analysis. Among these, vibration analysis is prevalent method. In this, cracks are of types transverse, longitudinal, slant cracks etc. And out of these, transverse cracks are very serious because it reduces the cross section of shaft. It is perpendicular to shaft axis. The vibrational response of rotating shaft changes due to defects in that shaft. These changes from rotating shaft can berepresented by graph for defect detection. It means by condition monitoring system.

Condition monitoring system is the process which predicts present and future condition of machinery when in operation. Vibration analysis is a most prevalent method for machine condition monitoring because it has some advantages like, it has quick response to change and also it more likely to, point to point actual faulty component.

Crack generation methods:
1) Ultrasonic Machining Method
2) Electro Discharge Machining Method
3) Electro Chemical Machining Method
4) Water jet machining method
5) Abrasive Water Jet Machining Method
6) Electron Beam Machining Method
7) Laser Beam Machining Method

Out of these methods, we use the Laser Beam Machining Method for crack generation, which having advantages such as,

1. Slots can be located accurately.
2. Very thin slots can be produced.
3. The operating cost is very low.

EXPERIMENTAL SETUP

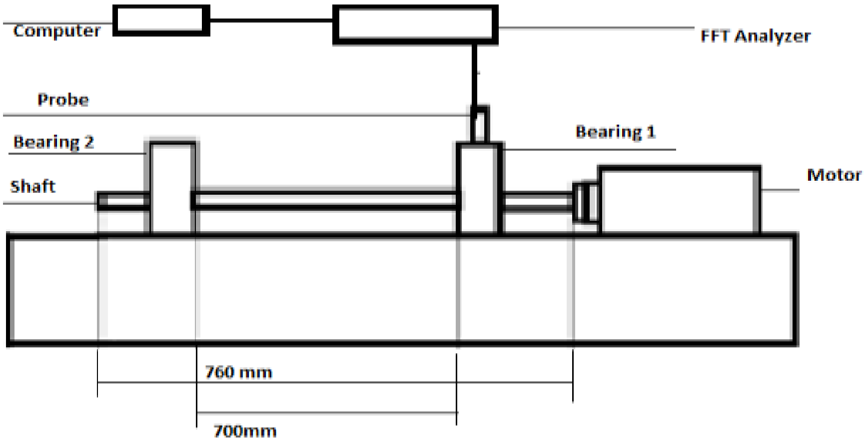


Fig. Experimental setup for FFT analyser.

Description:

Above fig shows the experimental set up for FFT Analyzer for detection of shaft having transverse crack. This set up contains a DC motor, FFT analyzer computer, probe, shaft, bearing, etc. As shown in above figure, the motor is mounted on concrete base. Then shaft is fitted into motor with the help of two pedestal bearings to have proper rotation with minimum vibration for example if The shaft is having total length 760 mm with 21 mm diameter and then mount the shaft in such a way that the distance between two bearings is 700 mm and leave 30 mm distance on both sides.

The probe is mounted on first bearing because the vibrations on the first bearing are more than the second one. Then probe is connected to FFT analyzer with the help of a cable. FFT analyzer is connected to computer FFT analyzer is converts the dynamic vibrations of shaft into physical quantity that can be measured and proceed it to the computer. Then readings are taken from computer in the form of amplitude and length.

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=$\frac{s}{2}(1-\frac{Bd}{Pd}\cos\emptyset)$

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

Varying compliance frequency(Vc):

When the rolling element set and the cage rotates with a constant angular velocity, aparametrically excited vibration is generated and transmitted through the outer race.

These vibrations are produced due to finite number of balls carrying load. The characteristicfrequency of this vibration is called the varying compliance frequency (VC) and is givenas:

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

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	25.00	77.04
2000	33.33	102.72

II. LITERATURE VIEW

In order to describe the state of the dot on cracked rotor related problems, the current work present the comprehensive theoretical, numerical & experimental approach adopted for crack detection in power plant rotating machinery.The rotating shaft has been tacked (faced) with and investigated for a long time[3,4].Two main features has been recognized i.e. local flexibility due to introduction of crack in relation to the affected shaft sections & opening-closing phenomenon of crack during rotation is known as breathing behavior.

The identification method and the relative theory are briefly presented, while three different types of cracks are considered.

1.The first is crack,therefore not actually a crack since it has not the typical breathing behavior.

2.The second is a small crack (14% of the diameter) &

3.The last is deep crack (47%of the diameter).

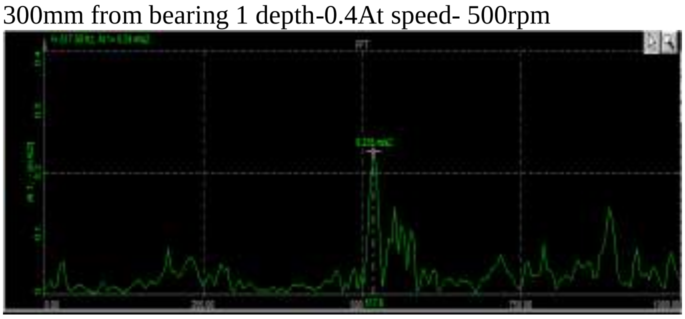
The Author know, they have been crack detected before the crack had goes to a critical path that means the occurrence of a catastrophic.In Inam's et al paper[7] The effect of presence of a crack is emphasized by huge bending loads & the crack detection in validatedby means of laboratory tests and measurements which are inapplicable to real machines during operation. It must be reminded that the possibility of detecting a crack depends highly from the position where the crack has developed, from loads that points where the effect are measured. Also crack- related thermal effect can help in identifying its presence.In presence work a new wavelet plot called cross wavelet transform has been applied to the time signal to obtain the phase angles. The advantage of the XWT is that it clearly indicates the phase angle between all the frequency components in the signal. For the invers problem of crack identification Artificial Neural Network (ANN) used.

All the works reported in E.S. Shekhar consider mainly the transverse crack that occurrence from the fatigue of the shaft material due to an excessive bending moment.

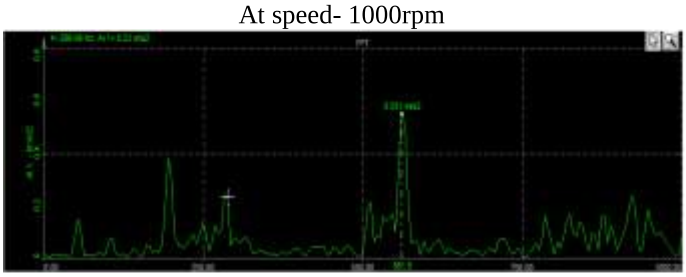
According toHemant G. Waikar's paperfor studying the vibration response of shaft, some terms like fundamental train frequency, varying compliance frequency are important.

III. ANALYSIS OF TRANSVERSE CRACK:

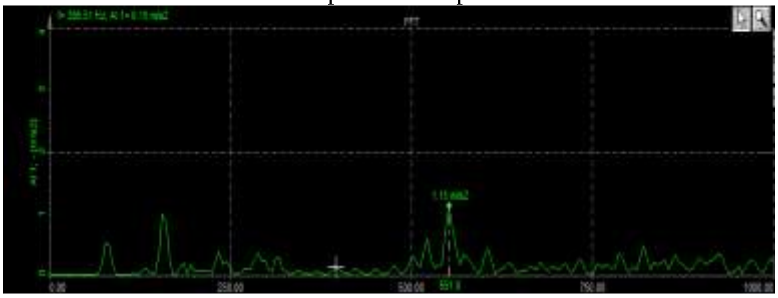
Case 1-crack location at 300mm from bearing 1 depth-0.4At speed- 500rpm



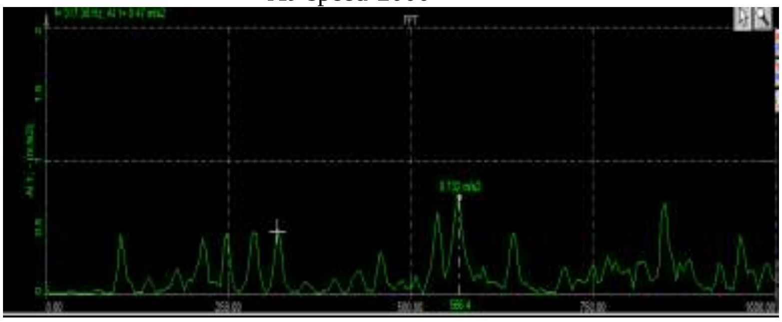
At speed- 1000rpm



At speed-1 500rpm

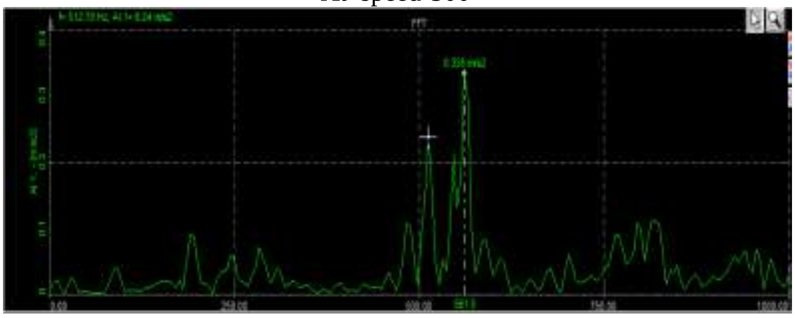


At speed-2000

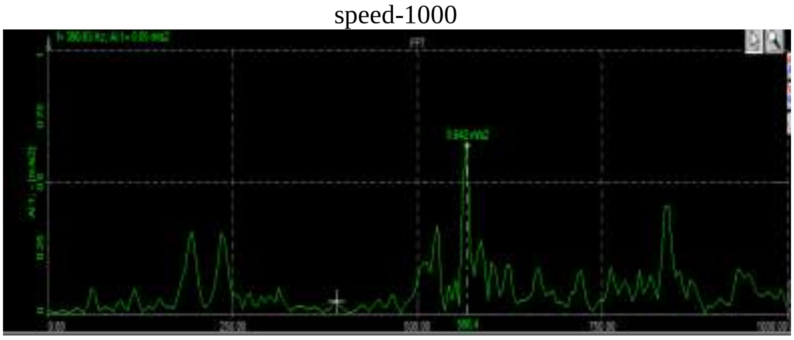


Case2- crack location at 150mm from bearing 1depth-0.3

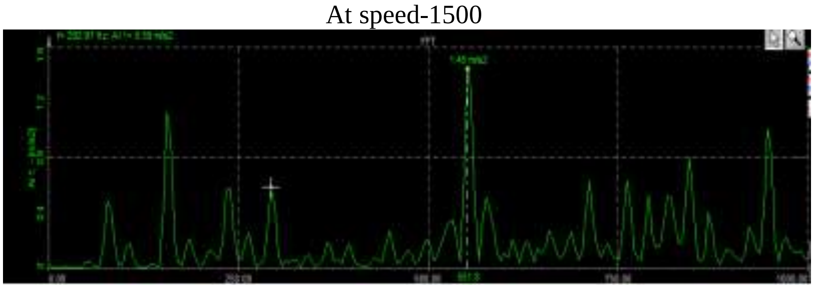
At speed-500



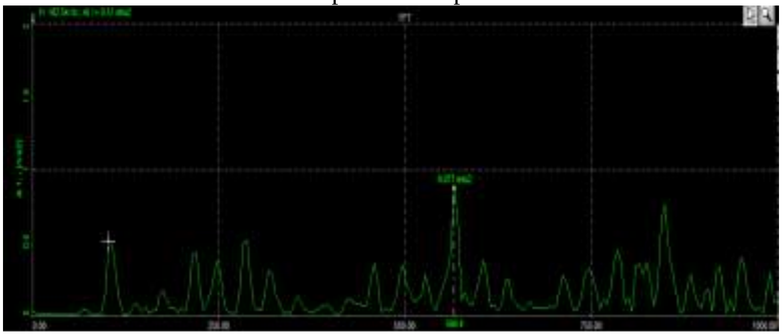
speed-1000



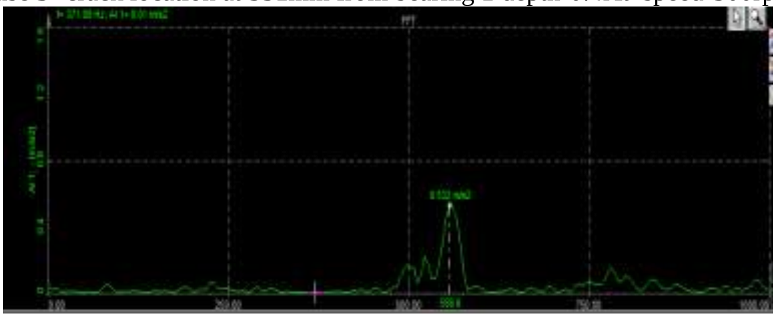
At speed-1500



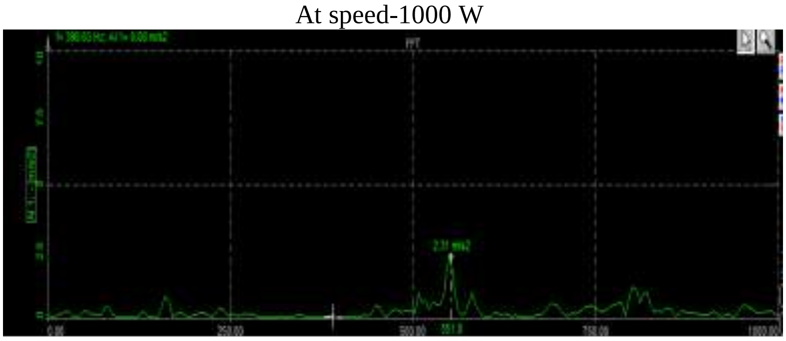
At speed-2000rpm



Case 3- crack location at 551mm from bearing 1 depth-0.4At speed-500rpm

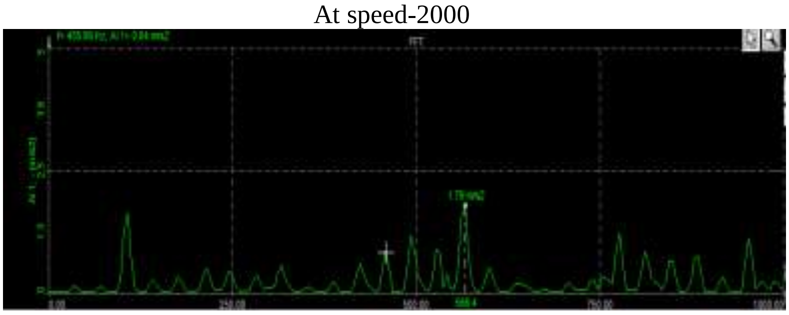


At speed-1000 W

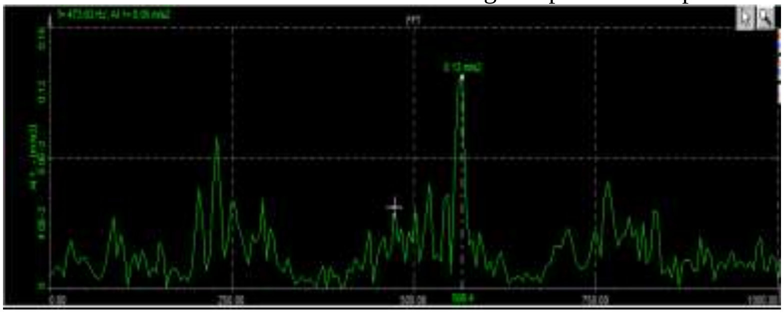


At speed-1500

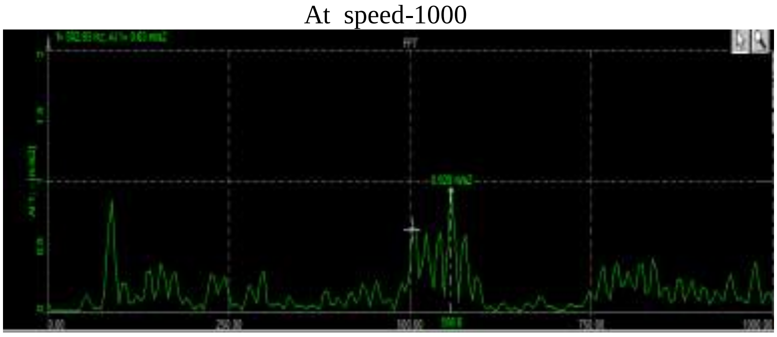
At speed-2000



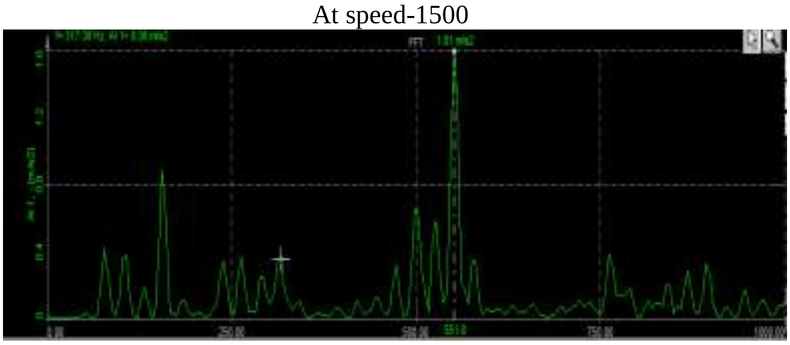
Case 4- crack location at 160mm from bearing 1 depth-5.7 At speed-500



At speed-1000



At speed-1500



At speed-2000

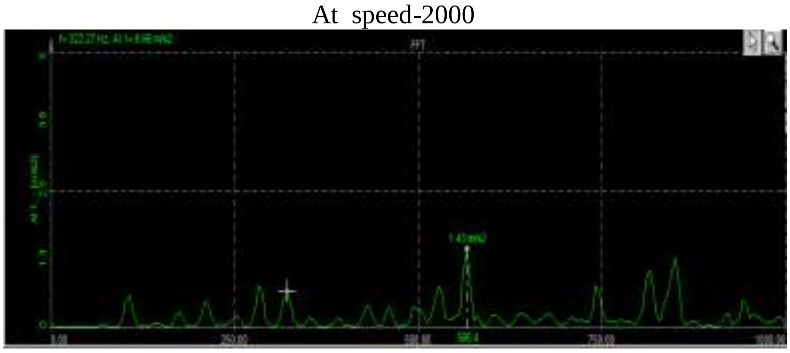
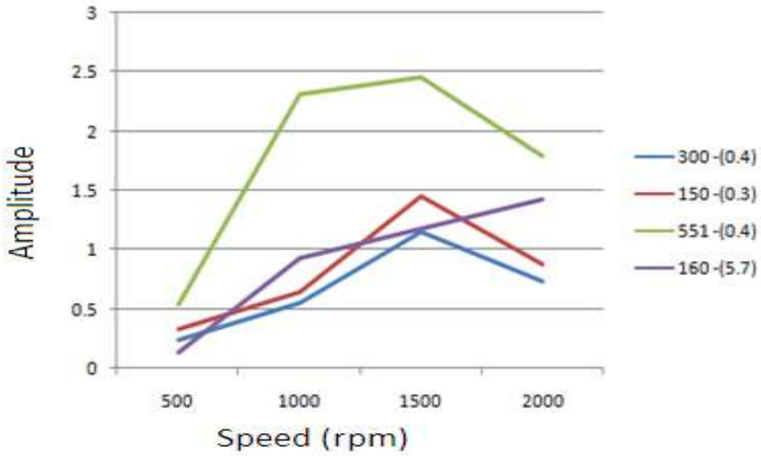


Table.2. Reading for SS304 shafthavingtransverse crack.

Crack location from bearing	**Rotational speed in rpm**			
	500	1000	1500	2000
300 -(0.4)	0.235	0.551	1.15	0.732
150 -(0.3)	0.335	0.642	1.45	0.877
551 -(0.4)	0.532	2.31	2.45	1.79
160 -(5.7)	0.13	0.929	1.18	1.43

Graph of vibration magnitude vs speed in rpm



IV. CONCLUSION

1) As speed of shaft increases, vibration amplitude also increases.
2) Amplitude of vibration depends on crack location, it is different for different crack location.

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