Crack Detection and Location in Propeller shaft by using Natural Frequency

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Abstract-The effects of crack on Dynamic characteristics like natural frequency, modes of vibration of structure has been the subject of many investigations. Present work deals with the vibration analysis of an Propeller shaft made with multiple transvers crack using finite element method. The effect of various parameters like crack location, crack depth, on the change in natural frequency of shaft is studied. It is observed that presence of crack in shaft decreases the natural frequency. The natural frequency further decreases with increase in depth of crack. These effect were interpolated by modal Analysis and validated by using FFT analysis on propeller shaft.

Index Terms- crack depth, transvers crack, natural frequency, modal analysis

1. INTRODUCTION

Propeller shaft is to transmit the driving torque from the engine or Gear unit to the wheels, while using propeller shaft, torsional stress and bending stress are produced. Crack identification in rotating machinery is a big challenge today research [1]. Such cracks can cause total shaft failure due to presence of cracks, failure require particular time, during this crack affect dynamic behavior. The importance of an early detection of cracks appears to be crucial for both safety and economic reasons because fatigue cracks are potential source of catastrophic structural failure. Cracks may be initiated and subsequently propagated in shaft and structure subjected to dynamic loadings[2]. Failure may results if the history of these crack is not recorded and precautionary measure are not taken.

From past studies various types of cracks are found like transverse, longitudinal, slant, Notches out of which transverse crack remains the most important type of crack. Transverse crack lead to dangerous and castrophic effect on dynamic behavior of rotating structure.[1]

Finite element method was used as stress analysis to determine the stress conditions at the failed section.

All of driveshaft is metal shafts or metal tubes [3]. Various techniques are used for crack determination such as vibration-based methods using modal and numerical analysis,

A. Non-traditional methods based on ultrasonic guided waves, magnetic induction, radiofrequency identification tag, acoustic intensity and acoustic laser-Doppler vibrometry.

B. Numerical procedures using fem in conjunction with modal analysis, wavelet transforms neural net works, genetic algorithms and fuzzy set theory.

Anjani kumar sinha, et al[1],studied vibrational analysis of propeller shaft with transvers crack by

considering three locations with different crack depth and operating angles.

Muvva Harish, et al[2] ,done work on vibrational analysis of propeller shaft and he compare the the results of modal and harmonic analysis on propeller shaft with the help of FEA . they have studied the parameter like deflection of shaft, natural frequency under various operating angles.

A.V.Deokar[3], presented the theory on crack detection in cantilever beam using natural frequency kept as basic criterion. Experimental modal analysis was performed on healthy beam and 3D graphs of frequency in form of crack position and width is studied. And they concluded that vibration behavior of beam is very sensitive to all parameters like location and depth.

Sri Raghava .et al[4], presented work on vibration analysis. They used to displacement matrix for the determination of amplitude of cracked rotor.

Dineshsingh R. Pardeshi, et al[5], prospectors identified vibration characteristics of cantilever and simply supported beam. They produced the axil crack and radial on beam and observed that natural frequency of beam is decreases with axial crack and increases with radial crack on beam as crack depth varies.

Dinesh R satpute et al[8], worked on natural frequency determination for multiple crack. They used to compare the FEA analysis and Experimental analysis

and observed that natural frequency decreases with increases in crack depth.

Vigneshkumar arumugum et al [9], presented the theory on vibrational analysis of drive shaft with the help of finite element analysis. From these studied the observation are the amplitude of drive shaft is increases with increase in crack depth. They used harmonic analysis for vibration analysis.

Ganesh Jadhav,et al[11], published work on vibrational analysis of automotive drive shaft and found that the maximum stress point and the dangerous area at cracked position. They used to compare modal analysis.

2. METHODOLOGY

Cracks produced in the propeller shafts because of manufacturing flaws or fatigue during operation. Failures could occur due to high or low cycle fatigue,

appeared crack potentially propagates sufficiently to

cause total failure of the propeller shaft. Transverse cracks frequently occur in the rotating shafts under rotating forces. Hence it's necessary to identify the presence of crack in a propeller shaft and its response

with respect to location and depth of the crack. The parameters considered in the vibration analysis are;

a. Location of the transverse crack,

b. Depth of the transverse crack,

2.1. *Types of Shaft crack*

Cracks are broadly classified into three groups:

i. Transverse cracks: This type of crack is perpendicular to the shaft axis. They reduce the shaft cross-sectional area and result in significant damages to rotors. These are the most serious and most common defects occur in rotating shaft.

ii. Longitudinal cracks. This type of crack is parallel to the shaft axis and is relatively rare and less serious.

iii. Slant cracks. This type of crack is at an angle to the shaft axis. It doesn't occur very frequently, but could appear in industrial machine shaft.

3. MATHEMATICAL FORMULATION

3.1. *Design of shaft.*

Sr.no.	Parameters of shaft	Dimensions(mm)
1	Outer diameter(do)	51
2	Inner diameter (di)	47
3	Thickness (t)	4
4	Overall length (L)	560

Table.1 Dimensions of drive shaft

1. Mass of drive shaft

m= ρAL= ρ × Π/4 × (do2- di2) ×L

Here m=mass of shaft

ρ= density of material

d0, di= outer and inner dia. Of shaft

2. Torque transmission capacity

T= Ss× Π /16 × [(do4- di4) × do]

T= Torque,

ss= tensile strength

Material Properties	Steel-SM45c
Density	7600 kg/m3
Poisson's ratio	0.3
Young modulus	207 Gpa

Table.2 Properties of material

3.2 Theoretical Natural frequency

To determine natural frequency Bernoulli-Euler beam theory used.

Fn = (Π p2) / 2L2 X √ (E Ix/m')

Where p= 1,2,3…

Ix= moment of inertia

m'=mass per unit length

E= young's modulus

L=overall length

Identification of crack location is calculated by using,

$$e=\frac{1}{\pi}\cos^{-1}[1-\frac{(\Delta f2/f2)/(\Delta f1/f1)}{2}].$$

Where Δfn = difference of natural frequencies of uncracked and cracked.

By using Bernoulli-Euler Beam Theory natural frequency for untracked shaft is determined and used for further comparison.

No. of modes	Natural Frequency
1	453.0977 Hz
2	1176.75 Hz
3	2192.99 Hz

Table.3Natural frequency table

3.3 Modeling

The fig.1 shows that the actual model of propeller shaft used in maruti Omni car for transmit ion.

Fig.1 actual model of propeller shaft

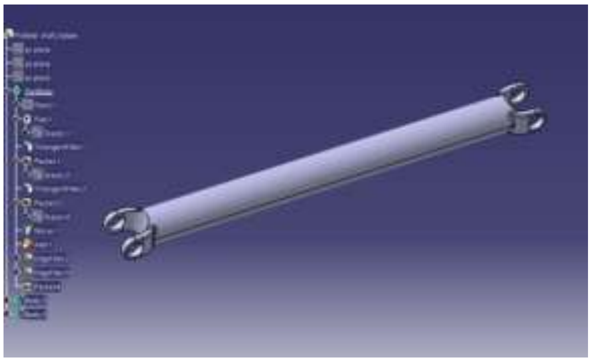

Fig.2 design of propeller shaft with U joints

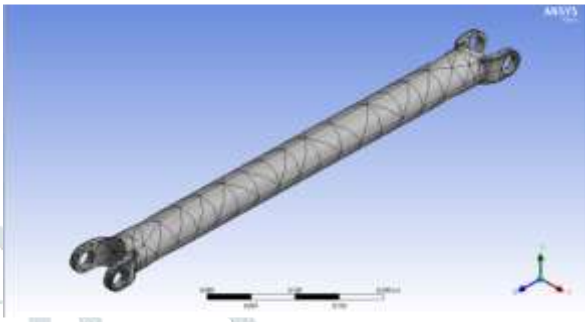

Fig.3 Meshed model of propeller shaft with U joints

Fig.3 shows that the meshed model of propeller shaft in ANSYS 15.0

3.4 Modal Analysis at crack location 200 mm

Modal analysis of propeller shaft is performed on ANSYS 15.0. Initially geometric crack is created at 200 mm location from one end. While doing this depth of crack is varied from 2 mm, 4 mm, and 6 mm. For that respective natural frequency of propeller shaft is obtained which is shown in table.

frequency	Uncrack	a=2 mm	a=4 mm	a=6 mm
1	461.65	459.48	457.88	455.9
2	468.42	467.03	460.95	457.02
3	1219.8	1216.5	1158.7	1136.6
4	1234.4	1237.7	1173.4	1166.1
5	1925.8	1913.6	1477	1458.4
6	2284.5	2266.8	2011.9	2025.0

Table.4 Frequencies at 200 mm crack location of shaft

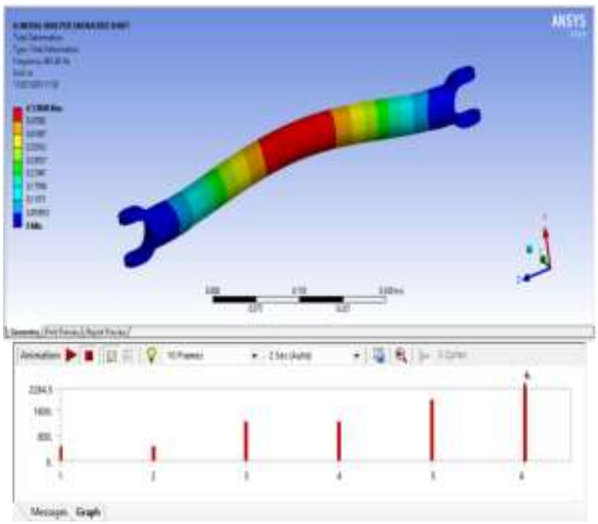

Fig.4 modal analysis results of uncracked shaft.

Fig.4 shows that the result of uncracked propeller shaft and the first natural frequency is found that 461.65 Hz.

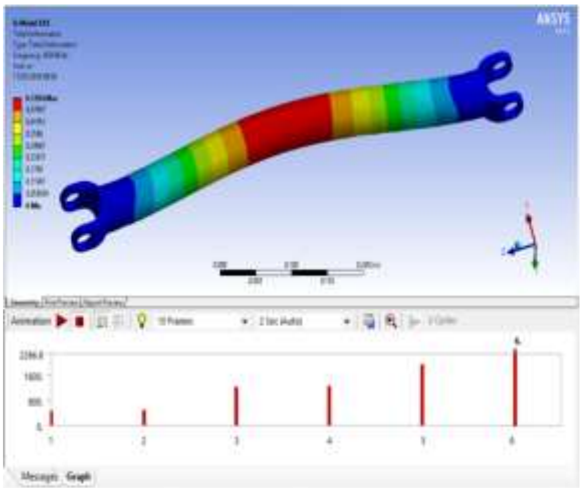

Fig.5 modal analysis of crack location 200 mm , depth 2 mm

Fig.5 shows that the FEA result of crack location 200 mm and depth of crack is 2 mm.The first natural frequencies obtained as 459.48 Hz.

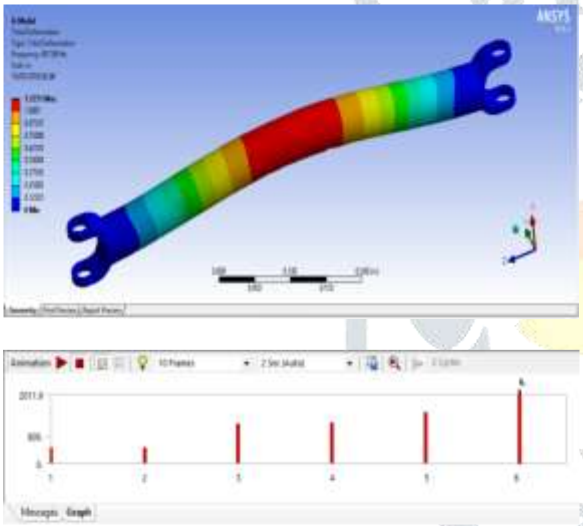

Fig.6 modal analysis of crack location 200 mm , depth 4 mm

Fig.6 shows that the FEA result of crack location 200 mm and depth of crack is 4 mm.The first natural frequencies obtained as 457.88 Hz. And for crack depth 6 mm the natural frequency is obtained as 455.9 Hz. Further results are obtained by varying the crack location like 300 mm and 400 mm with respect to variation in crack depth.

4. EXPERIMENTAL WORK

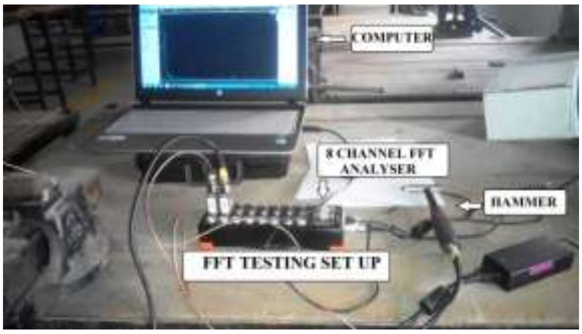

Fig.7 Experimental set up

The schematic of the experimental setup is shown in Fig 8. This setup consist of a propeller shaft, an exciter, controller/amplifier, transducers(e.g. accelerometer), a data-acquisition system, and a computer with signal display and processing software i.e. vibration analyzer.

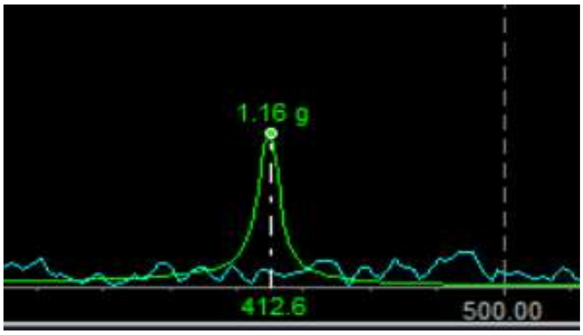

Fig.8 FFT result of Propeller shaft without crack

Fig.9 shows that graph of natural frequency for uncracked shaft. The highest peak is the natural frequency of shaft which is 412.6 Hz.

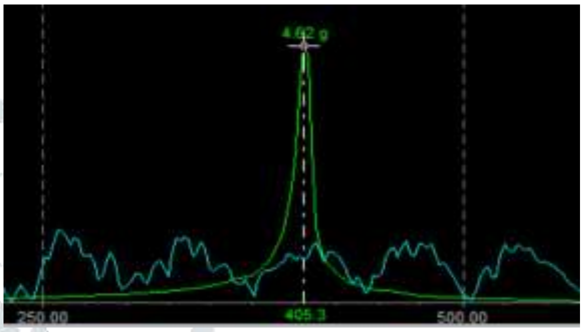

Fig.9 FFT result of cracked location 200 mm and depth 2 mm

Fig. 10 shows that the natural frequency 405.3 Hz obtained at crack location 200 mm and depth of crack 2 mm. The obtained natural frequency is reduced due to presence of crack in shaft compared with frequency of uncracked shaft 412.6 Hz.

In this way FFT analysis of propeller shaft is taken at various crack location i.e. crack location at 300 mm and 400 mm and simultaneously depth of cracks are varied by 2mm ,4mm, 6 mm and natural frequencies are recorded.

5. CONCLUSION

In this study it is observed that Cracks may induce in the propeller shafts either due to manufacturing defects or failure or fatigue during working operation. Failures take place due to high or low cycle fatigue. The cracks propagate to cause the failure of propeller shaft.

The modal analysis is conducted to find out the natural frequency of uncracked and cracked propeller shaft and it is observed that as however crack depth increases the natural frequency of shaft decreases.

By this decrease in natural frequency we can identify the cracks in a system and conditioning monitoring of system is done.

6. REFERENCES

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