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Crack determination in propeller shaft using natural frequency

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ABSTRACT

Present work gives an overview of currently available cracks and methods. This method is determined crack by using natural frequency. This natural frequency is determined by using Euler Beam theory. When cracks are present in structure, natural frequency are deviates from original frequency and result are validated by using FEA like ansys. This result deviation shows crack is present.
The main aim of proposed studies by using virtual analysis of propeller shaft to study critical area zone of failure specially cracks. In addition to this, related mathematical model and technique is incorporated. Further result will be validated using acoustic emission technique.

Keywords— **Propeller shaft, Crack determination, FEA, Vibration technique**

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I.INTRODUCTION

Crack identification in rotating machinery is a big challenge today research. Such cracks can cause total shaft failure due to presence of cracks, failure require particular time, during thiscrack affect dynamic behavior. 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]*.

D.P.Patil,S.K.Maiti uses forward and inverse method to determine cracks. For the forward the Governing differential equation for transverse vibration is used.

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 *[13]*.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.

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

A. Tlaisi1, a. Akinturk1, a. S. J. Swamidas1 & m. R. Haddara1 prospector identify the presence of a crack in a cylindrical overhanging shaft with a propeller at the free end proved by experimental and numerical investigations. Shaft response parameters for lateral (using anAccelerometer) and torsional vibrations (using shear strain gages fixed at three different locations) are obtained using the modal analysis software. A numerical method was developed for determining the location of a crack in varying depths when the lowest three natural frequencies of the cracked beam are known. S. P. Lele and S.K. Maitiuse frequency measurements for detection of location of crack in beams. *[6]*

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II.LITERATURE REVIEW

Cracks in shafts have long been identified as one of the main safety problems of Operating turbo- machines *[4]* Crack generation in a shaft is a Process in which fractures grow slowly. If a shaft crack goes undetected in an Operating machine, it grows continuously, so that the reduced cross section of the Rotor eventually is unable to withstand the dynamic loads applied to it. When this happens, the rotor will very rapidly fail in a brittle fracture mode once the crack reaches a critical size. This sudden failure releases a large amount of energy that is Stored in the rotating system. This can sometimes result in serious injury or costly Disruptions to the process. Clearly, detecting shaft cracks is an important issue. There are several predictive maintenance techniques used to monitor and analyze critical rotating machines and equipment in a typical plant. Such as Vibration analysis, ultrasonic, thermograph, tribology, process monitoring, visual inspection, and other non-destructive analysis techniques *[15]* .There are a few types of shaft cracks which can develop during the Operation of rotating machines. The transverse crack remains the most important Type of crack as the machine safety is significantly influenced by its occurrence.

The study of transverse cracks has been important because, being perpendicular to the shaft they reduce the cross-sectional area and result in significant damages to Rotors.

A. Cause of shaft cracks

The crack initiation and crack propagation of a shaft is a complex process that arises from machining imperfections. "Cracks may be caused by mechanical stress raisers, such as sharp keyways, abrupt cross-sectional changes, heavy shrink fits, dents and grooves, or factors such as fretting and/or metallurgical factors such as forging flaws, inclusions, porosity and voids.*"[15]*

A rotating shaft is always subjected to different types of stresses such as bending, torsional, shear, and static radial loads. In rotor systems, the stress field contains a mixture of bending and torsional stresses. If the shaft is subjected only to bending stresses, it is possible that a transverse crack will be developed. in rotating machinery, bending stress is usually the dominant component, thus a transverse crack will occur.

B. Types of shaft cracks

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.

III.MATHEMATICAL FORMULATION

Passenger car, small truck have torque transmission capacity more than 3500 Nm and for avoid of whirling vibration, natural bending frequency should be higher than 6500 rpm . To avoid vibration problem, shaft length should be large but due to space limitation, 2 piece propeller shafts is used.

A.Design of Drive Shaft

1. Mass of drive shaft

$m= \rho AL= \rho \times \Pi/4 \times (do^2- di^2) \times L$--------1)

Here m=mass of shaft

ρ= density of material

d_0, di= outer and inner dia. Of shaft

2. Torque transmission capacity

$T= Ss\times \Pi /16 \times [(do^4- di^4) \times d_o]$ ----------2)

T= Torque, s_s= tensile strength

A. Parameter *B.*	*C. Steel*	*D. HS – Carbon / Epoxy* *E.*
F. P	*G. 7600 kg/m^3*	*H. 1600 kg/m^3*
I. d_o	*J. 88 mm*	*K. 88mm*
L. d_i	*M. 83.2 mm*	*N. 83.2 mm*
O. L	*P. 950 mm*	*Q. 950 mm*
R. M	*S. 4.41 kg*	*T. 9.81 kg*
U. T	*V. 770 Nm*	*W. 875Nm*

Table No,1 Propeller Shaft Parameter Table

B.Calculation of Natural frequency

Crack detection has been mostly determined by using frequency and mode shapes data. While solving problem for crack detection, optimization method is used .in this method minimization of difference between theoretical and experimentaldata.

To determine natural frequency two method are used

1. Timoshenko beam theory
2. Bernoulli-Euler beam theory

Timoshenko beam theory considers both transverse shear deformation as well as rotary inertia effects. Natural frequency based on the Timoshenko beam theory is given by

fnt= Ks (30 Π p2) / L2 X √ (Er2 / 2ρ)----------3)

fnt= natural frequency base on Timoshenko beam theory, HZ

Ks = Shear coefficient of lateral natural frequency p = 1, first natural frequency

r = mean radius of shaft, Fs = Shape factor, 2 for hollow circular cross section

n = no of ply thickness, 1 for steel shafts

$1 / Ks^2 = 1 + (n^2\Pi\ 2\ r^2) / 2L2 X [1 + fs\ E / G]$ ---------4)

X. No.of Modes p	*Y. Natural Frequency*
Z. 1	*AA. 0.00934 HZ*
BB. 2	*CC. 0.0295 Hz*

Table No.2 Natural Frequency Table.

IV.ANALYSIS BY FEM

A. FINITE ELEMENT METHOD (FEM)

FEM simulates part or assemblybehavior by dividing the geometry of the part into a number of elements of standard shapes, applying loads and constraints, then calculating variables of interest deflection, stresses, temperature,

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pressures etc. The behavior of an individual element is usually described by a relatively simple set of equations. Just as the set of elements would be joined together to build the whole structure, the equation describing the behaviors of the individuals elements are joined into a set of equations that describe the behaviors of the whole structure.

FEM is

- A numerical method
- Mathematical representation of actual problem
- Approximate method

B. CAD MODEL

The cad model of the drive shaft was generated in CATIA and imported in Ansys workbench in IGS format. Figure 1 shows cad model.

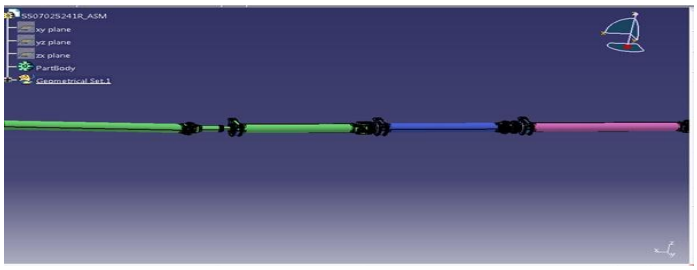

Figure.1 Cad model of propeller shaft

C. Meshed Model

The meshed model of drive shaft is shown in fig.2. The number of elements is equal to 10309 and number of nodes equal to 5299

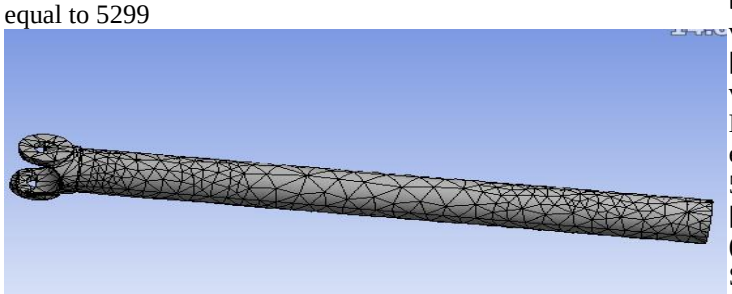

Figure 2 Meshed Model

D. RESULT

After applying boundary condition to propeller shaft then modal analysis is performed. Result is as shown fig.3

VI.CONCLUSION

The maximum stress point and dangerous areas are two frequency measuring technique found by the deformation analysis of drive shaft. The relationship between the frequency and thevibration modal is explained by themodal analysis of drive shaft .comparative study between two methods.

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