Model Analysis of Wind Mill Wound Rotor Using Various Modes of Frequencies

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Abstract: Vibration investigation of a damaged structure is one approach for fault diagnosis. Vibration diagnosis, as a non-destructive detection technique, has recently become of greater importance. Cracks in vibrating component can initiate catastrophic failures. The presences of Cracks change the physical characteristics of a structure which in turn alter its dynamic response characteristics. Therefore there is need to understand dynamics of cracked structures. Crack depth and location are the main parameters for the vibration analysis. A crack on a beam element introduces considerable local flexibility due to the strain energy concentration in the vicinity of the crack tip under load. In the present study, vibration analysis is carried out on a simply supported rotor shaft with open transverse crack, to study the response characteristics. It is verified from simulation analysis that the presence of crack decreases the natural frequency and amplitude of vibration. The mode shapes also changes considerably due to the presence of crack.

Keywords: Crack, depth and location, vibration analysis, Natural frequency, Amplitude.

I. INTRODUCTION

Rotating machinery is very common in the industry. Accurate prediction of dynamics of rotating shafts is necessary for a successful design. The vibratory phenomena associated to this kind of machine have been intensively studied to assure the best operational condition of the rotating machinery. The dynamic behavior of structures, in particular, that of a rotor, containing cracks is a subject of considerable current interest. Cracks are among the most encountered damage types in the structures. Cracks in rotating parts may be hazardous due to static or dynamic loadings, so that crack detection plays an important role for structural health monitoring applications.

The most common structural defect is the existence of a crack. Cracks are present in structures due to various reasons. The presence of a crack could not only cause a local variation in the stiffness but it could affect the mechanical behavior of the entire machine to a considerable extent. Cracks may be caused by fatigue under service conditions as a result of the limited fatigue strength. They may also occur due to mechanical defects. Another group of cracks are initiated during the manufacturing processes. Generally they are small in sizes. Such small cracks are known to propagate due to fluctuating stress conditions. If these propagating cracks remain undetected and reach their critical size, then a sudden structural failure may occur. Hence it is possible to use natural frequency measurements to detect cracks.

The objective is to carry out vibration analysis on a simply supported rotor shaft with and without crack. Simulation has been done in free-free condition. With this modal analysis natural frequencies are calculated for various modes. In first phase of the work a single transverse surface cracks are included in developing the analytical expressions in dynamic characteristics of structures.

II. PROPERTIES

To calculate natural frequencies and mode shapes for simply supported rotor shaft. The method described has been applied to a cracked Rayleigh beam. C15 steel has taken as the rotor shaft

Length of the shaft,	L	=	0.5m
Diameter of the shaft,	D	=	0.02m
Density		=	7800 Kg/m3
Modulus of elasticity		=	2.08 x 1011N/m2
Central mass		=	5.5 Kg
Poisson's Ratio		=	0.3
End condition of the rotor		=	both end fixed by flexible bearing.
Crack position ratio	X/L	=	0-0.5
Crack depth ratio	a/D	=	0.1–0.4
Location of force	Xf/L	=	0.04-0.5
Magnitude of force, F		=	15N

Where,
A - Crack depth.
X - Crack position from the left support end.
Xf - location of force from the left support end.

III. DESIGN OF ROTOR BEARING SYSTEM WITH RESULTS

The modeling of rotor shaft was done. The crack was modeled with a depth ratios of 0.1, 0.2, 0.3 and the position of ratios 0.1, 0.2, 0.3,0.4 from the left end of the support. Finally, we obtained the V-shaped open transverse crack. The model was imported into simulation software in IGES file format. The shaft was discretized into 27979 elements with 46102 nodes.

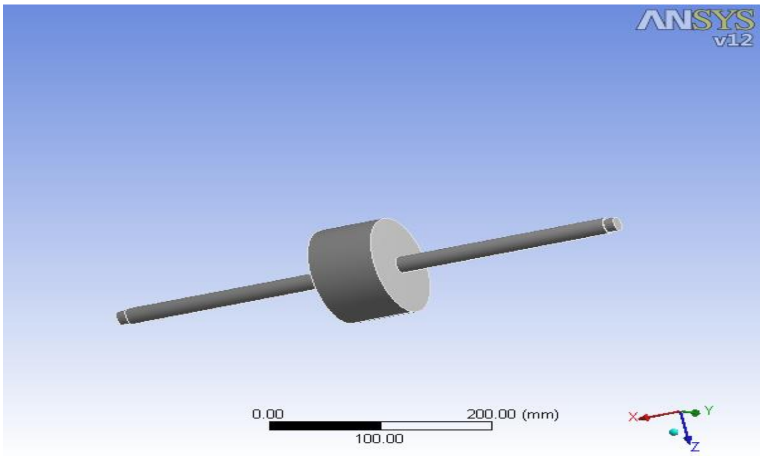

Fig. 1. Rotor shaft model without crack.

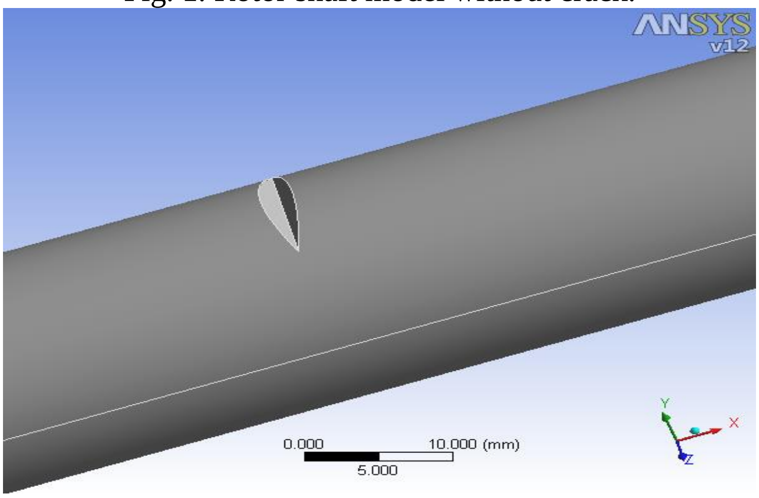

Fig.2. model of a rotor shaft with transverse open crack

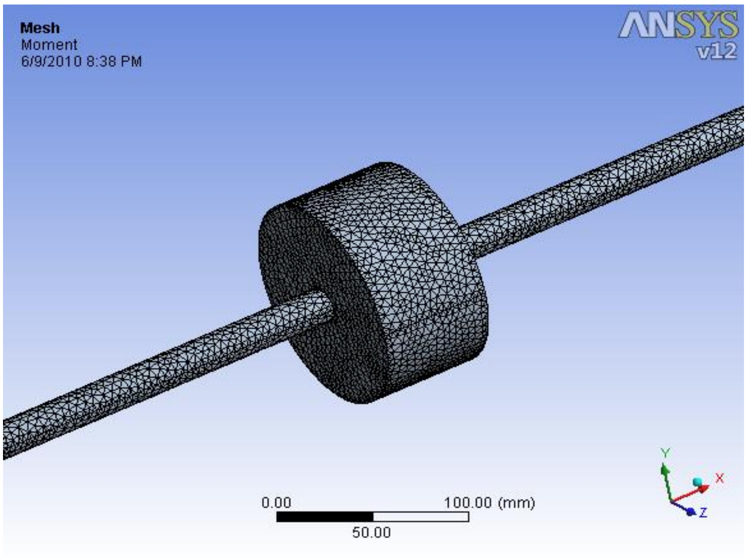

Fig.3. meshed model

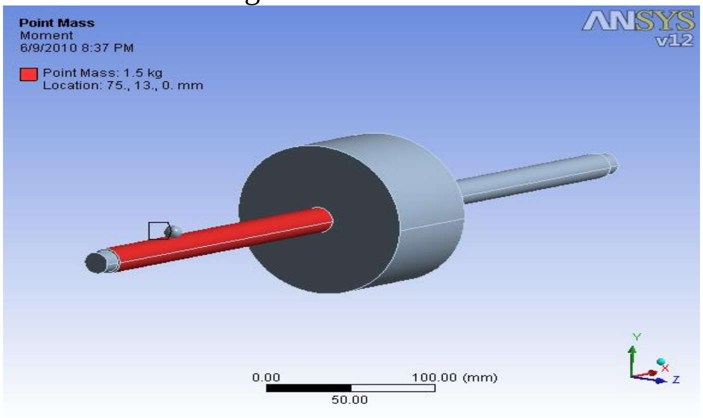

Fig. 4. Model with point mass

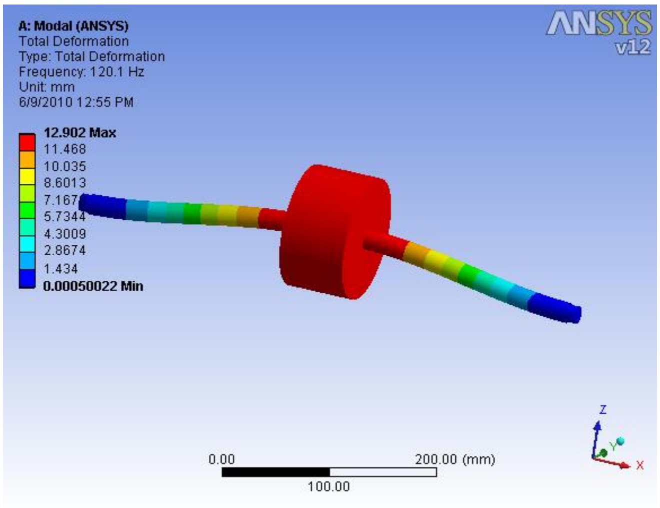

Fig.5. Mode – 1

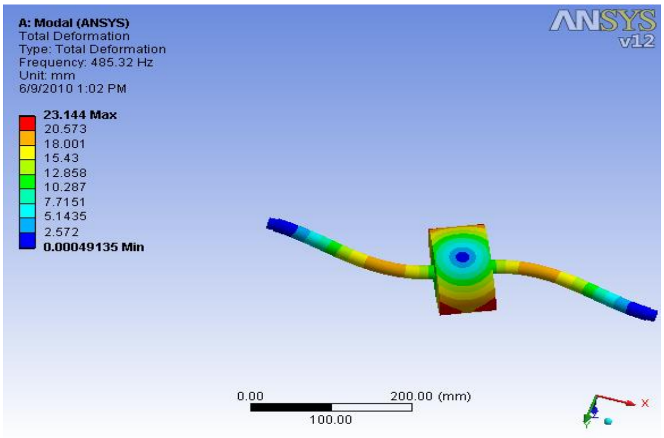

Fig.6. Mode - 2

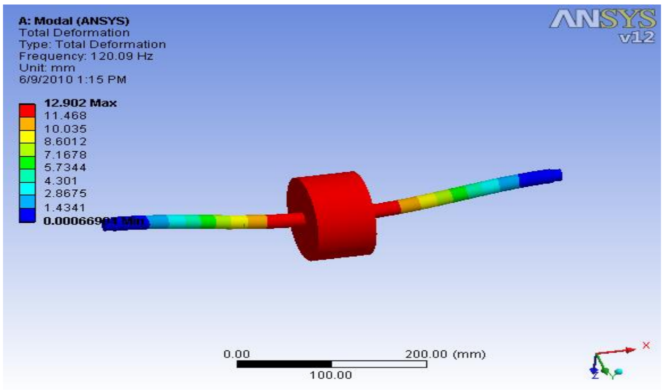

Fig.7. Mode - 3

IV. COMPARISON OF FREQUENCIES AT VARIOUS MODES AND CRACK DEPTH RATIOS

Table 1. Variation of frequencies at Different Relative Crack Depths When Relative Crack Location At X/L=0.1

Crack Depth ratio (a/D)	Mode 1 Frequency Hz	Mode2 Frequency Hz	Mode3 Frequency HZ
0	120.09	121.1	485.74
0.1	119.71	120.98	485.39
0.2	119.66	120.75	485.32
0.3	118.86	120.72	484.64

Table.2. Variation of frequencies at different Relative crack depths when Relative crack location at X/L=0.2

Crack Depth ratio (a/D)	Mode 1 Frequency Hz	Mode2 Frequency Hz	Mode3 Frequency HZ
0	120.09	121.1	485.74
0.1	119.77	121	485.62
0.2	119.57	120.8	485.44
0.3	119.05	120.09	484.92

Table.3. Variation of frequencies at different Relative crack depths when Relative crack location at X/L=0.3

Crack Depth ratio (a/D)	Mode 1 Frequency Hz	Mode2 Frequency Hz	Mode3 Frequency HZ
0	120.09	121.1	485.74
0.1	119.91	121.03	485.68
0.2	119.69	120.9	482.7
0.3	119.55	120.72	479.44

Table.4. Variation of frequencies at different Relative crack depths when Relative crack location at X/L=0.4

Crack Depth ratio (a/D)	Mode 1 Frequency Hz	Mode2 Frequency Hz	Mode3 Frequency HZ
0	120.09	121.1	485.74
0.1	119.96	121.08	484.72
0.2	119.48	120.94	480.59
0.3	119.09	120.71	472.86

V. COMPARISON OF NATURAL FREQUENCIES FOR VARIOUS CRACK DEPTH RATIOS AT VARIOUS MODES

The graph was drawn between frequency and crack depth ratio for various modes these graphical representation as follow as

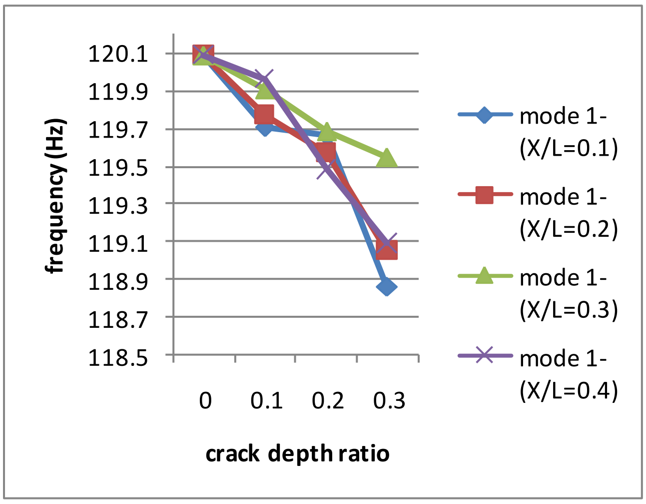

Fig.8. Comparison of natural frequencies at Mode -1

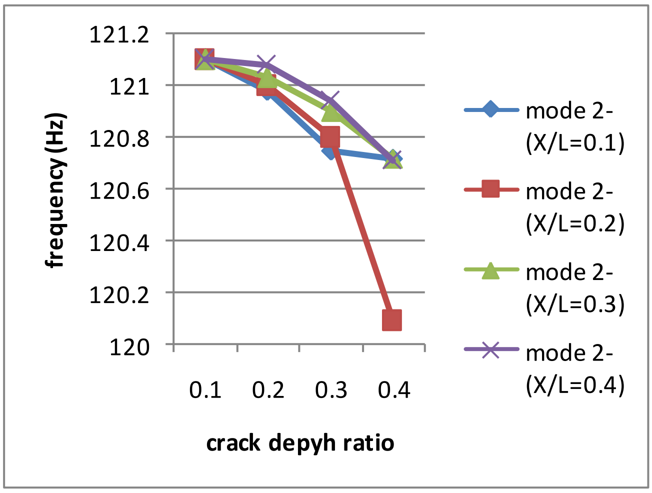

Fig.9.Comparision of natural frequencies Mode -2

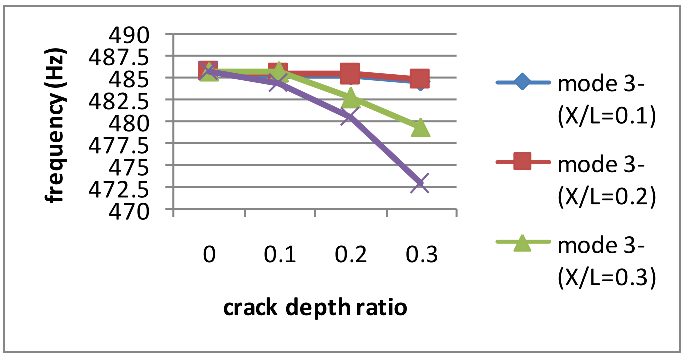

Fig. 10. Comparison of natural frequencies Mode -3

VI. Conclusion

The vibration behavior of rotor with open transverse crack in various position and depth was studied under free condition. The modal analysis was done and six modes of frequencies are calculated using simulation. It is shown that the natural frequency changes substantially due to the presence of cracks. The changes depending upon the location and size of cracks. The position of the cracks can be predicted from the deviation of the fundamental modes between the cracked and uncracked rotor shaft.

REFERENCES

[1]. A.S. Sekhar, A.R. Mohanty, S. Prabhakar, Crack detection by measurement of mechanical impedance of a rotorbearing system, Journal of the Acoustical Society of America, 2825–2830, 2002.
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[2]..H. Nahvi, M. Jabbari, Crack detection in beams using experimental modal data and finite element model, International Journal of Mechanical Sciences , pp.1477– 1497, 2005.

[3].Yang, Crack Identification in vibrating beams using the Energy Method, Journal of Sound and vibration, pp.339-357, 2001.

[4]. Darpe, Dynamics of a two-crack rotor, Journal of Sound and Vibration, pp.649–675, 2003.