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To study Effect of Crack on Natural Frequency by using FEA

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Abstract: A crack in a structural member introduces local flexibility that would affect vibration response of the structure. The presence of damage leads to changes in some of the lower natural frequencies and mode shapes. Damage detection is one of the important aspects in structural engineering for safety reasons. The traditional methods of damage detection include visual inspection or instrumental evaluation.Main problem is to detect existence of a crack together with its location and depth in the structural member.The presence of cracks causes changes in the physical properties of a structure which introducesflexibility, and thus reducing the stiffness of the structure with an inherent reduction in modal natural frequencies. Consequently it leads to the change in the dynamic response of the beam. In this paper, a model for free vibration analysis of a beam with an open edge crack has been presented. Variations of natural frequencies due to crack at various locations and with varying crack depths have been studied. A parametric study has been carried out. The cracked beams with different boundary conditions have been analyzed. The results obtained by FEA.

Keywords: Beam; Free vibration; Crack; Natural frequencies.

I. INTRODUCTION

Most of the members of engineering structures operate under loading conditions, which may cause damages or cracks in overstressed zones. The presence of cracks in a structural member, such as a beam, causes local variations in stiffness, the magnitude of which mainly depends on the location and depth of the cracks. The presence of cracks causes changes in the physical properties of a structure which in turn alter its dynamic response characteristics. The monitoring of the changes in the response parameters of a structure has been widely used for the assessment of structural integrity, performance and safety. Irregular variations in the measured vibration response characteristics have been observed depending upon whether the crack is closed, open or breathing during vibration. The vibration behavior of cracked structures has been investigated by many researchers. The majority of published studies assume that the crack in a structural member always remains open during vibration. However, this assumption may not be valid when dynamic loadings are dominant. In such case, the crack breathes (opens and closes) regularly during vibration, inducing variations in the structural stiffness. These variations cause the structure to exhibit non-linear dynamic behavior. A beam with a breathing crack shows natural frequencies between those of a non-cracked beam and those of a faulty beam with an open crack. In this paper, the natural frequencies of cracked and uncracked beams have been calculated using Euler’s beam theory. Parametric study has been carried out on beams with crack at various crack depths and crack locations.

II. LITERATURE REVIEW

Christides and Barr [1] developed a one-dimensional cracked beam theory at same level of approximation as Bernoulli-Euler beam theory. Ostachowicz and Krawczuk [2] presented a method of analysis of the effect of two open cracks upon the frequencies of the natural flexural vibrations in a cantilever beam.They replaced the crack section with a spring and then carried out modal analysis for each part of the beam using appropriate matching conditions at the location of the spring. Liang, Choy and Jialou Hu [3] presented an improved method of utilizing the weightless torsional spring model to determine the crack location and magnitude in a beam structure. Dimaragonas [4] presented a review on the topic of vibration of cracked structures. His review contains vibration of cracked rotors, bars, beams, plates, pipes, blades and shells. Shen and Chu [5] and Chati, Rand and Mukherjee [6] extended the cracked beam theory to account for opening and closing of the crack, the so called “breathing crack” model. Kisa and Brandon [7] used a bilinear stiffness model for taking into account the stiffness changes of a cracked beam in the crack location. They have introduced a contact stiffness matrix in their finite element model for the simulation of the effect of the crack closure which was added to the initial stiffness matrix at the crack location in a half period of the beam vibration. Saavedra and Cuitino [8] and Chondros, Dimarogonas and Yao [9] evaluated the additional flexibility that the crack generates in its vicinity using fracture mechanics theory. Zheng et al [10] the natural frequencies and mode shapes of a cracked beam are obtained using the finite element method. An overall additional flexibility matrix, instead of the local additional flexibility matrix, is added to the flexibility matrix of the corresponding intact beam element to obtain the total flexibility matrix, and therefore the stiffness matrix. Zsolthuszar [11] presented the quasi periodic opening and closings of cracks were analyzed for vibrating reinforced concrete beams by laboratory experiments and by numeric simulation. The linear analysis supplied lower and upper bounds for the natural frequencies. Owolabi, Swamidas and Seshadri [12] carried out experiments to detect the presence of crack in beams, and determine its location and size. Yoon, In-Soo Son and Sung-Jin

III. MATERIAL & METHODOLOGY

Structural steel beams have been considered for making specimens. The specimens were cut to size from readymade square bars. Total 05 specimens were cut to the size as length 700 mm and cross section area is10mmX10mm. The modulus of elasticity and densities of beams have been measured to be 210GPa and 7850 Kg/m3 respectively. Theoretical analysis is done by Euler's beam theory.

Material Geometry

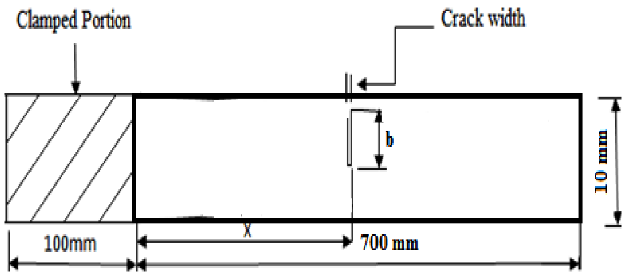

Fig.1CrackedSquare BeamSpecimen

TableI: DIFFERENT BEAM MODELS AND THEIR DIMENSIONS

Beam Model No.	Material(Structural Steel)	Cross section dimension (mm)	Cracked/Uncracked	Position and location of crack	
				Crack depth (mm)	Cracklocation (mm)
1	E= 210×10^9 N/m^2, ρ = 7850 Kg/m^3, l= 0.7m.	10×10	Uncracked	0	0
2		10×10	Cracked	1	175
3		10×10	Cracked	2	175
4		10×10	Cracked	1	350
5		10×10	Cracked	2	350

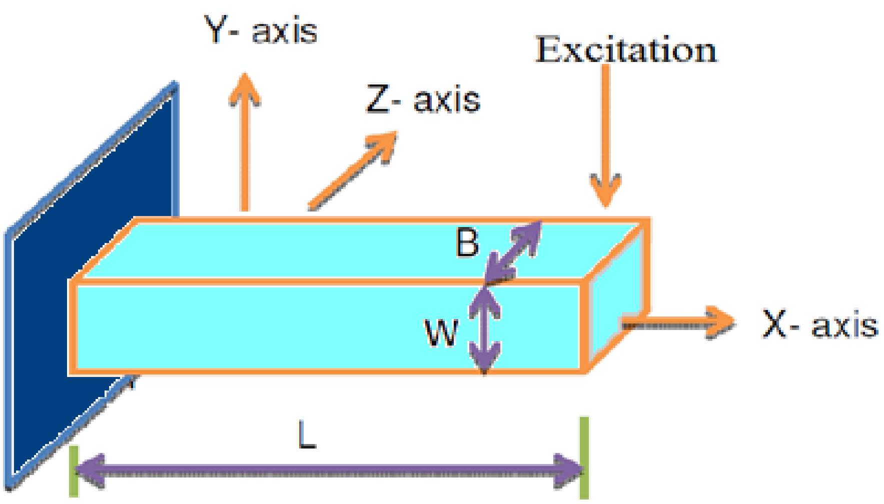

Fig.2 Model of Uncracked beam

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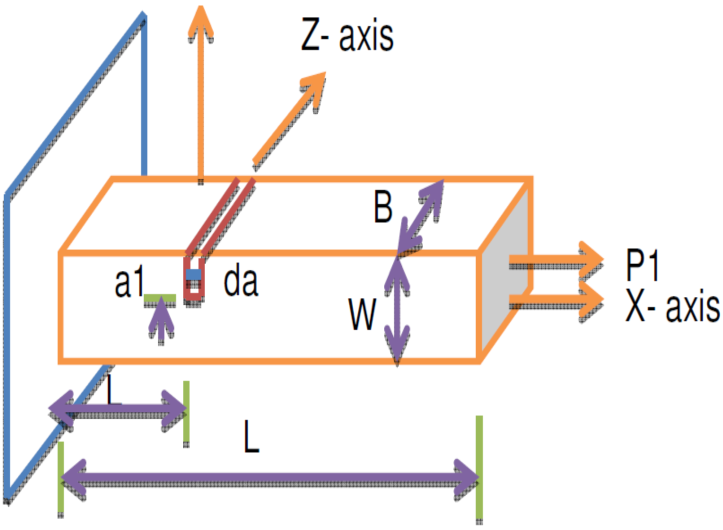

Fig.3 Model of crack beam

IV. FINITE ELEMENT ANALYSIS OF SHAFT BEAM

Following steps show the guidelines for carrying out Modal analysis.

A) Preprocessing

1. Set Preferences as Structural
2. Create a 3D model of shaft beam.
3. Define element type.
4. Define material properties.
5. Mesh the Volume.

B) Solution

1. Specify analysis types and options.
2. Apply boundary condition to the model.

C) Post-Processing

1. Results Summary.
2. Result Viewer.

The Finite Element Analysis of the beam was done using ANSYS 15.0 software. For this purpose a 3D model of the shaft beam was prepared and to model crack of width 0.27mm blocks of 0.7mm width was created and subtracted from the beam model. An element 20node186 was used to create FEA model. Boundary Conditions as cantilever beam was applied by making all degrees of freedom zero at one end of the shaft. A Block Lanczos method was used for extraction of natural frequency of free vibration.

FEA Result

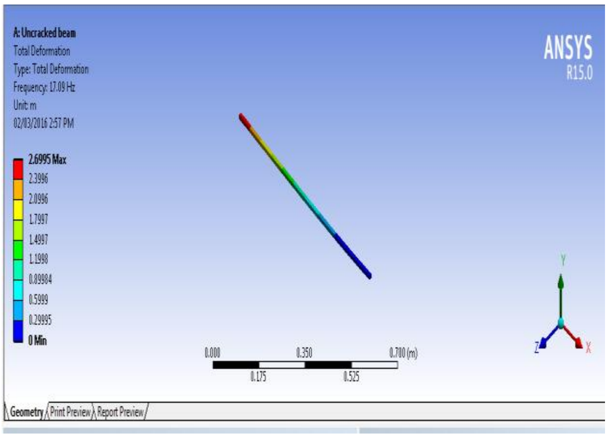

Fig. 4 1stMode of Vibration (Healthy beam)

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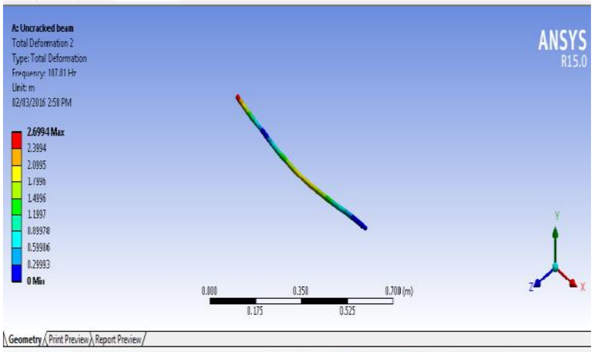


Fig. 5 2nd Mode of Vibration (Healthy beam)

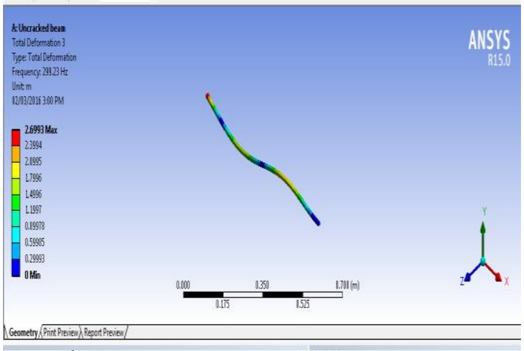


Fig. 6 3rd Mode of Vibration (Healthy beam)

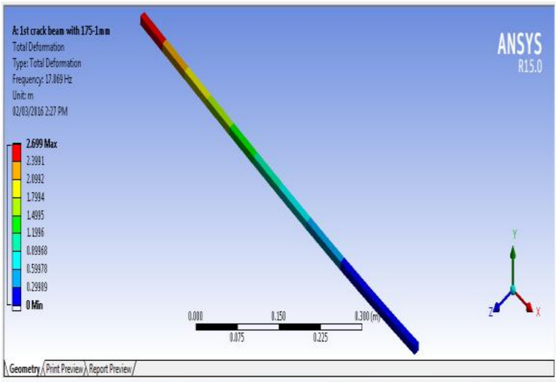


Fig. 7 1st Mode of Vibration (RCL=0.25, RCD=0.1)

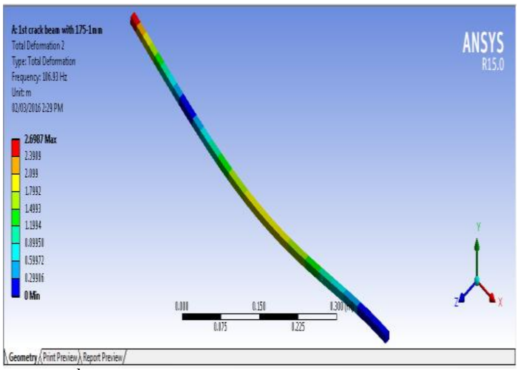


Fig. 8 2nd Mode of Vibration (RCL=0.25, RCD=0.1)

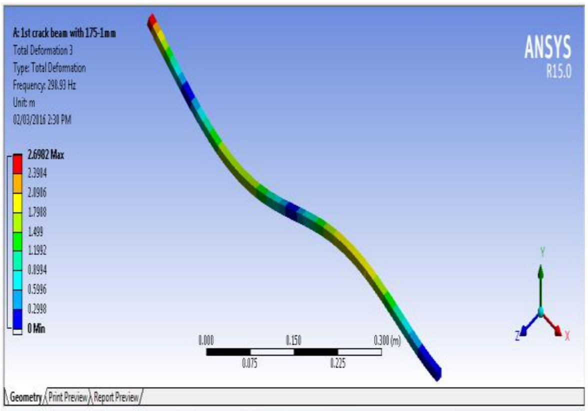


Fig. 9 3rd Mode of Vibration (RCL=0.25, RCD=0.1)

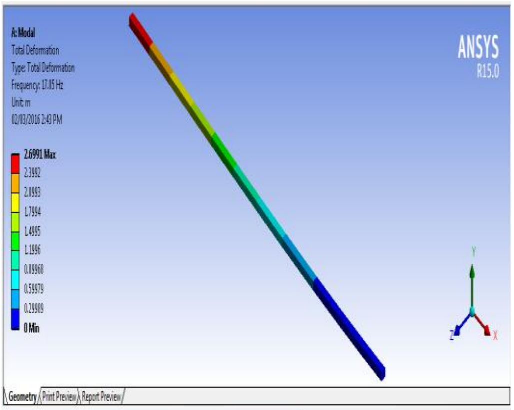
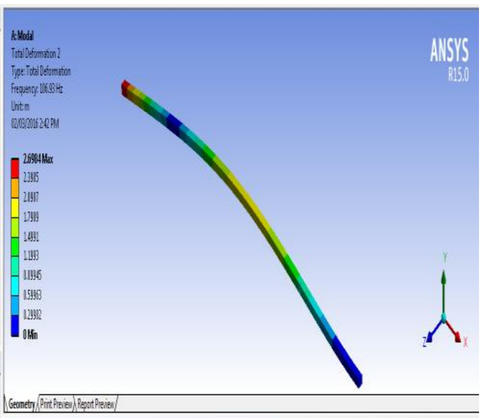


Fig. 10 1st Mode of Vibration (RCL=0.25, RCD=0.2)



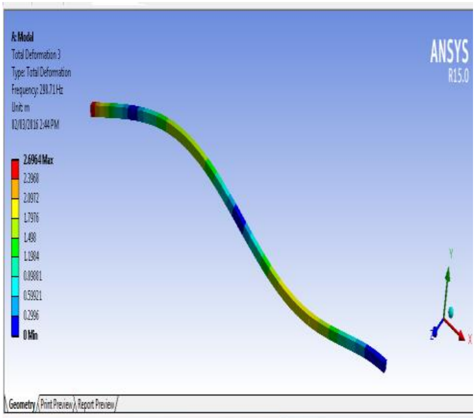


Fig. 11 2nd Mode of Vibration (RCL=0.25, RCD=0.2)Fig. 3.16 3rd Mode of Vibration (RCL=0.25, RCD=0.2)

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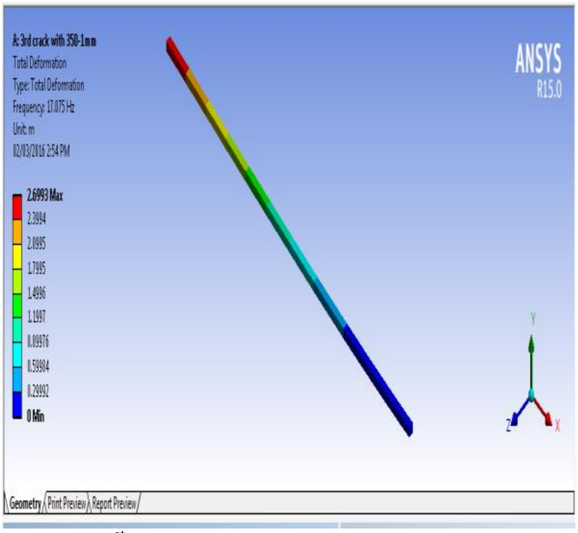

Fig. 3.17 1st Mode of Vibration (RCL=0.5, RCD=0.1)

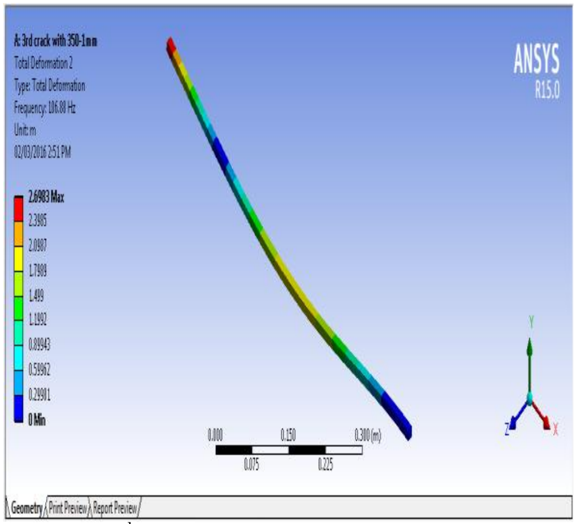

Fig. 3.18 2nd Mode of Vibration (RCL=0.5, RCD=0.1)

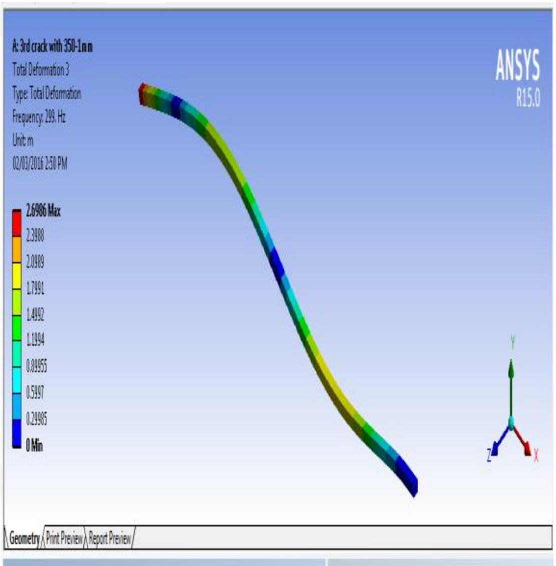

Fig. 12 3rd Mode of Vibration (RCL=0.5, RCD=0.1)

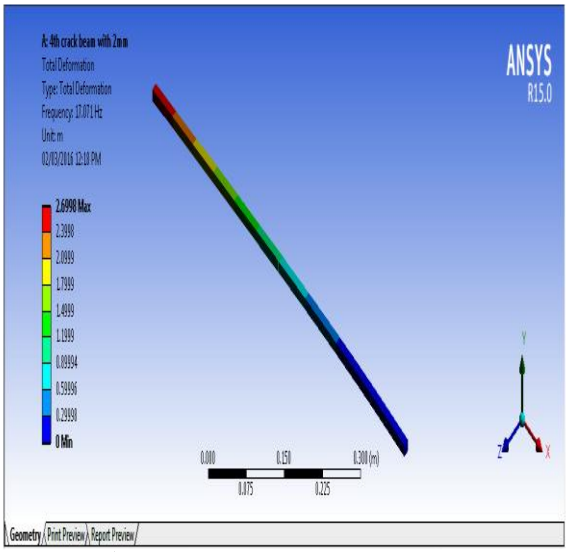

Fig. 13 1st Mode of Vibration (RCL=0.5, RCD=0.2)

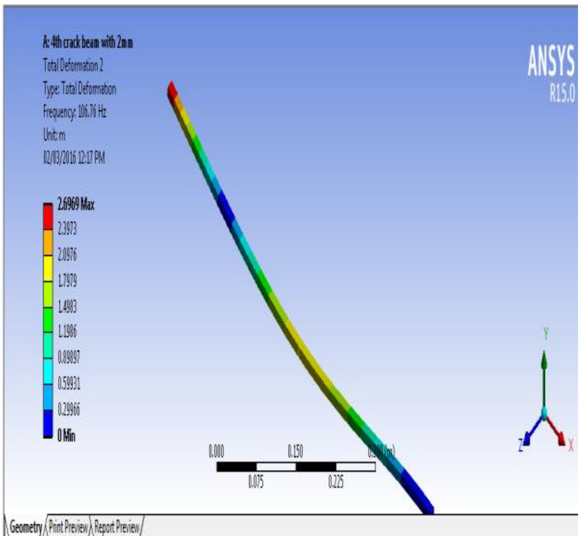

Fig. 14 2nd Mode of Vibration (RCL=0.5, RCD=0.2)

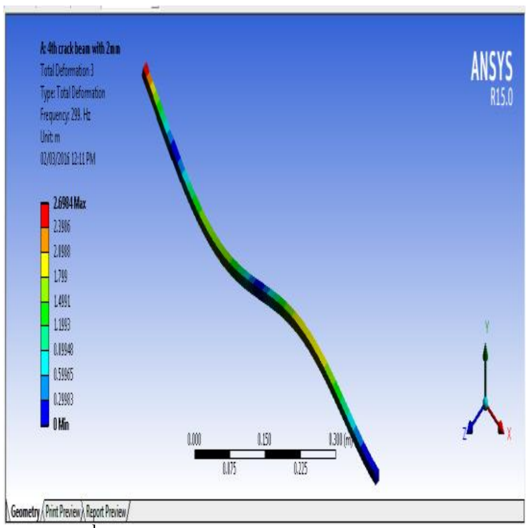

Fig. 15 3rd Mode of Vibration (RCL=0.5, RCD=0.2)

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Result of Finite Element Analysis.

Table 4FEA natural frequencies for the beam models

Beam model no.	RCD	RCL	First Natural Frequency	Second Natural Frequency	Third Natural Frequency
1	0	0	17.09	107.01	299.23
2	0.1	0.25	17.069	106.93	298.93
3	0.2	0.25	17.05	106.93	298.71
4	0.1	0.5	17.075	106.88	299
5	0.2	0.5	17.071	106.76	299

V. CONCLUSIONS

In this study the Finite Element Analysis of a cantilever beam with single transverse cracks was done in ANSYS. Mode shapes of first three modes of transverse vibration are plotted and comparison of mode shapes of healthy and cracked beam was done. It is observed that the natural frequency of vibration of all three transverse modes of vibrations decreases with increase in depth of the crack as the presence of crack in structural member introduces local flexibilities.

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