Modal Analysis of Cracked Beams Using Ansys

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Abstract-The beam undergoes different kinds of loading which causes cracks in the beam. These cracks and their location effect changes the natural frequency and mode shapes of the beam. In the current work the natural frequency of cracked and uncracked beam having one end fixed and other is simply supported is investigated numerically by using ANSYS software. The cracked beam having triangular crack of depth 2mm.Different crack locations are considered and results are compared with the beam having no crack. Structural steel and aluminum are considered as beam materials.

Index Terms- Crack, ANSYS, natural frequency, mode shape, simply supported.

I.INTRODUCTION

Many engineering components used in the aeronautical, aerospace and naval construction industries are considered by designers as vibrating structures, operating under a large number of random cyclic stresses. Cracks found in structural elements like beams and columns have different causes. They may be fatigue cracks that take place under service conditions as a result of the limited fatigue strength. They may be also due to mechanical defects, as in the turbine blades of jet engines. In these engines the cracks are caused by sand and small stones sucked from the surface of runway. Another group involves cracks which are inside the material. They are created as a result of manufacturing processes. The presence of vibrations on structures and machine components leads to cyclic stresses resulting in material fatigue and failure.

Major characteristics of structures, which undergo change due to presence of crack, are the natural frequency , Mode shape. Hence it is important to use natural frequency measurements to detect crack and its effects on the structure.

II.LITERATURE SURVEY

P. Yamuna [1] published a paper on vibration analysis of beam with varying crack location The objective of this study is to analyze the vibration behavior of a simply supported beam using FEM software ANSYS subjected to a single triangular crack under free vibration. Material properties of steel are considered for the simply supported beam. Besides this, information about the variation in location and depth of cracks in cracked steel beams is obtained using this technique. It can be found that at symmetric positions of the crack position of the beam the lowest fundamental frequencies have almost equal value. This shows that the dynamic response of crack at symmetric locations of the beam is similar.

A local flexibility will reduce the stiffness of a structural member, thus reducing its natural frequency. Thus most popular parameter applied in identification methods is change in natural frequencies of structure caused by the crack. In this paper, the natural frequencies of cracked and un-cracked beams have been calculated using Finite element software ANSYS.

J.Fernad Ndez-Sad Ez [2] has formulated approximate calculation of the fundamental frequency for bending vibration of cracked beam. A simplified method of evaluating the fundamental frequency for the bending vibrations of cracked Euler Bernoulli beams is presented. The method is based on the well-known approach of representing the crack in a beam through a hinge and an elastic spring, but here the transverse deflection of the cracked beam is constructed by adding polynomial functions to that of the uncracked beam. With this new admissible function, which satisfies the boundary and the kinematic conditions, and by using the Rayleigh method, the fundamental frequency is obtained. This approach is applied to simply supported beams with a cracked section in any location of the span. For this case, the method provides closed-form expressions for the fundamental frequency. Its validity is confirmed by comparison with numerical simulation results. In all the cases considered in this paper, the results are very close to those obtained numerically by the finite-element method.

Dr. Ravi Prasad et al. [3] proposed a work on a Modal analysis for process of describing a structure in terms of its natural characteristics which are the frequency, damping and mode shapes –its dynamic properties. The change of modal characteristics directly provides an indication of structural condition based on changes in frequencies and mode shapes of vibration. This paper presents results of an experimental modal analysis of beams with different materials such as Steel, Brass, Copper and Aluminum. The beams were excited using an impact hammer excitation technique over the frequency range of interest, 0-2000 Hz. Response functions were obtained using vibration analyzer. The FRFs were processed using NV solutions modal analysis package to identify natural frequencies, damping and the corresponding mode shapes of the beam.

Ranja Behra [4] has analyzed Aluminium cantilever beam specimen with & without crack having inclined crack at different crack location & crack depth experimentally on FFT & validation is done by finite element method. It is found that in first mode shape the amplitude decreases with increase in location from fixed end but in second and third mode shapes the amplitude increases with increase in location from fixed end at constant crack depth and constant crack inclination angle of the cracked cantilever beam. Moreover at particular location in the beam amplitude decreases with increase in crack depth in case of first mode shape, but amplitude increases with increase in crack depth in case of second and third mode shapes of the cracked beam at constant crack inclination angle.

Mr. R. S. Pawar [5] has presented Experimental Static Analysis of A Cantilever Beam With Nonlinear Parameters. The beam-like structures are typically subjected to dynamic loads. In this paper classical problem of deflection of a cantilever beam of linear elastic material, under the action of a uniformly distributed load along its length (its own weight), is experimentally and numerically analyzed. Paper presents the differential equation governing the behavior of this system and shows that these equations are difficult to solve due to the presence of nonlinear term. The experiment described in this paper is an easy way to introduce the concept of geometric nonlinearity in mechanics of material. Finally numerical result is carried out by ANSYS program and compared with the experimental results. Comparative static analysis of cantilever beam for mild steel material is carried out. The numerical results from Finite Element analysis showed in general a good agreement with the experimental static values.

III.MODELLING OF BEAM

Design of beam without crack is modeled in PRO-E software by using the properties given in table 1 and import in ANSYS software.

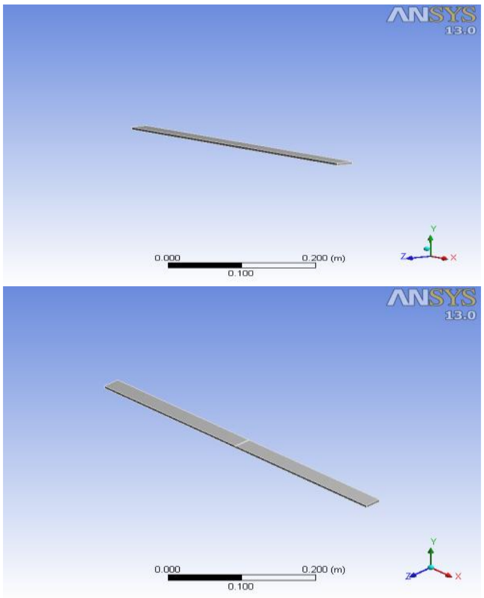

Fig. 2 Cracked beam

Design of Beam With Crack**:** For vibration analysis of a cracked beam, a triangular crack with a depth of 2 mm and width of 25 mm is considered. The initial position of the crack is taken at a location 100 mm from one end of the beam. Later, for comparative analysis the crack location is taken as 200mm,250mm,300m and 400mm. The volumetric model of cracked beam built in ANSYS is shown in Fig.1.

Table I : Properties of S.S. Beam and Aluminium beam

Parameters	Symbol	Value	
Material		S.S.	Aluminium
Total Effective Length	L	0.5 m	0.5 m
Width	B	0.025 m	0.025 m
Thickness	T	5×10^{-3}m	5 x 10-3m
Crack depth	a	2×10^{-3}m	2×10^{-3}m
Moment of Inertia	I	$2.60\times10^{-10}m^4$	$2.60\times10^{-10}m^4$
Young's Modulus	E	$207 \times 10^9 N/m^2$	$70 \times 10^9 N/m^2$
Mass Density	P	7850 kg/m^3	2770 kg/m^3

Boundary conditions:

The beam considered here has a fixed support at one end and simply supported at the other end of beam. For the fixed end all DOF are fixed as sown in fig 3.And at the simply supported end the displacement in Y direction is taken as free as shown in fig.4.

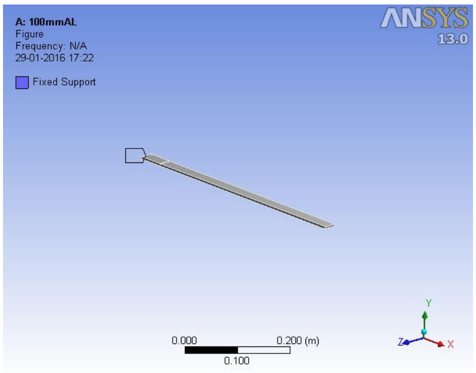

Fig.4 Fixed end

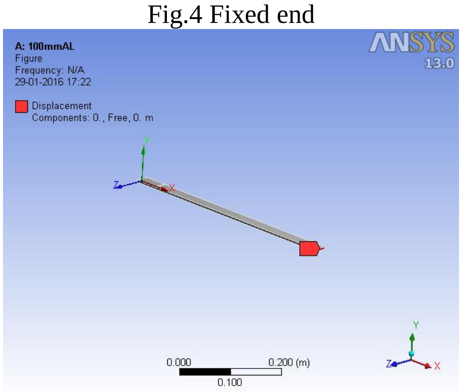

Fig 5 Beam with Y direction constrained

Vibration Analysis of Beam without Crack: The first step in the vibration analysis of the beam is to find its natural frequencies. In ANSYS, modal analysis used to find the eigen natural frequencies. Initially the beam is taken without any crack. A minimum of first three mode shapes and natural frequencies are obtained and shown in Table 1. The lowest frequency of the beam is found to be 26.287 Hz with a maximum displacement of 3.82 mm. The mode shape and obtained lowest frequency for the beam without crack are shown in Fig.8.

IV. ANALYSIS OF ALUMINUM BEAM

Table II: Frequencies of Aluminum beam without crack

Mode	Frequency [Hz]
1.	26.287
2.	142.06
3.	350.67

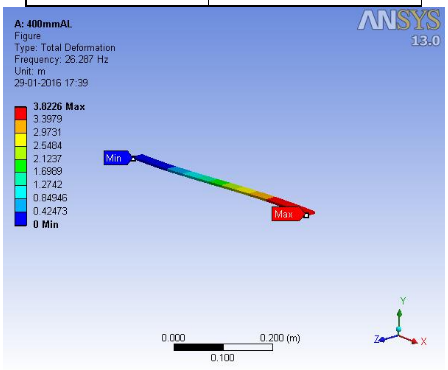

Fig. 6 Mode shape 1

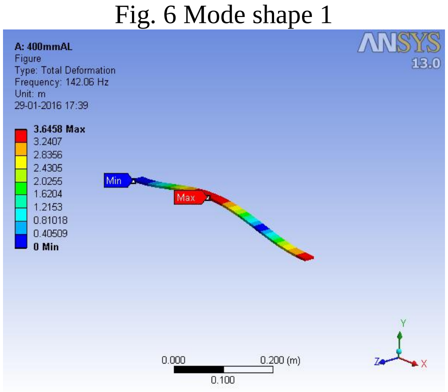

Fig.7 Mode shape 2

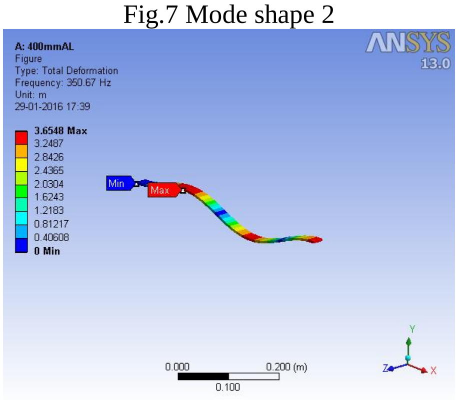

Fig.8 Mode shape 3

Vibration Analysis of Beam with Varying Crack Location: A triangular crack is introduced in the beam model for vibration analysis. Initially the triangular crack is assumed to be located at 100 mm from the fixed end of the beam model. And then crack is varying to 200mm ,250mm 300mm,400mm

Table III: Frequencies of Aluminium beam with crack located at 100 mm,200mm250mm,300mm and 400mm from fixed end

Crack at 100 mm		Crack at 200 mm	
Mode	Frequency [Hz]	Mode	Frequency [Hz]
1.	25.895	1.	26.132
2.	140.88	2.	140.89
3.	348.74	3.	345.59
Crack at 250 mm		**Crack at 300 mm**	
Mode	Frequency [Hz]	Mode	Frequency [Hz]
1.	26.203	1.	26.165
2.	140.54	2.	141.08
3.	348.85	3.	345.78
Crack at 400 mm			
Mode	Frequency [Hz]		
1.	26.064		
2.	141.24		
3.	349.42		

A. Frequencies of Aluminum beam with crack located at 100 mm from fixed end

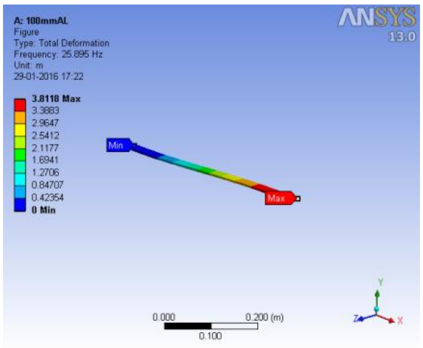

Fig 9 Mode shape 1

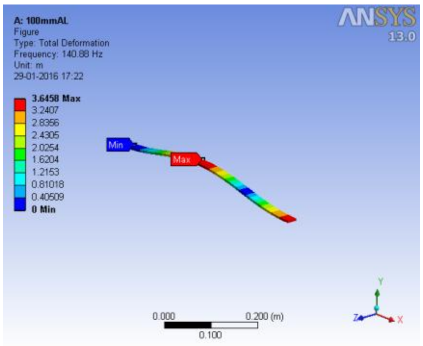

Fig.10 Mode shape 2

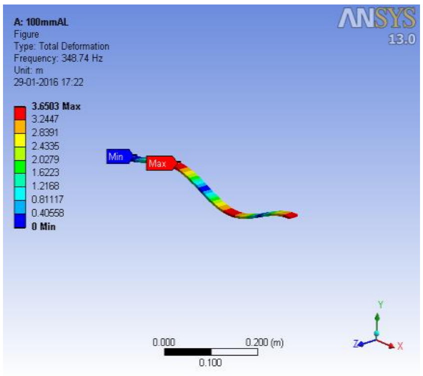

Fig.11 Mode shape 3

B. Frequencies of Aluminum beam with crack located at 200 mm from fixed end

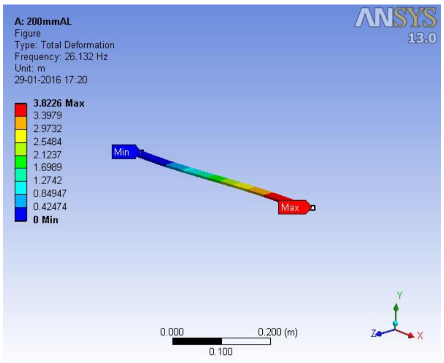

Fig 12 Mode shape 1

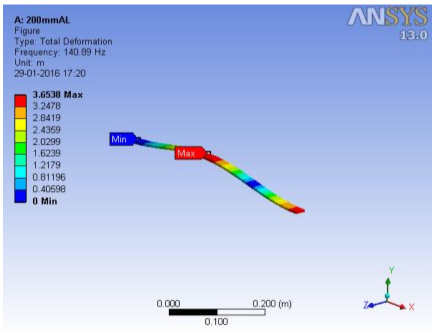

Fig.13 Mode shape 2

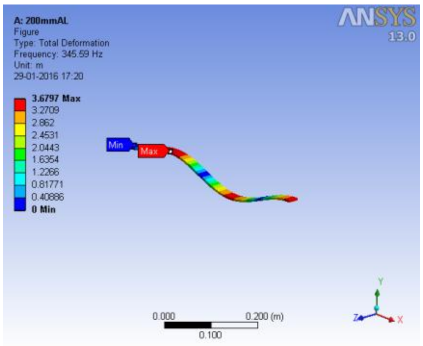

Fig.14 Mode shape 3

C. Frequencies of Aluminum beam with crack located at 250 mm from fixed end

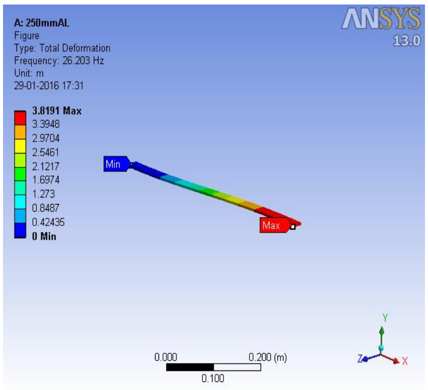

Fig 15 Mode shape 1

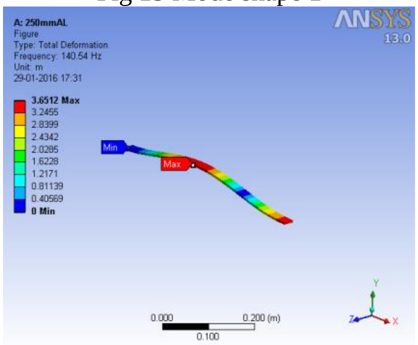

Fig.16 Mode shape 2

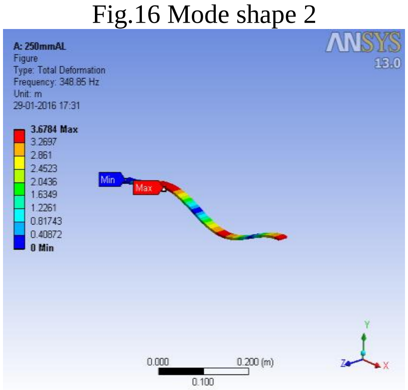

Fig.17 Mode shape 3

D. Frequencies of Aluminum beam with crack located at 300 mm from fixed end

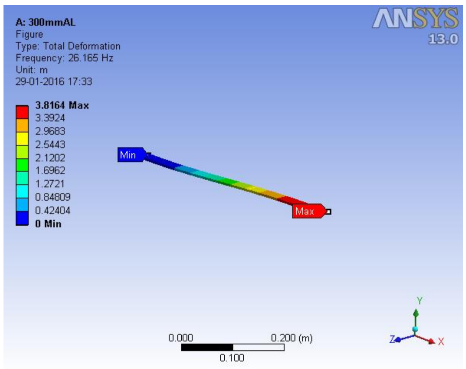

Fig 18 Mode shape 1

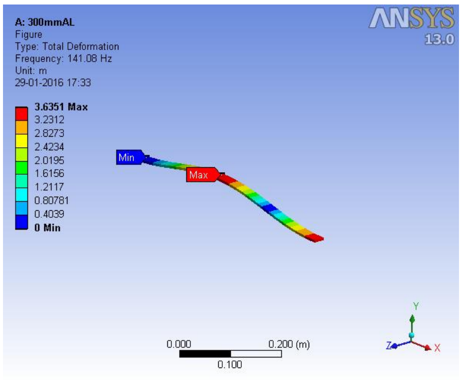

Fig.19 Mode shape 2

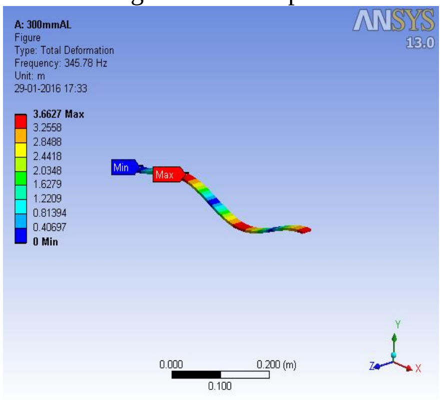

Fig.20 Mode shape 3

E. Frequencies of Aluminum beam with crack located at 400 mm from fixed end

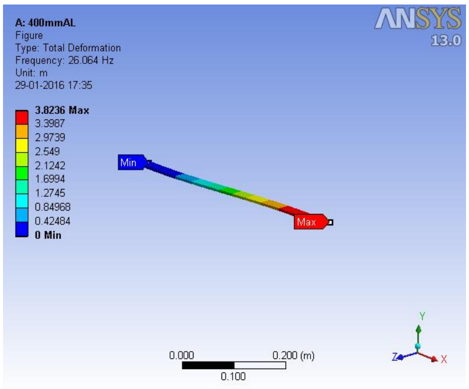

Fig. 21 Mode shape 1

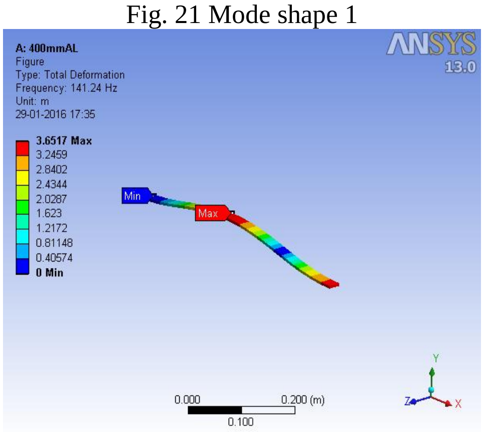

Fig.22 Mode shape 2

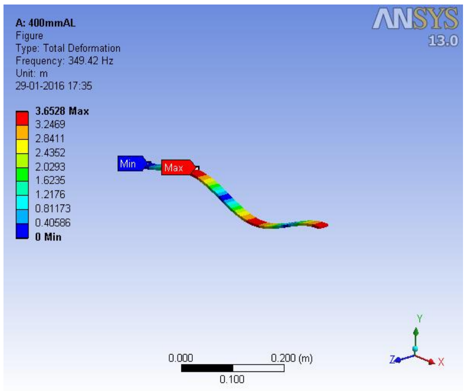

Fig.23 Mode shape 3

V. ANALYSIS OF STRUCTURAL STEEL BEAM

Table IV: Frequencies of SS beam without crack

Mode	Frequency [Hz]
1.	26.154
2.	141.33
3.	348.85

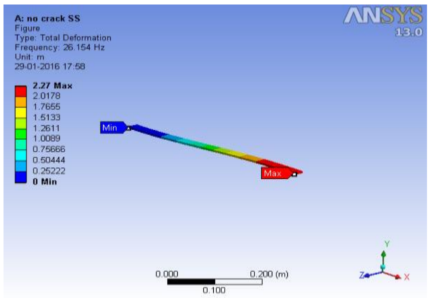

Fig.24 Mode shape 1

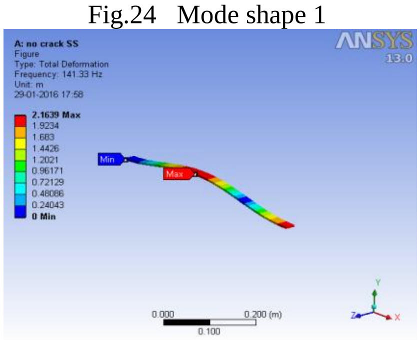

Fig.25 Mode shape 2

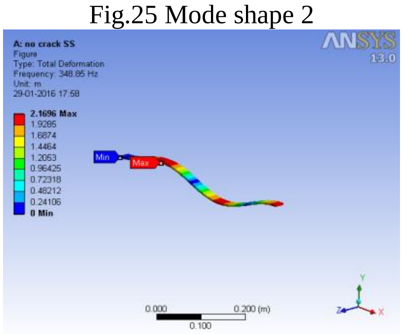

Fig.26 Mode shape 3

Table V: Frequencies of SS beam with crack located at 100 mm,200mm250mm,300mm and 400mm from fixed end

Crack at 100 mm from fixed end

Mode	Frequency [Hz]
1.	25.942
2.	140.89
3.	346.3

Crack at 200 mm from fixed end

Mode	Frequency [Hz]
1.	26.084
2.	139.89
3.	347.14

Crack at 250 mm from fixed end

Mode	Frequency [Hz]
1.	26.089
2.	139.89
3.	347.28

Crack at 300 mm from fixed end

Mode	Frequency [Hz]
1.	26.05
2.	140.45
3.	344.17

Crack at 400 mm from fixed end

Mode	Frequency [Hz]
1.	25.947
2.	140.61
3.	347.86

A. Frequencies of SS beam with crack located at 100 mm from fixed end

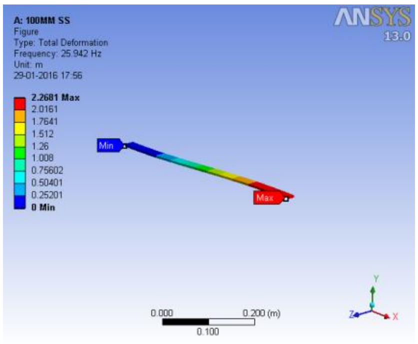

Fig.27 Mode shape 1

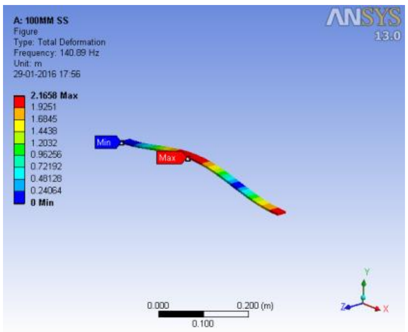

Fig.28 Mode shape 2

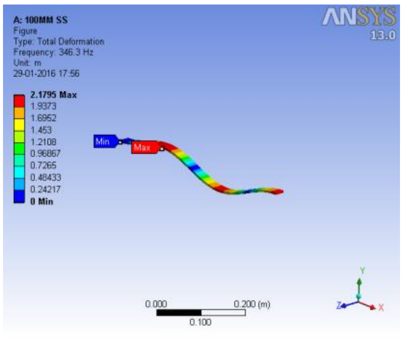

Fig.29 Mode shape 3

B. Frequencies of SS beam with crack located at 200 mm from fixed end

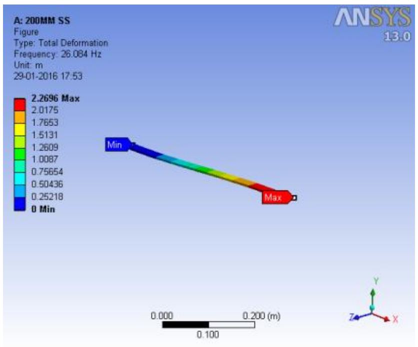

Fig .30 Mode shape 1

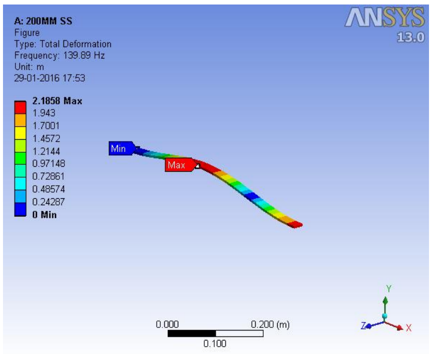

Fig.31 Mode shape 2

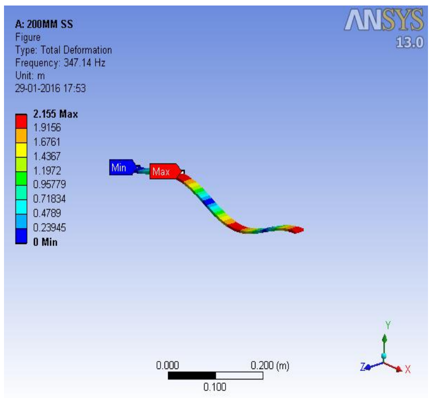

Fig.32 Mode shape 3

C. Frequencies of SS beam with crack located at 250 mm from fixed end

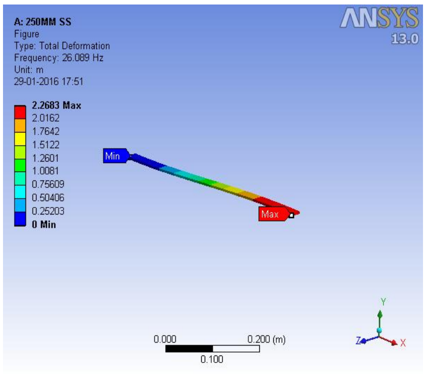

Fig.33 Mode shape 1

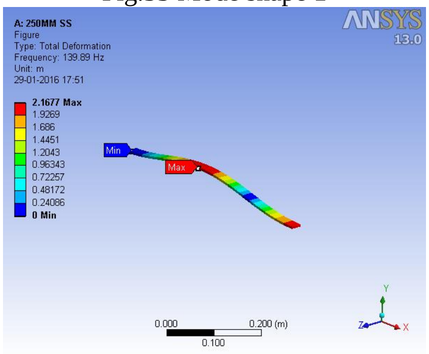

Fig.34 Mode shape 2

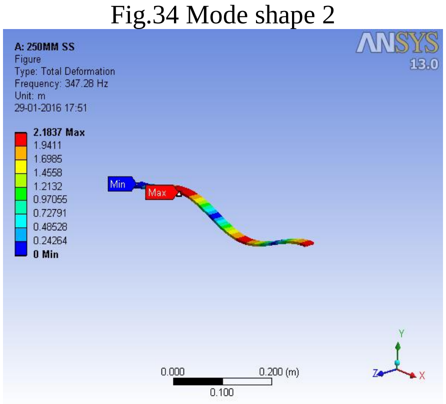

Fig.35 Mode shape 3

D. Frequencies of SS beam with crack located at 300 mm from fixed end

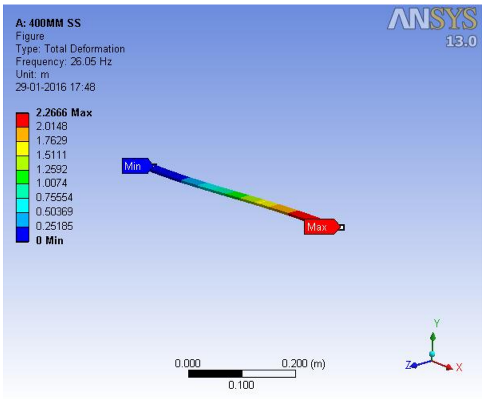

Fig.36 Mode shape 1

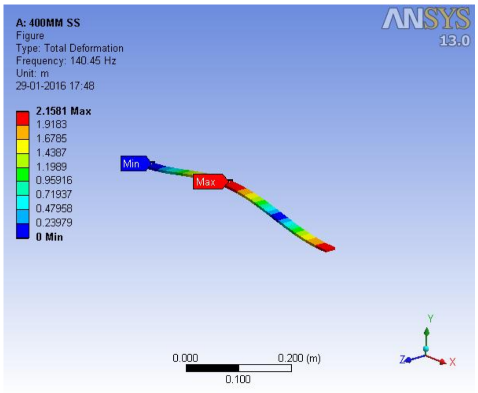

Fig.37 Mode shape 2

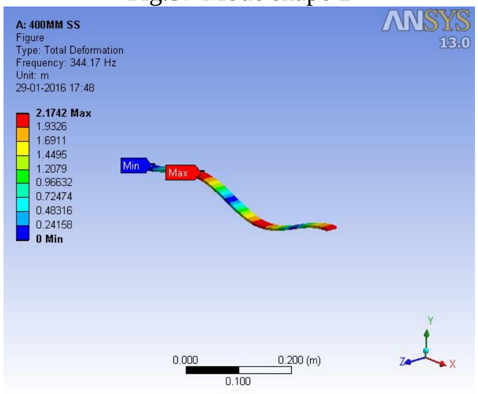

Fig.38 Mode shape 3

E. Frequencies of SS beam with crack located at 400 mm from fixed end

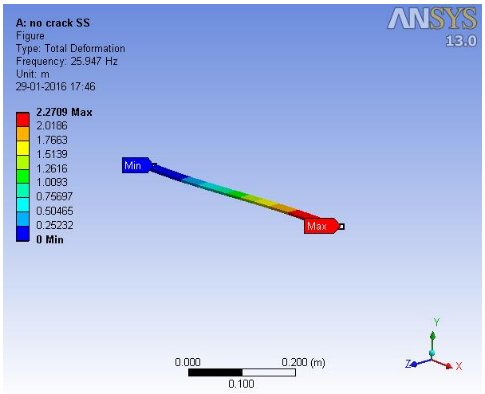

Fig.39 Mode shape 1

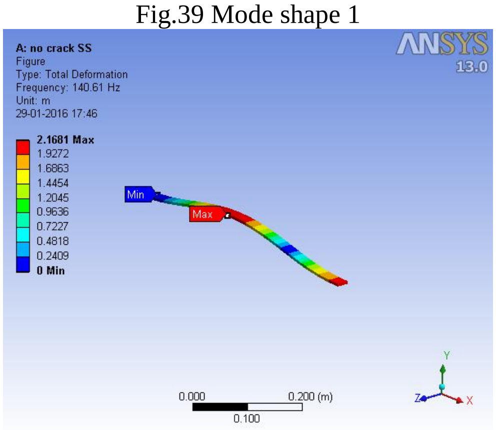

Fig.40 Mode shape 2

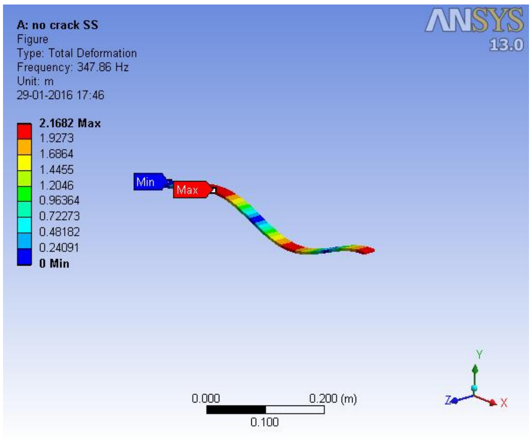

Fig.41 Mode shape 3

VI.CONCLUSIONS

The man objective of the present work is to study the dynamic characteristics of beam for structural steel and aluminum .As the crack location increases from fixed end the natural frequency increases up to the center of beam and after it decreases. The natural frequency of beam when crack at 100mm location is same as that of when crack at 400mm location which is 25.942Hz at 100mm and 25.947Hz at 400mm for Aluminium beam. And for structural steel having the natural frequency 25.895Hz at 100mm which is nearly same to 26.064Hz at 400 mm. The lowest frequency for aluminum beam without crack is 26.287Hz which is higher than 26.14Hz of structural steel beam.

REFRENCES:

[1] P.Yamun1, K.Sambasivarao,"Vibration Analysis Of Beam With Varying Crack Location", International Journal Of Engineering Research And General Science Volume 2,ISSN: 2091-2730,2014

[2] J. Fernad Ndez-Sad Ez, L. Rubio, C. Navarro," Approximate Calculation Of The Fundamental Frequency For Bending Vibration Of Cracked Beams", Journal Of Sound And vibration (1999) 225(2), 345}352

[3] D. Ravi Prasad and D.R. Seshu, "A study on Dynamic Characteristics of Structural Materials Using Modal Analysis", Asian Journal of Civil Engineering, Volume 9, Number 2, Pages 141-152, 2008

[4] Ranjan K.Behera, "Numerical and Experimental Verification of a Method for Prognosis of Inclined Edge Crack in Cantilever Beam Based on Synthesis of Mode Shapes", 2nd International Conference on Innovations in Automation and Mechatronics Engineering, ICIAME 2014

[5] Mr. R. S. Pawar, "Experimental Static Analysis Of A Cantilever Beam With Nonlinear Parameters", International Journal of Engineering Sciences & Research Technology, Vol. ISSN: 2277-9655,Augest 2014.