Modal Analysis of Beam with Varying Crack Depth

C.Ramachandran[1], R.Ponnudurai[2]

[1]PG student, Department of Civil Engineering, Thiagarajar College of Engineering, Madurai, Tamilnadu, India, crchandran6495@gmail.com
[2]Assistant Professor, Department of Civil Engineering, Thiagarajar College of Engineering, Madurai, Tamilnadu, India, rpdciv@tce.edu

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Abstract - *If a crack appears in the structure it will cause catastrophic failure in the structure. It also affects natural frequency of the structure. Cracks in the structure are identified early to avoid catastrophic failure. Changes in vibrational parameters are required to be analysed to identify the crack. Location and depth of crack are the important parameters to change the vibrational parameters of the structure. Modal analysis is the most widely used method for crack identification of structures. In this work modal analysis of beam with single edged notch having various depth was done by Finite Element Analysis software ANSYS Mechanical APDL 15.0. Vibrational parameters like mode shape and natural frequency of the beam were found by modal analysis. From these results inferred that the fundamental frequency of the beam reduces when the crack depth increases and it is due to reduction in stiffness of the beam.*

Key Words: Modal analysis, ANSYS, Crack depth, Natural frequency, Mode shape

1.INTRODUCTION

Many engineering components are considered as vibrating structures under cyclic stresses in aerospace and aeronautical industries. Cracks may produce in the structures due to cyclic stresses. Mainly fatigue cracks are produced due to fatigue strength of the material. And also some cracks are produced when small stones and sand sucked in the runway surface. These components under vibration leads to failure in the structures. Many engineering structures like tall buildings, long span bridges are modelled as beam for analysis.

Choubey A., et al. (2006) conducted to analyse the effects of cracks on natural frequencies in boilers and storage tanks structures by Finite Element Analysis. Analyse the various cases by changing the locations and size of cracks [1]. Parhi D. R., et al. (2012) have to study about orientation and location of crack in the beam like structures. Un-cracked and cracked beam having crack at various locations were considered for the analysis [2]. Mihir Kumar Sutar (2012) describes the relationship between the natural frequencies with crack location and crack depth by the use of FEA. Using ALGOR software analysis was performed and results obtained [3]. Chandradeep Kumar, et al. (2014) were found the higher frequencies with great accuracy has been done by MATLAB programming. Vibration analysis of instruments is necessary to determine the natural frequencies of the systems. The fundamental frequency is obtained easily with great accuracy, But it is hard to determine the higher frequencies [4].

Sharma P.K., et al. (2014) were conduct the work for finite element analysis of both un-cracked and cracked cantilever beam. CAD design developed using CATIA software was the input file for this analysis. Totally 10 models of cracked beam having various cross sections were analysed. The results obtained from the finite element analysis were verified by theoretical method [5]. Chandradeep Kumar, et al. (2014) were conduct the Finite element analysis of a beam using MATLAB and ANSYS then the results are compared with theoretical calculations. Lastly harmonic analysis also performed to check the results [6].

Yamuna P. and Sambasivarao K. (2014) were conduct the analysis of natural frequency of a simply supported beam with a triangular crack by finite element method using ANSYS. Effects of natural frequencies by various crack locations are considered and the results are compared with un-cracked beam [7]. Vipin Kumar, et al. (2015) were compute the vibration characteristics (natural frequencies and mode shapes) of the beams by the process of modal analysis. Beams having different materials (structural steel, cast iron) and cross sections (T and I) are designed and analysed using ANSYS [8].

Lanka Ramesh, et al. (2016) are using universal vibration apparatus to conduct the vibration analysis cracked and un-cracked cantilever beam. Cracked beam having two open transverse cracks. From the test results, find a relationship between the modal natural frequencies for various crack depths. Simulation model was established and analysed by vibration analysis using commercially available Finite element software package ANSYS. The results from Finite

Element Analysis are validated with the experimental results [9]. Priyanka P. Gangurde, et al. (2016) were analyse the natural frequency of un-cracked and cracked beam having triangular crack depth of 2mm by using ANSYS software. Beam having boundary conditions of one end fixed and other is simply supported. Consider various crack locations and results are compared with un-cracked beam [10].

Ganesh G. Gade, et al. (2016) were perform the vibration analysis of the model of a beam with an open edge crack using ANSYS. Crack at various locations and depths are considered for the analysis and the results show that natural frequencies are varied due to crack locations and depths. Cracked beam having different boundary conditions were analysed by FEA [11]. Shubham Kale, et al. (2016) were found the vibration response of a beam due to harmonic force by ANSYS. Finite element model is designed, various element types are considered and analysed then results are compared with the analytical results [12].

In this work, natural frequencies of un-cracked beam and beam with varying carck depth were found by modal analysis using FEA software ANSYS Mechanical APDL 15.0. Beam and Crack dimensions were taken from [7].

2.FE MODELLING

An isotropic, elastic, slender beam having 15mm width (W), 25mm depth (D), 500mm length (L) has been modelled by using ANSYS. For this analysis beam is considered as cantilever. From previous study, location of crack near the fixed end was more vulnerable than the other locations in the cantilever beam.

2.1.Beam without crack

Elements of PLANE 182 and SOLID 185 were selected initially. Material is considered as aluminium and its properties (Young's modulus (E) 70GPa, Poisson's ratio (μ) 0.35, Density (γ) 2700 kg/m^3) were assigned. By using Rectangle command, an area having dimensions of 500mm length, 25mm depth has been drawn. Smart size was selected and range was set as 4 in the Mesh Tool. Mesh option was selected then the area has been selected. Then the area has been discretized as well as meshed. Discretized volumetric model has been created by the use of Extrude option having 15mm offset in z – direction.

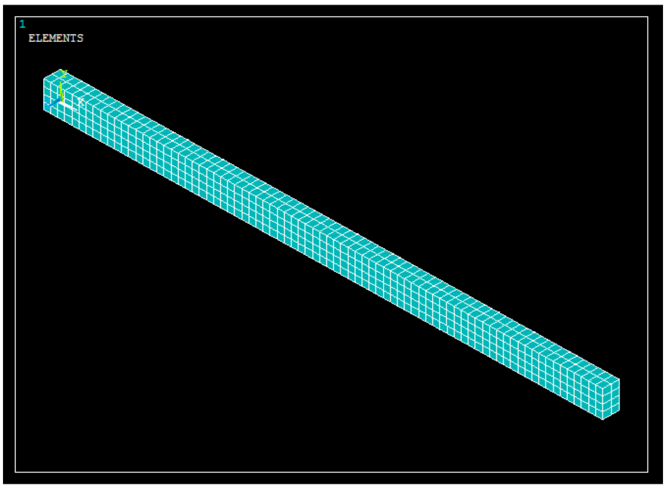

Fig -1: Discretized Volumetric Model

2.2.Cracked beam

Element types and material properties are considered as same as un-cracked beam. Areal model has been created like an un-cracked beam and a triangular area having width of 5mm and depth of 10mm has been drawn at the top of the beam at 50mm from the fixed end. Then using subtract command to subtract the triangular area then a notch has been created it acts like a crack and it is shown in figure 2. Initially notch having depth of 0.5mm and then the crack depth increases up to 10mm with an increment of 0.5mm. Meshing and volumetric model created was done like as an un-cracked beam.

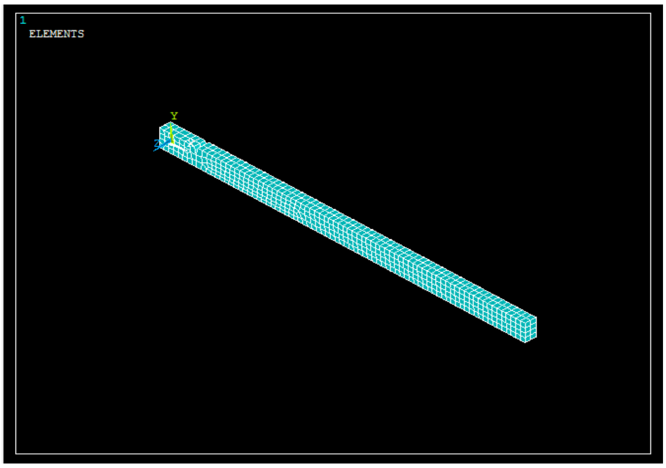

Fig -2: Discretized Volumetric Model of Cracked Beam

3. SUPPORT CONDITIONS

The support conditions of the cantilever beam are one end is fixed and another end is free. Displacements along all the directions are restricted. Constrained model of cantilever beam is shown in figure 3.

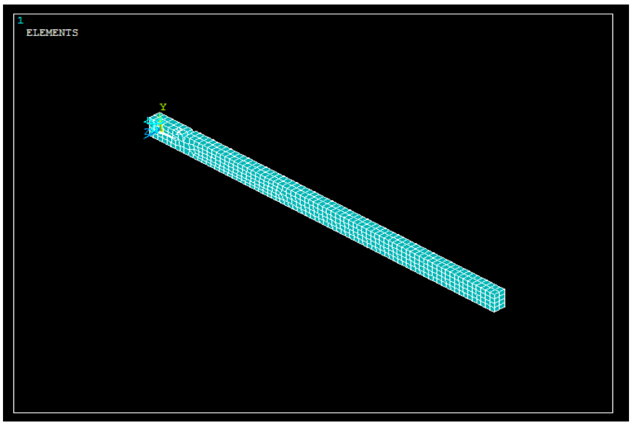

Fig -3: Constrained model of cantilever beam

4.MODAL ANALYSIS

Eigen natural frequencies of the beam for first five modes were obtained by Block Lanczos method from modal analysis using ANSYS under free vibration and as shown in table .1. Mode 1 frequency is the fundamental frequency of the beam which is found to be 83.5 Hz and it is shown in figure 4.

Table -1: Frequencies of Un-cracked Beam

Mode No	Frequency (Hz)
1	83.50
2	98.23
3	517.43
4	605.92
5	1424.00

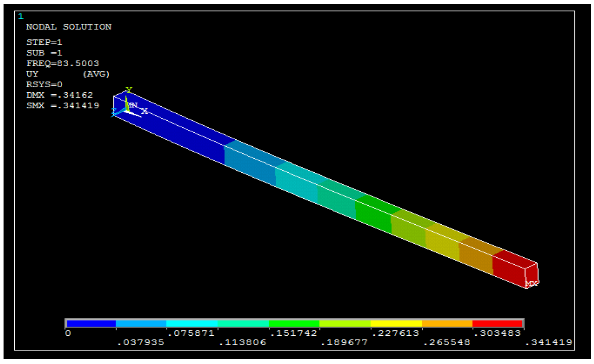

Fig -4: Mode 1 of Un-cracked Beam

Then the cracked beam was considered for modal analysis. Initially crack depth was taken as 0.5mm and it increases up to 10mm. A beam with varying crack depth was analysed and the first five frequencies of the cracked beam were found. The fundamental frequency (Mode 1 frequency) of the beam with varying crack depth from 0.5mm to 10mm were shown in figure 5 to 24.

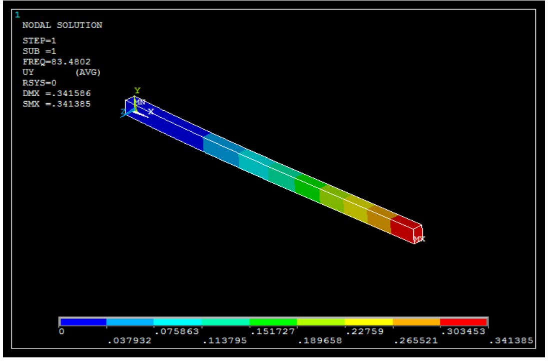

Fig -5: Mode 1 of cracked beam having crack depth of 0.5mm

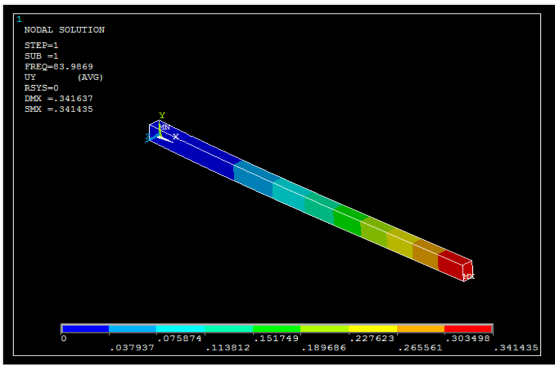

Fig 6: Mode 1 of cracked beam having crack depth of 1mm

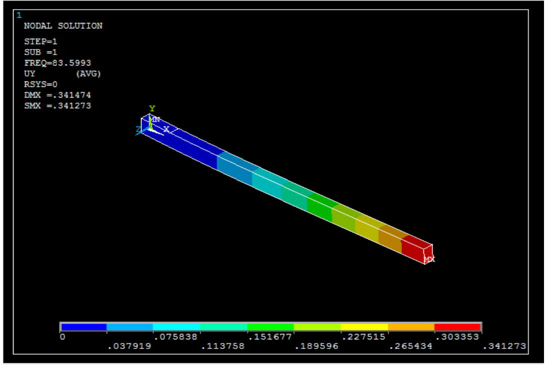

Fig -7: Mode 1 of cracked beam having crack depth of 1.5mm

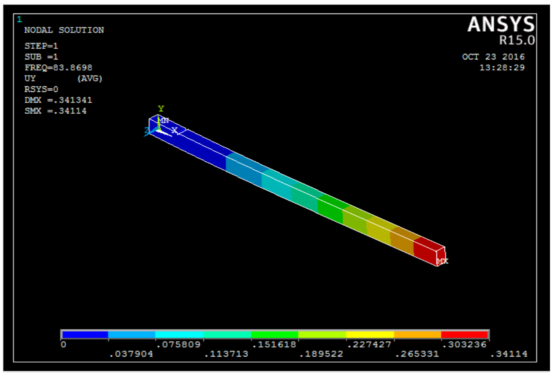

Fig -8: Mode 1 of cracked beam having crack depth of 2mm

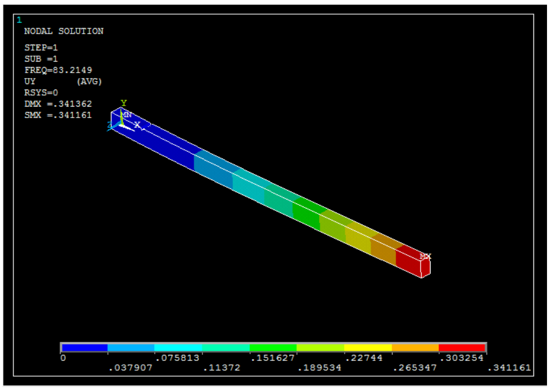

Fig -9: Mode 1 of cracked beam having crack depth of 2.5mm

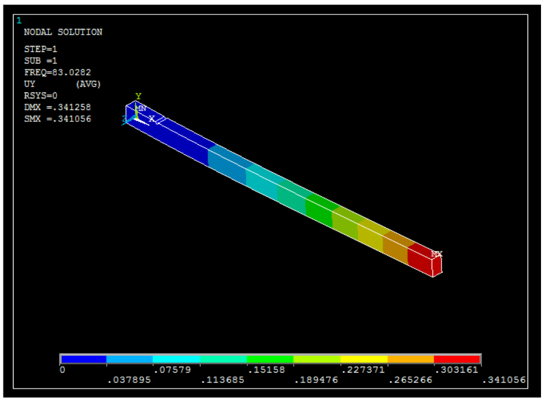

Fig -10: Mode 1 of cracked beam having crack depth of 3mm

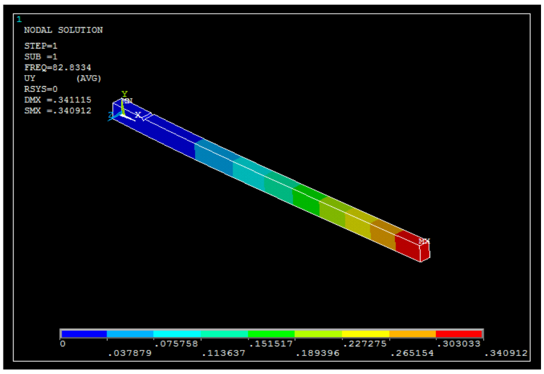

Fig -11: Mode 1 of cracked beam having crack depth of 3.5mm

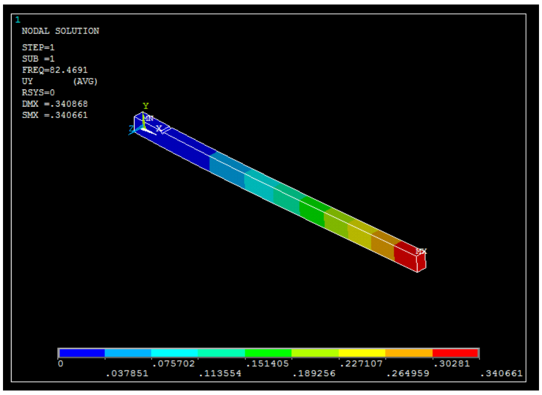

Fig -12: Mode 1 of cracked beam having crack depth of 4mm

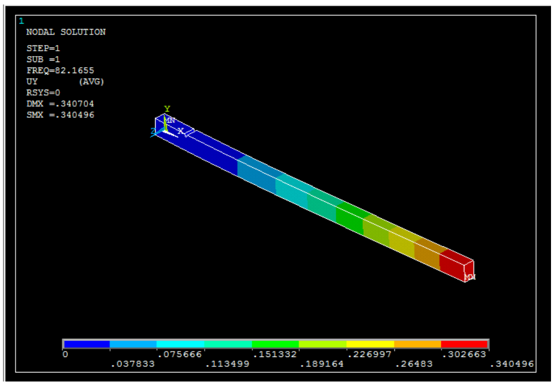

Fig -13: Mode 1 of cracked beam having crack depth of 4.5mm

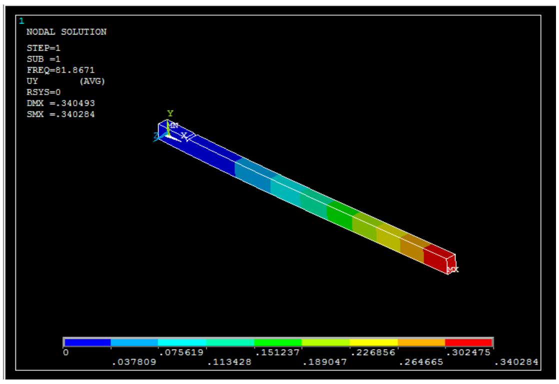

Fig -14: Mode 1 of cracked beam having crack depth of 5mm

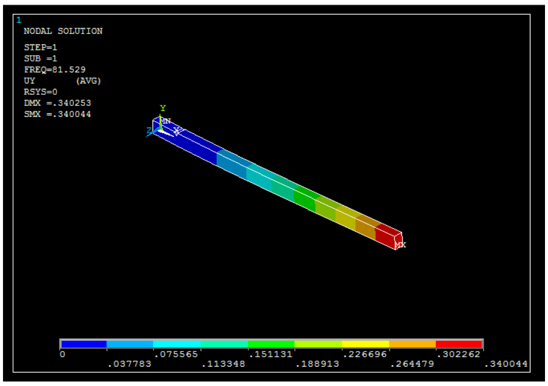

Fig -15: Mode 1 of cracked beam having crack depth of 5.5mm

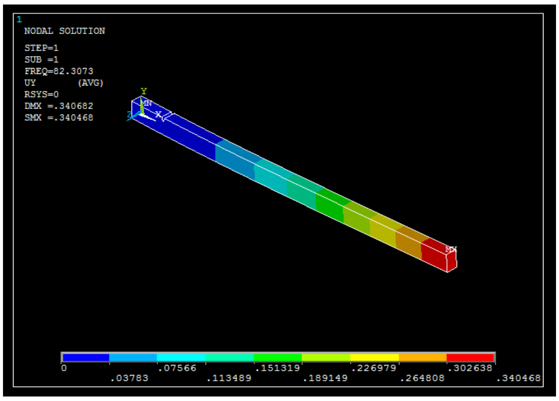

Fig -16: Mode 1 of cracked beam having crack depth of 6mm

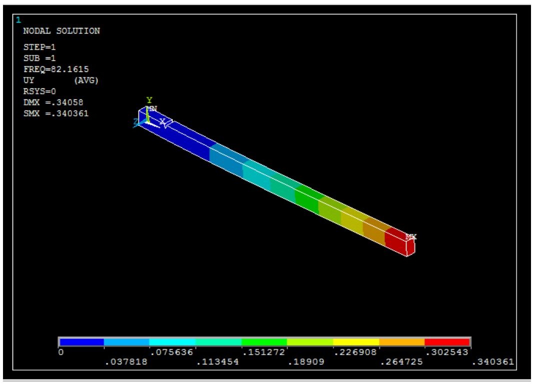

Fig -17: Mode 1 of cracked beam having crack depth of 6.5mm

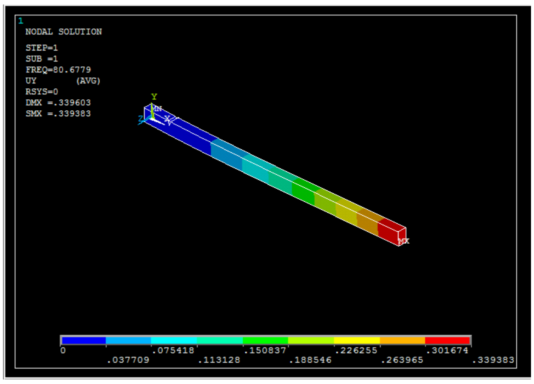

Fig -18: Mode 1 of cracked beam having crack depth of 7mm

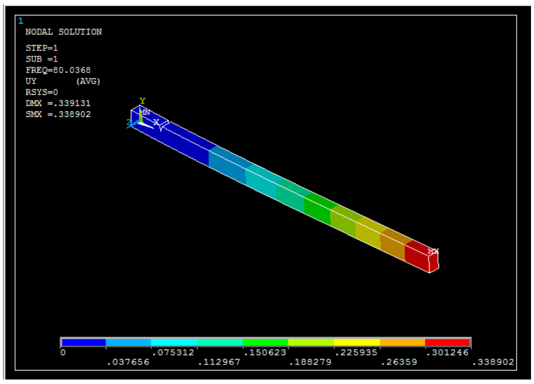

Fig -19: Mode 1 of cracked beam having crack depth of 7.5mm

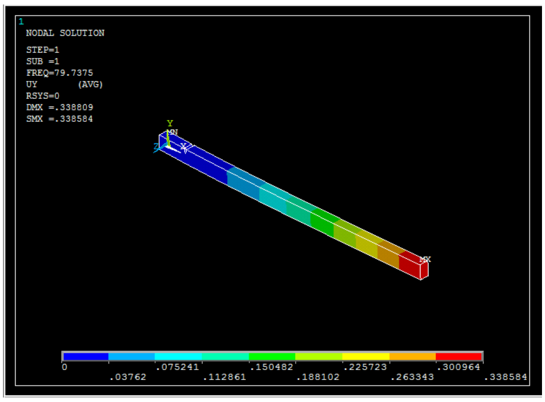

Fig -20: Mode 1 of cracked beam having crack depth of 8mm

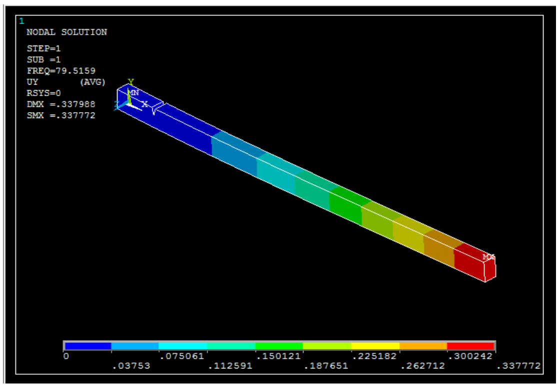

Fig -21: Mode 1 of cracked beam having crack depth of 8.5mm

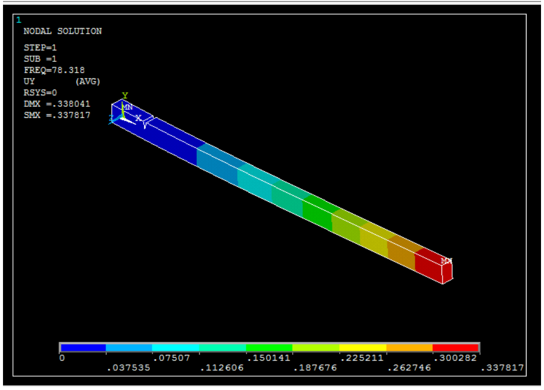

Fig 22: Mode 1 of cracked beam having crack depth of 9mm

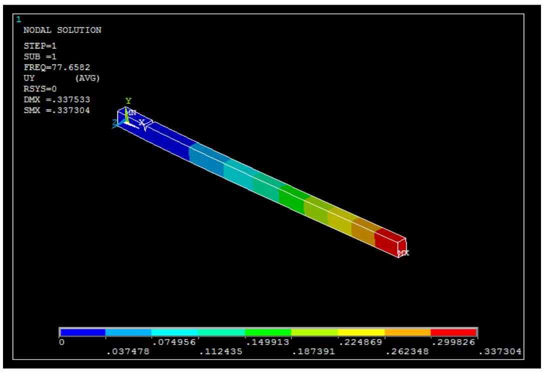

Fig -23: Mode 1 of cracked beam having crack depth of 9.5mm

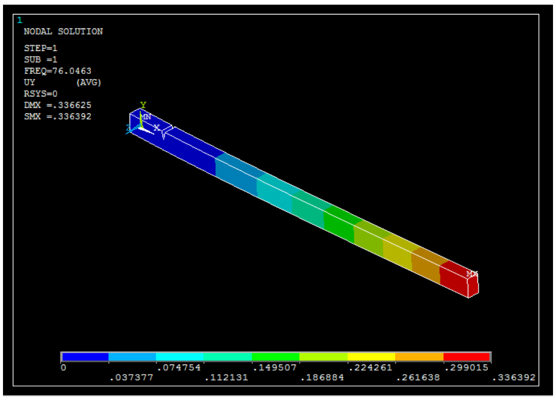

Fig -24: Mode 1 of cracked beam having crack depth of 10mm

The fundamental frequencies of the beam with varying crack depth are compared in Table 2. A graph plotted between crack depth at 50mm from the fixed end in 'mm' and fundamental frequency of the beam in 'Hz'. Chart 1 shows that the fundamental frequency of the beam reduces when depth of crack increases and it is due to stiffness reduction of the beam.

Table -2: Comparison of fundamental frequencies of the beam with varying crack depth crack depth at 50mm from the fixed end

Crack depth at 50mm from the fixed end (mm)	Fundamental frequency (Hz)
0.0	83.50
0.5	83.48
1.0	83.99
1.5	83.60
2.0	83.87
2.5	83.22
3.0	83.03
3.5	82.83
4.0	82.47
4.5	82.17
5.0	81.87
5.5	81.53
6.0	82.31
6.5	82.16
7.0	80.68
7.5	80.04
8.0	79.74
8.5	79.52
9.0	78.32
9.5	77.66
10.0	76.78

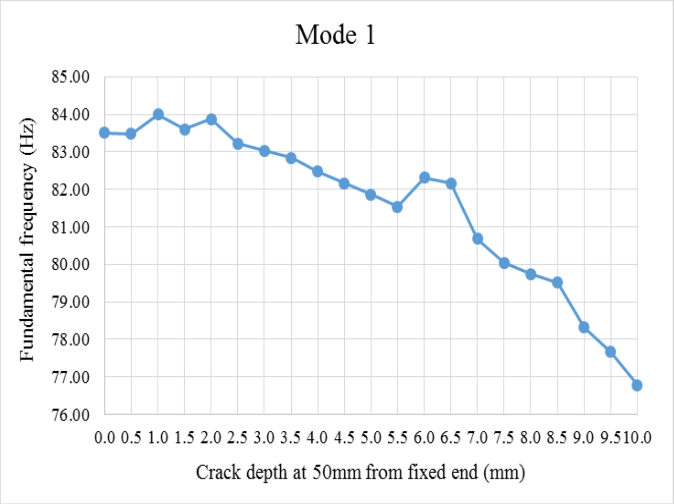

Chart -1: Plot comparison of fundamental frequencies of the beam with varying crack depth crack depth at 50mm from the fixed end

5. CONCLUSIONS

Modal analysis of an isotropic, elastic, slender beam having 15mm width (W), 25mm depth (D), 500mm length (L) under free vibration has been done by using ANSYS. Material of the beam was considered as aluminium. Natural frequencies of the beam with varying crack depth were found. From the results inferred that the fundamental frequency of the beam reduces when depth of crack increases and it is due to stiffness reduction of the beam.

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