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# Experimental and Finite Element Model Analysis of an un-cracked and cracked Cantilever beam

**Lanka Ramesh , P.Srinivasa Rao , K.Ch.Kishore Kumar, D.Kiran Prasad**

Assistant Professor, Mechanical Engineering Department, Gudlavalleru Engineering College, Sheshadri Rao Knowledge Village, Gudlavalleru- 521356 , Andhra Pradesh ,INDIA

Professor, Mechanical Engineering Department, Andhra University, Visakha Patnam-**530003,**Andhra Pradesh

Associate Professor, Mechanical Engineering Department, Gudlavalleru Engineering College, Sheshadri Rao Knowledge Village, Gudlavalleru- 521356, Andhra Pradesh ,INDIA

Associate Professor, Mechanical Engineering Department, Gudlavalleru Engineering College, Sheshadri Rao Knowledge Village, Gudlavalleru- 521356, Andhra Pradesh ,INDIA

**ABSTRACT :**Health monitoring and the analysis of damage in the form of crack in beam like structures are important not only for leading safe operation but also retraining system performance. Since long efforts are on their way to find a realistic solution for crack detection in beam structures in this regard many approaches have so far being taken place. When a structure suffers from damages, its dynamic properties can change and damage leads to reduction in stiffness also with an inherent reduction in natural frequency. The objective of this paper is to lend a viable relationship between the modal natural frequencies for the different crack depth for that vibration analysis is carried out on a cantilever beam with two open transverse cracks on universal vibration apparatus. Modelling and simulation is established using commercially available finite element analysis software package ANSYS.The results obtained from simulation are validated with the result obtained from the experiment.

**KEYWORDS***:* Experimental Modal Analysis, ANSYS, Cantilever Beam, Crack, Mode shape, Natural Frequency, universal vibration apparatus.

## I. INTRODUCTION

It is required that structures must safely work during its service life. But, damages initiate a breakdown period on the structures. Cracks are among the most encountered damage types in the structures. Cracks in a structure may be hazardous due to static or dynamic loadings, so that crack detection plays an important role for structural health monitoring applications. Beam type structures are being commonly used in steel construction and machinery industries. 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 behaviour of the entire structure 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. Studies based on structural health monitoring for crack detection deal with change in natural frequencies and mode shapes of the beam. So in this paper develops viable relationship between natural frequency and mode shape at the different crack depth.

In the past,. analytical expression for large amplitude free vibration of beam. They have also considered geometric non-linearity and have solved the expression using variational Iteration Method (VIM). Also the different nonlinear frequencies have been considered for different shapes of modes presented by Baghani, H. Mazaheri and H. Salarieh [1].study on variation of characteristics that are dependent on the amplitude of the functionally graded sandwich beams. The nonlinear characteristic of the material is also considered by applying it with the help of an exponential function. Also along with taking all this into consideration they have derived the governing equation of free vibration by means of finite element method carried by Allahverdizadeh, I. Eshraghi, M.J. Mahjoob and N. Nasrollahzadeh [2].Lianhua Wang, Jianjun Ma, JianPeng and Lifeng Li have investigated the nonlinear vibrations and the parametric instability of

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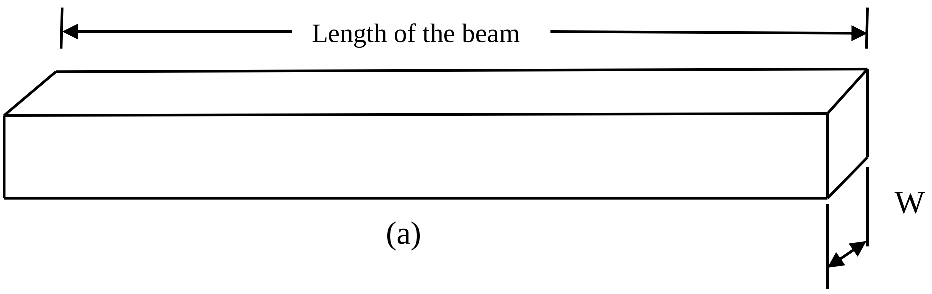
the structure on the elastic foundation. The motion equation is obtained by the Hamilton equation considering the in extension. The discrete modal is obtained by Galerkin equation [3]. Damage identification on a composite cantilever beam through vibration analysis using finite element analysis software package ANSYS is established by Ramanamurthy and Chandrasekaran [4]. An analytical, as well as experimental approach has been developed by Nahvi (2005) to detect the crack in cantilever beams by vibration analysis.[5] .T. Kocatürk, M. Şimşek [6] have studied the dynamic response of pre-stressed beam under harmonic loads. The constraints are considered using the Lagrange multiplier. The effects of the value of eccentricity of compressive load and the frequency are studied in detail. Two Damage identification algorithms are established for assessment of damage using modal test data by Hu et al. [7].Which are similar in concept to the subspace rotation algorithm or best feasible modal analysis method. Moreover, a quadratic programming model is set up the two methodologies to damage assessments.Salawu [8] has reviewed various methods of damage identification using natural frequencies.

## II. EXPERIMENTAL INVESTIGATION

An experiment on aluminium beam has been performed by using universal vibration apparatus. Here cantilever beam of length 850 mm and cross-section 25 x 10 $mm^2$ was clamped at a vibrating table.Before the experimental study the beams surface has been cleaned and organized for straightness. Subsequently, Two transverse cracks are deemed on the beam at 300 mm and 600mm from fixed end of the beam, the depth of cracks are varied from 0.5mm to 3mm at the interval of 0.5mm .During the experiment the cracked and undamaged beams have been vibrated at their 1st, 2nd and 3rd mode of vibration by using an exciter and a function generator. The vibrations characteristics such as natural frequencies and mode shape (amplitude) of the beams correspond to 1st, 2nd and 3rd mode of vibration have been recorded by placing frequency analyzer along the length of the beams and displayed on the frequency analyser. It has been observed that the experimental results are in close justification with Finite Element Analysis results.

Figure represents schematic block diagram of experimental set-up and figure represents view of the experimental setup.




(a)

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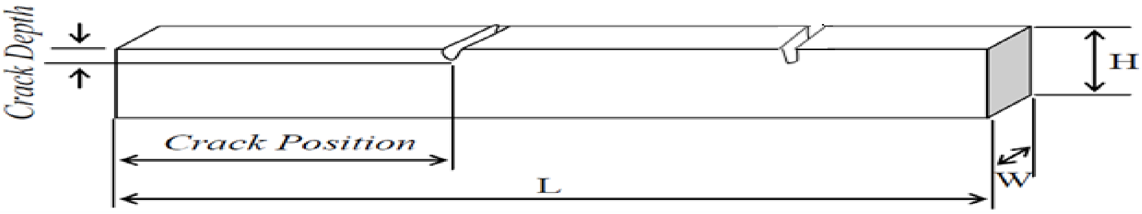


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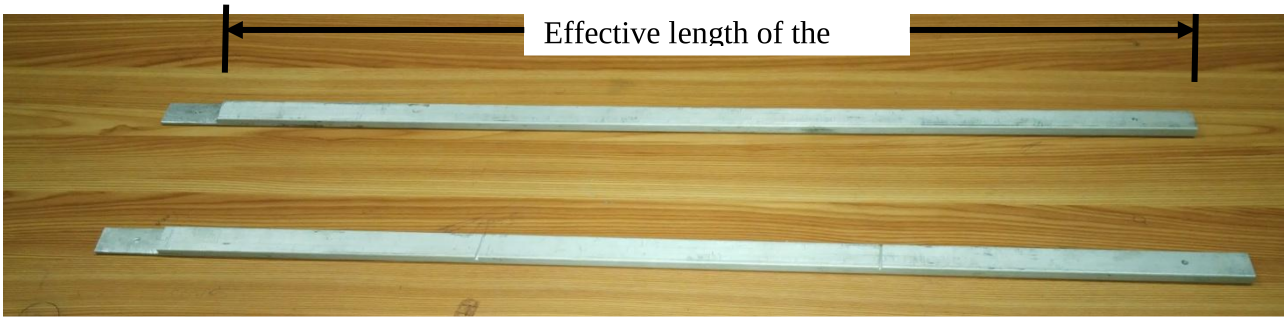
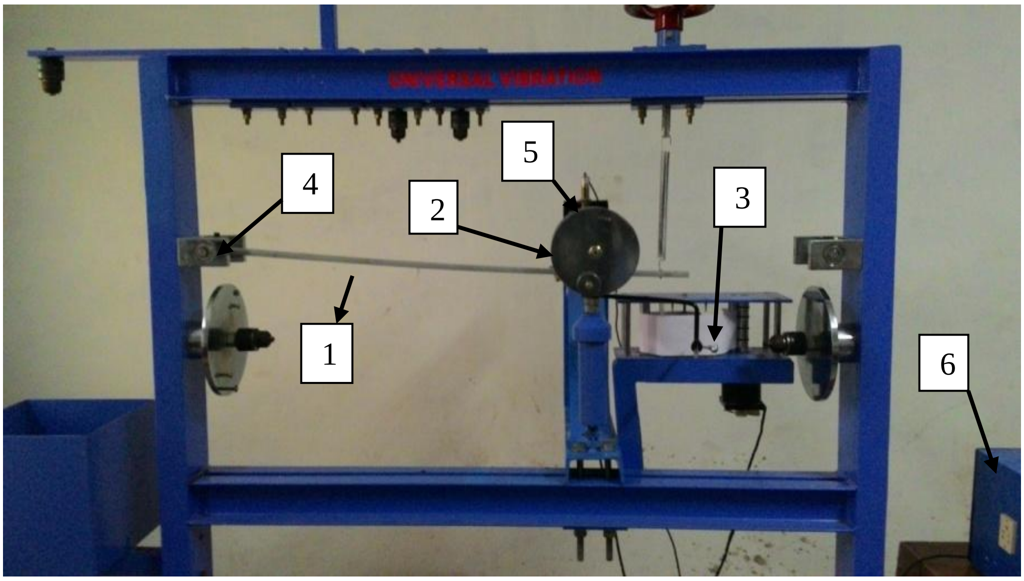



(c)

Fig1: Dimension and Un cracked and cracked and crack position of aluminium beam (a) Dimension of Un cracked beam (b) Dimensions of sample (c) Un cracked and cracked and crack position of aluminium beam

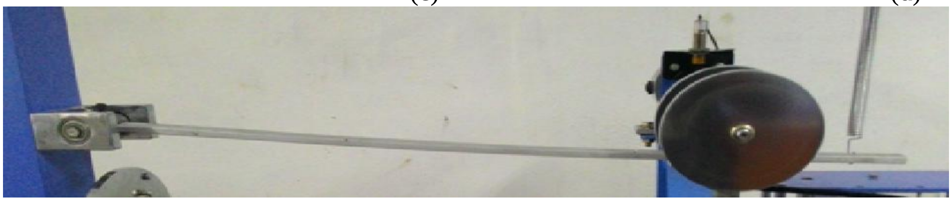



(a)

(b

(c)

(d)



(e)

Fig.2: The universal vibration apparatus (a) 1. Cantilever beam, 2.Vibration exciter, 3.Frequency analyzer 4. Fixer, 5.Motor, 6.Power amplifier (b) Frequency analyzer(c) Vibration exciter (d) Power amplifier (e) Cantilever beam

## III.FINITE ELEMENT ANALYSIS

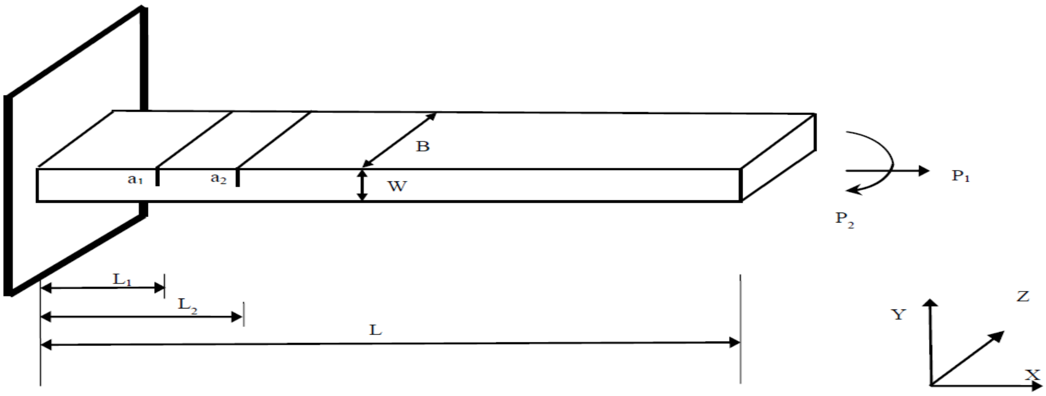



Fig3: Modeling of Crack on Cantilever Beam

The finite element analysis is brought out for the cracked beams (Cantilever) to locate the mode shape of transverse vibration at different crack depth. The crack modeling has been very important aspect, FEM software package ANSYS has been used to modeled the cracks are deemed on cantilever beam with relative crack location at $L_1$ and $L_2$ (300mm and 600mm) from fixed end and the analysis has been done using general purpose finite element software ANSYS on un-cracked and cracked cantilever beam to obtain natural frequencies and mode shape of transverse vibration at different crack depth.

The cracked beams of the current research have the following properties and dimensions:

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Table 1. Material Properties and Dimensions of Aluminium Beam

| Properties and Dimensions of Aluminium Beam | |
|---|---|
| Length of the beam | 0.8 m |
| Width of the beam | 0.0256 m |
| Thickness of the beam | 0.0096 m |
| Density | 2700 kg/$m^3$ |
| Elastic modulus of the beam | $0.724 \times 10^{11}$ N/$m^2$ |
| Poisson's ratio | 0.35 |

Table 2: First three Natural Frequencies of Aluminium Beam

| Mode | Experimental $f_n$ (Hz) | Simulation(ANSYS) $f_n$ (Hz) |
|---|---|---|
| 01 | 12.712 | 12.543 |
| **02** | 78.300 | 77.299 |
| **03** | 227.939 | 216.22 |

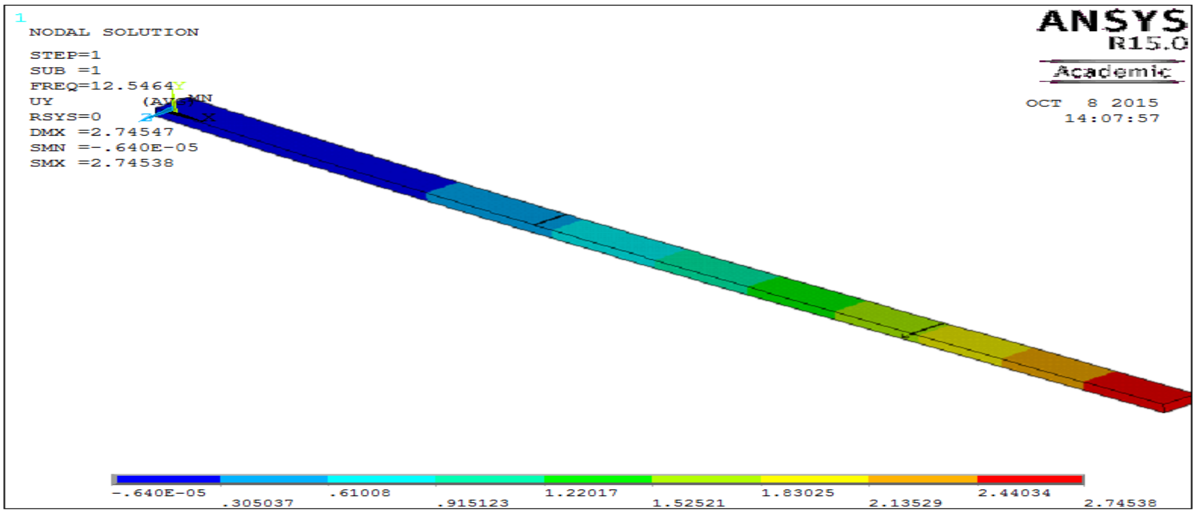


Fig4: First Mode shape of Un cracked cantilever beam

## IV.RESULTS

The effects of the crack on natural frequency and mode shape of a cantilever beam were investigated for various crack depths is plotted in figures 5 to10.And it was observed that in all the cases the modal natural frequencies decrease and mode shape increase with increase in crack depth.

The effects of the crack on Frequency and mode shape of cantilever beam:

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Table 3: Natural of First Three Mode of Cantilever Beam for Various Crack Position and Crack Depth.

| Crack Position(mm) | Crack Depth(mm) | Experiment Results | | | ANSYS Results | | |
|---|---|---|---|---|---|---|---|
| | | Mode 1 | Mode 2 | Mode 3 | Mode 1 | Mode 2 | Mode 3 |
| 300 and 600 | 0 | 12.712 | 78.300 | 227.93 | 12.543 | 77.299 | 216.22 |
| | 0.5 | 12.981 | 78.257 | 227.54 | 12.339 | 77.258 | 216.00 |
| | 1 | 12.962 | 78.162 | 227.06 | 12.332 | 77.183 | 215.66 |
| | 1.5 | 12.953 | 78.055 | 226.42 | 12.322 | 77.044 | 214.88 |
| | 2 | 12.936 | 77.860 | 225.39 | 12.305 | 76.853 | 213.95 |
| | 2.5 | 12.923 | 77.615 | 224.24 | 12.289 | 76.612 | 212.45 |
| | 3 | 12.904 | 77.305 | 223.15 | 12.267 | 76.302 | 211.13 |

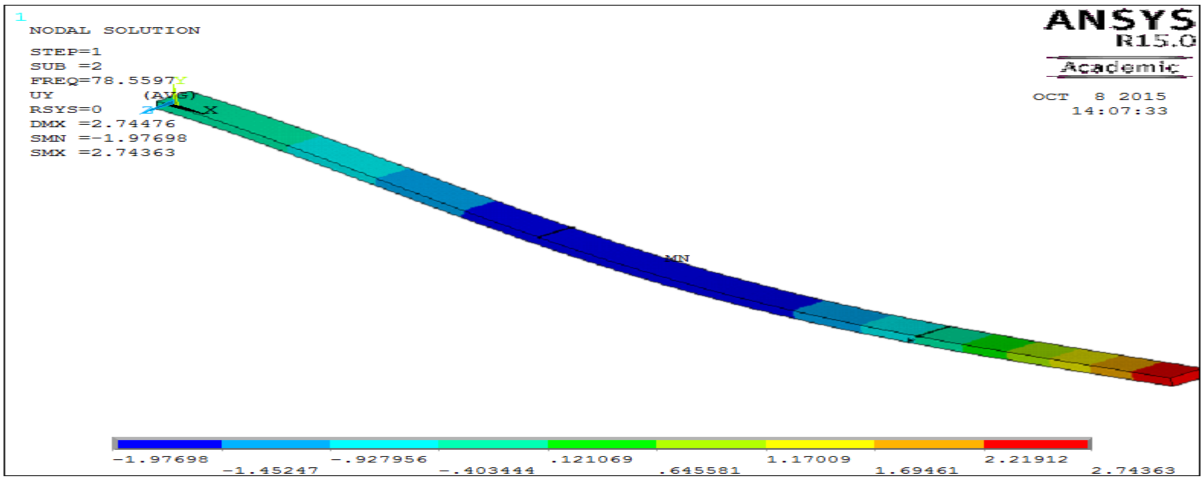


Fig5: Second Mode shape at crake depth 0.5mm

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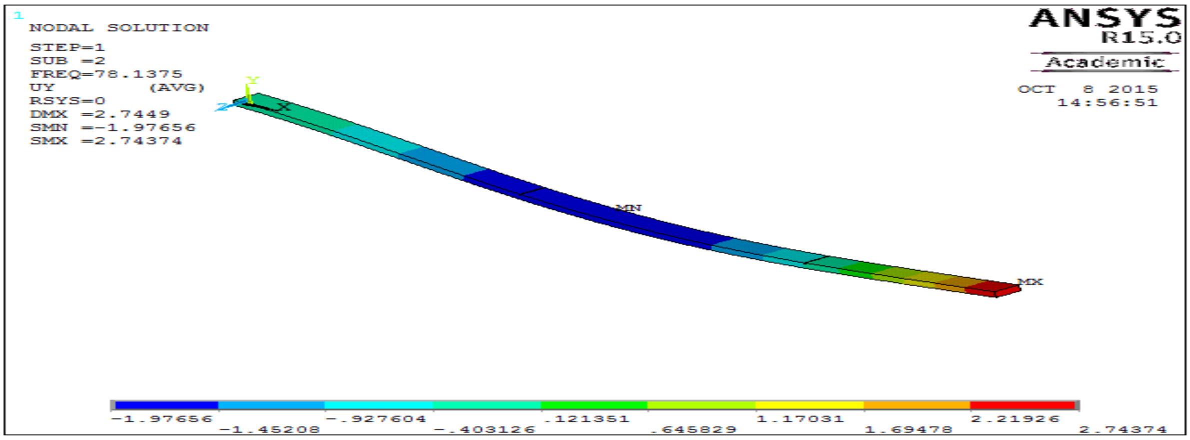


Fig6: Second Mode shape (Cantilever Beam) at crake depth 2.0 mm

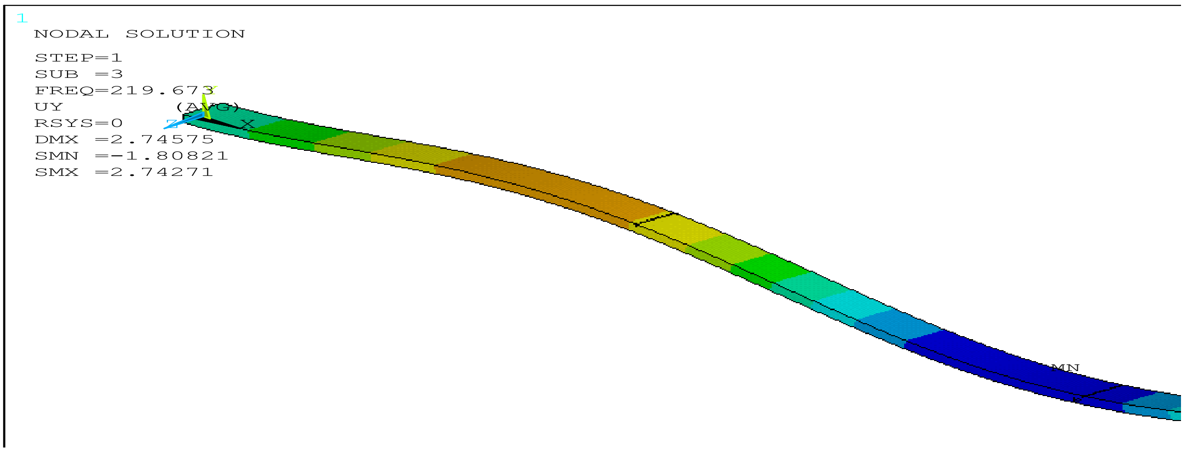


Fig7: Third Mode shape at crake depth 3.0mm

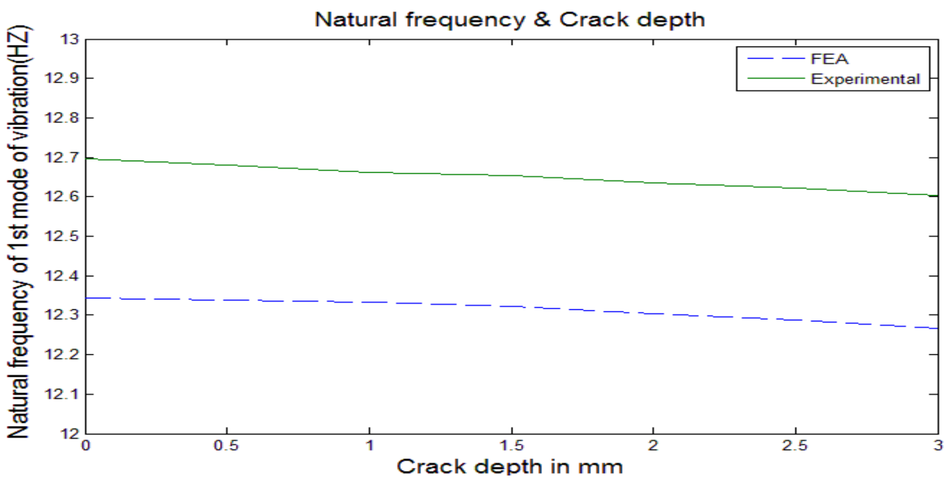


Fig8: First Mode Nature Frequency versus Crack depth

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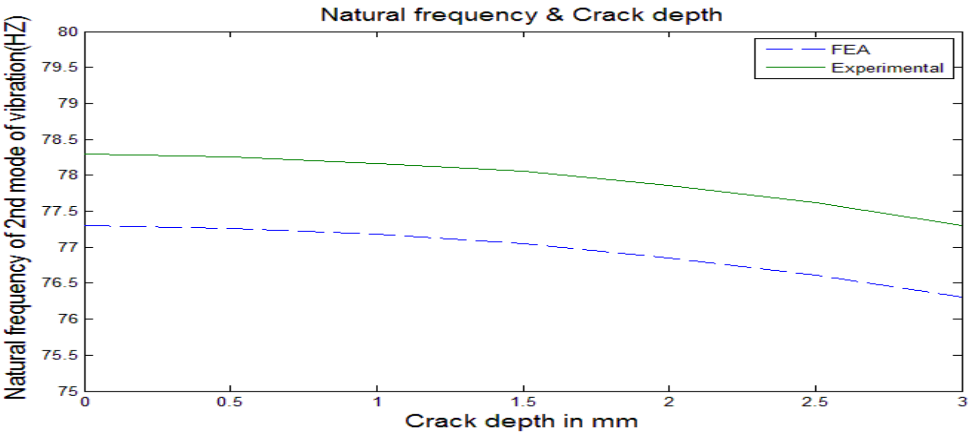


Fig.9: Second Mode Nature Frequency versus Crack depth

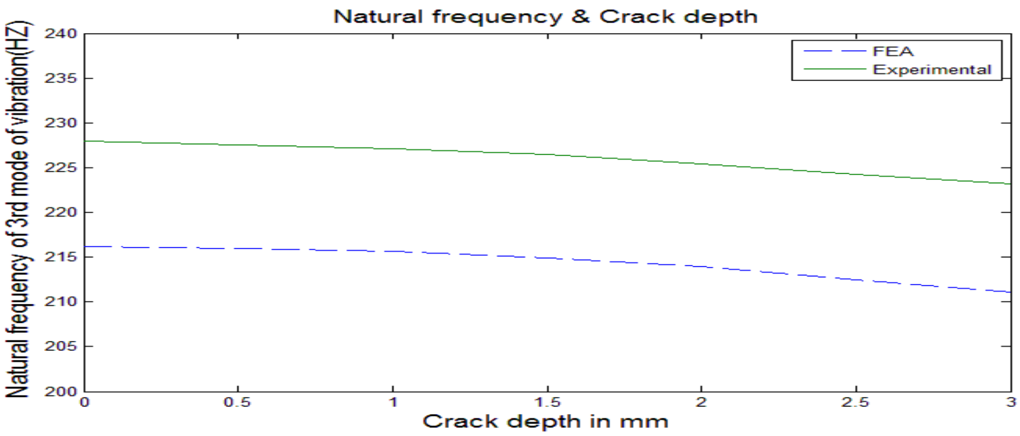


Fig10: Third Mode Nature Frequency versus Crack depth

## V.CONCLUSIONS

It is an established fact that the use of various techniques for crack diagnosis is aimed at determining the physical stability of the structure subjected to vibration. It has been observed that the changes in natural frequencies and mode shapes are two important parameters that determine crack size and location of the crack respectively. In this paper comprehensive investigations of the effects of cracks on the vibration signatures of a dynamically vibrating uniform cracked cantilever beam have been presented. The vibration analysis has been done using experimental and finite element analysis. It is seen that natural frequencies increase and Mode shapes decrease as the crack depth increases. Experiment and finite results are in good agreement.

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