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Investigations on Effect of Notch/Crack on Cantilever Beams

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ABSTRACT

Beams are very important as per engineering application is conscern and it undergoes different type of loading.Because of different type of loadings there may be chances of failure of structures due to generation of crack or notch.Therefore crack or notch depth and location are the main parameters for the vibration analysis of beams.These crack or notch depth and their position may affect the natural frequency.Therefore it is essentail to study the effect of crack or notch depth and its position on modal natural frequency of the beam for the good performance and its safety. This research work focus on the examination of these changes, which is useful for identification of crack or notch position.The material of the beam is taken as aluminum and mild steel. In this work the detailed analysis of cantilever beam with & without notch or crack has been done using theoretical analysis and finite element method (FEM) with the help of ANSYS and experimentally using modern National Instruments (NI) Lab-view software technique.An experimental set up was developed in which a cracked cantilever beam was excited by a hammer and the response was obtained using an accelerometer.This method describes the relation between the modal natural frequency and crack depth, modal natural frequency with crack location. This paper includes the study of dynamic properties of cantilever beams subjected to free vibration under the influence of crack or notch at different positions along the length.

Keywords— **Cantilever beam, Finite Element Method (FEM), NI Lab-view**.

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I. INTRODUCTION

Beams are used all around us in many mechanical and structural engineering applications. They are commonly used to create a foundation or internal support for a larger structure, such as a building or a bridge. There are a lot of cases that we heard recently which happened because of mother nature that caused many structures cracked, failed or collapsed..Therefore it is necessary to study dynamic characteristics of beam such as natural frequencies and mode shape during existence of crack subjected to the vibration. This dynamic behavior of a structure is affected due to the presence of a crack as the stiffness of that structural element is altered.

A large number of studies have been carried out on conventional (dye penetrant, magnetic particle induction, ultrasonic etc.) and modern approaches to non-destructive testing and evaluation. The conventional methods have been well developed, implemented in widely marketed equipment, and accepted by industry and regulatory agencies as practically applicable nondestructive valuation (NDE) methods. The modern NDE methods are still under development, implemented in a limited manner in some equipment and not fully accepted by the industry and regulatory agencies as practicably applicable NDE methods. One of these modern methods is the vibration-based inspection methodology. Vibration principles are the inherent properties of the physical science applicable to all structures subjected to static or dynamic loads. All structures again due to their rigid nature develop some irregularities in their life span which leads to the development of crack. The problem on crack is the basic problem of science of resistance of materials. Considering the crack as a significant form of such damage, its modeling is an important step in studying the behaviour of damaged structures. Knowing the effect of crack on stiffness, the beam or shaft can be modeled using either Euler-Bernoulli or Timoshenko beam theories. The beam boundary conditions are used along with the crack compatibility relations to derive the characteristic equation relating the natural frequency, the crack depth and location with the other beam properties. Researches based on structural health monitoring for crack detection deal with change in natural frequencies and mode shapes of the beam.Beams are used all around us in many mechanical and structural engineering application like Building,Bridges,wings of aeroplane can be act as cantilever beam as shown in Fig.1.Therefore our research work focuses on cantilever beam.

Fig.1 Wings of aeroplane acts as a cantilever beam

II. LITERATURE REVIEW

Loutridisa et al.[1] developed a new method for crack detection in beams based on instantaneous frequency and empirical mode decomposition.They investigated the dynamic behaviour of a cantilever beam with a breathing crack under harmonic excitation using both theoretically and experimentally.

Sethi, et al.[2] has analyzed the vibration behaviour of cantilever beam using Ansys software by generating cracks at different location for various depth on cantilever beam. Owolabi et al.[3] considered two beams namely cantilever and fixed beam for investigation, after that they initiated a cracks at seven different location one end to the other end(along the length of the beam),with different range of crack depth ratio. They measured acceleration frequency responses at seven different points on each beam. From the experimental work, they observed that the crack can be detected by analyzing change in natural frequency and amplitudes of frequency response functions. Agarwalla et al. [4] has experimentally analyzed effect of an open crack on the modal parameters of the cantilever beam subjected to free vibration and compared with result obtained from numerical method. Nahy and Jabbari [5] have established an analytical as well as experimental approach for crack detection in cantilever beams by vibration analysis. An experimental setup was designed in which a cracked cantilever beam is excited by a hammer and the response is obtained by an accelerometer attached to the beam. To identify the crack, contours of the normalized frequency in terms of the normalized crack depth and location are plotted. Georgiades et al.[6] has performed a theoretical linear modal analysis of Euler–Bernoulli L-shaped beam structures by solving two sets of coupled partial differential equations of motion. Huang and Zhang[7] have illustrated the mechanism of modal coupling in cantilever plate flutter using the full Theodorsen airfoil theory within the linear framework. An accurate, pseudo- spectral method is employed to calculate the fluid loading and the eigen value problem is solved numerically using Galerekins method. Jassim et al. [8] determined analytical and experimental investigations on the effects of a crack on the cantilever steel beam with circular cross section. They determined the extent of the damage magnitude and the location of the cantilever beams. They observed that monitoring the change of the natural frequency, is a feasible and viable tool to indicate the damage occurrence and magnitude. Nguyen [9] has analyzed mode shapes of a cracked beam with a rectangular cross section beam using finite element method. He determined the existence of the crack can be detected based on the mode shapes, when the mode shapes are space curves. Also, when there is a crack, the mode shapes have distortions or sharp changes at the crack position. Thus, the position of the crack can be determined as a position at which the mode shapes exhibit such distortions or sharp changes. Khiem and Toan [10] have proposed method for calculating the natural frequencies of a multiple cracked beam and detecting unknown number of multiple cracks from the measured natural frequencies. Thalapil and Maiti [11] has developed an analytical method to address both forward problem of determination of natural frequencies knowing the beam and crack geometry details as well as inverse problem of detection of crack with the knowledge of changes in the beam natural frequencies. Both long(Euler–Bernoulli) and short(Timoshenko) beams have been examined numerically. Nejad et al. [12] has given an analytical estimation based on the Rayleigh's method, extended for a beam having one or two cracks to find natural frequencies and mode shapes in order to overcome weakness of solving eigen value problem. They developed an algebric equation which must be solved numerically and then coefficients of trigonometric and hyperbolic terms in mode shapes are found using matrices obtained from compatibility conditions at each point of cracks and boundary conditions. The advantage of analytical estimation based on the Rayleigh's method over the eigen analysis method is that, the Rayleigh method obtains explicit expression for both natural frequencies and mode shapes in which effect of parameters such as crack size and location on natural frequencies and mode shapes can be investigated analytically. Singh and Tiwari [13] have presented experimental verification of an algorithm for detection and localization of multiple cracks in a simple shaft system. The algorithm is based upon detecting the slope discontinuity due to cracks. Jena et al. [14] has given the fault detection of Multi cracked slender Euler Bernoulli beams through the knowledge of changes in the natural frequencies and their measurements. The method is based on the approach of modeling a crack by rotational spring. Barad et al. [15] has presented detection of the crack presence on the surface of beam-type structural element using natural frequency. Sutar [16] described the finite element analysis of a cracked cantilever and analyzes the relation between the modal natural frequencies with crack depth, modal natural frequency with crack location. Also he analyzed the relation among the crack depth, crack location and natural frequency. Prasad et al. [17] find out effect of location of crack from free end to fixed end on crack growth rate along vibrating cantilever beam.Saavedra and cuitino [18] presented a theoretical and experimental dynamic behaviour of different multi-beams systems containing transverse crack.Their proposed method is used to evaluate the dynamic analysis response of cracked free-free beam and a U-frame when harmonic force is applied. Vigneshwaran and Behera [19] studied the dynamic characteristics of a beam with multiple breathing cracks.They developed a a systematic approach which has been adopted to develop theoretical expressions for evaluation of natural frequencies and mode shapes.Saptarshi and Ramanjaneyelu presented [20] a methodology for detection and quantification of structural damage using modal information obtained from transfer matrix technique.Dawari and Vesmawala [21] have detected and located the damage in beam models with different boundary condtion by using modal based damage detection method.Seyed ,Ehsan , Amin, Mehrshad [22] proposed a numerical method for open edge-crack detection in an Euler–Bernoulli cantilever beam. By numerical simulations and experimental tests they have detected location and depth of crack.Barad,Sharma, Vyas founded out crack presence by using natural frequency as a parameter.They have given effect of crack depth and location on natural frequency.

In this era, the world now had become unstable because of many factors. From the case as explained in early part of the introduction, failure or collapse of buildings and bridges (for example Tacoma Bridge in London) had a lot of scope for study and investigation. Again from literature review it is seen that a lot of work is performed on detection of crack by using natural frequency and amplitudes of frequency response functions for simply supported structures and cantilever beams Hence in this paper focus is on the investigation of cantilever beams behaviour with crack and notch at different locations.

III. A CANTILEVER BEAM WITH CRACK

The three natural frequencies i.e. 1st, 2nd & 3rd are determined by the numerical method (FEM) using ANSYS. First the cantilever beam of the dimensions 500mm x 25mm x 10 mm is being modeled with crack using wirecut EDM process (depth 2mm, 4mm, 6mm) at two different positions i.e at 100mm and 200 mm from free end.By modal analysis three natural frequencies are obtained.These natural frequencies are compared with natural frequencies obtained by theoretical method and NI Lab-view.Fig.2 shows the cantilever beam with crack.A material for the beam is taken as mild steel.

E=210 Gpa, $A = 25 \cdot 10$ mm^2, $\rho = 7.85 \cdot 10^{-6}$ kg/mm^3, μ =0.32

A. *Theoretical method*

In this study, a cantilever beam having a length L, height H,width B and transverse open edge-crack of depth d is considered as shown in Fig.2

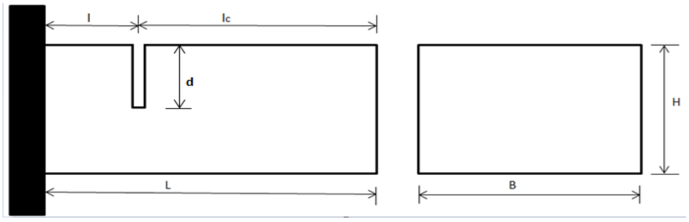


Fig.2 A cantilever beam with crack

A cracked cantilever beam is divided in to two parts in order to find out natural frequencies, which are supposed to be joined by a torsional spring as shown in Fig.3.

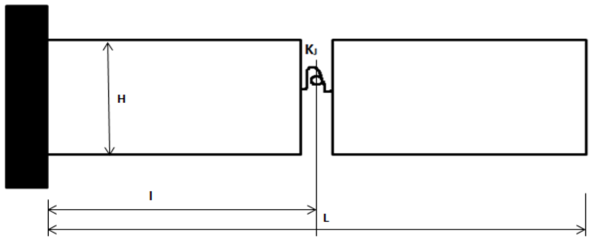


Fig.3 A cracked cantilever beam with torsional spring

Increasing crack depth affects the natural frequency of beam.Stiffness of torsional spring is calculated based on the crack depth an gemoetry of the beam.The coefficeint of the torsional spring, is calculated based on, K_J ,is calculated based on the following equation.

$$K_J = \frac{EI}{6(1-\mu^2)} \times \frac{1}{Z} \quad (1)$$

Where E , I and μ are Young modulus, second moment of inertia and Poisson’s ratio.The parameter Z is calculated as follows:

$$Z = 1.86 \times S^2 - 3.95 \times S^3 - 16.38 \times S^4 - 37.23 \times S^5 + 76.81 \times S^6 - 126.9 \times S^7 + 172 \times S^8 - 143.97 \times S^9 + 66.56 \times S^{10} \quad (2)$$

1) *Governing Equation for cantilever beam with crack :* To derive the governing equation a cantilever beam with torsion spring in case of crack is taken as mathematical model as shown in Figure 2.The equations describing the cantilever beam is divded into two new function as $Y_1(x)$ and $Y_2(x)$,which describe the beam equations in the left and right sides of the spring, respectively.The variable x is measured from fixed end of the beam.Crack is assumed to be at l as shown in Figure 1.

$$W = \int_0^{l_c} (\frac{1}{2} \cdot m(\frac{\partial y_1}{\partial t})^2) \cdot dx + \int_{l_c}^{L} (\frac{1}{2} \cdot m(\frac{\partial y_2}{\partial t})^2) \cdot dx \quad (3)$$

$$X = \int_0^{l_c} (\frac{1}{2} \cdot EI(\frac{\partial y_1}{\partial x})^2) \cdot dx + \int_{lc}^{L} (\frac{1}{2} \cdot EI(\frac{\partial y_2}{\partial x})^2) \cdot dx + \frac{1}{2} \cdot K_J \cdot ((\frac{\partial y_1}{\partial t}) - (\frac{\partial y_1}{\partial t}))^2 \Big|_{x=l_c}$$

(4)

Where m is mass per unit length of the beam.

After derivation of kinematic and potential energy relationships and also using Hamilton equation, the equations of motion is obtained, the equation of motion is obtained as given in equation (6).

$$\delta\int_{t_1}^{t_2}(W-X)\cdot dt=0 \quad (5)$$

$$m(\frac{\partial^2 y_1}{\partial t^2})+EI(\frac{\partial^2}{\partial x^2}(\frac{\partial^2 y_1}{\partial x^2}))=0 \quad (6)$$
$$m(\frac{\partial^2 y_2}{\partial t^2})+EI(\frac{\partial^2}{\partial x^2}(\frac{\partial^2 y_2}{\partial x^2}))=0$$

By applying the seperation of variables $y(x,t)=Y(x).T(t)$ to Eq. (6), the final equations of transverse vibration can be given in equation (7) and (8) for the left and right of crack as follows:

$$Y_1(x)=B_1\cdot\cosh(\frac{\lambda x}{L})+B_2\cdot\sinh(\frac{\lambda x}{L})+B_3\cdot\cos(\frac{\lambda x}{L})+B_4\cdot\sin(\frac{\lambda x}{L}) \quad (7)$$

$$Y_2(x)=B_5\cdot\cosh(\frac{\lambda x}{L})+B_6\cdot\sinh(\frac{\lambda x}{L})+B_7\cdot\cos(\frac{\lambda x}{L})+B_8\cdot\sin(\frac{\lambda x}{L}) \quad (8)$$

Where $Y_1(x)$ and $Y_2(x)$ are the equation of the beam for the left and right side of the crack.In these relations, λ is defined as follows:

$$\lambda=\sqrt[4]{\frac{\omega^2\rho AL^4}{EI}}$$

Where ω , ρ , A ,natural frequency , density and cross-section area of cantilever beam.

In case of cantilever beam boundary conditions are given as follows

1) Bending moment and shear force at free end is zero.
2) Slope and dispacement at fixed end is zero
3) Also displacement,bending moment,shear force at the left and right hand side of the crack are equal.

Above conditions are given in the following equations

$$y_1\Big|_{x=0}=0;\ \frac{\partial y_1}{\partial x}\Big|_{x=0};\ \frac{\partial^2 y_2}{\partial x^2}\Big|_{x=L}=0;\ \frac{\partial^3 y_2}{\partial x^3}\Big|_{x=L}=0 \quad (9)$$

$$\frac{\partial^2 y_1}{\partial x^2}=\frac{\partial^2 y_2}{\partial x^2}\Big|_{x=l_c};\ \frac{\partial^3 y_1}{\partial x^3}=\frac{\partial^3 y_2}{\partial x^3}\Big|_{x=l_c};\ (\frac{EI}{K_J}(\frac{\partial^2 y_1}{\partial x^2})+(\frac{\partial y_1}{\partial x})=(\frac{\partial\ y_2}{\partial x^2}))\Big|_{x=l_c}$$

(10)

Substituting boundary conditions (9) and (10) in to the equation (7) and (8) , the result can be wrriten in the following form equations as

$$\begin{bmatrix} 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 \\ A_1 & A_2 & A_3 & A_4 & -A_1 & -A_2 & -A_3 & -A_4 \\ A_2 & A_1 & A_4 & -A_3 & -A_2 & -A_1 & -A_4 & A_3 \\ A_1 & A_2 & -A_3 & -A_4 & -A_1 & -A_2 & A_3 & A_4 \\ 0 & 0 & 0 & 0 & A_5 & A_6 & -A_7 & -A_8 \\ 0 & 0 & 0 & 0 & A_6 & A_5 & A_8 & -A_7 \\ A_1+KA_2 & A_2+KA_1 & -A_3+KA_4 & -A_4+KA_3 & -KA_2 & -KA_1 & KA_4 & -KA_3 \end{bmatrix}\cdot\begin{bmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \\ B_5 \\ B_6 \\ B_7 \\ B_8 \end{bmatrix}=0$$

(11)

Where

$$A_1=\cosh(\frac{\lambda l_c}{L}),\ A_2=\sinh(\frac{\lambda l_c}{L}),\ A_3=\cos(\frac{\lambda l_c}{L}),\ A_4=\sin(\frac{\lambda l_c}{L})$$

(12)

$$A_5=\cosh(\lambda),\ A_6=\sinh(\lambda),\ A_7=\cos(\lambda),\ A_8=\sin(\lambda),\ K=\frac{K_J L}{EI\lambda}$$

(13)

Natural frequency can be obtained by equating the determinant of coefficient of matrix of equation 11 to zero.Since for non-trival solution determinant must be zero.Thus characteristic equation can be obtained from this determinant by converting $\sin$, $\sinh$, $\cos$, $\cosh$ terms into polynomial by using taylors series expansion.Thus from the above polynomial equation determinant can be solved by using Matlab Software.From the solved determinat characteristic equation can be obtained.From this equation natural frequencies of cracked cantilever beam can be obtained.

B. *Experimental Method*

In order to study the effect of crack on cantilever beam, the required experimental setup as shown in Fig.4 is developed.It contains instruments likedata acquisition hardware (with specifications as shown in Table1), accelerometer (with specifications as shown in Table2), impact hammer (with specifications as shown in Table3), a loaded personal computer [pc] or labtop,test-specimen, power supply for the pc and vibration analyzer, connecting cables for the impact hammer and accelerometer.The experimental analysis is carried out for the cantilever beam to find the natural frequencies of transverse vibration.

Table1 Specification of Data acquisition system

Sr.No.	Parameter	Specification
1	Brand Make	National Instruments
2	Number of channel	4
3	Maximum sampling	51.2 ks/s per channel
4	Voltage input	5V
5	Dynamic range	102 DB

Table 2 Specification of accelerometer

Sr.No.	Parameter	Specification
1	Brand Make	National Instruments
2	Model no.	PCB 352C33
3	Voltage sensitivity	100mv/g
4	Frequency range	0.3 to 12000Hz
5	Electrical connector	Type/location 5-44 coaxial/side

Table 3 Specification of Hammer

Sr.No.	Parameter	Specification
1	Brand Make	National Instruments
2	Model no.	PCB086C03
3	Voltage range	10 DB
4	Sensitivity element	Material/type quartz/Epoxy
5	Electrical connector	type/location BNC/Bottom of handle

Fig.4 Experimental setup

C. Analytical method

We are investigating cantilever beam using the ANSYS program, acomprehensive finite element package. We use the ANSYS structural package to analysis the vibration of fixed free beam with and without crack.A Fig.5 shows a meshed cantilever beam.

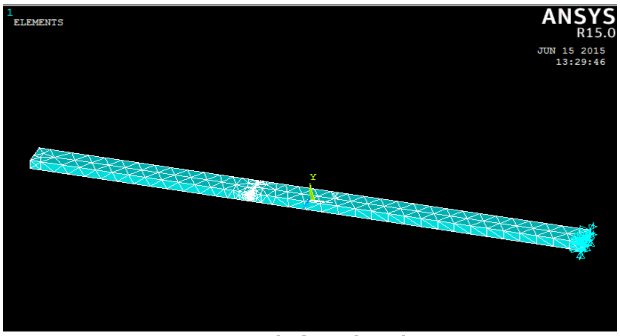


Fig.5 A meshed cantilever beam

IV. RESULTS AND DISCUSSIONS FOR CRACK

From the theoretical method we can easily find out the natural frequencies for different crack depth and its different positions. Table 4 shows the ratio of natural frequency(ratio of natural frequency of cracked beam to the natural frequency of uncracked beam) vs crack depth for various crack location.The experimental data for cantilever beam obtained from NI-Labview.The material for cantilever beams were taken as mild steel.The FRFs obtained were curve fitted automatically using this software.The experimental data obtained from Labview were tabulated, and plotted in the form of (ωc/ωn)(ratio of natural frequency of cracked beam to the natural frequency of uncracked beam) verses crack depth for various crack location.Table 5 shows the variation of frequency ratio with repect to crack location and crack depth for cantilever beam obtained experimentally using Labview.

The effect of crack depth and its position on natural frequency ratio were validated by using finite element method.FEM software package ANSYS has been used.The values of natural frequencies obtained were tabulated and plotted in the same form as that of experimentally method. Table 6 shows the variation of frequency ratio with repect to crack location and crack depth for cantilever beam obtained using ANSYS software.Table 4 and Table 5, Table 6 shows the position of crack from free end.(i.e. 100 mm and 200 mm were the position of the crack fom free end of cantilever beam)

After that reults are compaired for graphs obtained from Table 4,Table 5 and Table 6.

Table 4 Result table for theoretical readings

Mode	Ratio of natural frequency (ωc/ωn)					
	2 mm		4mm		6mm	
	(100 MM)	(200 MM)	(100 MM)	(200 MM)	(100 MM)	(200 MM)
1	0.96	0.96	0.95	0.9	0.942	0.87
2	0.938	0.933	0.897	0.873	0.799	0.733
3	0.9858	0.975	0.94	0.931	0.877	0.828

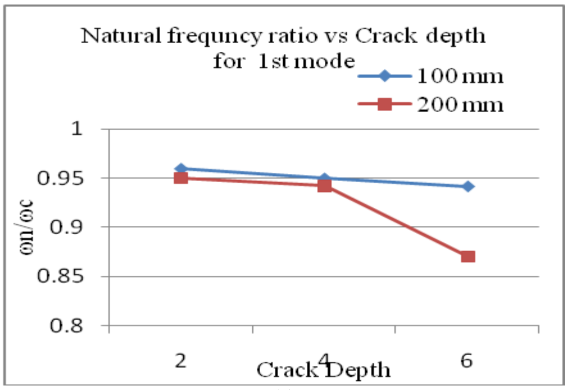
Table 5 Result table for experimental readings

Mode	Ratio of natural frequency (ωc/ωn)					
	2 mm		4mm		6mm	
	(100 mm)	(200 mm)	(100 mm)	(200 mm)	(100 mm)	(200 mm)
1	0.821	0.765	0.802	0.683	0.489	0.421
2	0.921	0.84	0.799	0.706	0.714	0.649
3	0.997	0.923	0.99	0.91	0.97	0.89

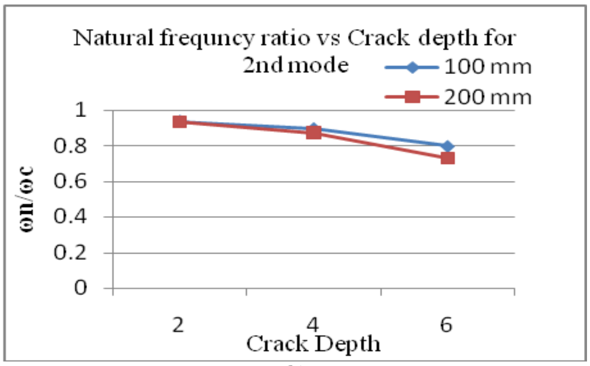
Table 6 Result table for ANSYS readings

Mode	Ratio of natural frequency (ωc/ωn)					
	2 mm		4mm		6mm	
	(100 MM)	(200 MM)	(100 MM)	(200 MM)	(100 MM)	(200 MM)
1	0.945	0.943	0.9	0.89	0.89	0.88
2	0.85	0.83	0.83	0.82	0.82	0.8
3	0.898	0.895	0.8	0.89	0.79	0.77

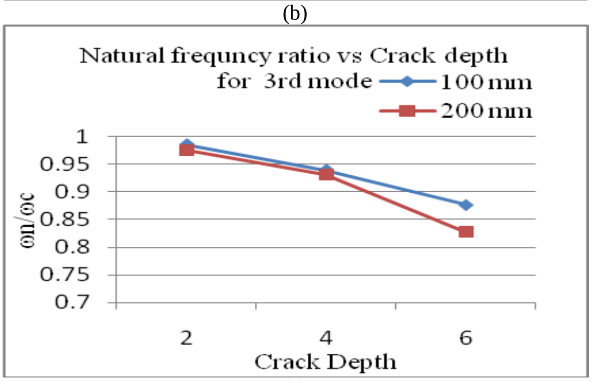
Fig.6 (a) (b) (c) shows the frequency ratio variation for three modes interms of crack position for various crack depth respectively.These graphs are plotted from Table 4.



(a)



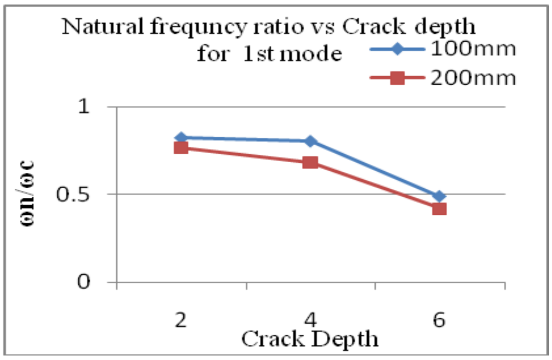
(b)



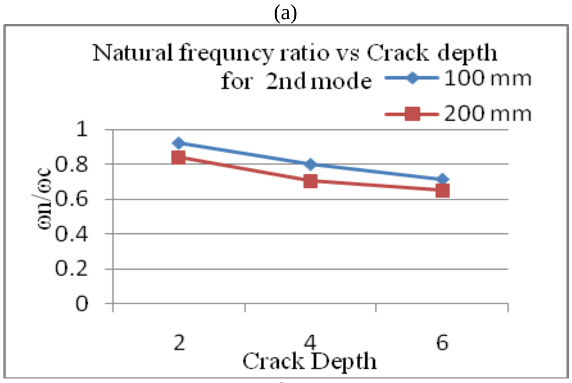
(c)

Fig.6 Natural frequency ratio versus crack depth varaition for (a) first mode (b) second mode (c) third mode for different position using theoretical method

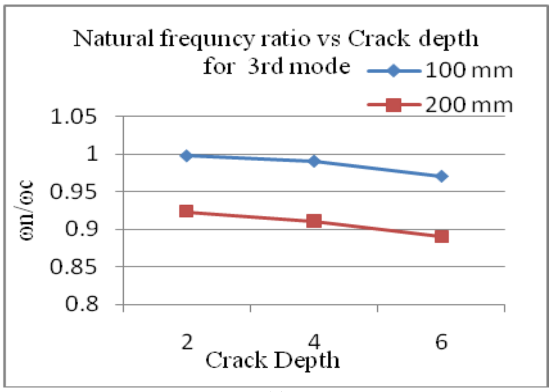
Fig.7 (a) (b) (c) shows the frequency ratio variation for three modes interms of crack position for various crack depth respectively.These graphs are plotted from Table 5.



(a)



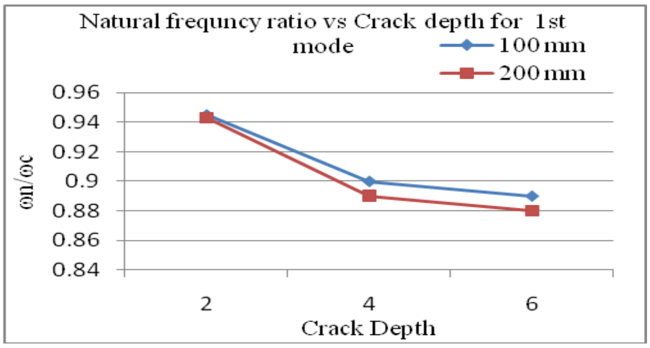
(b)



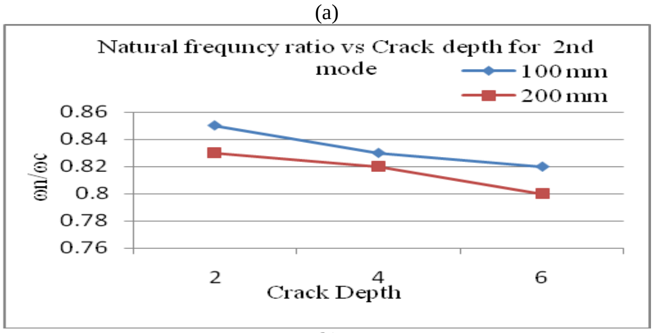
(c)

Fig.7 .Natural frequency ratio versus crack depth varaition for (a) first mode (b) second mode (c) third mode for different position experimentally

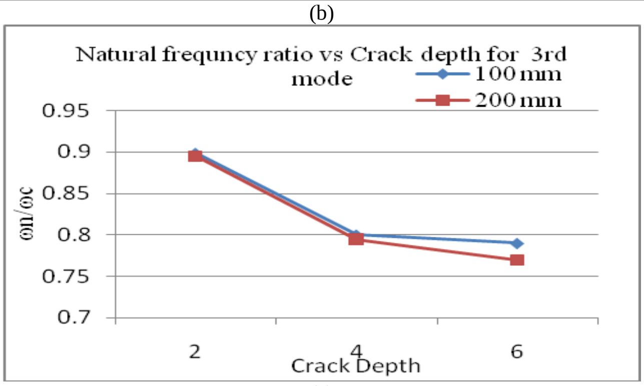
Fig.8 (a) (b) (c) shows the frequency ratio variation for three modes interms of crack position for various crack depth respectively.These graphs are plotted from Table 6.



(a)



(b)



(c)

Fig.8 Natural frequency ratio versus crack depth varaition for (a) first mode (b) second mode (c) third mode for different position using ANSYS

From Table 4,Table 5, Table 6and Fig.6, Fig.7, Fig.8, it is observed that natural frequencies of cantilever beam were greatly affected by depth of crack and position of crack.It is seen that natural frequency of vibration decreases as depth of crack increases.Therefore it seems that decrease in frequency is the function of crack depth.This because the fact that as crack depth increases implies stiffness of the structure decreases.Thus fundamental frequency decreases as crack depth increases.The frequency was mostly affected by crack when it was located at 200mm from free end which is shown in Fig.6,7 and 8.Therefore,for cantilever beam it could be conclude that natural frequency decreases significantly as crack position moves towards fixed end.This could be explained by the fact that decrease in frquencies were greatest for the crack located were the bending moment is maximum.Therefore it seems that change in frequency is the function of crack position.

V. A CANTILEVER BEAM WITH NOTCH

The three natural frequencies i.e. 1st, 2nd & 3rd are determined by the numerical method (FEM) using ANSYS . First the aluminum cantilever beam of the dimensions 500mm x 25mm x 10 mm is being modeled with'V' notch (depth 4mm, 6mm, 8mm) at two different positions i.e at 125mm and 250mm from free end.By modal analysis three natural frequencies are obtained.These natural frequencies are compared with natural frequencies obtained byNI Lab-view.Fig.9 shows the cantilever beam with notch.E=70 Gpa, $A = 25 \cdot 10\,\text{mm}^2$, $\rho = 2.7 \cdot 10^{-6}$ kg/mm^3, μ =0.32.

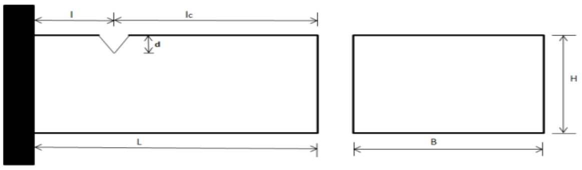


Fig.9 A cantilever beam with notch

VI. RESULTS AND DISCUSSIONS FOR NOTCH

The experimental data for cantilever beam obtained from NI-Labview.The material for cantilever beams were taken as aluminium.Here instead of crack a handmade notch has been generated using triangular hack-saw for different depth and different position.Different FRFs were obtained experimntally.The FRFs obtained were curve fitted automatically using NI-Labview.The experimental data obtained from Labview were tabulated, and plotted in the form of (ωc/ωn)(ratio of natural frequency of cracked beam to the natural frequency of uncracked beam) verses notch depth for various notch location.Table 7 shows the variation of frequency ratio with repect to notch location and notch depth for cantilever beam obtained experimentally using Labview. The effect of notch depth and its position on natural frequency ratio were validated by using finite element method.FEM software package ANSYS has been used.The values of natural frequencies obtained were tabulated and plotted in the same form as that of experimentally method. Table 8 shows the variation of frequency ratio with repect to notch location and notch depth for cantilever beam obtained using ANSYS software. Table 7 and Table 8 shows the position of notch from free end i.e. 125 mm and 250 mm were the position of the notch fom free end of cantilever beam.

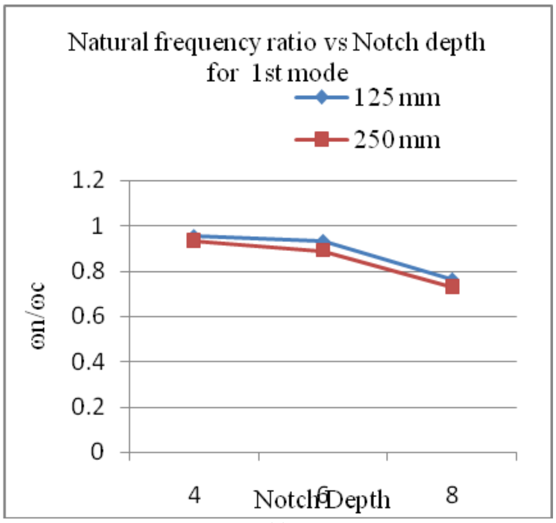
Table 7 Result table for experimental readings

Mode	Ratio of natural frequency (ωc/ωn)					
	4 mm		6 mm		8 mm	
	(125 mm)	(250 mm)	(125 mm)	(250 mm)	(125 mm)	(250 mm)
1	0.957	0.935	0.935	0.892	0.763	0.731
2	0.973	0.93	0.914	0.828	0.887	0.813
3	0.973	0.97	0.962	0.955	0.95	0.94

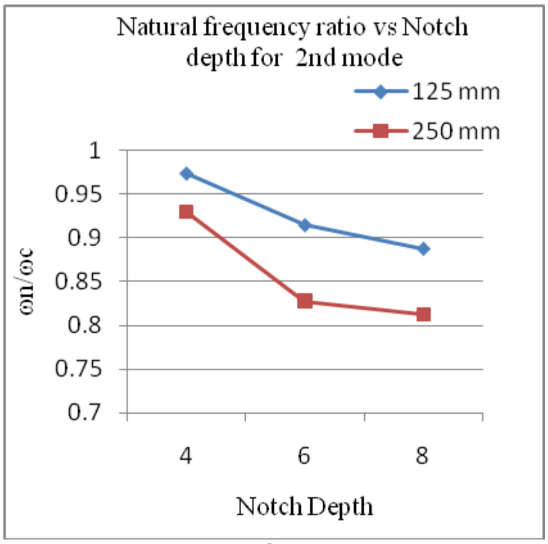
Table 8 Result table for ANSYS readings

Mode	Ratio of natural frequency (ωc/ωn)					
	4 mm		6 mm		8 mm	
	(125 mm)	(250 mm)	(125 mm)	(250 mm)	(125 mm)	(250 mm)
1	0.988	0.964	0.977	0.955	0.958	0.942
2	0.964	0.932	0.945	0.917	0.927	0.914
3	0.947	0.893	0.911	0.871	0.905	0.859

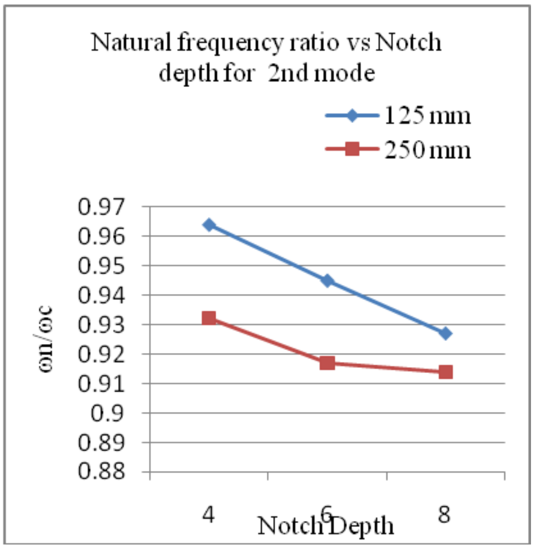
Fig.10 (a) (b) (c) shows the frequency ratio variation for three modes interms of notch position for various notch depth respectively.These graphs are plotted from Table 7.Fig.11 (a) (b) (c) shows the frequency ratio variation for three modes interms of notch position for various notch depth respectively.These graphs are plotted from Table8.From Table 7,Table 8 and Fig.10, Fig.11, it is observed that natural frequencies of cantilever beam were greatly affected by depth of notch and position of notch.It is seen that natural frequency of vibration decreases as depth of notch increases.Therefore it seems that decrease in frequency is the function of notch depth.This is because the fact that as notch depth increases implies stiffness of the structure decreases.Thus fundamental frequency decreases as notch depth increases.The frequency was mostly affected by notch when it was located at 225mm from free end which is shown in Fig.10 and 11.Therefore,for cantilever beam it could be conclude that natural frequency decreases significantly as notch position moves towards fixed end.This could be explained by the fact that decrease in frquencies were greatest for the notch located were the bending moment is maximum.Therefore it seems that change in frequency is the function of notch position.



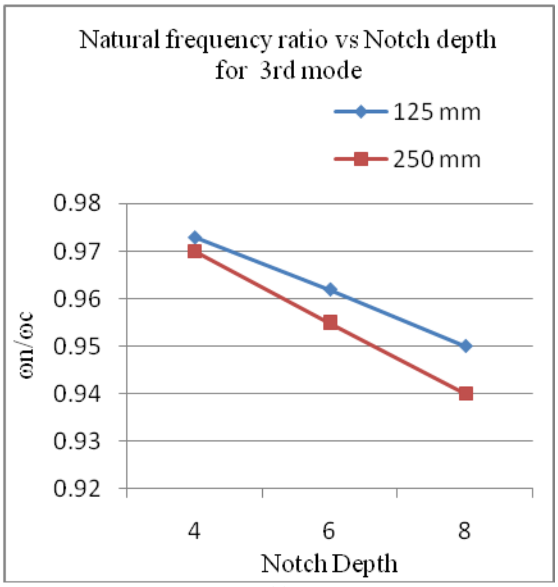
(a)



(b)

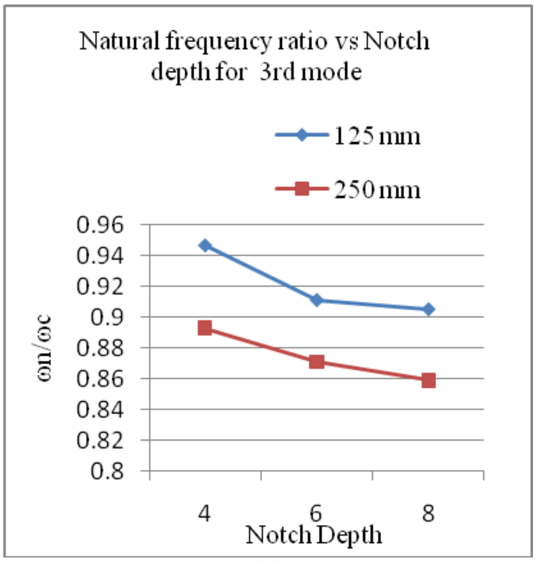


(b)



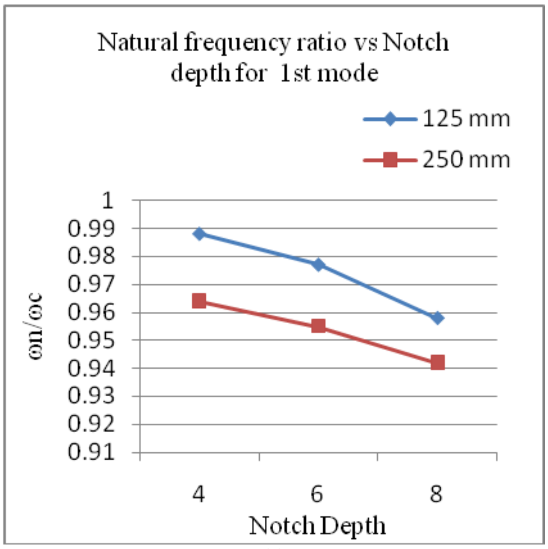
(c)

Fig.10 Natural frequency ratio versus notch depth varaition for (a) first mode (b) second mode (c) third mode for different position experimentally



(c)

Fig.11 Natural frequency ratio versus notch depth varaition for (a) first mode (b) second mode (c) third mode for different position using ANSYS.



(a)

VII. CONCLUSION

The primary objective of this paper is study the phenomenon of transverse vibrations in cantilever beam due to variations in position of crack and notch affect on natural frequencies. This objective was achieved with the help of extensive analytical work, computer aided simulation tools, some experimental investigations.From the analytical, numerical and experimental investigations it is seen that natural frequency of vibrating structure is susptible to change under the influence of crack and notch and its position. The natural frequencies of the vibrating beam are changes significantly in the presence of crack. There is decrease in natural frequency of cantilever beam due to the effect of crack.For cantilever beam it could be concluded that natural frequency decreases significantly as crack position moves towards fixed end.Therefore generated crack on mild steel and its position affects the natural frequency of vibration.Same results has been obtained for the aluminium having a notch.Therefore we can conclude that natural frequency affects the depth and position of the crack or notch.

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