STUDY ON EFFECT OF CRACK INCLINATION AND LOCATION ON NATURAL FREQUENCY FOR INCLINED EDGE CRACKED BEAM USING FREE VIBRATION

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Abstract –

Damages like inclined crack in vibrating component can initiate catastrophic failures. The presences of cracks change the physical characteristics of a structure which in turn alter its dynamic response characteristics. Therefore there is need to understand dynamics of cracked structures. Crack inclination, depth and location are the main parameters for the vibration analysis. So it becomes very important to monitor the changes in the response parameters of the structure to access structural integrity, performance and safety. This paper focuses on the vibration analysis of a beam with fixed free (Cantilever) boundary condition and investigates the mode shape and its frequency. The existence of inclined crack in a structural element leads a local stiffness that changes its vibration response. Finite Element Analysis (ANSYS) has been accomplished to derive the vibration signatures of the inclined cracked cantilever beam.

Key Words: ANSYS, Crack Depth, Inclined crack, Mode shape, Modal Natural Frequency

1.INTRODUCTION

Damages like inclined crack in vibrating component can initiate catastrophic failures. The presences of cracks change the physical characteristics of a structure which in turn alter its dynamic response characteristics. Therefore there is need to understand dynamics of cracked structures. Crack inclination, depth and location are the main parameters for the vibration analysis. So it becomes very important to monitor the changes in the response parameters of the structure to access structural integrity, performance and safety. Cracks in a structural element in the form of initial defects within the material or caused by fatigue or stress concentration can reduce the natural frequencies and change the vibration mode shapes due to the local flexibility introduced by the crack. Understanding the dynamic characteristics of cracked structures is of prime importance in structural health monitoring and non-destructive damage evaluation because the predicted vibration data can be used to detect, locate, and quantify the extent of the cracks or damages in a structure.

Classification of Crack

Based on geometries, cracks can be broadly classified as follows::

Transverse crack : These are cracks perpendicular to beam axis. These are the most common and most serious as they reduces the cross section as by weaken the beam .They introduce a local flexibility in the stiffness of the beam due to strain energy concentration in the vicinity or crack tip.

Longitudinal cracks : These are cracks parallel to beam axis. They are not that common but they pose danger when the tensile load is applied at right angles to the crack direction i.e. perpendicular to beam axis.

Open cracks : These cracks always remain open .They are more correctly called “notches”. Open cracks are easy to do in laboratory environment and hence most experimental work is focused on this type of crack

Breathing crack : These are cracks those open when the affected part of material is subjected to tensile stress and close when the stress is reversed.

Many researchers to develop various techniques for early detection of crack location, depth, size and pattern of damage in a structure. Some nondestructive methodologies for crack detection have been use in global. However the vibration based method is fast and inexpensive for crack/damage identification. Hence it is possible to use natural frequency measurements to detect cracks.

Abdul Salam *et. al*, has presented simplified formula for the stress correction factor in terms of the crack depth to the beam height ratio, f(a/h). The natural frequencies of the cracked beam are determined numerically by solving the characteristic equation of the beam.[1] Abhijit Naik and Pawan Sonawane studied on vibration based Crack/damage diagnosis techniques presented by various researchers for cracked structures. These methods use “finite element analysis techniques, together with experimental results, to detect damage in a fiber reinforced composites, laminated composites and non composite structures for its vibration analysis.[2] Dayal. R. Parhi, Prases. K. Mohanty, Sasmita Sahu and Amiya Kumar Dash have presented analytical as well as experimental methods to locate and quantify the size of damage in beam type structure from vibration mode.[3] Kaustubha V. Bhinge *et. al*, tried to establish a systematic approach to study and analyze the crack in cantilever beam. It is addresses the inverse problem of assessing the crack location and crack size in various beam structures. The study is based on measurement of natural frequency, a global parameter that can be easily measured at any point conveniently on the structure.[4] Ranjan K. Behera, Anish Pandey, Dayal R. Parhi in their research work has developed the theoretical expressions to find out the natural frequencies and mode shapes for the cantilever beam with two transverse cracks.[5] In the present investigation a number of literatures published so far have been surveyed, reviewed and analyzed. Most of researchers studied the effect of single crack on the dynamics of structures. However in actual practice structural members such as beams are highly susceptible to transverse cross-sectional cracks due to fatigue. Therefore to attempt has been made to investigate the dynamic behavior of basic structures with crack systematically. Condition based monitoring is one of the preventive maintenance method used in the plant maintenance. The present work is aimed at finding the natural frequency of a cantilever having inclined crack with variation in crack angle, depth and location. The objective of the work is to study effect of crack inclination and location on natural frequency for inclined edge cracked beam.

2 FINITE ELEMENT ANALYSES

Premature identification of damages in dynamic structures during their service period is the key challenge to the researchers because of its importance. At early stage of damages, it is very difficult to find out damages using visual inspection. It may be identified by Non-Destructive Techniques (NDT) such as ultrasonic, magnetic particle, radiography or shaft voltage drop etc. Though dynamic based damage diagnosis has been advanced for last three decades and there are many literatures, still there are so many problems avoid doing it from application. There are many techniques to solve the problem of a cracked beam such as numerical, wavelet, artificial intelligence, analytical, semi-analytical, experimental etc. FEA (Finite Element Analysis) is a common technique to obtain the stiffness matrix of the cracked beam element.

2.1 MODELING OF BEAM USING ANSYS

The Beam is modeled in ANSYS Software. Element SOLID185 is used for the 3-D modeling of solid structures. Material properties are provided which is briefly listed in Table 1. After that 16 models are prepared with various inclination angles for crack with the location of crack as L/2 and L/4 of the beam. After that the beam is meshed Fig. 2. Modal analysis is carried out using the Block Lanczos method for finding the natural frequencies. Fixed free boundary (ccantilever) condition was applied by constraining the nodal displacement in both x and y direction. The results are tabulated in Table 2, Table 3 and Table 4. The four mode shapes of beam with and without crakes for various locations are shown in Fig.3, Fig.4 and Fig 5.

Table 1 Material Property and Dimensions of beam

Dimensions and Properties	Aluminum
Length	0.3 m
Width	0.05 m
Thickness	0.006 m
Density	2700 kg/m^3
Young modulus	70 Gpa
Poisson's ratio	0.3

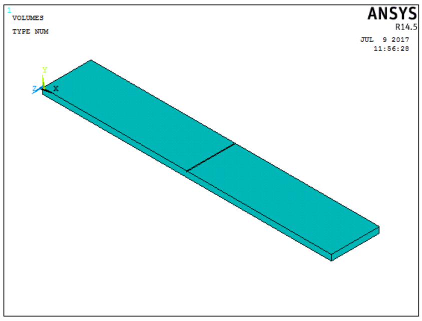


Figure 1 Cracked Beam Modeled in ANSYS (Crack Location L=l/2)

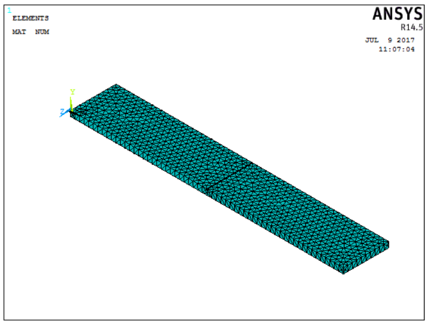
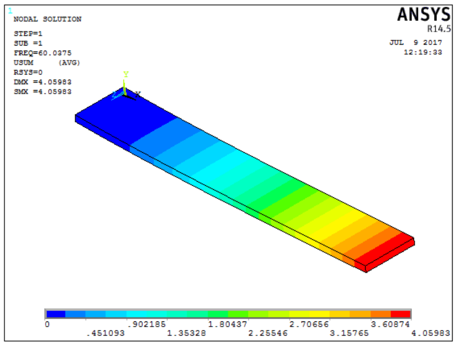


Figure 2 Meshed Beam



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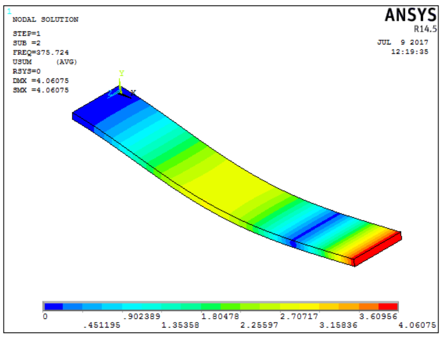

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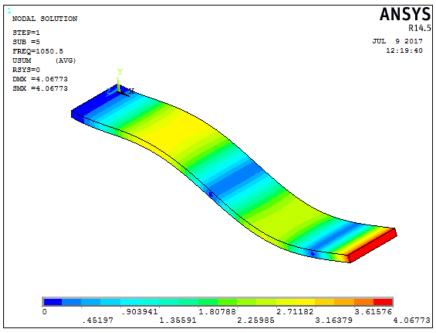

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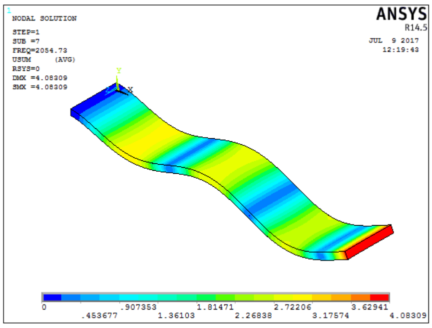

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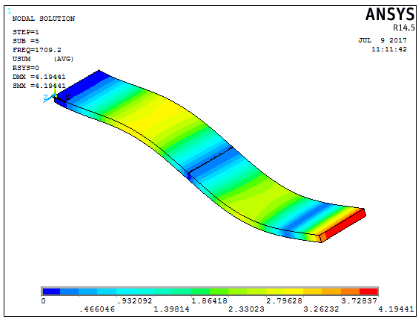
Figure 3 Mode Shape of Cantilever Un-cracked Beam with cantilever Condition



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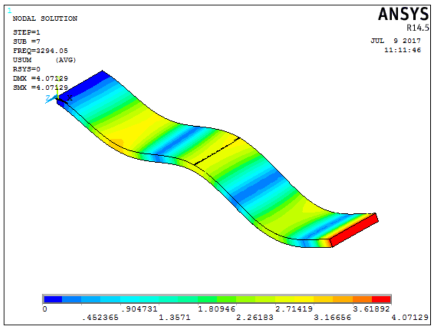

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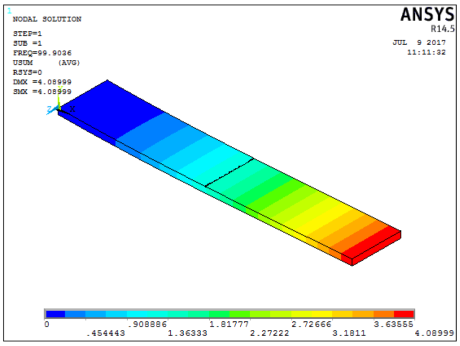
Figure 4 Mode Shape of Cracked Cantilever Beam (θ=15^0, α= 0.1 and L= l/2)

Table 2 Natural Frequencies of Un- cracked beam (ANSYS)

	Natural Frequency in Hz			
Condition	**I st Mode**	**II nd Mode**	**III rd Mode**	**IV th Mode**
Cantilever Beam	60.037	375.724	1050.500	2054.730



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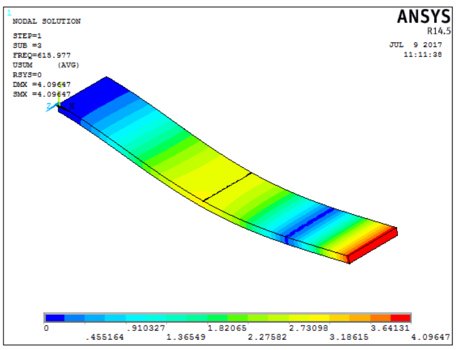

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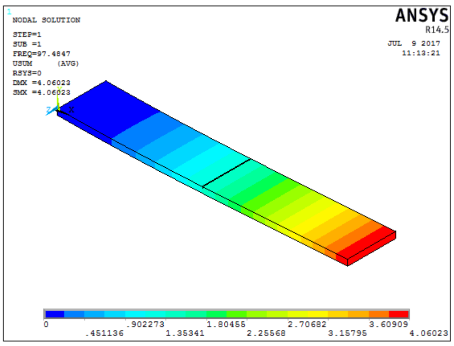

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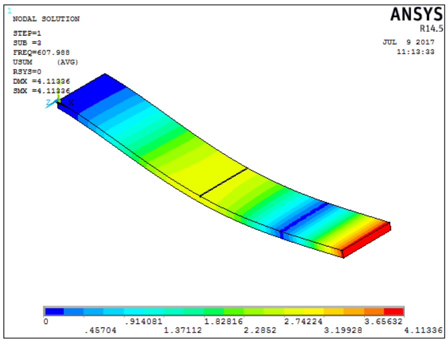

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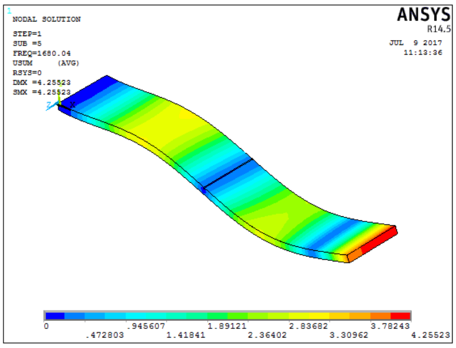

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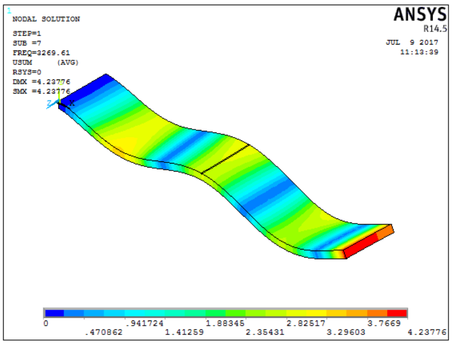
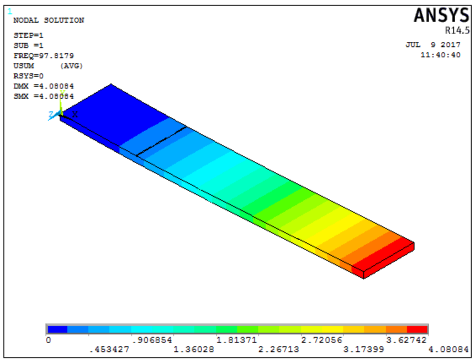


Fourth Mode

Figure 5 Mode Shape of Cracked Cantilever Beam (θ=15^0, α= 0.2 and L= l/2)

Table 3 Natural Frequencies of Cantilever cracked beam with varies crack Inclination angle and depth of crack by Using ANSYS (L=l/2)

Crack angle θ	Location	α	Natural Frequency			
			I st Mode	II nd Mode	III rd Mode	IV th Mode
0	L/2	0.1	98.87	606.25	1696.67	3256.01
0	L/2	0.2	98.07	612.05	1654.93	3276.84
15	L/2	0.1	99.90	615.98	1709.20	3294.05
15	L/2	0.2	97.48	607.99	1680.04	3269.61
30	L/2	0.1	99.76	613.59	1710.94	32.87.57
30	L/2	0.2	98.45	610.95	1693.40	3273.96
45	L/2	0.1	98.42	612.35	1685.18	3278.49
45	L/2	0.2	98.20	611.19	1684.59	3288.03



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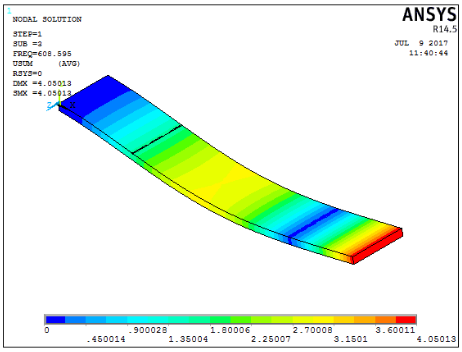

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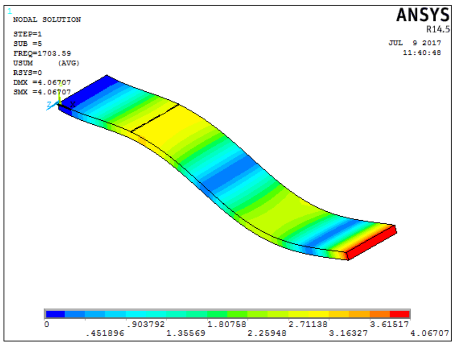

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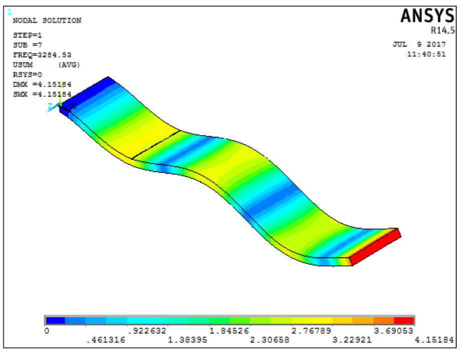

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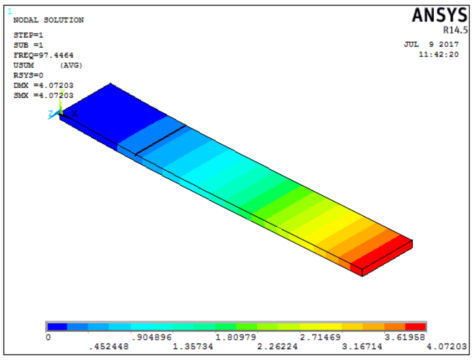
Figure 6 Mode Shape of Cracked Cantilever Beam (θ=15^0, α= 0.1 and L=l/4)



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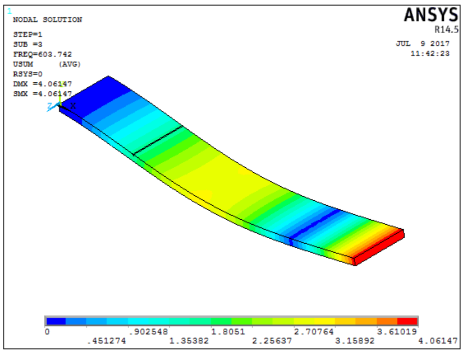

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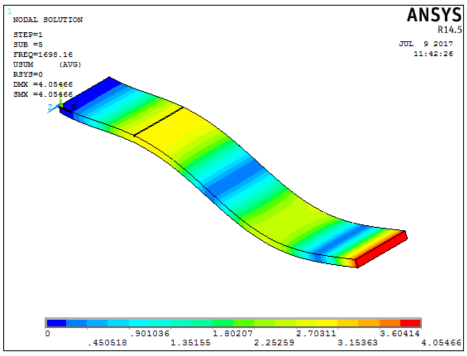

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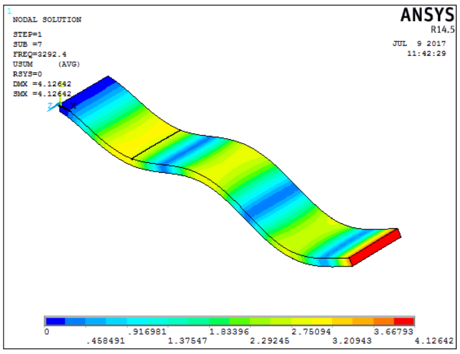

Fourth Mode

Figure 7 Mode Shape of Cracked Cantilever Beam (θ=15^0, α= 0.2 and L=l/4)

Table 4 Natural Frequencies of Cantilever cracked beam with varies crack Inclination angle and depth of crack by Using ANSYS (L=l/4)

Crack angle θ	Location	α	Natural Frequency			
			I st Mode	II nd Mode	III rd Mode	IV th Mode
0	L/4	0.1	97.2034	603.924	1694.62	3277.18
0	L/4	0.2	96.5915	602.306	1686.71	3261.43
15	L/4	0.1	97.8179	608.595	1703.59	3284.53
15	L/4	0.2	97.4464	603.742	1698.16	3292.4
30	L/4	0.1	97.545	603.941	1694.76	3279.55
30	L/4	0.2	96.6085	599.396	1690.08	3268.2
45	L/4	0.1	98.6132	608.954	1711.9	3214.96
45	L/4	0.2	97.7978	604.397	1705.13	3291.26

3. RESULTS AND DISCUSSION

Figures 3 show that natural frequency of the beam without crack. Figure 4 and Figure 5 shows that natural frequencies of the cantilever beam with inclined edge crack at location L=l/2, angle of inclination is 15^0 and depth 0.1 and 0.2 respectively for first, second, third and fourth modes of vibration. Figure 6 and Figure 7 shows that natural frequencies of the cantilever beam with inclined edge crack at location L=l/4, angle of inclination is 15^0 and depth 0.1 and 0.2 respectively for first, second, third and fourth modes of vibration. Results show that there is an appreciable variation between natural frequency of cracked and un-cracked cantilever beam. It is observed that natural frequency of the cracked beam decreases both with increase in crack inclination and crack depth due to reduction in stiffness.

4. CONCLUSIONS

It has been observed that the natural frequency changes significantly due to the presence of cracks depending upon inclination and depth of cracks. The results of the crack parameters have been obtained from the comparison of the results of the un-cracked and cracked cantilever beam during the Modal analysis using ANSYS software. It has been observed that the natural frequency changes substantially due to the presence of cracks depending upon location and size of cracks. It has been observed that when the crack positions are constant i.e. at particular crack location, the natural frequencies of a cracked beam are inversely proportional to the crack depth. The natural frequency of the cracked beam decreases with increase the crack depth. the change in frequencies is not only a function of crack depth, and crack inclination, but also of the mode number.

REFERENCES

[1] Abdul Salam Y. Alsabbagh, Osama M. Abuzeid , Mohammad H. Dado, "Simplified stress correction factor to study the dynamic behavior of a cracked beam", Applied Mathematical Modelling, Vol. 33 (2009), pp. 127–139

[2] Abhijit Naik and Pawan Sonawane, "Vibration Analysis of a Cracked Beam Using Various Techniques - A Review", International Journal of Innovative Research in

Science, Engineering and Technology, Vol. 3, Issue 12, December 2014,pp. 17913-17915

[3] Dayal. R. Parhi, Prases. K. Mohanty, Sasmita Sahu and Amiya Kumar Dash, "Identification of Crack Location and Magnitude in Beam Type Structure Using Finite Element Method", International Journal of Applied Artificial Intelligence in Engineering System 3(1), 2011, pp. 35-41

[4] Kaustubha V. Bhinge, P. G. Karajagi, Swapnil S.Kulkarni "Crack detection in cantilever beam by vibration Techniques", International Journal of Advanced Engineering Research and Studies, July-Sept.,2014,pp.80-86

[5] Ranjan K. Behera, Anish Pandey and Dayal R. Parhi, "Numerical and Experimental Verification of a Method for Prognosis of Inclined Edge Crack in Cantilever Beam Based on Synthesis of Mode Shapes", ICIAME, Procedia Technology , (2014), pp.67-74

[6] P. V. Fegade, J. A. Mahajan, G. P. Bhole "Study on Vibration Analysis of an Un-crack and Cracked Cantilever Beam", International Journal of Emerging Technologies in Computational and Applied Sciences, 10(4), SeptemberNovember, 2014, pp. 340-343