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Vibration Analysis & Effect of Dynamic Impact Loading On Cracked Beam

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ABSTRACT

Crack affects the optimum performance of a machine. Presently most of the failures encountered by machines are due to material fatigue. Presence of crack changes the physical characteristics of a structure which in turn alter its dynamic response characteristics. Therefore crack detection and localization is the main topic of discussion for various researchers across the world. The dynamic behavior of a whole structure is affected due to the presence of a crack as the stiffness of that structural element is altered. The cracks in the structure change the frequencies, amplitudes of free vibration and dynamic stability areas to a foreseeable extent. Cracks in vibrating component can initiate catastrophic failures. Therefore there is need to understand dynamics of cracked structures. Crack 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. So an analysis of the changes allows the experimenter to identify the cracks without aborting the system applications. The effect of a crack on the modal parameters of the cantilever beam subjected to free vibration is analyzed and the results obtained from the numerical method i.e. .finite element method (FEM) and the experimental method are compared.

Keywords— **Catastrophic failure, Crack, Finite element analysis, Stress analysis, Vibration analysis.**

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I. Introduction

For the last several years, a considerable amount of research work has been undertaken to investigate the faults in structures. It has been observed that most of the structural Members fail due to the presence of cracks. Cracks are present in the structure due to various reasons. The cracks are developed mainly due to fatigue loading. Therefore the detection of cracks is an important aspect of structural design. Damage is defined as any deviation introduced to a structure, either purposely or unintentionally, which adversely affect the current or future performance of that system. The presence of a crack could not only cause a local variation in the stiffness but also affects the mechanical behavior 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 [2].

The most common structural defect is the existence of a crack. Cracks are among the most encountered damage types in the structure due to fatigue or manufacturing defects. Crack will initiate in a structure when the stresses near the crack tip will exceed the permissible limit. Cracks found in structural elements may arise due to fatigue cracks that take place under service conditions as a result of the limited fatigue strength. Cracks may also occur mechanical defects or defects due to manufacturing processes. Mechanical accidents, fatigue, erosion, corrosion, as well as environmental attacks, are issues that can lead to a crack in a mechanical structure. Generally cracks are small in sizes. Such small cracks are known to propagate due to actuating stress conditions.

If these propagating cracks remain undetected and reach their critical size, then a sudden structural failure may occur [3].

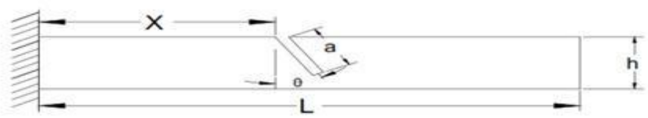
It is required that structures must safely work during its service life. But, damages initiate a breakdown period on the structures. Cracks in a structure may be hazardous due to static or dynamic loadings, so that crack detection plays an important role for structural health monitoring applications. It has been observed that the presence of cracks in structures or in machine members lead to operational problem as well as premature failure. A number of researchers throughout the world are working on structural dynamics and particularly on dynamic characteristics of structures with crack. Due to presence of cracks the dynamic characteristics of structure changes [8, 9].

Beams are one of the most commonly used structural elements in numerous engineering applications and experience a wide variety of static and dynamic loads. Cracks may develop in beam-like structures due to such loads. Considering the crack as a significant form of such damage, its modeling is an important step in studying the behavior 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 [7].

However, if the load applied to a structure is suddenly applied then one will observe that such dynamically applied load will create higher stresses, compare to statically applied load for a short time. We need to know the effect of suddenly applied loads such as earthquake, collision between cars or trains which create dynamic loads and hence higher damage takes place than statically applied loads. The following aspects of the crack greatly influence the dynamic response of the structure.

II. OBJECTIVE

In this work we consider the cracked cantilever beams of a relatively large aspect ratio. The objective of this project is to analyze experimentally and numerically the vibration analysis and effect of dynamic load on the cracked cantilever beam.



III. LITERATURE REVIEW

W. D. Zhu et al. [1] has studied a robust iterative algorithm for to identify the locations and extent of damage in beams using only the changes in their first several natural frequencies. The algorithm, which combines a first-order, multiple-parameter perturbation method and the generalized inverse method, and which is tested through experimentally and numerically.

Zhang Xiaoqing et al. [2] have developed an analytical approach for the detection of a beam with multiple cracks. The method is based on the bending vibration theory of Euler-Bernoulli beam and the cracks are treated as mass less rotational springs, by which the cracked beam is separated into a number of segments of perfect beams. It gives the relationship between the position and depth of the crack with the help of measured natural frequencies and validated with the existing and measured experimental data.

D.K.Agarwalla et al. [3] gives the effect of an open crack on the modal parameters of the cantilever beam subjected to free vibration. The results obtained from the numerical method i.e. finite element method (FEM) which is compared with experimental data and identify the changes in cantilever beam. They found changes in Mode shapes and natural frequencies of the vibrating structures.

Sadettin Orhan [6] has performed a free and forced vibration analysis of a cracked beam. It give dynamic response of the forced vibration better describes changes in crack depth and location than the free vibration in which the difference between natural frequencies corresponding to a change in crack depth and location.

IV. EXPERIMENTAL WORK

A. Specimen Geometry

Aluminum beams have been considered for making specimens. The specimens were selected of size having 20mm* 10mm cross sectional area. The specimens were cut to size from ready-made rectangular bars. Total 7 specimens were cut to the size of length 500mm and cross section area as 20mm*10mm. for experimentation work first we consider uncracked beam as a base line model and remaining six beam with crack having 4 mm depth. Total six beams cracked at specified location and having specified crack depths and which are used for experimental modal analysis.

Properties:
Width of the beam = 20mm
Height of the beam = 10mm
Length of the beam = 500mm
Poisson's Ratio = 0.334
Elastic modulus of the beam = 72.4GPa
Density = 2780kg/m3
End condition of the beam = One end fixed and other end free.

TABLE I
DIFF. SPECIMEN FOR IMPACT LOADING

Case No	Crack Location(mm)	Crack Position(x°)	Crack Depth(mm)
First	250	0°	4
Second	250	15°	4
Third	250	30°	4
Fourth	250	45°	4
Fifth	250	60°	4
Sixth	250	90°	4

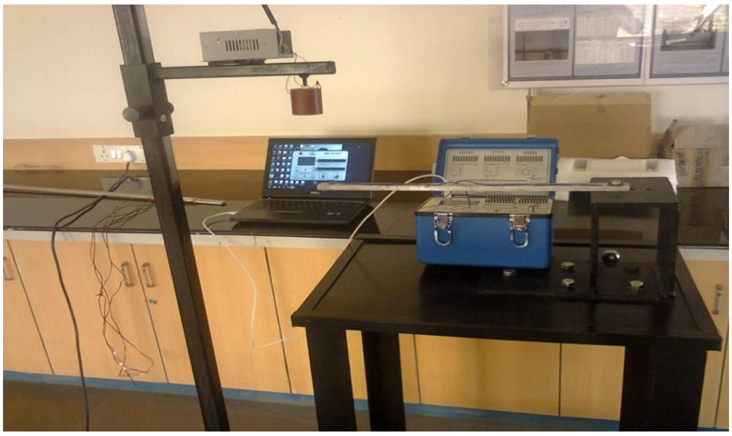


Fig.1 Experimental set up for Impact loading

TABLE II
IMPACT STRESSES IN UNCRACKED BEAM

Crack Angle	**Weight (N)**	**Height (mm)**	**Stress (N/mm2)**
Uncracked	1.089 N	100	49.49
	1.089 N	150	58.50
	1.089 N	200	74.46

TABLE IIII
IMPACT STRESSES IN 0°CRACKED BEAM

Crack Angle	**Weight (N)**	**Height (mm)**	**Stress (N/mm2)**
0°	1.089 N	100	49.49
	1.089 N	150	55.188
	1.089 N	200	75.48

TABLE IVII
IMPACT STRESSES IN 15°CRACKED BEAM

Crack Angle	**Weight (N)**	**Height (mm)**	**Stress (N/mm2)**
15°	1.089 N	100	53.58
	1.089 N	150	63.072
	1.089 N	200	76.06

TABLE VV
IMPACT STRESSES IN 30°CRACKED BEAM

Crack Angle	**Weight(N)**	**Height(mm)**	**Stress (N/mm2)**
30°	1.089 N	100	50.51
	1.089 N	150	61.46
	1.089 N	200	76.35

TABLE V
IMPACT STRESSES IN 45°CRACKED BEAM

Crack Angle	**Weight(N)**	**Height(mm)**	**Stress (N/mm2)**
45°	1.089 N	100	55.18
	1.089 N	150	69.05
	1.089 N	200	86.87

TABLE VI
IMPACT STRESSES IN 60°CRACKED BEAM

Crack Angle	**Weight (N)**	**Height (mm)**	**Stress (N/mm2)**
60°	1.089 N	100	51.24
	1.089 N	150	77.23
	1.089 N	200	105.55

TABLE VII
IMPACT STRESSES IN 90°CRACKED BEAM

Crack Angle	**Weight (N)**	**Height (mm)**	**Stress (N/mm2)**
90°	1.089 N	100	54.45
	1.089 N	150	77.23
	1.089 N	200	101.90

V. FINITE ELEMENT ANALYSIS

Structural analysis consists of linear and non-linear models. Linear models use simple parameters and assume that the material is not plastically deformed. Non-linear models consist of stressing the material past its elastic capabilities. The stresses in the material then vary with the amount of deformation. . Vibration analysis is used to test a material against random vibrations, shock, and impact. Each of these incidences may act on the natural vibration frequency of the material which, in turn, may cause resonance and subsequent failure. Fatigue analysis helps designers to predict the life of a material or structure by showing the effects of cyclic loading on the specimen. . Such analysis can show the areas where crack propagation is most likely to occur. Failure due to fatigue may also show the damage tolerance of the material. This chapter represents finite element modeling of the cracked and uncracked beam to represent the laboratory beams. Numerical studies have been increased in recent years, especially, by use of finite element package programs. Physical systems can be modeled and simulated close to its real condition, by using these programs.

A. Solid modeling of Uncrcked Beam

Solid model of beam is created by CATIA software which makes modeling so easy and user friendly. Fig.1 shows a solid model of uncracked beam.

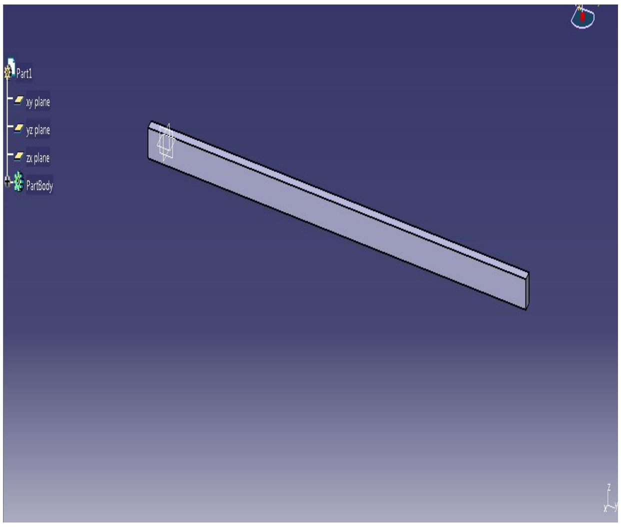


Fig.2 Solid model of Beam

B. Stress analysis

The numerical analysis is carried out for the cracked cantilever beam to find the stresses and strain values of beam. the analysis of beam are done in ANSYS. Solid model of beam is created by CATIA software then this model is saving in IGES format and export into the FEA software ANSYS 14.5. The uncracked and cracked beam is analyzed in FEA software. Following steps are used to find analysis results,

1) Beam Material properties
2) Beam geometry
3) Meshing of beam
4) Loads and boundary condition.
5) Results

C. Meshing of beam

The meshing of uncracked and cracked beam was done in ANSYS 14.5(Workbench) software. Fig.2 shows the meshing of uncracked beam.

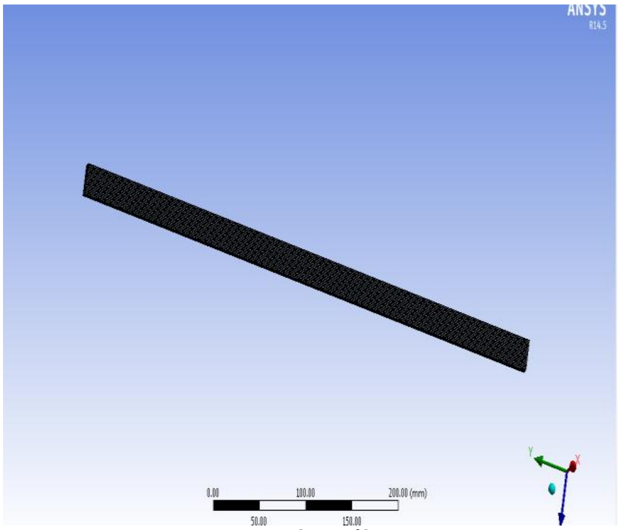


Fig. 3 meshing of beam

D. Boundary Conditions

Transient analysis was performed to determine equivalent (von-mises) stresses and total deformation of uncracked and cracked beam by ANSYS software. For this above boundary conditions are used: Fixed support and Force. Uncracked and cracked beam.

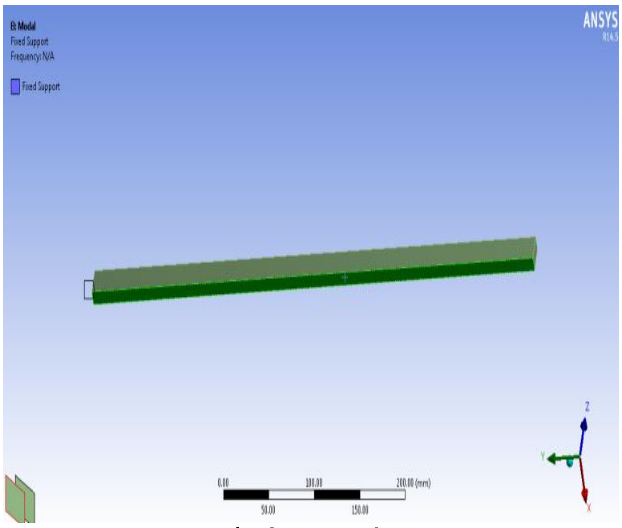


Fig. 4 fixed support on beam

E. Analysis results of Equivalent (von-mises) stress

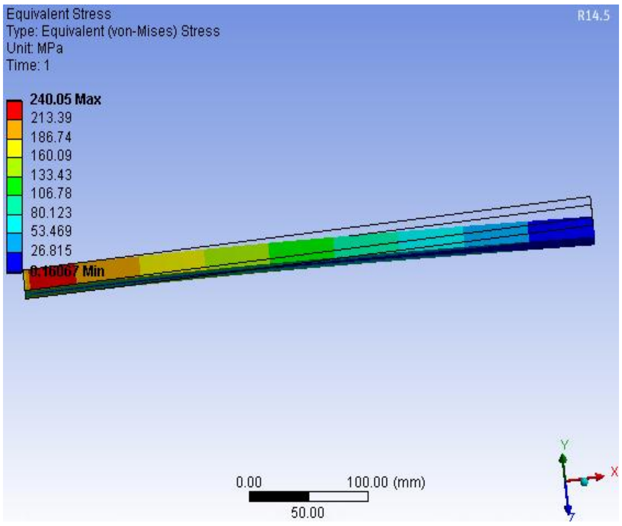


Fig.5 Stresses in uncracked beam

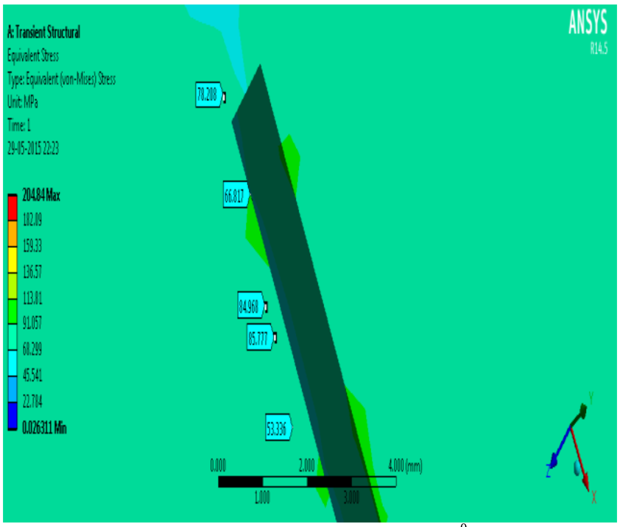


Fig.6 Stresses in cracked beam at 0^0

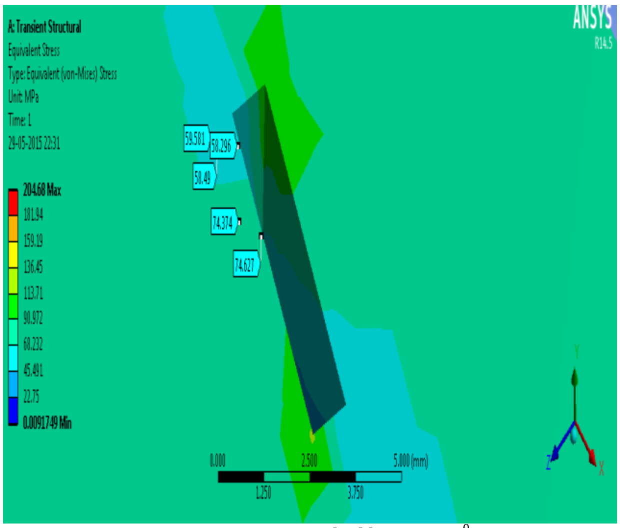


Fig.7 Stresses in cracked beam at 15^0

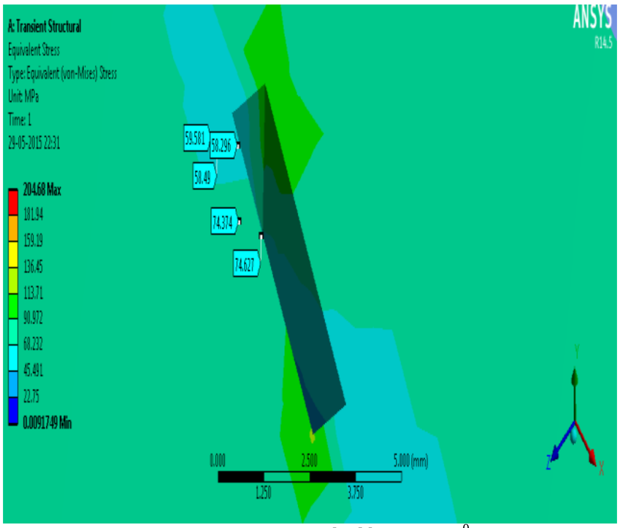


Fig.8 Stresses in cracked beam at 30^0

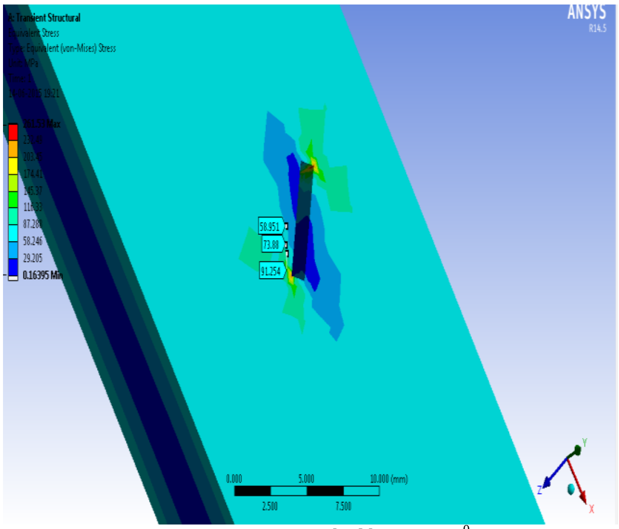


Fig.9 Stresses in cracked beam at 45^0

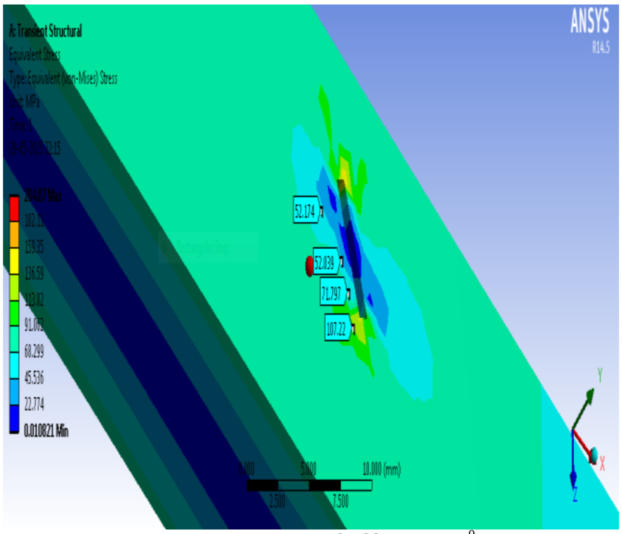


Fig.10 Stresses in cracked beam at 60^0

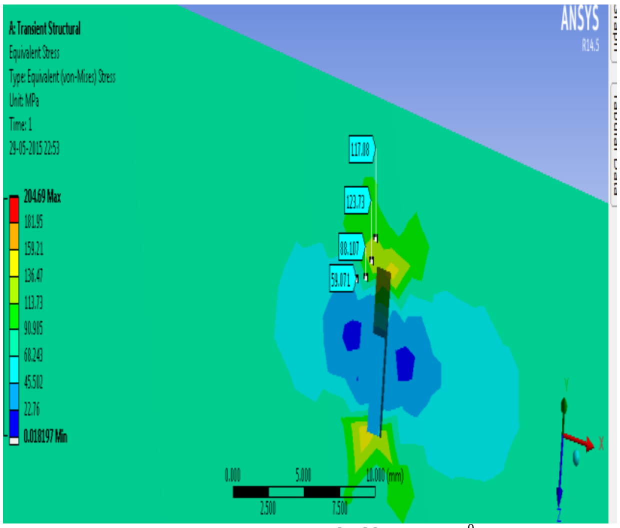


Fig.11 Stresses in cracked beam at 90^0

VI. RESULTS AND DISCUSSION

TABLE VIIVI

COMPARATIVE RESULT ANALYSIS

Crack	Experimental stress (N/mm^2)	Numerical stress (N/mm^2)	Percentage error
Uncracked	49.49	55.23	10.39
	58.502	65.20	10.27
	74.46	84.97	12.44
0^0	49.49	56.88	12.99
	55.188	63.5	13.08
	75.48	78.82	13.08
15^0	53.58	59.37	9.75
	63.07	58.502	7.24
	76.06	74.46	2.10
30^0	50.51	55.17	8.44
	61.46	70.48	12.79
	76.36	88.09	13.31

Crack	Experimental stress (N/mm^2)	Numerical stress (N/mm^2)	Percentage error
45^0	55.18	58.18	1.63
	69.05	73.55	0.63
	86.87	91.93	0.76
60^0	51.24	52.52	2.38
	77.23	70.01	9.34
	105.55	106.01	0.5
90^0	54.45	58.92	7.58
	77.23	87.92	12.15
	101.90	123.38	17.40

Above table shows the relationship between stress and crack position. Crack at 30° and 60° stress value goes on decreasing compared to other 15°, 45°, 90° but it goes on increasing compared to uncracked beam. Based on impact theory analysis of cracked and uncracked beam under impact load in failure regime and the obtained dynamic test results have showed that their correlation of impact load and stress was in similar order of magnitude.

When height of Impact loading is 150 mm & 200 mm, the value of stresses goes on increasing. Crack at 30° stress value goes on decreasing compared to 15°.45°,60° and 90° but it goes on increasing compared to uncracked beam when crack at 60° and 90° the stress value suddenly goes on increasing as compared to other crack position.

VII. Conclusion

When height goes on increasing for impact the stress value goes on increasing for all cracked beam as compared to uncracked beam. If crack at an 60° and 90° then the stress value suddenly goes on increasing. Stress value goes on increasing from crack opening to crack closing. The variation of stress values are 10-30% as compared to uncracked beam.

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References

[1] G. Y. Xu, W. D. Zhu, and B. H. Emory, Experimental and Numerical Investigation of Structural Damage Detection Using Changes in Natural Frequencies, Journal of Vibration and Acoustic. Volume 129 (December 2007): pp. 686-700.

[2] Zhang Xiaoqing, Han Qiang and Li Feng, Analytical Approach for Detection of Multiple Cracks in a Beam, Journal of Engineering Mechanics. (ASCE March 2010):pp.345-357.

[3] D.K. Agarwalla, D.R. Parhi, E_ect of Crack on Modal Parameters of a Cantilever Beam Subjected to Vibration, Elsevier (NUiCONE 2012) Procedia Engineering 51(2013) PP.665 669.

[4] M Kisa, J Brandon, M Topcu, Free vibration analysis of cracked beams by a combination of finite elements and component mode synthesis methods, Pergamon Journal of Computers and Structures 67 (1998) pp. 215-223.

[5] A.S. Bouboulas, N.K. Anifantis, A frequency based algorithm for identication of single and double cracked beams via a statistical approach used in experiment,Elsevier Journal of Engineering Structures 30 (2008); pp. 894901.

[6] Sadettin Orhan, Analysis of free and forced vibration of a cracked cantilever beam,International Journal of NDT and E 40 (2007): pp. 443450.

[7] A. S. J. Swamidas, X.Yang and R. Seshadri Identication of Cracking in Beam Struc- tures Using Timoshenko and Euler Formulations, Journal of Engineering Mechanics(ASCE / November 2004): pp.1297-1308.

[8] Isham Panigrahi and Dayal Ramakrushna Parhi Dynamic analysis of Cantilever beam with transverse crack, 14th National Conference on Machines and Mechanisms (NaCoMM09).

[9] Subhasis Chatterjee, Sushovan Chatterjee Breathing Crack In Beam And Cantilever Using Contact Model Dynamic Analysis A Study, International Journal of Wisdom Based Computing, Vol. 1 (3), December 2011.

[10] Advance stress analysis, L.S.Srinath; Tata McGraw-hill.

