MODAL ANALYSIS OF A CRACKED CANTILEVER BEAM USING ANSYS WORKBENCH

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ABSTRACT: Structure health monitoring using finite element software such as ANSYS workbench is an emerging trend in recent years to detect damage in structures used in mechanical, civil constructions, aerospace, locomotive, automobile, turbine blades etc. In this paper, modal analysis on a Cantilever beam is considered to identify the effect and severity of damage detection with and without crack on beam near to the fixed end. The load applied at free end of the cantilever beam is considered as 100N. The forced vibration on Timoshenko beam model considered for study. Natural frequencies of the beam are compared for identification of optimal results.

KEYWORDS: Structure health monitoring, ANSYS workbench, Cantilever beam, Crack, Modal analysis

1.0 INTRODUCTION:

Cantilever beams are the basic fundamental structures of mechanical components used for manufacturing several engineering applications. These beams may have internal voids, uneven distributed material surface formed as a structural defect leads to failure. Crack is serious form of a structural which must be encountered to reduce its propagation. Crack is an advanced formed fracture mode of Failure when a component or machine part subjected to extreme load. It actually starts from internal irregularities of materials such as voids, cavities, cracks which are difficult to identify. Structural health monitoring is a technique to identify crack propagation and arrest it to a confined region which leads to reduction of stress concentration around the catastrophic failure of damage areas of structures. These stress concentration, when left unattended, will lead to growth of the crack and cause structural failure. There are several methods to detect crack propagation.

Vibration of a component is time dependent displacements of a particle or a system of particles with respect to an equilibrium position. If these displacements are repetitive which are executed at equal interval of time with respect to equilibrium position the resulting motion is said to be periodic Gawali A.L. and Sanjay C. K [1].

1.1 CLASSIFICATION OF CRACK :

A crack in a gap created on a structural component which is formed due to failure of component and it is a local flexibility that would affect vibration response of the structure. The structural health monitoring used for vibration analysis detects the existence of a crack together its location and depth in the structural member Gawali A. L. and Sanjay C. K [1]. The major classification of a crack is based on geometry, location, position, direction which is given below:

- Transverse crack
- Longitudinal crack
- Open cracks
- Breathing crack
- Slant crack
- Surface crack
- Subsurface crack

1.2 OBJECTIVE:

The main objective of this analysis is represented in following points below:

- To sketch the 3D cantilever beam with accurate dimensions using SOLIDWORKS part drawing module.
- To import the model into ANSYS WORK BENCH 14.0 and the component mesh.
- Model analysis is performed to find natural frequency for cracked and uncracked beam model.
- Better comparisons are to be made for natural frequency when crack depth and position are changed

1.3 PROBLEM STATEMENT:

A Timoshenko model cantilever beam made of steel is considered from Leszek Majkut [6] with following dimensions such as $E = 2.1\ X\ 10^{ll}$ Pa, $G = 8.1X10^{IO}$ Pa, $\rho = 7860$ kg/m^3, length l = 1m and cross-section $b \times h = 0.05 \times 0.08$m². The value of crack depth ranges from 0.005, 0.01, 0.015m. The normalized crack position from fixed end β increased to length i.e 0.079 m. The frequency, mode shape are calculated for beam with and without crack using ANSYS workbench software.

2.0 LITERATURE REVIEW:

As there is a wide scope on damage detection techniques, many researchers focused on structure health monitoring by considering a simple model of a cantilever beam with and without crack under dynamic vibration analysis using finite element analysis.

Nirbhay Singh et al. [2] Calibrated model analysis of a steel simply supported beam is carried out with the finite element analysis. The structure is taken in this analysis is a simply supported beam its one end carry a hinge support and other end is carry a roller support. In the validation process previous result with one crack is taken and the natural frequencies with vibration analysis are carried out with finite element analysis which is used to compare with the results of multiple cracks in the beam of rectangular cross section.

Priyanka .P et al. [3] determined natural frequency and mode shapes of the beam for triangular cracked of 2mm depth and uncracked beam having one end fixed and other is simply supported is investigated numerically by using ANSYS software. Different crack locations are considered and results are compared with the beam having no crack. Structural steel and aluminum are considered as beam materials.

K. H. Barad et al. [4] detected the crack presence on the surface of beam-type structural element using natural frequency. First two natural frequencies of the cracked beam have been obtained experimentally and used for detection of crack location and size. Detected crack locations and size are compared with the actual results. The effect of crack location and depth on natural frequency is presented and compared.

J. R. Chaudhari et al. [5] considered rectangular aluminium beam modelled in cantilever configuration with surface bonded piezoelectric patches where the disturbance is produced using exciter. The piezoelectric sensors are used to detect the vibration. The feedback controller sends correction information to the actuator that minimizes the vibration. The study uses ANSYS-11 software to derive the finite element model of the smart plate. Based on this model, the optimal sensor locations are found and actual smart beam is produced. In this experiment a suitable control methodology is find by which the controller gain optimizes to get more effective vibration control with minimum control input.

D. Mateescu et al. [8] performed dynamic analysis of structures with piezoelectric sensors and actuators used to establish a method for crack detection in aerospace structures. Piezoelectric strips used as sensors and actuators are bonded on both sides of a thin structure which executes flexural oscillations. The differential voltage outputs of the piezoelectric sensors are used to detect the presence of cracks in the structure. The structural analysis uses a finite element formulation for the piezoelectric strips coupled with the structure and a nonlinear model for the cracks. The results of the dynamic analysis in the frequency domain of healthy and cracked plates undergoing forced flexural vibrations generated by a pair of piezoelectric actuators submitted to an oscillatory voltage excitation. The peaks in the differential voltage output obtained in the case of a cracked plate at several frequencies during the frequency sweep were found to be indicative measures for the presence of a crack in the structure.

3.0 FINITE ELEMENT METHOD:

ANSYS workbench is a robust software tool used to find forced vibrations for cracked and uncracked beam to obtain optimal results with less effort, computational time which can be considered as added advantages compared to theoretical numerical approaches. For this scenario the cantilever beam model is imported for machine and analysis procedure. The machine is done using quadratic mesh. With the geometry of 1000mm x 80 x 20 considered as length, height, thickness. The number of elements generated 25272, the number of nodes generated as 130217 based on boundary conditions given to the cantilever beam which is constrained at one end and free at another end where force is applied at free end. A transverse crack is introduced on 3D beam component with 3different crack positions and depth. This modal analysis method is used to calculate 10 natural frequencies for cracked and uncracked beam.

3.1 MODAL ANALYSIS:

Modal analysis is a study of dynamic properties of system in the frequency domain. A typical example would be testing structures under vibration excitation. The modal analysis is a field of measuring or calculating and analyzing the dynamic response of structures or other system during excitation

The following step by step procedure for modal analysis is listed below:

- In workbench Click on modal and drag into standalone system.
- Then Click on geometry and browse the solid work part.
- For editing the modal, click on right key by selecting the modal edit option is displayed.
- Modal (A4) part will automatically created.
- Select Modal (A5) click on support, select fixed support and then one end of the beam has to fix then click on solve.
- Click on analysis setting select maximum nodes=10 then solve it.

- In Geometry part select assignment for material structural steel then beam appears in green color.
- Click on mesh select sizing, use advance size function on proximity and curvature, relevance that is equal to medium, minimum size of 0.001, edge length can be considered 0.001.
- Click on solution information, in tabular data select all frequency value then select create mode shape result, click on solve.

4.0 RESULT:

Design of beam with and without crack is modeled in SOLIDWORKS software and import in ANSYS software. Modal analysis of single rectangular cantilever plate has been carried out in various conditions and natural frequencies are obtained. The results of various crack depths are validating with ANSYS 14.0 software in tabular form.

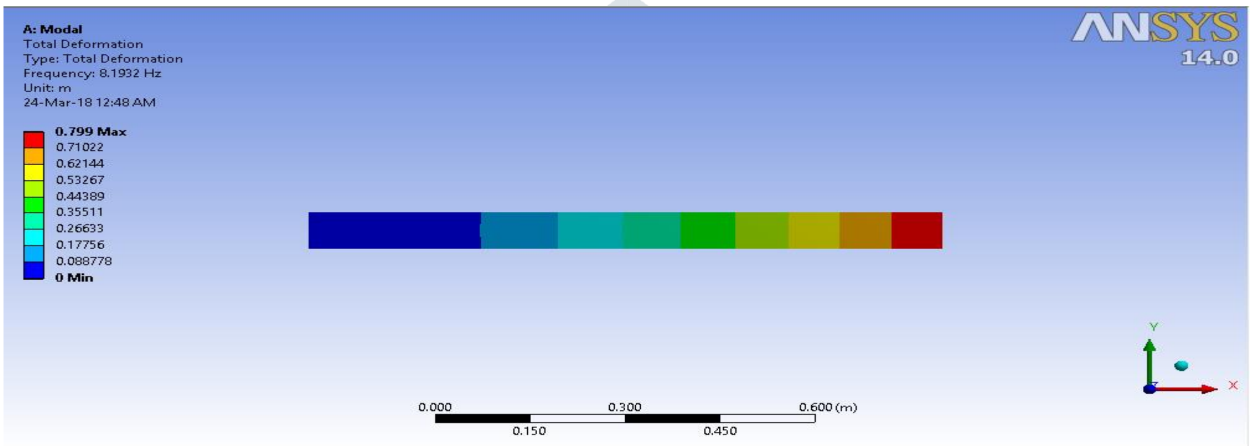

Fig 1: Mode shape 1 without crack on a cantilever beam

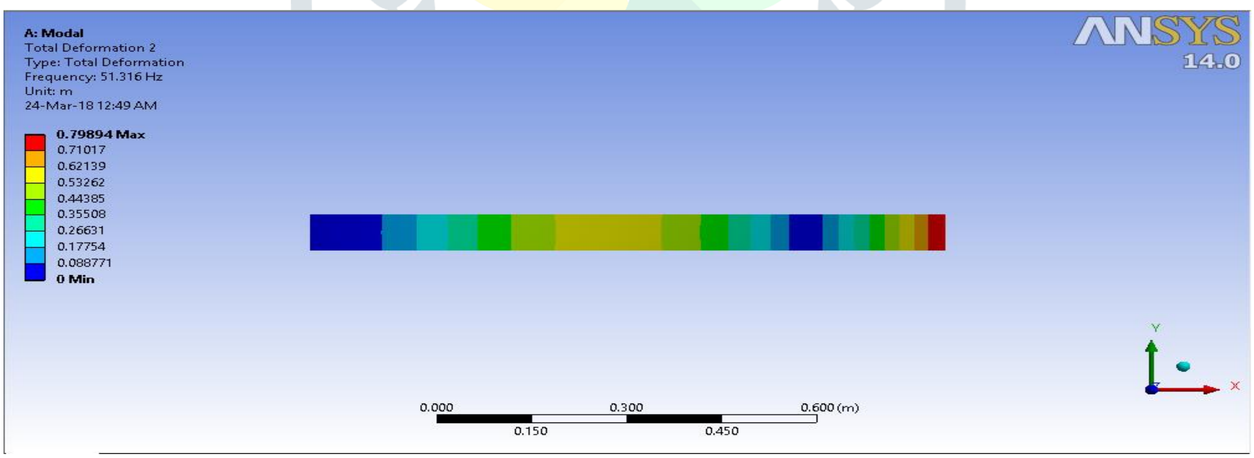

Fig 2: Mode shape 2 without crack on a cantilever beam

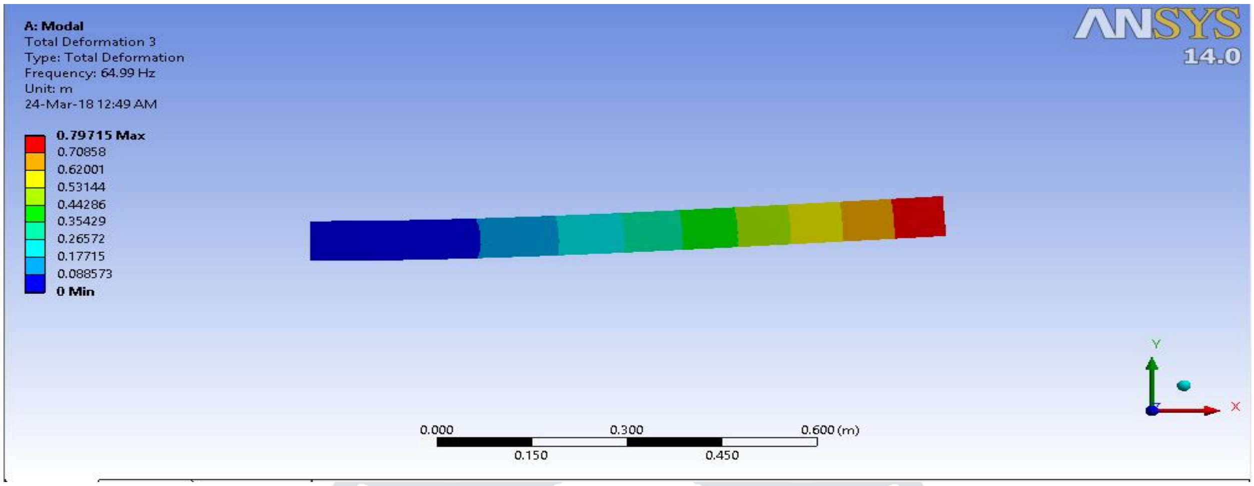

Fig 3: Mode shape 3 without crack on a cantilever beam

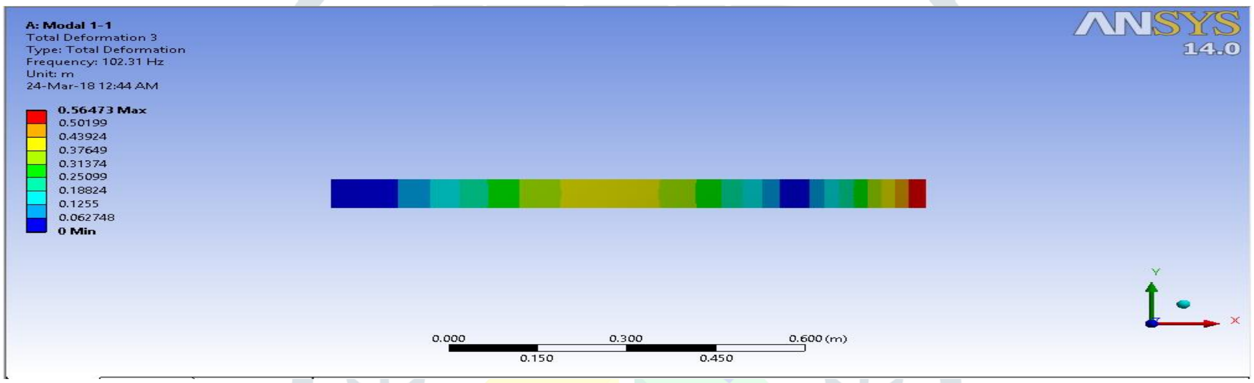

Fig 4: Mode shape 1 on a cantilever beam with 5mm crack depth at position 0.790m from fixed end.

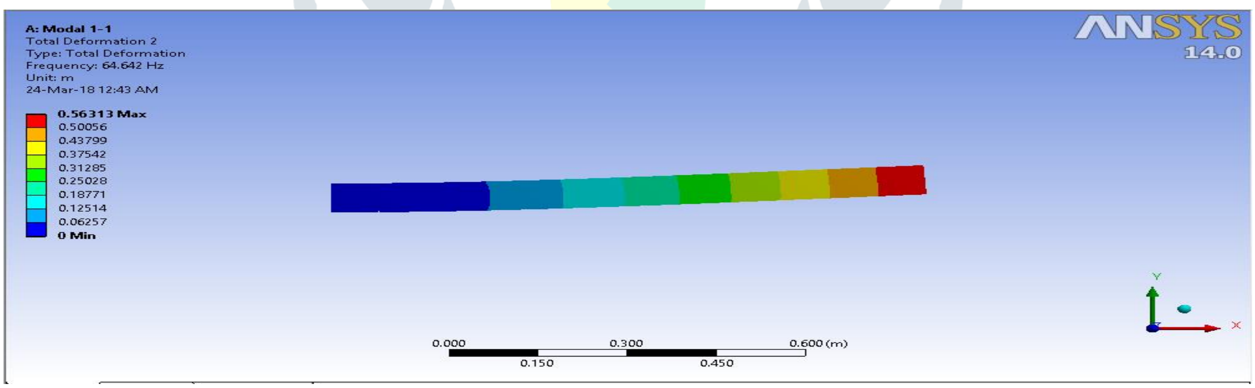

Fig 5: Mode shape 2 on a cantilever beam with 5mm crack depth at position 0.790m from fixed end.

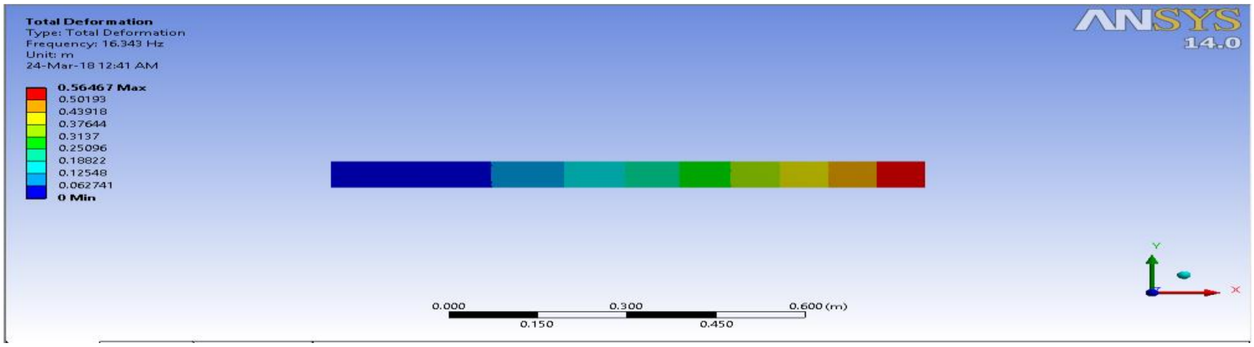

Fig 6: Mode shape 1 on a cantilever beam with 5mm crack depth at position 0.790m from fixed end.

The change in natural frequency for different crack position and depth is represented in tabular form below for comparison.

Table 1: The position of crack on cantilever beam is 0.790m

Crack position	Crack depth (mm)	0	5	10	15
790mm From Fixed end	frequency (Hz)	8.1932	16.343	16.285	16.2
		51.316	64.642	63.662	62.134
		64.99	102.31	102.13	101.86
		143.64	285.85	285.63	285.31
		189.96	353.9	353.28	352.15
		281.41	394.9	392.24	388.27
		395.79	558.27	558.13	557.89
		465.1	918.66	918.48	918.11
		571.73	1062.2	1059.8	1056.0
		694.57	1064.4	1062.7	1059.6

Table 2: The position of crack on cantilever beam is 0.520m

Crack postion	Crack depth (mm)	5	10	15
520mm From Fixed end	Frequency (Hz)	16.367	16.36	16.349
		64.967	64.84	64.632
		102.29	102.06	101.73
		285.94	285.9	285.84
		354.04	353.75	353.22
		394.52	390.75	384.82
		557.82	556.69	555.04
		918.6	918.32	917.85
		1062.9	1062.4	1061.6
		1064.7	1063.6	1061.8

Table 3: The position of crack on cantilever beam is 0.820m

Crack postion	Crack depth (mm)	5	10	15
820mm From Fixed end	Frequency (Hz)	16.371	16.372	16.374
		65.018	65.022	65.025
		102.39	102.38	102.36
		285.86	285.66	285.37
		354.16	354.16	354.14
		395.85	395.64	395.28
		557.93	557.05	555.75
		917.78	915.67	912.58
		1062.	1059.	1054.
		1064.8	1064.1	1062.8

5.0 CONCLUSION:

The investigation analysis of the present work is to conduct modal analysis of cantilever beam made of structural steel consist of with and without crack. As the crack location increases from fixed end the natural frequency increases up to the center of beam and after it decreases. The natural frequency of beam decreases with increasing when crack depth from 5mm to 15mm. The lowest and highest frequency of beam with crack position 0.079m and crack depth of 15mm are shown as 16.2 Hz, 1059.6 Hz and without crack is 8.1932 Hz, 694.57 Hz which are having huge difference in natural frequency.

FUTURE SCOPE:

The investigation on forced vibration of Timoshenko model cantilever beam can be derived mathematically to obtain green function which can be compared to experimental results for better validity. Multiple cracks which change in force may be added to above calibrated values

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