HARMONIC ANALYSIS OF A CRACKED CANTILEVER BEAM USING ANSYS WORKBENCH

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ABSTRACT:

In this present paper, Structure health monitoring is performed by harmonic analysis which is a widely acceptable finite element method using ANSYS workbench to detect damage in a healthy and a cracked structure. Harmonic 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 beam is considered as 100N. The forced vibration on Timoshenko beam model is considered for this study. Amplitude, deformation of the beam is compared for identification of optimal results with the change of crack depth and position.

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

1.0 INTRODUCTION:

The structure health monitoring is most widely accepted and accurate method used to identify the damage in a component which has a superior quality of changes in the response parameters of a structure compared to traditional non destruction methods for the assessment of structural integrity, performance and safety. Irregular variations in the measured vibration response characteristics show whether the crack is closed, open or breathing during vibration. Harmonic analysis is an expression of a periodic function as a sum of sin and cosin specifically by Fourier series. Industrial sector follow a basic damage detection technique before manufacturing procedure to identify the structure health.

Kulkarni A. S. et al. [3] obtained a reduced order model for a cracked turbine rotor blade modeled cantilever beam. Accurate dynamical model of this system using Finite Element would typically possess large number of degrees of freedom due to refinement of the mesh near crack and contact, which makes the system computationally intensive for long term analysis. Breathing crack is modeled as piecewise linear system with bilinear natural frequency while geometric nonlinearities are incorporated in a cubic Duffing's term. The reduced order model was able to match the original FEM data to desired accuracy with only first two POD modes of the system and capture the change in frequency introduced by the damage. Robustness of the macromodel is checked under different loading conditions viz. changed forcing frequency, pressure loading and damping. Natural frequency of the cracked beam reduces due to presence of local flexibility in the form of breathing crack and is observed from FFT of the forced vibration response.

S K SAHU and B ROHINI et al. [5] Mild steel specimens of square area of cross section are considered for the experiment and experimental results are contrasted with numerical analysis using Finite Element Method (FEM) in MATLAB environment. The variation of natural frequency with respect to the uniform cantilever beam with single crack is studied and compared with Shiffrin et al [6]. The crack considered is transverse crack which open in nature. Due to the presence of crack, the total flexibility matrix is established by adding local additional flexibility matrix to the flexibility matrix of the corresponding intact beam element. The local additional flexibility matrix is obtained from Linear Elastic Fracture Mechanics theory.

Malay Quila et al. [7] proposed that the presence of cracks causes changes in the physical properties of a structure with an inherent reduction in modal natural frequencies which leads to the change in the dynamic response of the beam. Theoretical analysis of transverse vibration on a fixed cantilever beam of Euler-Bernoulli model includes mode shape, natural frequency using ANSYS software and co relate the theoretical values with the numerical values to find out percentage error between them. Variations of natural frequencies due to crack at various locations and with varying crack depths have been studied.

N. S. Köksal et al [8] conducted fatigue analysis of a notched cantilever beam using Ansys Workbench. The loading is assumed to be zero based. The effects of notch size and fatigue load are analyzed. The safe design life of the material and critical notch sizes are determined in the analyses for loadings in the elastic region. Fatigue life, stress life estimation of a notched structural steel beam is studied based on Stress-Cycle curves which includes loading type, fatigue damage sensitivity, fatigue factor of safety and equivalent alternating stress. The maximum damage and equivalent alternating stress, and minimum factor of safety occurred at the tip of the notch. Load compared with cycle graph shows notch angles (45° and 90°) and various notch depths are considered to study the variation. Notch sensitivity increased with increasing notch angle. On the other hand, the fatigue life decreased slightly up to a certain notch size (20mm) and considerably after that value.

W. Al-Ashtari [9] worked on the cracked beam with Piezoelectric Patches the cracked beam with closed form solutions describing the deflection of a beam subjected to static load at two cases are introduced. The first case for a beam contains a crack, while the second case for a beam contains a crack and is repaired with a piezoelectric patch.

K.M. Babu et al [10] Mechanical structures during their functional operations may be vulnerable to damage and therefore cannot be guaranteed definite fault free operational and successful exploitation. The modal analysis for the use of PZT actuator in repair of cracked cantilever aluminum beam by using Finite Element Analysis ANSYS software. Cantilever beam vibration response is analyzed and the numerical results of undamaged, damaged beam type with piezoelectric patch at different locations compared to different location and depth of single transversal notch. By using the piezoelectric patch the dropped natural frequency are tried to be restored to the natural frequency of healthy beam.

1.1 IMPORTANCE OF FORCED VIBRATIONS:

When any vibration occurred in a component can be damped to some extent when there is no requirement of it. In free vibration energy is neither added nor removed from the vibrating system. It just keeps vibrating forever at the same amplitude. There are no perfect free vibrations in nature. Forced vibration occurs when object is forced to vibrate at a particular frequency by a periodic input of force.

1.2 OBJECTIVE:

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

- Creating the cantilever beam using SOLIDWORKS software with proper dimensions and import into ANSYS workbench for mesh and modal analysis.
- Drag the harmonic response into solution part for keeping load in free end and deformation of the beam for getting amplitude, phase angle and frequency values.
- Harmonic analysis is performed to find amplitude, phase angle, natural frequency for cracked and uncracked beam model.
- Better comparisons are to be made between amplitude and phase angle when crack depth and position are changed.

II. METHODOLOGY

Mild steel specimens of geometry and mechanical properties are represented in table below is considered for harmonic analysis. The experimental results are contrasted with Finite Element Method in ANSYS WORKBENCH environment. The crack considered is open transverse in nature and changed its positions values as 0.052, 0.790, 0.860 m and crack depth is considered as 5mm, 10mm, 15mm. Amplitude, Phase angle are compared with natural frequency. The model is sketched in SOLIDWORKS software and imported into ANSYS to mesh.

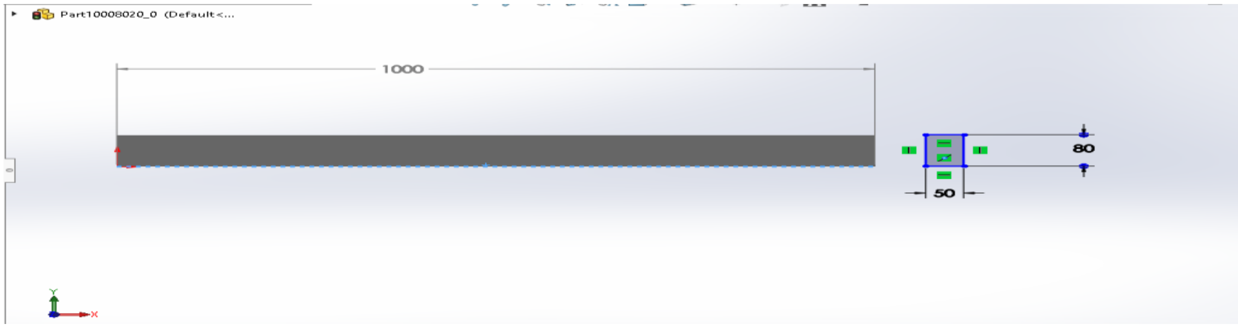

Fig1: Illustrate of cantilever beam in SOLIDWORKS

TABLE 1: Properties of structural steel

Sl.no	Parameters	Specification
1	Length of beam	1000mm
2	Width	80mm
3	Thickness	50mm
4	Young's Modulus	$E = 2.1\ X\ 10^{11}$ Pa
5	Mass Density	$\rho = 7860$ kg/m^3
6	Modulus of rigidity	$G = 8.1X10^{10}$ Pa

3.0 FINITE ELEMENT METHOD FOR HARMONIC ANALYSIS:

A harmonic analysis is Periodic excitation generally occurs in under steady-state operation used to determine the response of the structure under a steady-state sinusoidal loading at a given frequency. The harmonic analysis procedure is very similar to performing a linear static analysis. Finite element software provide analytical results based on Timoshenko beam model.

The following step by step procedure is considered for harmonic analysis represented below:

- Attach Geometry of cantilever beam
- For the cantilever beam Assign Material Properties i.e structural steel
- If applicable, Define Contact Regions
- Define Mesh Controls based on the type of analysis
- Include Loads on free end of a cantilever beam.
- Harmonic Tool is used to calibrate Results for amplitude, natural frequency.
- Set Harmonic Analysis Options and solve the Model.
- Review Results in the form of graphical representation.

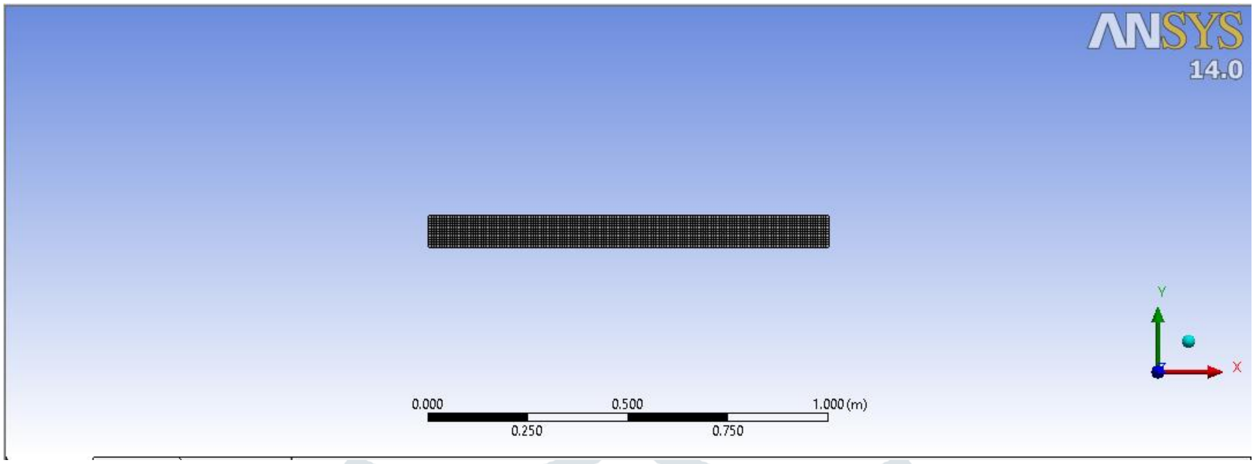

FIG2: Meshing of cantilever beam using ANSYS workbench

4.0 RESULTS

Design of beam with and without crack is modeled in SOLIDWORKS software and import in ANSYS software. Harmonic analysis is performed for a single rectangular cantilever beam to find amplitude, phase angle, natural frequency for cracked and uncracked beam model. The results of various crack depths are validating with ANSYS 14.0 software in tabular form. The three different crack positions considered as 0.079, 0.52, 0.86 m and for every crack positions crack depth considered as 5, 10, 15 mm. The comparison for amplitude with natural frequency values are drawn in result which are shown in graph below.

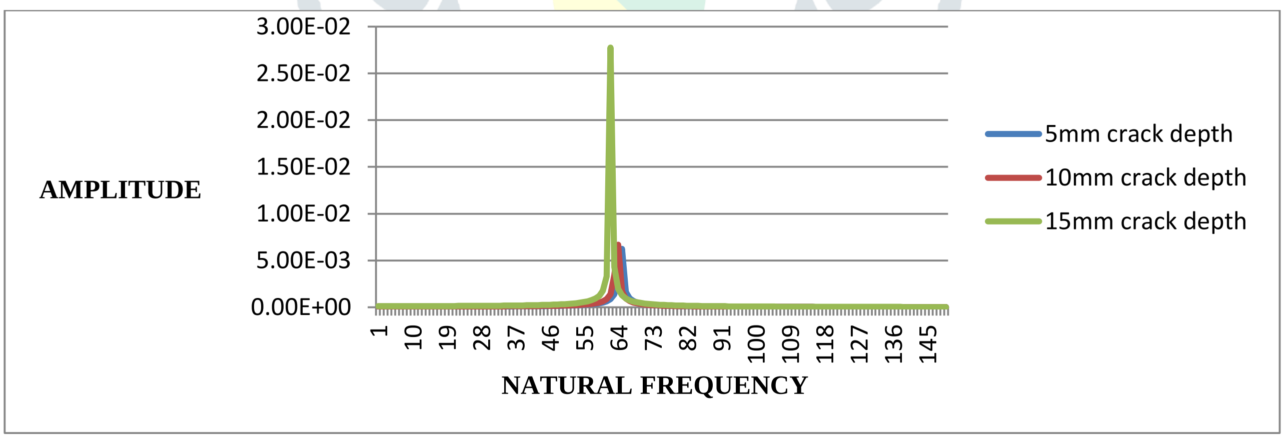

FIG 3: The crack position of cantilever beam is 0.079m

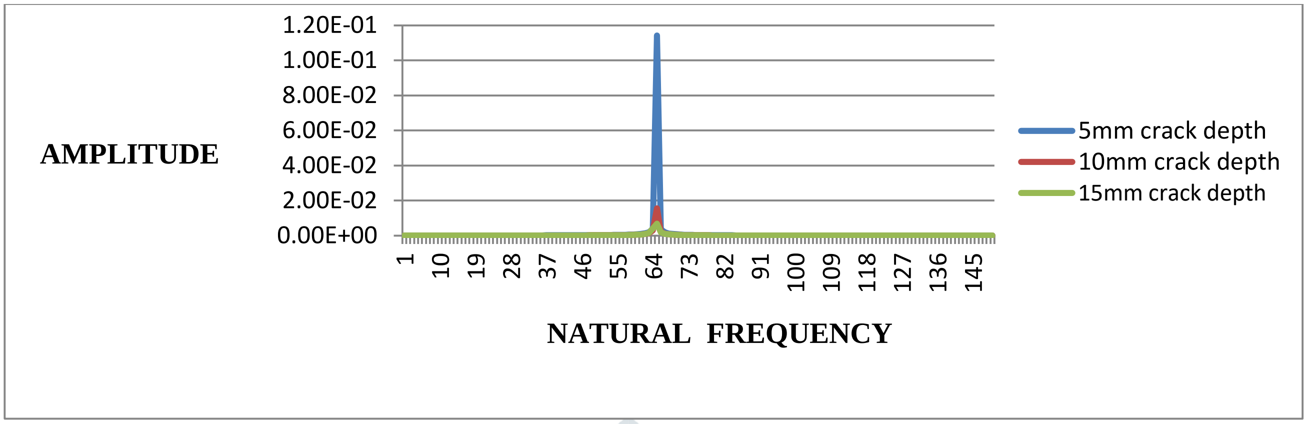

FIG 4: The crack position of cantilever beam is 0.52m

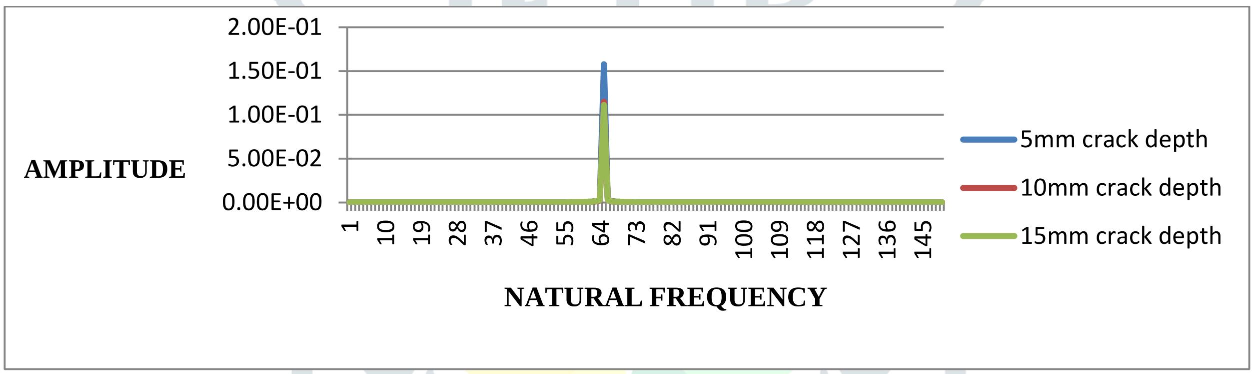

FIG 5: The crack position of cantilever beam is 0.86m

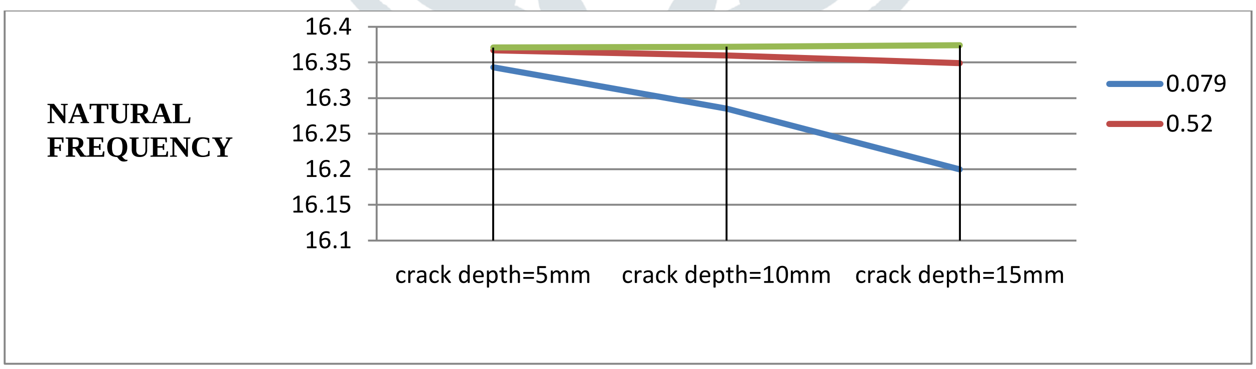

FIG 6: The comparison of natural frequency with crack depth for natural frequency 1

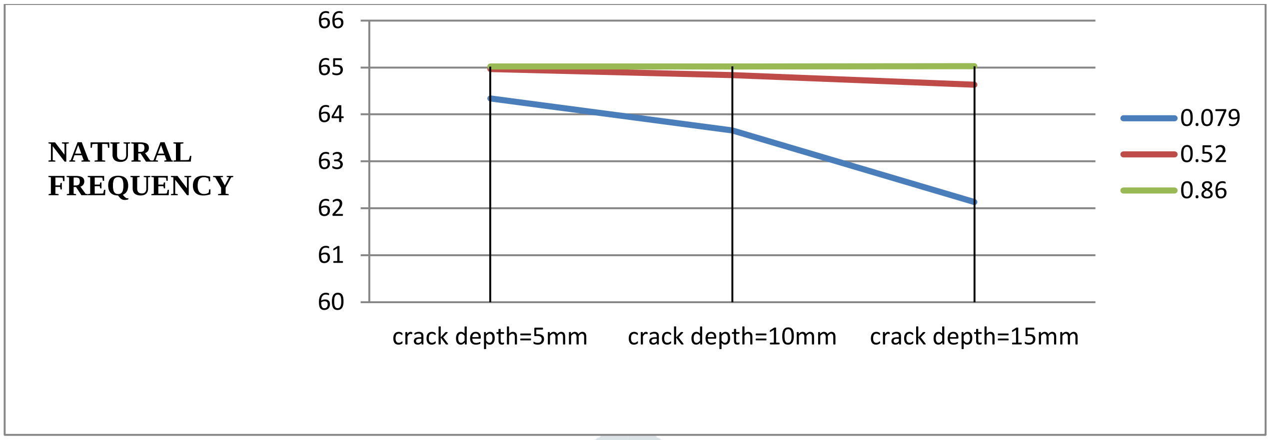

FIG 7: The comparison of natural frequency with crack depth for natural frequency 2

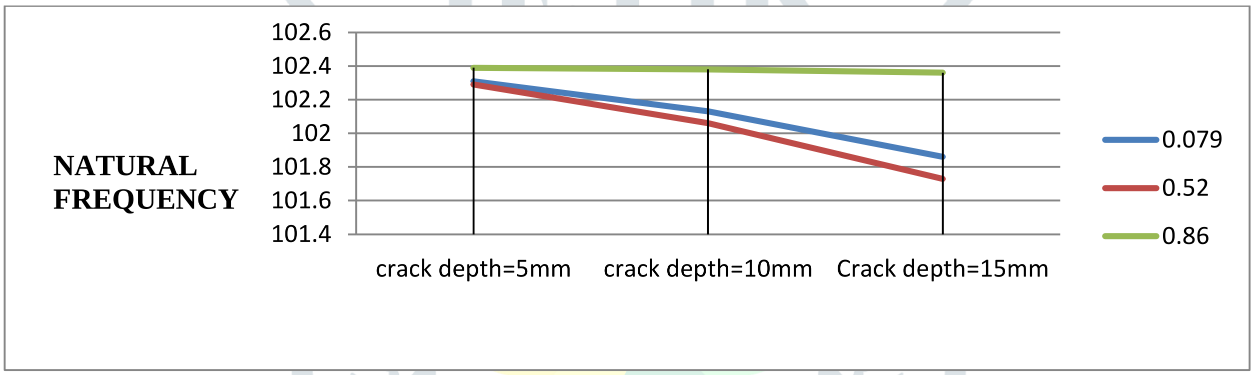

FIG 8: The comparison of natural frequency with crack depth for natural frequency 3

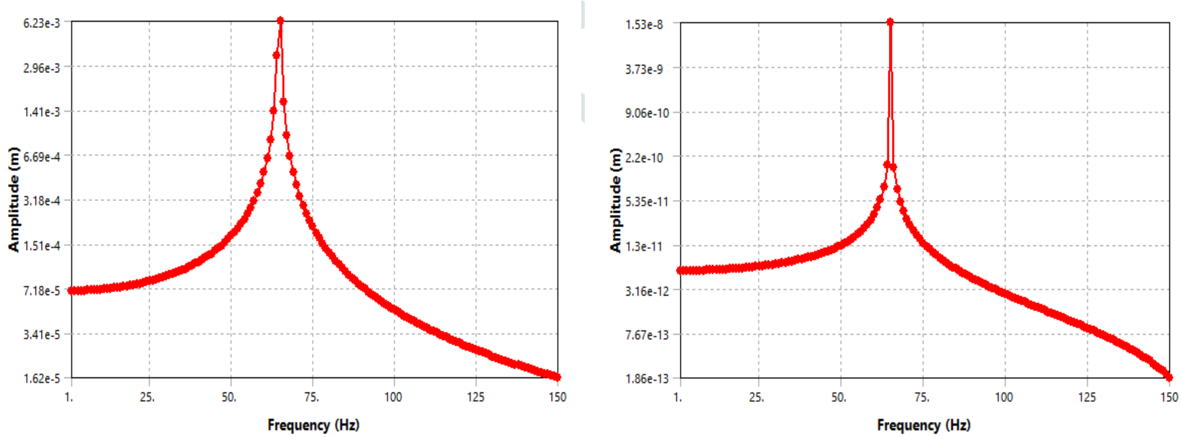

Fig: The comparison of amplitude vs frequency (a) with 5mm crack at 0.079 m crack position (b) without crack.

5.0 CONCLUSION:

The investigation analysis of the present work is to conduct on harmonic 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.

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