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***Research paper***

# Crack investigation by employing finite element method with fuzzy logic tool for a steel cantilever rod

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**Abstract**

The present study is aiming to investigate crack presence in the rigid steel beam in order to take this in account in structural design .FEM has been used in ANSYS software to simulate whole steel body with three different frequencies with a magnitude force that subjected at the free end of the beam. Furthermore MATLAB has been conducted to find the crack by employing Fuzzy Logic. Both approach s has been governed by The Euler- Bernoulli theory for free vibration for motion equations. As well as the other main target of this study to evaluate results that has been got by ANSYS software with MATLAB coding for the same boundary conditions of the case.

***Keywords***: *ANSYS Analysis; MATLAB Analysis; Fuzzy Logic Tool; Crack Detection; FEM Approach.*

## 1. Introduction

Steel beams are commonly used machinery industries and construction, health monitoring and the analysis of damage in the form of crack in Beam structures poses a vital mean. Since long efforts are on their way to find a feasible solution for crack detection in beam structures in this regard many approaches have so far being taken place. [1]. [2] have presented a procedure to evaluate the difference between two corresponding modal characteristics i.e. mode shapes of the beam and its natural frequencies that lead to the identification of crack in a damaged beam. They have simulated the crack by considering an equivalent spring at the crack position. They have established a clear relationship between cracks in the shaft of a turbo-rotor assembly and vibration parameters. The purpose of their study is to show a non-linear effect of the proposed model. The papers [3-4] have introduced a local flexibility at the location of a dynamically vibrating cracked structure and have studied its vibration responses. [5] have developed a methodology for investigating crack position and crack depth of a vibrating beam structure with an open transverse crack of a stationary shaft without its disengagement from its system assuming a local spring at the crack position.
[6] have established a suitable methodology for damaged detection in a beam having a transverse cracks which is under a state of dynamic vibration assuming the crack as a transverse open crack. They have presented a co-relation between crack location, crack depth and their corresponding mode difference [7]. The methodology uses Eigen modes of beam structure under vibration mode. In the current paper the main targets are to confirm and verificate results that conducted by Fuzzy logic approach and the results the is done by finite element method which is done by ANSYS .Forever to make comparison with these approach.

## 2. Theory

The Euler- Bernoulli approach has been assumed for both MATLAB analysis and finite element method that is employed by ANSYS. The crack in this special case is considered to be an open crack and as well as in this case damping has not been considered in this theory. Single transverse crack is considered for the formulation.

### 2.1. Governor equations

The free bending vibration of an Euler-Bernoulli beam of a constant rectangular cross section is given by the following differential equation as given in:

$$EI\,(d^4y/dx^4) - m\omega^2 = 0 \tag{1}$$

Where ‘m’ is the mass of the beam per unit length (kg/m), ‘ωi’ is the natural frequency of the ith mode (rad/s), E is the modulus of elasticity (N/m2) and I is the moment of inertia (m4). By defining $£^4 = m\ \omega^{2y}/EI$ equation is rearranged as a fourth-order differential equation. The general solution to the equation is:

$$y = A\cos £ix + B\sin £i\,x + C\cosh £i\,x + D\sinh £i\,x \tag{2}$$

Where A, B, C, D are constants and ‘£i’ is a frequency parameter. Adopting Hermitian shape functions, the stiffness matrix of the two noded beam element without a crack is obtained using the standard integration based on the variation in flexural rigidity.
The element stiffness matrix of the un cracked beam is given as:
[Ke]= ∫ [B(x)] T EI [B(x)] dx as mention in [8] Hamilton approach has been used to find shape of the geometry
Ke = the stiffness of rod without crack
KC= the stiffness of crack
$K_c^e$ = Ke- KC The stiffness of rod with crack as mention in [9], [10]

Now applying moment of inertia for shape with and without crack as follow as mentioned [11]

$$I=BW^3/12 \quad (3)$$

In order to locate position (γ) of crack following formula of moment of inertia should be used

$$I= B\,(W\text{-}a)^{3}/12 \quad (4)$$

The equation in characterization form that showed above is a function of position of the crack (γ), stiffness matrix (K) , circular frequency (ω) and r crack depth (φ). Figure 2 shows the pictorial view of a -free end rod geometry with dimensions (a1) as crack depth, (L1) as crack location and (BxW) as cross-sectional area which is under the influence of axial force (P1) that subject the beam to a single effect.

### 2.2. Fuzzy logic analysing theory

Fuzzy logic refers to a computing based approach that considers quantity of truths without assigning numerical for true or false i.e. (1,0). This approach uses specific functions for its linguistic variables [8]. Fuzzy logic has wide area of applications ranging from control theory to artificial intelligence. Traditional computing makes use of precise data with certainty but soft computing can use imprecise data and can compute to generate precise output. Fuzzy logic employs words rather than numbers for defining certain mapping rules.

## 3. Boundary condition set up

### 3.1. Matlab (coding) set up

MATLAB has been conducted to analys input data by using fuzzy logic tool and input data as follow:
First frequency = “FF”
Second frequency = “SF”
Third frequency = “TF”
For the output of fuzzy logic controller process, following terms has been used
Crack depth = “CD”
Crack length= “CL”
[9] According to the fuzzy logic subset the rules fuzzy are known with a general code as follows:
“If (FF is FFi and SF is SFj and TF is TFk) then (CD is CDijk and CL is CLijk) Where i= 1to 9, j=1 to 9, k=1 to 9 (13)” Because of “FF”, “SF”, “TF” there are nine functions. Two kinds of rules could be written “If (FF is FFi and SF is SFj and TF is TFk) then CD is CDijk (14 a) If (FF is FFi and SF is SFj and TF is TFk) then CL is CLijk”

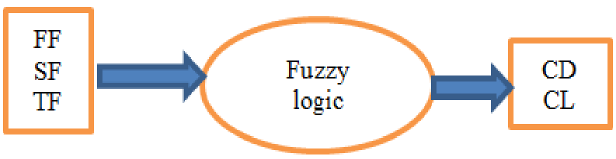


**Fig. 2:** Flow Chart of the Process.

### 3.2. ANSYS software set up

Finite element method has been employed in ANSYS software to simulate the crack location in steel bar by depending on natural frequency. The Euler- Bernoulli governor equation has been considered as governor equation for the finite element formulation.

#### 3.2.1. Geometry and mesh setting

The square cross section area rod with a cross crack is fixed at right end, free at lift end and has regular shape with constant square cross section of 1000 × 50 × 50 mm. drawing has been done by using Design Modular in ANSYS. Software The meshed model uses the elements of Tri type pave in complicated areas and Quad type paves in the rest areas. ANSYS provides complete mesh flexibility with amorphous meshes the solution and it may be polished or roughened the grid depending on the solution once the grid had been read into ANSYS [12].

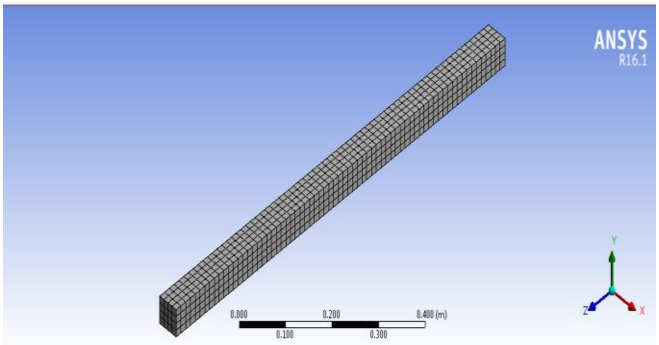


**Fig. 3:** Mish Generation.

#### 3.2.2. Primary boundary conditions

Three different values of frequency will be conducted in this study as follow
First frequency = FF
Second frequency = SF
Third frequency = TF
The assumption is 5mm crack located at distance L1 from clamped end. With a vertical load that subjected at the free end of beam (10 KN). By vivification with the with results that taken by MATLAB, can find the correct location of the crack. The table 1 shown mechanical properties of steel that required for simulation.

**Table 1:** Mechanical Properties of Steel

| Items | Value |
|---|---|
| Young’s Modulus Of Elasticity | 200GPa |
| Density of material | 7800kg/m3 |
| Passion ratio | 0.25 |

## 4. Results

### 4.1. Grid independent study

Based on the outcomes, it is seen that the frequency is proportionate to the number of elements,. Crack has been set has been sat 5 mm for four different the frequencies ,the first attempt is was set 100Hz when number of elements was261794. moreover, there is no change in frequency when the number of elements increasing to 282893 at both 300,400 Hz .therefor 282893 elements are considered for this study..

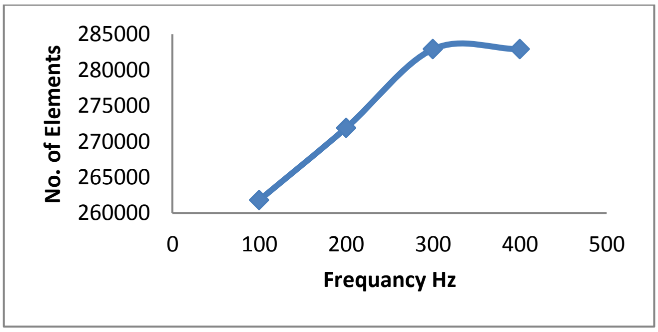


**Fig. 4:** The Grid Independent Study.

### 4.2. Crack investigation

Three different of frequencies 100,200,300 Hz has been considered to simulate in ANSYS structural. Assumption is crack depth is 5 mm and locate at distance L1 from fixed end. Figures follow show the simulation result for those different frequencies .structural analysis has been done in ANSYS for total deformation that is done by frequency.

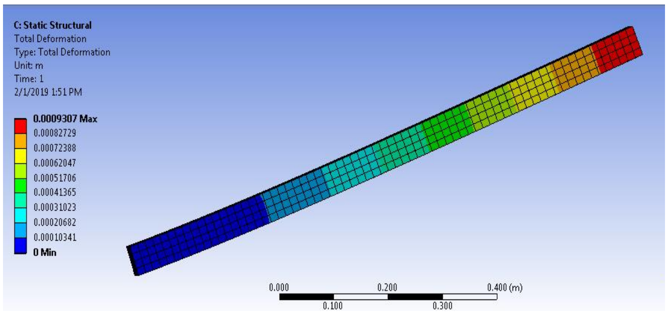


**Fig. 5:** Shows Total Deformation in Steel Bar at 100 Hz.

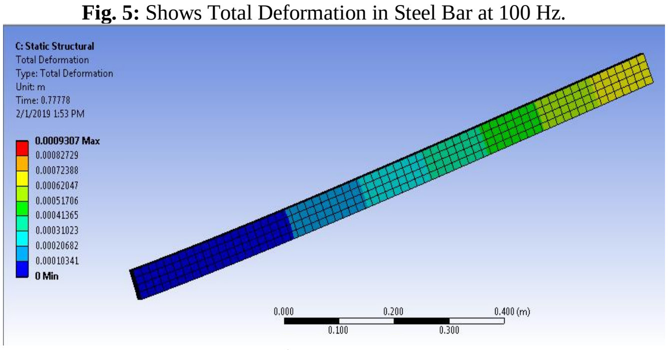


**Fig. 6:** Shows Total Deformation in Steel Bar at 200 Hz.

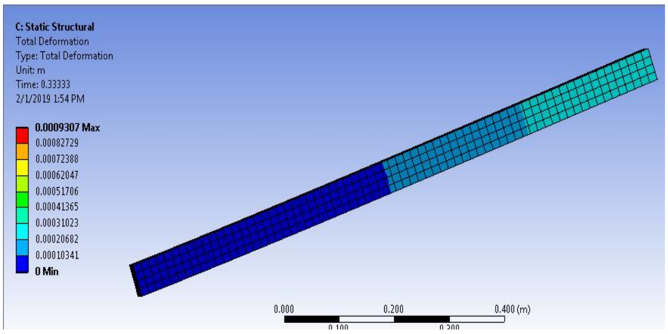


**Fig. 6:** Shows Total Deformation in Steel Bar at 200 Hz.

## 5. Conclusion

The main target of current study is to confirm result that is got by MATLAB analysis with the FEM simulation by using ANSYS . For simulation, that is done by ANSYS the natural frequencies and modes of simply supported continuous square section beam with crack and without crack of material structural steel. It is showed that when the natural frequencies is slightly , the crack depth of beam is increase. In other hand MATLAB analysis is used by using fuzzy logic tool to detect the location and depth of crack. Both approaches of these methods are governed by same motion equation which totally depending on The Euler- Bernoulli theory.

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