DYNAMIC ANALYSIS OF A SIMPLY SUPPORTED BEAM WITH CRACK

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

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CERTIFICATE

This is to certify that the thesis entitled, "**Dynamic Analysis of A Simply Supported Beam With Crack**" submitted by **Sri Ashish Kumar Sahu** in partial fulfilment of the requirements for the award of **Bachelor of Technology in Mechanical Engineering** at **National Institute of Technology, Rourkela** (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma.

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ACKNOWLEDGEMENT

I wish to express my deep sense of gratitude and indebtedness to **Prof. R.K. Behera** Department of Mechanical Engineering, N.I.T Rourkela for introducing the present topic and for his inspiring guidance, constructive criticism and valuable suggestion throughout this project work.

I would also like to sincerely thank our **Head of the Department Dr. R.K.Sahoo,** who with his valuable comments and suggestions during the viva-voce helped me immensely. I would thank him because he was the one who constantly evaluated me corrected me and had been the guiding light for me.

I am also thankful to all staff members of Department of Mechanical Engineering NIT Rourkela.

I feel a deep sense of gratitude for my family members who formed a part of my vision and taught me the good things that really matter in life.

Last but not least, sincere thanks to all my friends who have patiently extended all sorts of help for accomplishing this undertaking.

10th MAY 2011 ASHISH KUMAR SAHU

ROLL NO: 107ME026

CONTENTS

ABSTRACT

The crack present in the structure changes the physical nature of it as well as changes the dynamic response towards the vibration. For the analysis the depth and location of the crack are important parameters which change the response. So it is important to study these changes for the structural integrity, performance and safety. In the current project titled "Dynamic Analysis of A Simply Supported Beam with Crack" the response nature of both cracked and uncracked beam is predicted. Also the responses for different crack depths are studied. In the present study, vibration analysis is done on a simply supported beam with and without crack. The beam is considered to be an Euler-Bernoulli beam which is the most ideal case for simple calculation. The methods used here are both non-dimensional and parametric. At first the problem was solved using the boundary conditions and the normal equations to find out the natural frequency of the beam. Then the cracked beam was studied taking all the effects of the crack into consideration and the physical property of the material. Here the cracked beam is considered to be two beams connected by a mass less spring at the crack point. The proposed method had been compared with the analytical calculation and then with the help of MATLAB the frequency response had been plotted to see the deviation from the natural response.

CHAPTER 1

INTRODUCTION

1.1 Introduction

The crack present in any mechanical or structural part influences its vibrational behaviour like its frequency and resonance. The crack may be a result of cyclical load or some other factor and it propagates with the increase of the load through the structure. The amplitude and resonance starts to shift as the crack parameters changes. So the structure fails after some repetitive load which is due to incapability of carrying the load. For this reason finding the cracks in a structure is more important from an engineering point of view to eliminate such failure and risk. In structure like beam column, bridges etc. the damages are due to long service, impact. The crack present in beam reduces its physical properties and also its dynamic response to the load. By monitoring this different response to the load we can detect the presence of crack in the design and take safety measures. The dynamic response depends on the crack types which may be open, close or breathing during vibration.

Different theories have been generated till these days for the analysis of the bending of beams and the analysis of its behaviour under the influence of the load in different conditions. Among the theories two of them are popular which is explained below.

- Euler – Bernoulli Beam Theory
  It is the most classical theory among all the analysis. According to this theory, it is assumed that the straight lines perpendicular to the mid-plane before bending remains straight and perpendicular to it after bending also. As a result of that, transverse shear strain is neglected. Although this theory is useful for slender beams and plates, it didn't give exact solution for the thick plate and beam.
- Timoshenko Theory
  In this the previous assumption is slightly modified so as to consider all possible problems. In this theory, it is assumed that the lines perpendicular to the mid plane before bending remains straight but no longer perpendicular to the mid plane after bending.

For a simply supported beam, the load applied in the transverse direction causes the bending and shearing of the beam. This force gives the response to the vibration of the beam. The frequency of the beam will differ from its natural frequency if there will be a crack in its length. So in recent time this crack estimation is an important and essential part of any design and for that many new technique has been developed. A crack on a structural member introduces a local flexibility which is a function of the crack depth. Major characteristics of structures, which undergo change due to presence of crack, are

• The natural frequency

• The amplitude response due to vibration

• Mode shape.

Hence it is possible to use natural frequency measurements to detect cracks

For a beam with transverse load, the effect of transverse vibration will be more than that of the longitudinal one for ideal case which is consider in this project work.

1.2 Transverse Vibration

Let a beam of mass per unit length m and amplitude of assumed deflection curve is

$$T_{max} = \frac{1}{2}\int \bar{y}^2{}_{max} dm$$

Where $\bar{y}$ is the mean deflection of the beam mid plane from the normal position.

Strain energy of the beam is the work done on the beam which is stored as elastic energy.

$$\boldsymbol{V = \int \frac{1}{2} M\, d\theta}$$

Usually the deflection of the beam is very small

So $\boldsymbol{\frac{1}{R} = \frac{d\theta}{dx} = \frac{d^2y}{dx^2}}$

From the beam theory $\frac{M}{I} = \frac{E}{R}$ where R is the radius of the curvature of the beam & EI is the flexural rigidity of the structure. Thus

$$V = \frac{1}{2}\int \frac{M}{R} dx = \frac{1}{2}\int EI(\frac{d^2y}{dx^2})^2 dx$$

From that we can deduce the equation for the frequency as below,

$$\omega^2 = \frac{\int EI(\frac{d^2y}{dx^2})^2 dx}{\int y^2\, dm}$$

This equation gives the lowest natural frequency of the transverse vibration. Here the vibration is assumed to be sinusoidal and the value of “Y” with respect to “x” should be known for the calculation.

Dynamic analysis of the beam means the study of the vibration modes and responses of the structure with its physical parameters and analysing them for any defect. This type of analysis is mainly dependent on the geometrical parameter of the design rather than on the physical property of the material of the section.

CHAPTER 2

LITERATURE REVIEW

The effect of the crack or local defects in the dynamic response of the structure is known long ago. Different researchers have found new methods for the detection of the damage or crack in the beams. They are summarized below.

In recent years, structural analysis has gain momentum and so as on the non-destructive damage detection methods. It is well known that damage can reduce the stiffness of a system and the crack in it changes the dynamic response of it. That ultimately reduces the natural frequency and the mode shape in vibration. For crack identification change in natural frequency and modal value has been studied. In some cases crack properties are used to obtain the dynamic behaviour as in [1-4] and sometimes inverse methods are used [5-8].

Narkis [9] used first two natural frequencies to identify the crack and later Morassi [10] used it on simply supported beam and rods. Although it can be solved by using 2D or 3D finite element method (FEM), Analysis of this approximate model results in algebraic equations which relate the natural frequencies of beam and crack characteristics. These expressions are then applied to studying the inverse problem—identification of crack location from frequency measurements. It is found that the only information required for accurate crack identification is the variation of the first two natural frequencies due to the crack, with no other information needed concerning the beam geometry or material and the crack depth or shape. The proposed method is confirmed by comparing it with results of numerical finite element calculations the researchers still try to detect it with the help of physical parameters of the crack i.e. crack depth, position and support condition to the beam.

Freud and Herrmann [17] modelled the problem using a torsional spring in the place of crack whose stiffness is related. The first model is used to Euler-Bernoulli cracked beam with different end conditions [4, 11, 19-23, 18] and recently on Timoshenko beams [24, 25].

Rubio et al [26] obtained closed-form expression for natural frequency for Euler-Bernoulli beams with different end conditions using perturbation technique.

Some studies are directly related to the analysis of the frequency response which is called direct problem. Some other deals with the crack properties through the knowledge of dynamic behaviour of the beam called inverse problem.

Cracked beam is modelled as two segments of beams connected with a massless rotational spring [10] whose stiffness is related to the crack length by the Fracture Machine Theory [11]. So the cracked section behaves as a discontinuity in the rotation due to bending must be considered. In using the fracture mechanics model, the local stiffness at the crack section is calculated using Castigliano's second theorem as applicable to fracture mechanics formulations. The calculated local stiffness is then modelled by a flexural spring for the bending vibration of a cracked beam. To establish the vibration equations, the cracked is represented by two structures connected by flexural spring. These models are applied to the Euler beams with varying conditions [5, 12-16].

Lele and Maiti have modelled the presence of the crack as a rotational spring in the Euler-Bernoulli cracked beam problem. Krawczuk et al. [30] used the same method for Timoshenko cracked beam for the development of spectral finite element. But in these above cases the transverse deflection is neglected.

Matvev et al. [31] expressions for bending vibrations of an Euler-Bernoulli cracked beam have been analysed. They have studied the effects of the ratio of crack location to the length of the beam and also ratio of depth of the crack to the height of the beam. They have investigated the variation of the natural frequency of the cracked beam.

Springer et al. [32] have examined the free longitudinal vibration of a bar with free ends and two cracks located symmetrically at the centre of the span. The cracks have been modelled in two ways. One is using linear springs; the other is using reductions in cross-sectional area. The changes in natural frequencies are close to those obtained from experiments

Papadopoulos [35] has examined the torsional vibrations of rotors with transverse surface crack. The crack has been modelled by a local flexibility matrix which was measured experimentally. The result agreed with both theoretical and experimental values.

Both analytical and experimental study has been conducted by Wang and Qiao [39] to develop efficient and effective damage detection techniques for beam-type structures. The uniform load surface (ULS) was employed in this study due to its less sensitivity to ambient noise. In combination with the ULS, two new damage detection algorithms, i.e., the generalized fractal dimension (GFD) and simplified gapped-smoothing (SGS) methods, had been proposed. Both methods are then applied to the ULS of cracked and delaminated beams, from which the damage location and size were determined successfully. Based on the experimentally measured curvature mode shapes, both the GFD and SGS methods are further applied to detect three different types of damage in carbon/epoxy composite beams. Damage detection in vibrating beams or beam systems had been done by Fabrizio and Danilo [40] by discussing the amount of frequencies required locating and quantifying the damage uniquely.

Irwin [28, 29], A crack on an elastic structural element introduces considerable local flexibility due to the strain energy concentration at the crack tip under load. This effect has been known long ago. A local compliance has been used to quantify, in a microscopic way, the relation between the applied load and the strain energy concentration around the tip of the crack.

Silva and Gomez [33-35] have performed experimental dynamic analysis for the location and the depth of cracks in straight beams. They have described the experimental techniques and presented the results obtained for various locations and depths of crack.

Qian et al. [36] have used a finite element model to analyse the effect of crack closure on the transverse vibration of a beam. The stiffness matrix of the system has been calculated from the stress intensity factors, and it gives two values, one for the close crack (uncracked beam) and for the other for the open crack. The sign of the stress on the crack faces has been used to determine if the crack is open or closed.

Dimarogonas, et al. [37] have studied the influence of a circumferential crack upon the torsional dynamic behaviour of a shaft. He found that due to the presence of crack, the torsional natural frequencies decreases due to the added flexibility. The strain energy release function is related to the compliance of the cracked shaft due to the introduction of a crack.

Mermertas, et al. [38] have studied the effect of mass attachment on the transverse vibration characteristics of a cracked cantilever beam. Theoretically investigation of the cracked beam has been carried out. The governing equation for free vibrations of the cracked beam was constructed from the Bernoulli-Euler beam elements. To model the transverse vibration, the crack is represented by a rotational spring. The crack was located in two different distances from the fixed end of the beam. The results for the changes of the natural frequencies of a cracked beam carrying a point mass are compared with the results of the beam without a crack.

Nahvi, et al. have developed another method for crack detection in cantilever beams by vibration analysis. To avoid non-linearity, they assumed that the crack is always open. To identify the crack, the normalized frequency is plotted against the normalized crack depth and location. The intersection of contours with the constant modal natural frequency planes is used to relate the crack location and depth. The approach for identifying the cracked element within the cantilever beam is minimized.

CHAPTER 3

CRACK THEORY

3.1 Classification of cracks

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

• Cracks perpendicular to the beam axis are known as “transverse cracks”. These are the most common and most serious as they reduce the cross-section and thereby weaken the beam. They introduce a local flexibility in the stiffness of the beam due to strain energy concentration in the vicinity of the crack tip.

• Cracks parallel to the beam axis are known as “longitudinal cracks”. They are not that common but they pose danger when the tensile load is applied is at right angles to the crack direction i.e. perpendicular to beam axis or the perpendicular to crack.

• “Slant cracks” (cracks at an angle to the beam axis) are also encountered, but are not very common. These influence the torsion behaviour of the beam. Their effect on lateral vibrations is less than that of transverse cracks of comparable severity.

• Cracks that open when the affected part of the material is subjected to tensile stresses and close when the stress is reversed are known as “breathing cracks”. The stiffness of the component is most influenced when under tension. The breathing of the crack results in non-linearity’s in the vibration behaviour of the beam. Cracks breathe when crack sizes are small, running speeds are low and radial forces are large. Most theoretical research efforts are concentrated on “transverse breathing” cracks due to their direct practical relevance.

• Cracks that always remain open are known as “gaping cracks”. They are more correctly called “notches”. Gaping cracks are easy to mimic in a laboratory environment and hence most experimental work is focused on this particular crack type.

• Cracks that open on the surface are called “surface cracks”. They can normally be detected by techniques such as dye-penetrates or visual inspection.

• Cracks that do not show on the surface are called “subsurface cracks”. Special techniques such as ultrasonic, magnetic particle, radiography or shaft voltage drop are needed to detect them. Surface cracks have a greater effect than subsurface cracks on the vibration behaviour of shafts.

Physical parameters affecting Dynamic characteristics of cracked structures:

Usually the physical dimensions, boundary conditions, the material properties of the structure play important role for the determination of its dynamic response. Their vibrations cause changes in dynamic characteristics of structures. In addition to this presence of a crack in structures modifies its dynamic behaviour. The following aspects of the crack greatly influence the dynamic response of the structure.

(i) The position of crack

(ii) The depth of crack

(iii) The orientation of crack

(iv) The number of cracks

Stress Intensity Factor (SIF), K: - It is defined as a measure of the stress field intensity near the tip of an ideal crack in a linear elastic solid when the crack surfaces are displaced in the opening mode (Mode I). (SIFs) are used to define the magnitude of the singular stress and displacement fields (local stresses and displacements near the crack tip). The SIF depends on the loading, the crack size, the crack shape, and the geometric boundaries of the specimen. The recommended units for K are MPa$\sqrt{m}$. it is customary to write the general formula in the form $K=Y\sigma\ \pi a$ where σ is the applied stress, a is crack depth, Y is dimensionless shape factor.

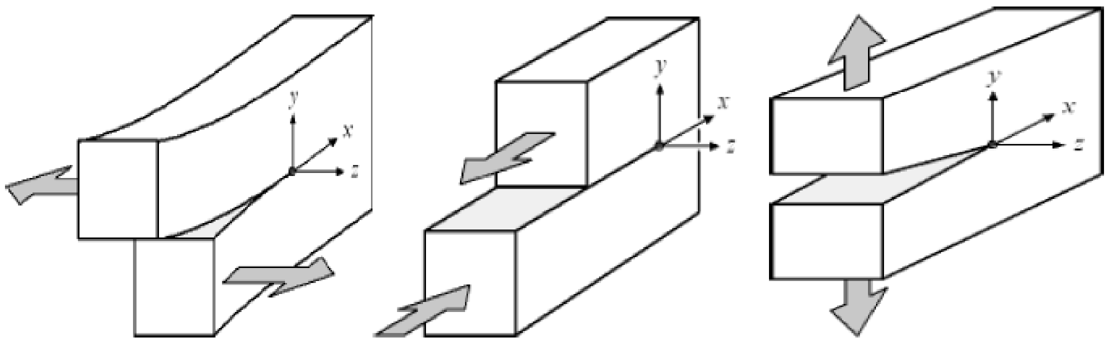

Figure 3.1 Three basic modes of fracture

Modes of Fracture: -The three basic types of loading that a crack experiences are

• Mode I corresponds to the opening mode in which the crack faces separates in a direction normal to the plane of the crack and the corresponding displacements of crack walls are symmetric with respect to the crack front. Loading is normal to the crack plane, and tends to open the crack. Mode I is generally considered the most dangerous loading situation.

• Mode II corresponds to in-plane shear loading and tends to slide one crack face with respect to the other (shearing mode). The stress is parallel to the crack growth direction.

• Mode III corresponds to out-of-plane shear, or tearing. In which the crack faces are sheared parallel to the crack front.

CHAPTER 4

VIBRATION OF CRACKED SIMPLY SUPPORTED BEAM

4.1 PROBLEM DEFINITION

The problem involves calculation of natural frequencies and mode shapes for simply supported beam with a crack of different crack depths. The results calculated analytically are validated with the results obtained by simulation analysis.

Stability of the elastic supports for different end conditions is also analysed under buckling load.

4.2 FREQENCY ANALYSIS OF BEAM WITHOUT CRACK

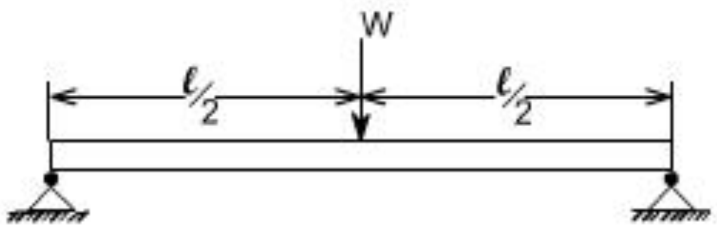

Fig 4.1 simply supported beam

A simply supported beam with length, width and height as L, B, and H respectively, vibrates in the X-Y plane. Considering it to be an Euler-Bernoulli beam, the natural frequency for the ith can be calculated as follows:

$$w_i^{nc} = \left(\frac{i\pi}{L}\right) 2\sqrt{\frac{I}{A}}\,.\,c \qquad (1)$$

Where c being the propagation speed.

$$c = \sqrt{\frac{E}{\rho}} \qquad (2)$$

Where I is the moment of inertia of the beam and the A belongs to the cross sectional area of the beam. E and ρ are the Young's modulus and the mass density of the beam respectively.

For the cracked beam the vibration analysis gets changed due to the crack present in the structure which is considered to be open. Let the depth be a and position measured from one end to be b.

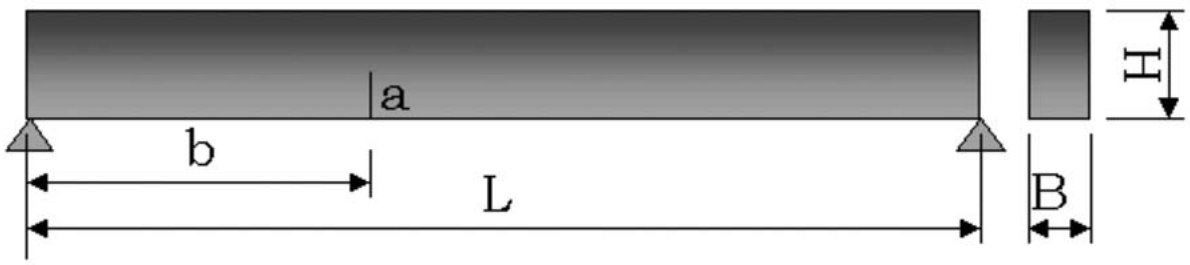

Fig 4.2: simply supported beam with a crack

The wave propagation speed c is also an unknown variable, which allows the material of the beam to be known through the relation between Young's modulus E and the mass density ρ.

In order to take into account the presence of the crack, the cracked beam can be modelled with two beams connected by a torsional. The model leads to a discontinuity in the slope of the beam, which is proportional to the bending moment M as follows:

$$\boldsymbol{\Delta\theta = F.M} \tag{3}$$

where F is the flexibility constant that can be expressed as

$$\boldsymbol{F = \frac{H}{EI} m} \tag{4}$$

Where m is a function depending on the dimension of the crack depth ratio β=a/H and the geometry of the cross section. For rectangular section the function m is as below [27]:

$$\mathrm{m}(\beta)=2.\left(\frac{\alpha}{1-\alpha}\right)^2 [5.93 - 19.69\beta + 34.14\beta^2 - 35.84\beta^3 + 13.2\beta^4] \tag{5}$$

Each part of the cracked beam is assumed to be connected through a spring to each other whose stiffness constant is related to crack dimensions. So the displacement of each part can be given by the basic equation as

$$y_j(x,t) = B_j(x)\sin(\omega^* t) \qquad \text{(j= 1, 2)} \tag{6}$$

Where subscript j=1 belongs to left part and 2 shows the right part of the cracked beam. The ω* is the frequency for the cracked beam and $A_j(x)$ is the transverse deflection. The solution can be calculated from the differential equation shown below:

$$EI\frac{d^4B_j}{dx^4} - \omega^*\rho AB_j = 0 \qquad \text{(j= 1, 2)} \tag{7}$$

The boundary conditions for simply supported beam are,

$$B_1(0) = B_2(L) = 0 \tag{8}$$

$$\frac{d^2 B_1(0)}{dx^2} = \frac{d^2 B_2(L)}{dx^2} = 0 \tag{9}$$

And for the cracked section the equations are:

- Transverse deflection continuity,

$$B_1(b) = B_2(b) \tag{10}$$

- Slope discontinuity,

$$\Delta\theta = \frac{dB_2(b)}{dx} - \frac{dB_1(b)}{dx} = EIF\frac{d^2 B_2(b)}{dx^2} \tag{11}$$

- Bending moment,

$$\frac{d^2 B_1(b)}{dx^2} = \frac{d^2 B_2(b)}{dx^2} \tag{12}$$

- Shear force continuity,

$$\frac{d^3 B_1(b)}{dx^3} = \frac{d^3 B_2(b)}{dx^3} \tag{13}$$

The equation has leaded us to a pair of solutions for each part of the cracked beam:

$$B_1 = C_1 \sin(\lambda^* x) + C_2 \cos(\lambda^* x) + C_3 \sinh(\lambda^* x) + C_4 \cosh(\lambda^* x) \tag{14}$$

$$B_2 = C_5 \sin(\lambda^* x) + C_6 \cos(\lambda^* x) + C_7 \sinh(\lambda^* x) + C_8 \cosh(\lambda^* x) \tag{15}$$

Where the x coordinate notifies the distance of the point from the left end of the beam and

$${\lambda^*}^2 = \omega^* \sqrt{\frac{\rho A}{EI}} \tag{16}$$

The coefficients of the solution can be calculated using the boundary equations shown above. The natural frequency can be determined by equating the determinant to zero.

Now assuming two parameters for the easy calculation as $\propto^* = \lambda^* L$ and for the position parameter of the crack $s = 2\delta - 1$ (where δ=b/L). Taking the eight conditions to find the eight unknown parameters the equation reduces to a non-trivial solution whose coefficient matrix should be equal to zero and the final equation becomes

$$\mathbf{4\,sin}(\propto^*)\,\mathbf{sinh}(\propto^*) + \propto^* \frac{\boldsymbol{H}}{\boldsymbol{L}} \boldsymbol{m}(\boldsymbol{\beta})[\mathbf{sinh}(\propto^*)\{\mathbf{cos}(\propto^*) - \mathbf{cos}(\boldsymbol{s} \propto^*)\} + \mathbf{sin}(\propto^*)\{\mathbf{cos}(\propto^*) - \mathbf{cos}(\boldsymbol{e} \propto^*)\}] = \mathbf{0} \qquad (17)$$

Knowing the position and depth of the crack in the beam we can calculate the frequency of the structure.

Using all the boundary condition equations and relating the natural frequency of the cracked beam with that to the uncracked beam the relation will be as below

$$(\boldsymbol{\omega}_i^*)^2 = (\boldsymbol{\omega}_i^{nc})^2 - \boldsymbol{F} \frac{(\boldsymbol{EI}\frac{d^2 B_{oi}(b)}{dx^2})^2}{\int_0^L \rho A (B_{oi})^2 dx} \qquad (18)$$

The displacement B_{oi} can take different values depending on the end conditions of the beam support. As the case study for the present project is a simply supported beam, so the expression will be written as

$$\boldsymbol{B_{oi}} = \mathbf{sin}(\frac{i\pi x}{L}) \qquad (19)$$

Putting the equation 19 in the equation 18 and taking into consideration the 1st equation the following expression can be obtained:

$$\frac{\omega_i^*}{\omega_i^{nc}} = [1 - 2\frac{H}{L}.m.\sin^2(i\pi y)]^{1/2} \qquad (20)$$

The above equation 20 is a non-dimensional relation between the cracked and uncracked frequency of the faulty beam. So to know the dynamic response of the beam we have to know only the dimensions of the crack with its location from one end with the physical property of the material.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 RESULTS

Let us take the parameters for the beam which is simply supported.

Length (L) = 1 m

Breadth (B) = 0.5 m

Height (H) = 0.3 m

Area of the cross section = 15*10^{-2} m^2

Tabulation for the following physical properties of the material of the beam

Young's modules € = 80 GPa

Shear modules (G) = 30 GPa

Material density (ρ) = 2500 kg/m^3

Considering 3 cases for the cracked beam as follows: for first two cases the lateral distance ratio is 0.3 (ϒ= b/L) and the crack depth ratio (α=a/H) are 0.1 and 0.5 respectively. For the 3rd case the lateral ratio is 0.5 and that for the depth ratio is 0.25.

So calculating both the natural frequency of the cracked beam and the uncracked beams for four frequencies, the results are tabulated below:

Table No: 5.1

FREQUENCY(Hz)	UNCRACKED	CASE 1	CASE 2	CASE 3
ω_1^*	62.8098	62.8092	62.7999	62.8068
ω_2^*	251.2391	251.230	251.0817	251.1914
ω_3^*	565.2880	565.2445	564.4910	565.0465
ω_4^*	1004.9565	1004.8191	1002.4379	1004.1937

We can see all the frequencies belonging to the cracked beam are near to the natural frequency of the uncracked beam with in the limit of 0.4% of error.

When the same cases were studied with the dimensional analysis the results were graphically shown below. The equations expressed before were analysed for mode shape of the beam in cracked case.

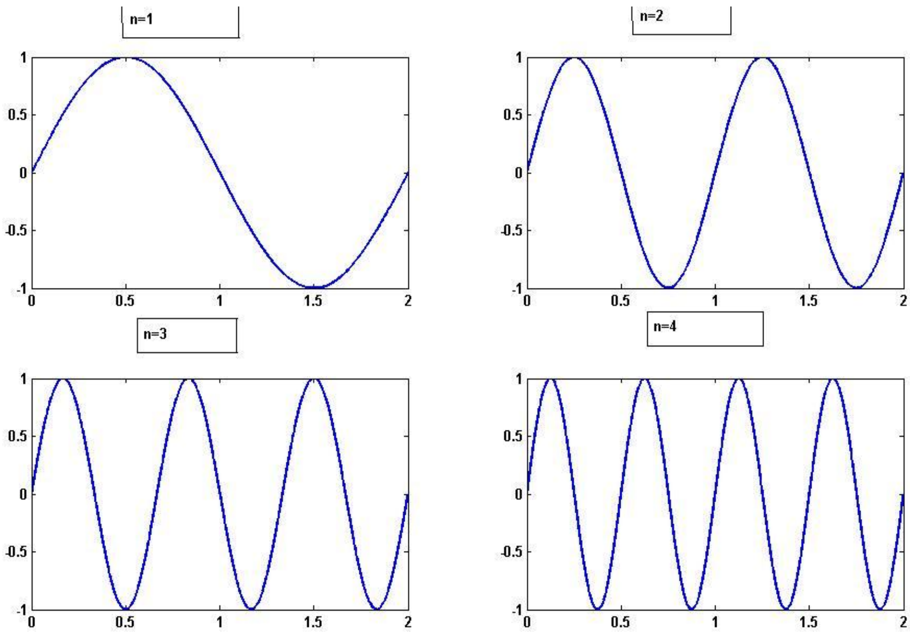

Fig 5.1: Frequency Response of the Uncracked Beam

The above graphical diagram shows the normal frequency modes of the uncracked beam for four consecutive values. It can be seen that these are pure sinusoidal curves. They behave in the normal way as expected from the theoretical analysis.

For the cracked beam, the frequency behaviour is different from that of the normal one with dependence on the crack position and the depth ratio of it. The crack parameters are fully influencing the dynamic response of the beam under vibration in transverse direction. The graphs for all the three cases have been plotted and shown below with a wider range of x value.

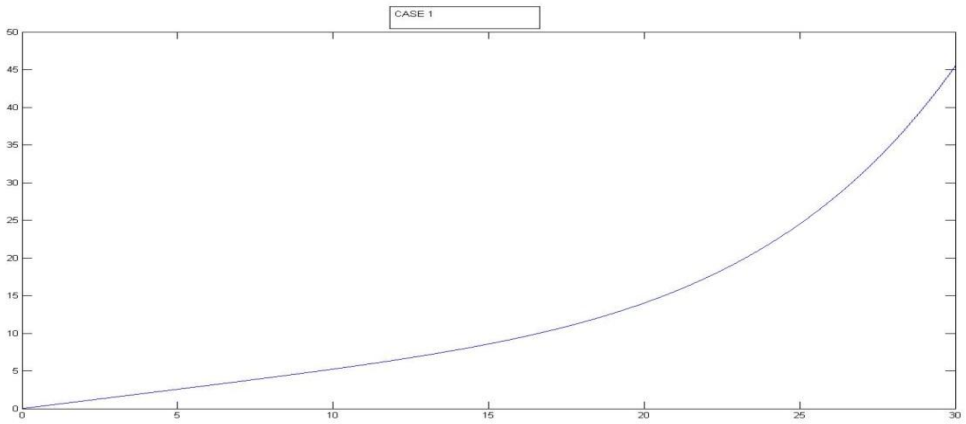

Fig 5.2: Frequency Response of Case 1

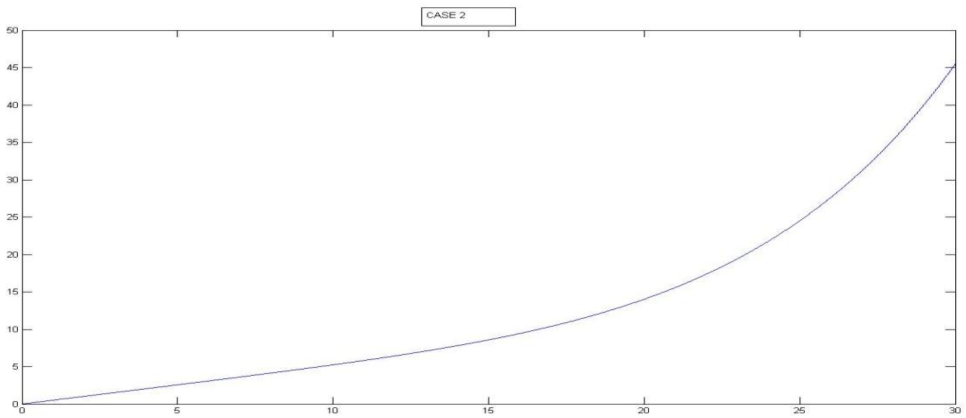

Fig 5.3: Frequency Response of Case 2

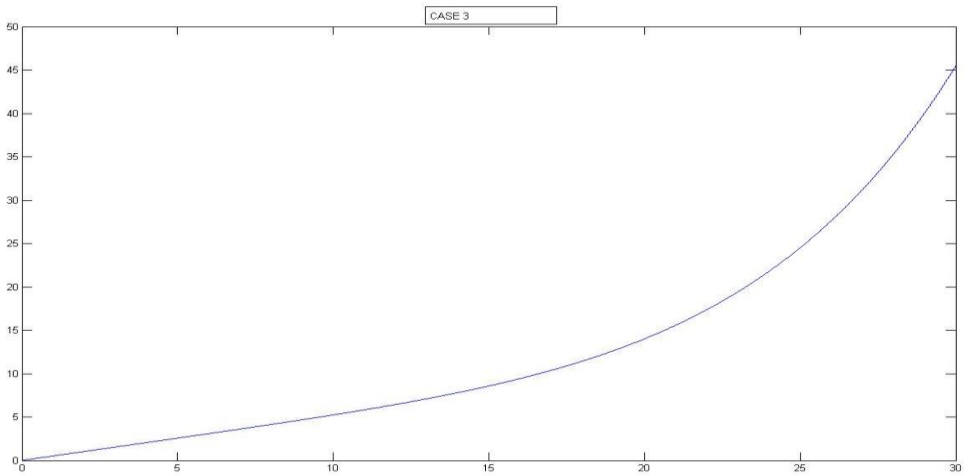

Fig 5.4: Frequency Response of Case 3

It can be clearly deduce from the above graphs that the crack influences a lot in the dynamic response of the beam with deviation from the normal frequency response of it. All the three cases show the influence of the crack parameters on the dynamic response.

CHAPTER 6

CONCLUSION

This is a simple and efficient method for the dynamic analysis of the cracked beam with known crack parameters. This method uses only the knowledge of the crack position and not necessarily requires the physical property of the material property such as young's modulus, and the mass density of it. This method can also be inversely used for the detection of the crack position in the member of the structure with ease. This method is quite easy to be used in case of the Euler- Bernoulli simply supported beam. The sensitivity of the method depends on the crack depth ratio and the lateral ratio i.e. the position from one end of the beam.

The numerical results are shown in Table 5.1 and the simulation analysis results are shown in fig 5.1-5.4.it is observed that the natural frequency of beam for a single crack decreases as compared to the uncracked simply supported beam condition. The frequency of the cracked simply supported beam decreases with increase in the crack depth for the all modes of vibration.

For small crack depth, minor change in mode shapes between the cracked and uncracked beam. For moderate crack depth ($a = 3$mm) the change in mode shapes are quite marginal. For deep crack ($a \geq 5$mm) the change in mode shapes can be easily recognized.

FUTURE SCOPE:

- The cracked simply supported beam can be analysed under the influence of external forces.
- The dynamic response of the cracked beams can be analysed for different crack orientations.
- Effect of the longitudinal vibration can also be taken into consideration.
- Stability study of the cracked beams should be done.

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