



STUDY ON VIBRATION ANALYSIS OF AN UN-CRACK AND CRACKED CANTILEVER BEAM

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Abstract: An important task for engineers is to determine the effect of the damage like transverse cracks on the stability characteristic of structures. The presence of cracks causes changes in the physical properties of a structure and its dynamic response characteristics. This paper focuses on the theoretical analysis of transverse vibration of a cantilever beam and investigates the mode shape frequency. Finite element analysis using ANSYS software is adopted for the dynamic analysis of the beam. Variations of natural frequencies due to crack at various locations and with varying crack depths have been studied. A parametric study has been carried out. The analysis is performed using ANSYS software.

Keywords: ANSYS, Cantilever Beam, Crack, Mode shape, Natural Frequency

I. Introduction

The cracks in a structural member may develop from flaws due to applied cyclic loads, mechanical vibrations, aerodynamic loads, rocket fuel exhaust or acoustical fatigue. In civil engineering, structures like beam, bridges, piles, etc will bear damages due to long term service, collision, impact, etc. An important task of engineers is to determine the effect of these damages on the stability characteristic of these structures. The presence of cracks causes changes in the physical properties of a structure which in turn alter its dynamic response characteristics. The monitoring of the changes in the response parameters of a structure has been widely used for the assessment of structural integrity, performance and safety. Irregular variations in the measured vibration response characteristics have been observed depending upon whether the crack is closed, open or breathing during vibration, the degree of severity and modal type. These variables consequently affect the effectiveness of structural integrity assessment. The study of vibration analysis of cantilever beam with crack is a problem of practical interest and finds applications in aerospace, mechanical and civil engineering. So a comprehensive literature study covering the above aspects of the beam is carried out. The fact that a crack or local defects affect the dynamic response of a structural member was known long ago. In the past, various researchers conducted investigations into the vibration and buckling characteristics of cracked structures. *Murphy Kevin et al.* investigated vibration and stability characteristics of a cracked beam translating between fixed supports. They developed equations of motion for the beam using Hamilton's principle and fracture mechanics throughout the analysis, the crack was assumed to be open and shallow. *Jiki Peter N.* proposed how to use Liapunov's functional method to find critical load for pre-cracked thin walled beam-columns rather than solving a set of differential equations.^[3] *Monsalve et. al* studied stability and free vibration analysis of a Timoshenko beam-columns with a crack along its span, they modeled the crack as an intermediate flexural connection of zero length with rotational discontinuity and identical lateral deflection between two sides of the crack, they also studied the coupling effect of shear and bending deformation along the span of the member.^[4] *M. Chati, R. Rand and Mukherjee* extended the cracked beam theory to account for opening and closing of the crack, the so called "breathing crack" model.^[5]

The present work is aimed at finding the natural frequency of a cantilever beam with a single crack and double crack using finite element analysis ANSYS software.

II. Parameters Affecting Dynamic Characteristics Ofcracked 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 behavior. 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

III. Classification of Crack

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 behavior 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 known as “breathing cracks”. The stiffness of the component is most influenced when under tension. The breathing of the crack results in nonlinearity’s in the vibration behavior 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 behavior of shafts.

IV. Free Vibration Analysis of Cantilever Beam

For a simple elastic beam problem with uniform cross-sectional area, a well-known natural frequency can be calculated by,

$$\omega = (\beta l)^2 \sqrt{E_b I / \rho A L_b^4}$$

Where, A and L_b are the area of cross-section and the length of the flexible beam, respectively, E_b is the Young’s Modulus and I is the moment of inertia of beam. The dimensions and the material constant for the cantilever beam investigated in this paper are mentioned in Table 1. The first three natural Frequency of cantilever beam are listed in Table 2 and first mode shape of the beam given in Figure 1.

Table 1: Material Properties and Dimensions of Aluminium Beam

Dimensions/Properties	Aluminium
Length	0.4 m
Width	0.03 m
Thickness	0.005 m
Density	2700 kg/m ³
Young modulus	70 Gpa
Poisson’s ratio	0.3

Table 2: First Three Natural Frequencies of Aluminium Beam

Mode	f_n Analytical (Hz)	f_n ANSYS (Hz)
1	25.651	25.817
2	162.887	161.731
3	450.412	448.825

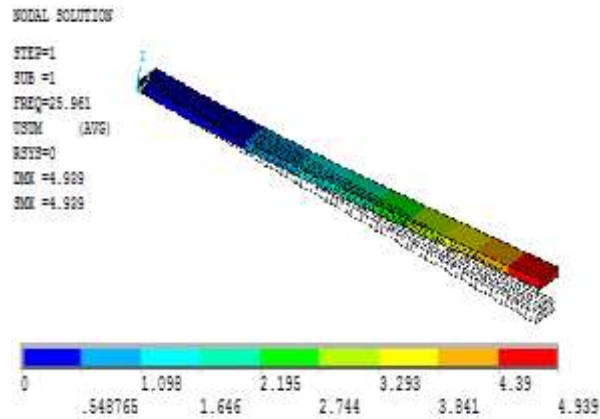


Figure 1: First Mode Shape of Un-Cracked Cantilever Beam.

V. Modeling of Crack on Cantilever Beam

Cracks in the beam create changes in geometrical properties so it becomes complex to study the effect of cracks in the beam. The crack modeling has been very important aspect. The analysis has been done using finite element method. FEM software package ANSYS has been used. Cracked beam has been modeled and free vibration analysis has been performed considering geometric and material non linearity.

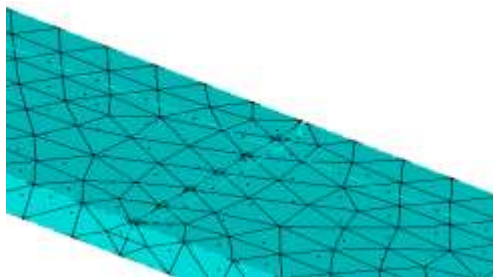


Figure 2: Modeling of Crack on Cantilever Beam in ANSYS

Table 3: Natural Frequency of First Three Mode of Cantilever Beam for Various Crack Position and Crack Depth.

Crack Position (mm)	Crack Depth (mm)	Natural Frequency (Hz)		
		1 st mode	2 nd mode	3 rd mode
100	0.5	47.535	303.117	859.755
	1.5	47.350	301.355	845.284
	2.5	46.563	304.032	837.179
	3.5	45.102	303.655	819.380
200	0.5	48.422	300.302	840.216
	1.5	48.261	297.775	842.455
	2.5	47.929	289.661	842.165
	3.5	47.559	281.476	842.399
100 and 200	0.5	47.955	299.451	839.355
	1.5	46.821	293.403	822.985
	2.5	45.621	287.825	816.566
	3.5	44.048	280.295	800.827

VI. Effects of the Crack on Natural Frequency

The effects of the crack on natural frequency of a cantilever beam were investigated for various crack depths and crack locations which is shown in Table 3.

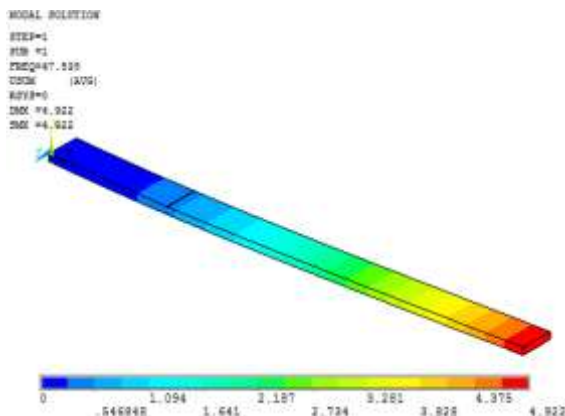


Figure 3: First Mode Natural Frequency of Cracked Cantilever Beam

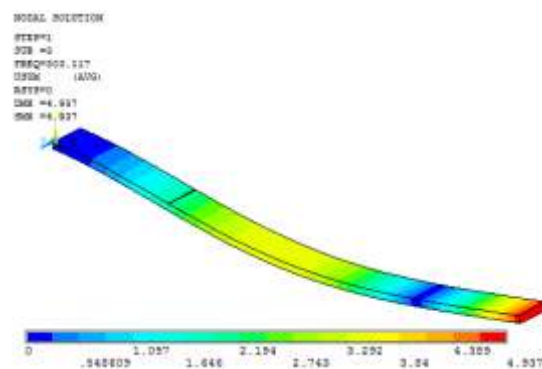


Figure 4: Second Mode Natural Frequency of Cracked Cantilever Beam

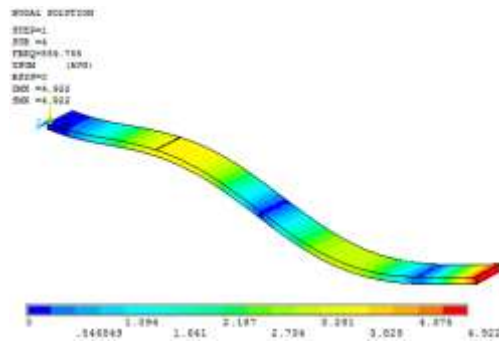


Figure 5: Third Mode Natural Frequency of Cracked Cantilever Beam

VII. Result and Discussion

Figure 3, Figure 4 and Figure 5 shows the natural frequencies of the cantilever beam with a single crack at 100 mm from fixed end crack locations and 0.5 mm crack depths for first, second and third modes of vibration respectively. By comparing Table 2 and Table 3 shows that there is an appreciable variation between natural frequency of cracked and un-cracked cantilever beam. It is observed that natural frequency of the cracked beam decreases both with increase in crack distance and crack depth due to reduction in stiffness. It appears that the change in natural frequencies is not only a function of crack depth and crack location but also of the mode number.

VIII. Conclusion

A method for identifying the crack location and depth of the cantilever beam was developed by using the linear fracture mechanics theory. The finite element model of the cracked beam is constructed and used to determine its natural frequencies. It has been observed that the natural frequency changes substantially due to the presence of cracks depending upon location and size of cracks. The frequency of the cracked cantilever beam decreases with increase in the crack depth for the all modes of vibration. As largest effects are observed at the centre for cantilever beam we can say, decrease in frequencies is more for a crack located where the bending moment is higher.

IX. References

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