International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 5, May - 2014

Vibration Analysis of Cantilever beam with Single Crack using Experimental Method

Yogesh D. Shinde
Department of ME, Mechanical Engineering Dept., SKN Sinhgad College of Engg College, Pandharpur,413304,India

Prof. S. D. Katekar
Department of ME, Mechanical Engineering Dept., SKN Sinhgad College of Engg College, Pandharpur,413304,India

***Abstract*— In the present study, vibration analysis of a cantilever beam with single open transverse crack for different crack depth and different crack locations is done using experimental method. For this analysis two cases are considered, first is without load and second case is with transverse load. For transverse load condition a spherical object is taken and dropped on free end of cantilever beam from certain height. This analysis is done to study the response characteristics (i.e. frequency and amplitude) of cracked cantilever beam and to find effect of crack on these response characteristics. From the modal test data, it is found that, as crack depth increases natural frequency decreases and as crack position shifted towards fixed end natural frequency decreases.**

***Keywords*—cantilever beam, crack, crack depth, crack location, natural frequency.**

I. INTRODUCTION

Structural health monitoring and analysis of structures like cantilever beam with cracks is of great importance from safety as well as system performance point of view. When a structure suffers from damages like cracks, its dynamic properties can change. Crack damage leads to reduction in stiffness also with an inherent reduction in natural frequency [3]. Kaushar H. Barad et. al. [1] presented a method for detection of crack in cantilever beam which is based on frequency measurement. Experimental method and finite element method is used to analyze modal parameters of the cracked cantilever beam by D.K. Agarwalla and D.R. Parhi [2].Irshad A Khan and Dayal R Parhi [3] studied the vibration characteristics of cantilever beam with two cracks. Two types of beams are considered for study i.e. cantilevers beam and fixed-fixed beam. Dong Wei et. al. [4] proposed analytical method for solving the free vibration of cracked functionally graded material (FGM) beams with axial loading, rotary inertia and shear deformation.

Celalettin Karaagac et. al. [7] studied the effects of crack ratios and positions on the fundamental frequencies and buckling loads of slender cantilever Euler beams with a single-edge crack are investigated both experimentally and numerically using the finite element method, based on energy approach. SadettinOrhan [12] analyzed cracked cantilever beam under free and forced condition numerically by FEM. Samer Masoud Al-Said [13] proposed a simple algorithm based on a mathematical model to identify crack location and depth in a stepped cantilever Euler–Bernoulli beam carrying a rigid disk at its tip. The proposed identification algorithm utilizes the first three natural frequencies shift of the beam caused by a crack to estimate its location and depth. To identify the crack, contours of the normalized frequency in terms of the normalized crack depth and location are plotted. The intersection of contours with the constant modal natural frequency planes is used to relate the crack location and depth. G.M. Owolabi et. al. [14] investigated the effect of crack on vibration characteristics by experimental method. For damage detection, change in first three natural frequencies and corresponding amplitudes is measured. S. P. Lele et. al. [15] proposed a method of detection of location of crack in beams based on frequency measurements. This method is based on measurement of change in first natural frequency.

II. EXPERIMENTAL SET-UP AND PROCEDURE

1) Experimental Setup Description

Mild steel beams were used for this experimental investigation. The set consisted of 13 beam models with the fixed-free ends. Each beam model was of cross-sectional area 30mm X 20mm with a length of 500 mm from fixed end. It has the following properties:

TABLE I. GEOMETRIC AND MATERIAL PROPERTES

Material	Mild Steel
Length	500 mm
Width	20 mm
Height	30 mm
Modulus of elasticity	200 GPa
Density	7850 kg/m^3
Poisson’s ratio	0.3

Fig.1 shows that, two heavy plates are used to clamp the one end of cantilever beam with the help of fasteners. Accelerometer is kept on beam at a distance of 50mm from fixed end for both the cases i.e. for no load condition and for loading condition. Accelerometer is connected to FFT analyzer for data acquisition. For no load condition Modal test is conducted. For vibration analysis under loading condition impact hammer is not required. To apply load, a spherical object is dropped from different heights. In this paper spherical object is dropped from 400mm height.

2) Experimental Procedure

The fixed–free beam model was clamped at one end, in a fixture supported over a stiff steel I-section beam. In modal test, the accelerometer is kept at 50mm distance from

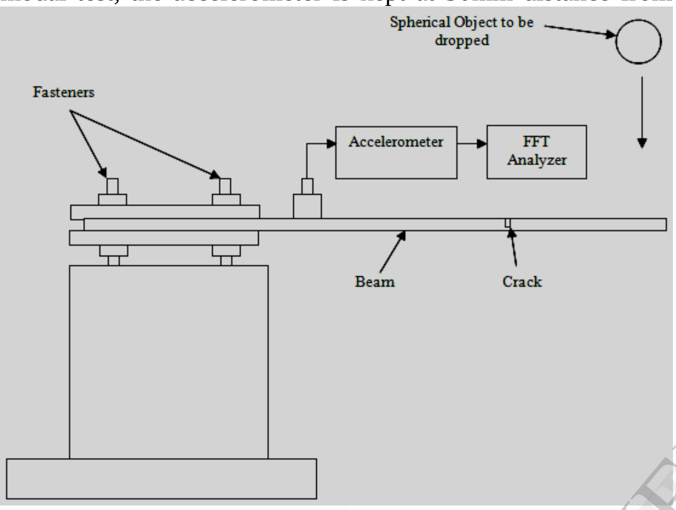

Fig.1Block diagram of Experimental Setup

fixed end and impact is given by impact hammer at different points on beam to extract natural frequency values. By using modal test first three natural frequencies are extracted. Cracks were generated to the desired depth using a wire cut EDM (around 0.35mm thick); the crack always remained open during dynamic testing Total 12 beam models were tested with cracks at different locations starting from a location near to fixed end and 1 beam model was tested without crack. The crack depth varied from 4mm to 12mm at each crack position. Each model was excited by an impact hammer. This served as the input to the system. It is to be noted that the model was excited at a point, which was a few millimeters away from the center of the model. This was done to avoid exciting the beam at a nodal point (of a mode), since the beam would not respond for that mode at that point. The dynamic responses of the beam model were measured by using light accelerometer placed on the model as indicated in Fig. 1. The response measurements were acquired, one at a time, using the FFT analyzer.

For vibration analysis under loading condition, spherical object is dropped at a distance of 50mm from free end, from height of 400mm for all the cases i.e. 12 beams with crack and 1 beam without crack. Data acquisition is done using accelerometer and FFT analyzer.

III. Result And Discussions

1) For no load condition (Modal test)

Results obtained from Modal test using FFT analyzer are given in following Table II. Results consist of first three natural frequencies for different beam specimens which are made of different crack depth and different crack locations. From following Table 1 it observed that, crack causes decrease in natural frequency of cantilever beam. The decreasing trend of natural frequency is not found for third natural frequency for all cases. Results obtained from modal test can be use to find the effect of crack depth and crack location on natural frequency.

TABLE II. Results of Modal Test

Crack Location from Fixed End (mm)	Crack depth (mm)	Natural frequency (Hz)		
		1st	2nd	3rd
Uncrack	Nill	66.827	96.718	416.35
100	4	66.868	99.45	417.79
	8	66.386	97.019	417.63
	12	65.642	92.646	417.4
200	4	66.979	100.05	416.97
	8	66.789	99.067	415.22
	12	66.496	97.19	412.54
300	4	67.048	100.3	416.98
	8	67.009	100.09	414.58
	12	66.941	99.593	410.78
400	4	67.075	100.42	417.71
	8	67.091	100.42	417.23
	12	67.102	100.41	416.3

Following Fig. 2, Fig.3, Fig. 4 and Fig.5 shows the variation of second natural frequency with crack depth, for crack location at 100mm, 200mm, 300mm and 400mm distance from fixed end respectively.

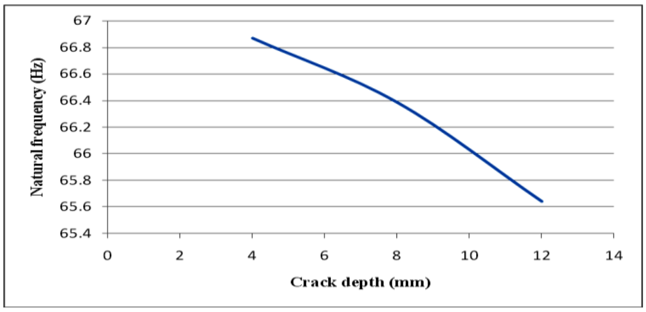

Fig. 2 Crack depth Vs. first Natural frequency for crack at 100mm distance

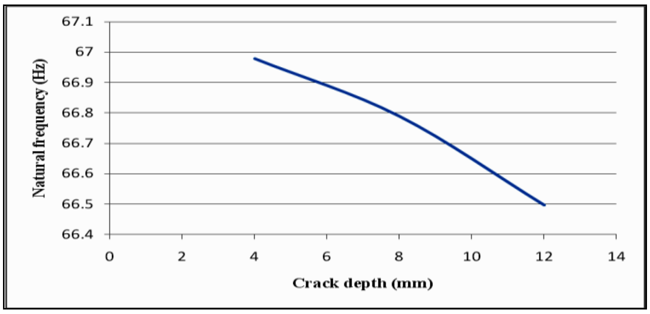

Fig. 3 Crack depth Vs. first Natural frequency for crack at 200mm distance

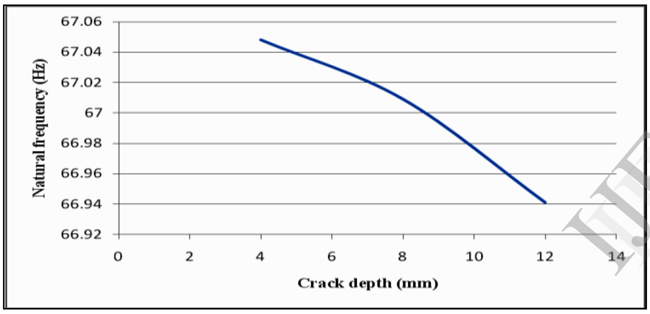

Fig. 4 Crack depth Vs. first Natural frequency for crack at 300mm distance

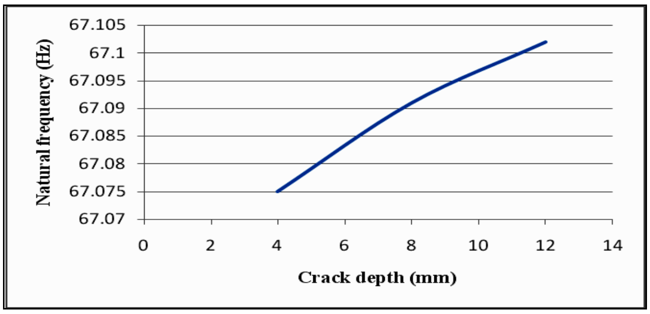

Fig. 5 Crack depth Vs. first Natural frequency for crack at 400mm distance

From above Fig. 2, Fig. 3 and Fig. 4, it is observed that, as crack depth increases natural frequency decreases but from Fig. 5 it is observed that, natural frequency increases as crack depth increases.

Following Fig 6, Fig.7 and Fig. 8 shows the variation of second natural frequency with crack location for crack depth 4mm, 8mm and 12mm respectively.

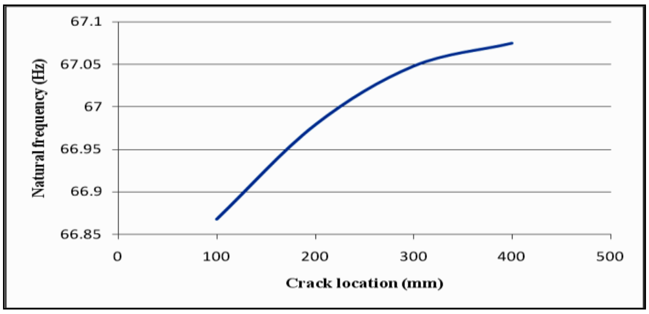

Fig.6 Natural frequency Vs. Crack location for 4mm crack depth

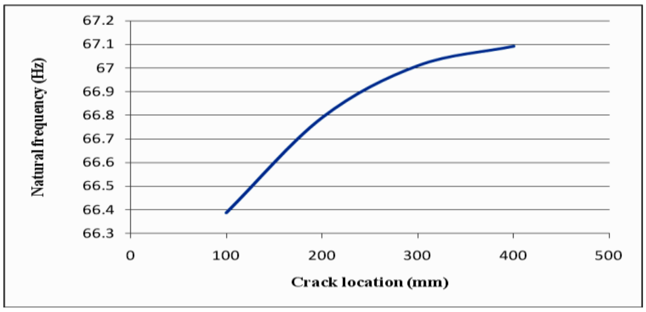

Fig.7 Natural frequency Vs. Crack location for 8mm crack depth

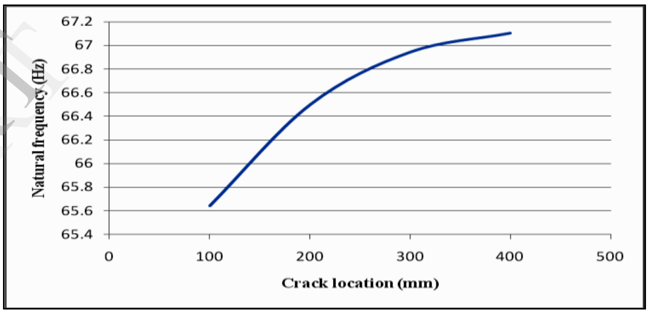

Fig.8 Natural frequency Vs. Crack location for 12mm crack depth

From above Fig. 6, Fig. 7 and Fig. 8, it is observed that, as crack location moves away from fixed end, natural frequency increases gradually.

2) For loading codition

For the analysis of cracked cantilever beam under loading condition, Root Mean Square (RMS) values, Crest factor and Peak values of acceleration are calculated from the time domain data obtained from FFT analyzer.

Formulae used for calculation of Peak values, Root Mean Square (RMS) values and Crest factor are given in following equations,

$$peak = \frac{1}{2}(\max(x(t)) - \min(x(t))) \quad (1)$$

$$RMS = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x(i) - \bar{x})^2} \quad (2)$$

$$CrestFactor = \frac{peak}{RMS} \quad (3)$$

ISSN: 2278-0181
Vol. 3 Issue 5, May - 2014

Where,

max(x(t)) = maximum acceleration

min(x(t)) = minimum acceleration

N = total number of data

x(i) = instantaneous acceleration

$\bar{x}$ = average acceleration

Following Table III shows the values of Peak, Root mean square and crest factor calculated using equation (1), equation (2) and equation (3) respectively.

TABLE III. RESULTS OF CRACKED BEAM UNDER LOADING

Crack location (mm)	Crack depth (mm)	Peak	RMS	Crest Factor
Healthy	Nill	516.653	339.120	1.52
	4	663.555	339.489	1.95
100	8	781.085	339.882	2.30
	12	769.376	340.051	2.26
	4	525.955	310.663	1.69
200	8	526.250	323.561	1.44
	12	526.834	339.139	1.55
	4	515.002	339.007	1.51
300	8	676.975	339.416	1.99
	12	826.387	339.583	2.43
	4	866.112	347.394	2.49
400	8	707.763	340.218	2.08
	12	658.608	339.777	1.93

Following Fig. 9, Fig. 10, Fig 11 and Fig. 12 shows the variation of Root Mean Square (RMS) of acceleration with crack depth for crack located at 100mm, 200mm, 300mm and 400mm distance from fixed end respectively.

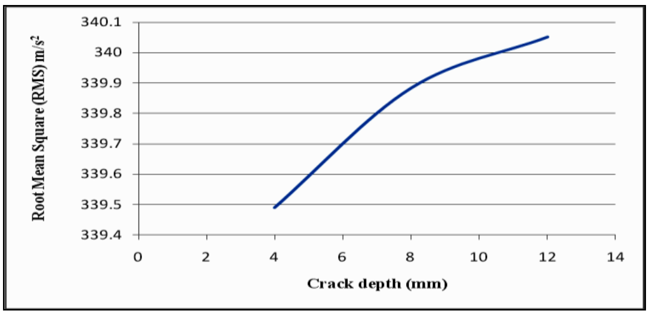

Fig. 9 RMS Vs Crack depth for crack at 100 mm distance

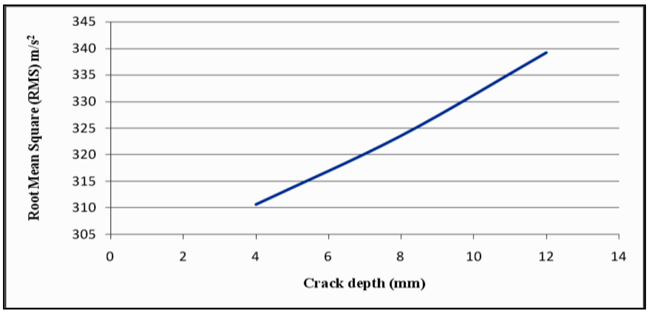

Fig.10 RMS Vs Crack depth for crack at 200 mm distance

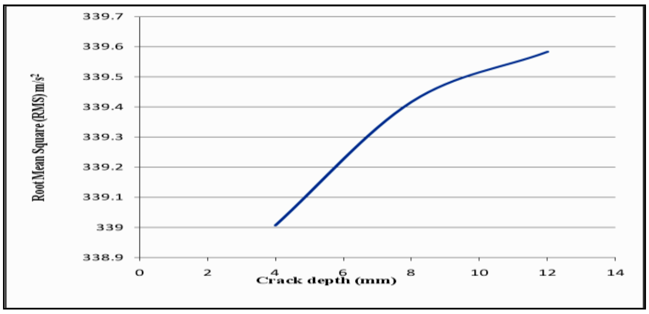

Fig.11 RMS Vs Crack depth for crack at 300 mm distance

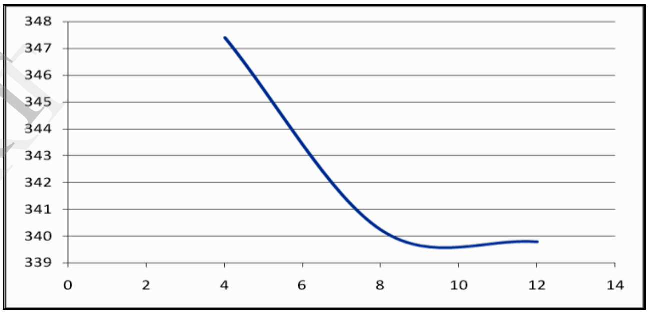

Fig.12 RMS Vs Crack depth for crack at 400 mm distance

From above Fig. 9, Fig. 10, Fig. 11, it is observed that, as crack depth increases Root Mean Square of acceleration increases for crack located at 100mm, 200mm and 300mm distance respectively. But for crack located at 400mm distance from fixed end, as crack depth increases Root Mean Square of acceleration decreases up to approximate crack depth of 9mm and beyond that crack depth it increases slightly, as shown in Fig.12.

IV. CONCLUSIONS

Detailed experimental investigations of the effects of cracks on the first three modes of vibrating cantilever beams have been presented in this paper. The vibration behavior of the beams is shown to be very sensitive to the crack location, crack depth.

From experimental measures of cracked cantilever under no load, it is found that, as crack depth increases natural frequency decreases. Also, when crack location moves away from fix end the natural frequency increases.

From experimental measures of cracked cantilever under load of spherical object (which is dropped from a 400 mm height), it is found that, as crack depth increases the Root Mean Square of acceleration also increases for crack locations of 100mm, 200mm and 300mm. But for crack location of

400mm, as crack depth increases the Root Mean Square of acceleration decreases.

ACKNOWLEDGMENT

The authors would like to acknowledge the Excel Engineers Ltd. Sangali (India) for providing the test samples of Cantilever beam required for the experimentation. The gratitude is also extended to SKN Sinhgad College of Engineering, Pandharpur for providing facilities during experimentation.

REFERENCES

[1] Kaushar H. Barad, D. S. Sharmaa, Vishal Vyas, "Crack detection in cantilever beam by frequency based method", (Procedia Engineering, vol. 51, (2013), pp. 770 – 775)

[2] D.K. Agarwalla, D.R. Parhi, "Effect of Crack on Modal Parameters of a Cantilever Beam Subjected to Vibration", (Procedia Engineering, vol. 51, (2013), pp.665 – 669)

[3] Irshad A Khan, Dayal R Parhi, "Finite Element Analysis of Double Cracked Beam and its Experimental Validation", (Procedia Engineering, vol. 51, (2013), pp. 703 – 708)

[4] Dong Wei,YinghuaLiu, Zhihai Xiang, "An analytical method for free vibration analysis of functionally graded beams with edge cracks", (Journal of Sound and Vibration, vol. 331, (2012), pp.1686–1700)

[5] A.L.Gawali, Sanjay C. Kumawat, "Vibration Analysis Of Cracked Cantilever Beam With Suitable Boundary Conditions",(International Journal of Research in Engineering, IT and Social Sciences, vol.2, (2012), pp. 52-69)

[6] F. Nazari, S. Baghalian, "A New Method for Damage Detection in Symmetric Beams Using Artificial Neural Network and Finite Element Method", (International Journal of Engineering and Applied Sciences (IJEAS), vol.3, (2011), pp.30-36)

[7] Celalettin Karaagac, Hasan Ozturk, Mustafa Sabuncu, "Free vibration and lateral buckling of a cantilever slender beam with an edge crack: Experimental and numerical studies", (Journal of Sound and Vibration, vol. 326, (2009), pp. 235–250)

[8] Jinhee Lee, "Identification of multiple cracks in a beam using vibration amplitudes", (Journal of Sound and Vibration, vol. 326, (2009), pp. 205–212)

[9] Jinhee Lee, "Identification of multiple cracks in a beam using natural frequencies", (Journal of Sound and Vibration, vol. 320, (2009), pp. 482–490)

[10] K. Mazanoglu, I.Yesilyurt, M.Sabuncu, "Vibration analysis of multiple-cracked non-uniform beams", (Journal of Sound and Vibration, vol. 320, (2009), pp. 977–989)

[11] Shuncong Zhong, S. Olutunde Oyadiji, "Analytical predictions of natural frequencies of cracked simply supported beams with a stationary roving mass", (Journal of Sound and Vibration, vol. 311, (2008), pp. 328–352)

[12] Sadettin Orhan, "Analysis of free and forced vibration of a cracked cantilever beam", (NDT&E International, vol. 40, (2007), pp. 443-450)

[13] Samer Masoud Al-Said, "Crack identification in a stepped beam carrying a rigid disk", (Journal of Sound and Vibration, vol. 300, (2007), pp. 863–876)

[14] D.A. Mendelsohn, "Free vibration of an edge-cracked beam with a Dugdale–Barenblatt cohesive zone", (Journal of Sound and Vibration, vol. 292, (2006), pp. 59–81)

[15] D.P. Patil, S.K. Maiti, "Experimental verification of a method of detection of multiple cracks in beams based on frequency measurements", (Journal of Sound and Vibration, vol. 281, (2005), pp. 439–451)

[16] H. Nahvi, M. Jabbari, "Crack detection in beams using experimental modal data and finite element model", (International Journal of Mechanical Sciences, vol. 47,(2005), pp. 1477–1497)

[17] G.M. Owolabi, A.S.J. Swamidas, R. Seshadri, "Crack detection in beams using changes in frequencies and amplitudes of frequency response functions", (Journal of Sound and Vibration, vol. 265, (2003), pp. 1–22)

[18] S. P. Lele and S. K. Maiti, "Modelling of Transverse Vibration of Short Beams for Crack Detection and Measurement of Crack Extension", (Journal of Sound and Vibration, vol. 257, (2002), pp.559-583)

[19] V.P. Singh, "Mechanical Vibrations", Dhanpat Rai Publication, 3rd, Edition (2011)