VIBRATION ANALYSIS OF SIMPLY SUPPORTED BEAM WITH 'V' NOTCH CRACK

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Abstract - ***Dynamic behavior of simply supported cracked beam subjected to loading condition is analyzed in this paper. A systematic approach has been adopted in the present investigation by FEA Software ANSYS 11 for evaluation of natural frequencies and mode shapes. A simple elastic simply supported beam with crack at the different locations and also having different crack depth is considered for the modal analysis. It is found that the frequency of beam when the crack is in the middle position is less than the frequency with crack near the end position and the natural frequency of beam decreasing with increasing of crack depth due to decreasing of beam stiffness at any location of crack in beam. The beam is of mild steel material having properties as Young's modulus (E)= 210 GPA, Poisson's ratio= 0.28, density= 7860kg/mm³***

Keywords— Crack, crack depth, crack location, loading condition.

1. Introduction

A structure is subjected to different types of loadings such as tension, bending, torsion or combined loads of tension and torsion or bending and torsion. Region where stress increase known as local stress concentrations, in this regions cracks are developed with an extremely high magnitude of stresses. Under repeated loading, cracks may develop at the surface and grow across the section. The presences of crack not only cause a local variation in the stiffness but it also affects the mechanical behavior of the entire structure to a considerable extent. A crack or local defect affects the vibration response of structural member. It results in changes of natural frequencies and mode shapes. Also crack may be classified on the basis of geometry and orientation as cracks parallel to shaft axis are known as longitudinal cracks, cracks that are open and close when affected part of material is subjected to alternative stresses are known as breathing crack, crack which are perpendicular to the axis of shaft are known as transverse crack, cracks on surface which are not visible known as sub-surface crack, crack which appear on the surface are known as surface crack. Surface cracks either circumferential or semi elliptical shape. Modal analysis is a worldwide used methodology that allows fast and reliable identification of system dynamics in complex structures. In the last decades several methods have been developed in quest to improve accuracy of modal models extracted from test data and to enlarge the applicability of modal analysis in industrial context. Structures vibrate in special shapes called mode shapes when excited at their resonant frequencies. A mode shape is the characteristics deformation shape defined by relative amplitudes of the extreme positions of vibration of a system at a single natural frequency. The research work in two decades has been published on the detection and diagnosis of crack developed by using vibration and acoustic methods. The literature survey of some papers given below: Hai-Ping Lin [2] has studied an analytical transfer matrix method, is used to solve the direct and inverse problems of simply supported beams with an open crack. The crack is modeled as a rotational spring with sectional flexibility. The natural frequencies of a cracked system can easily be obtained through many of the structural testing methods. When any two natural frequencies of a cracked simply supported beam are obtained from measurements, the location and the sectional flexibility of the crack can then be determined from the identification equation and the characteristic equation. Shuncong Zhong et.al.[4] has studied Natural frequencies of a damaged simply supported beam with a stationary roving mass. The transverse deflection of the cracked beam is constructed by adding a polynomial function, which represents the effects of a crack, to the polynomial function which represents the response of the intact beam. Kevin D. Murphy et.al. [5] has investigated vibration and stability characteristics of a cracked beam translating between fixed supports Using Hamilton's principle and elementary fracture mechanics, the equations of motion for the beam are developed. Throughout this analysis it is assumed that the crack is shallow and always remains open, i.e., crack closure and the associated impact conditions are not considered. In addition to describing the change in stiffness, fracture mechanics is also used to develop a loading criterion that signals the initiation of crack closure. B. Faverjon et.al. [6] has studied the damage detection, based on the constitutive relation error updating method, is used for the identification of the crack's location and size in a simply-supported beam. The cracked beam is modeled by taking into account the flexibility due to the presence of the open transverse crack and by reducing the second moment of area of the element at the crack's location. J-J. Sinou et. al. [10] analyzed the influence of transverse cracks in a rotating shaft. In order to conduct this study, the dynamic response of a rotor with a breathing crack is evaluated by using the alternate frequency/time domain approach. It is shown that this method evaluates the nonlinear behavior of the rotor system rapidly and efficiently by modeling the breathing crack with a truncated fourier series. J. Fernandez-sadez et.al [11] has studied the flexibility influence function method which is used to solve the problem leads to an eigen value problem formulated in integral form. The influence of the crack was represented by an elastic rotational spring connecting the two segments of the beam at the cracked section. P. K. Jena et. al. [12] analyzed the changes in natural frequencies of multi cracked slender Euler Bernoulli beams. The spring model of crack is applied to establish the frequency equation based on the dynamic stiffness of multiple cracked beams. Theoretical expressions for beams by natural frequencies are formulated to find out the effect of crack depths on natural frequencies and mode shapes. It is found that, any decrease in the natural frequency is largest if the cracks are near to each other; when the distance between the cracks increases the frequencies of the beam natural vibrations also tend to the natural vibration frequencies of a system with a single crack

2. METHODOLOGY AND VALIDATION OF SIMPLY SUPPORT CRACKED BEAM:

The numbers of specimens of beam used for experimentation are 13. Out of 13 specimens one is healthy and remaining specimens are having cracks at different locations with different crack depth having constant crack width and crack length. Following table 1 shows specimens having different crack locations with different crack depth.

Table No.1: Specimens with different crack locations and different crack depth

Specimen	Crack Location (mm)	Crack Length(mm)	Crack Width (mm)	Crack Depth (mm)			
1.	120	20	1.5	0	2	6	10
2.	220	20	1.5	0	2	6	10
3.	320	20	1.5	0	2	6	10
4.	420	20	1.5	0	2	6	10

2.1 Numerical Approach (Finite Elements Method)

In this method, First natural frequency of the cracked beam under the loading condition is determined by using the ANSYS program (ver.11). The three dimensional model were built and the element (Solid Plane 42) were used. A sample of meshed beam is shown in Fig. 1.

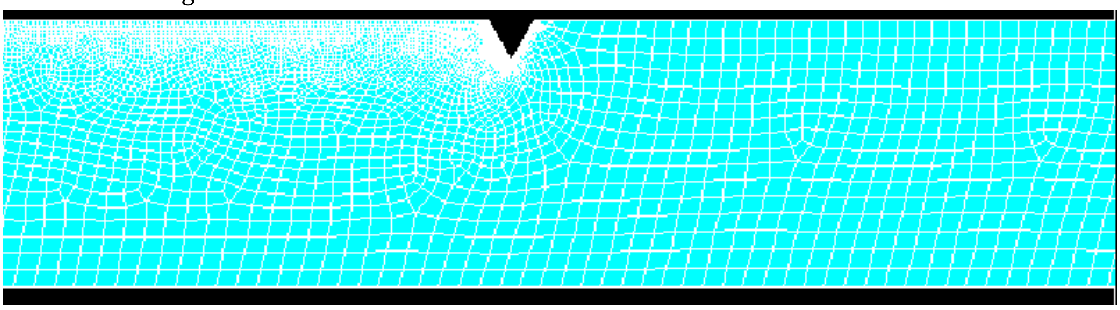

Fig.1. Meshed beam with 'v' notch crack

2.2 Experimental Approach

Experimental Analysis plays a vital role in the research work. Experimental Analysis is being carried out to justify the validation of theoretical analysis and for localization and identification of crack. For the analysis, the experimental setup is made to measure the Natural frequency for healthy and cracked simply supported beam under loading condition. Mild steel beam specimen of length 840 mm, width 20 mm and height 20 mm is selected for the experimental analysis

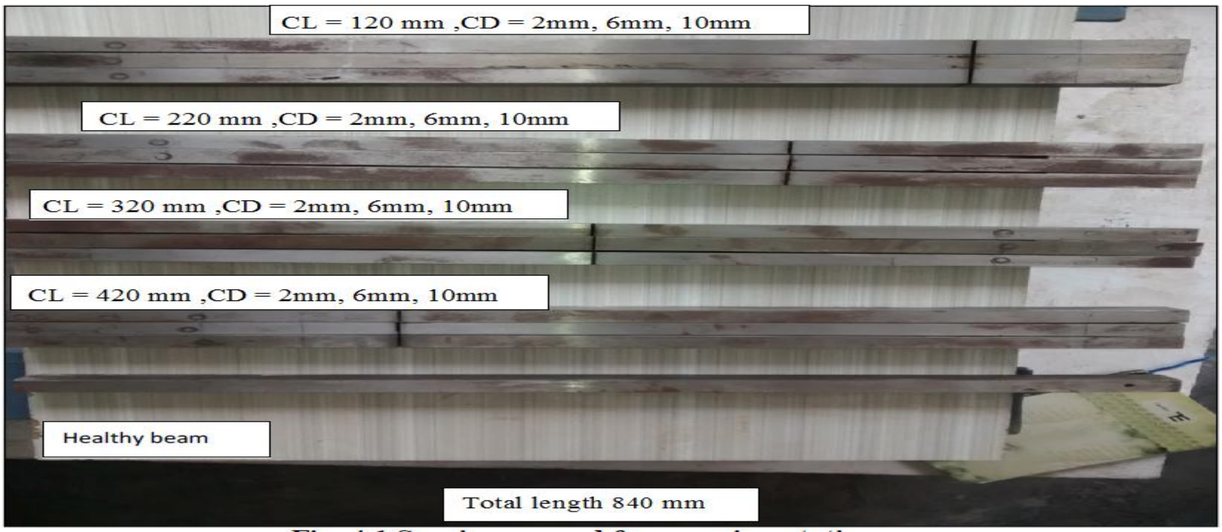

Fig.2.Specimens with different crack location and crack depth

Results obtained from FEA (ANSYS) metod and Experimental method under the loading condition for first natural frequeny are as follows

Table No.2: Natural Frequencies at different crack location and crack depth

Sr. No.	Crack location (mm)	Crack Depth (mm)	Frequency (Hz)		%Error
			ANSYS	EXPERIMENT	
1	0 (Healthy)	0	103.51	97.656	5.65
2.	120	2	94.044	87.89	6.54
		6	77.271	73.24	5.21
		10	71.865	68.36	4.87
3	220	2	84.136	78.125	7.14
		6	72.646	68.359	5.90
		10	68.975	61.035	11.51
4	320	2	98.957	87.89	11.18
		6	85.022	78.13	8.10
		10	76.763	73.24	4.58
5	420	2	89.221	83.01	6.95
		6	80.425	70.80	11.96
		10	68.216	63.48	6.94

From above ANSYS and Experimental results, graphs are plotted to find out the effect of crack depth and crack location under the loading condition on natural frequencies.

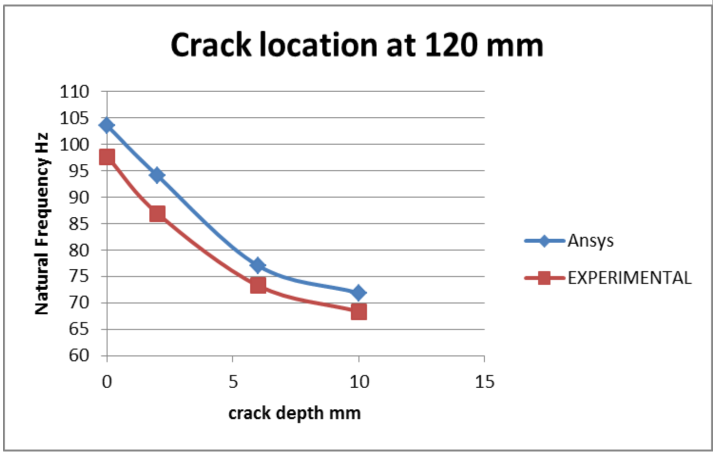

Fig.3. Effect of crack depth on frequency at CL 120mm

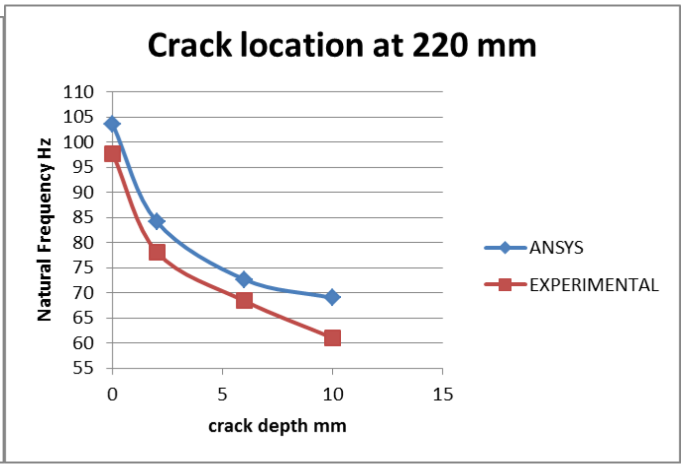

Fig.4. Effect of crack depth on frequency at CL 220mm

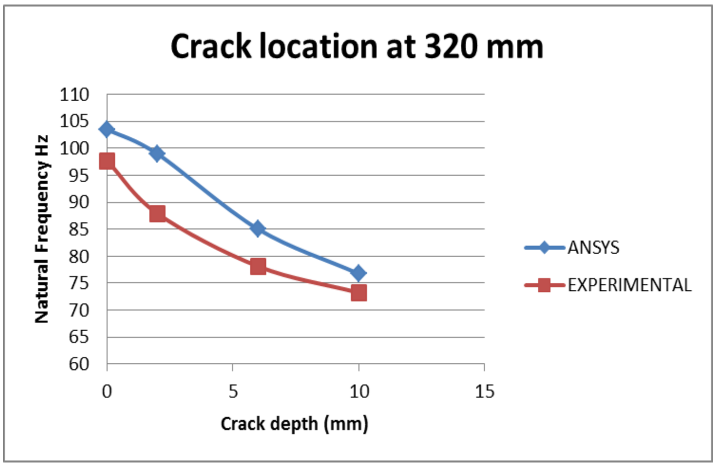

Fig.5. Effect of crack depth on frequency at CL 320mm

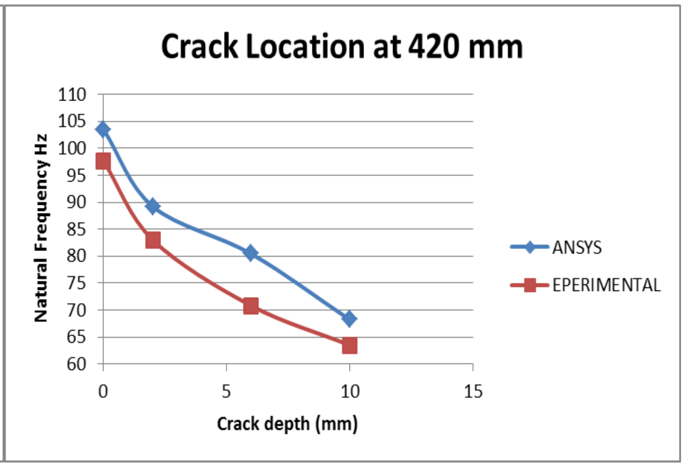

Fig.6. Effect of crack depth on frequency at CL 420mm

Following table 3 shows, the comparison of experimental and ANSYS results of amplitude for cracked simply supported beam under loading condition. An ANSYS result shows good agreement with experimental results. The average percentage error is 10.50

Table No.3: Amplitude at different crack location and crack depth

Crack Location (mm)	Crack depth (mm)	Vibration Amplitude (m/s2)		Percentage error (%)
		ANSYS results	Experimental results	
0.0 (Healthy)	0	0.8717	0.731	16.14
120	2	0.8925	0.788	11.67
	6	0.8935	0.796	10.91
	10	0.8958	0.813	9.24
220	2	0.8756	0.764	12.74

	6	0.8790	0.790	10.125
	10	0.8850	0.823	7.005
320	2	0.8720	0.753	13.64
	6	0.8738	0.783	10.39
	10	0.8759	0.82	6.38
420	2	0.8906	0.827	7.14
	6	0.8936	0.836	6.44
	10	0.8950	0.857	4.24

From above ANSYS and Experimental results, graphs are plotted to find out the effect of crack depth and crack location under the loading condition on amplitude.

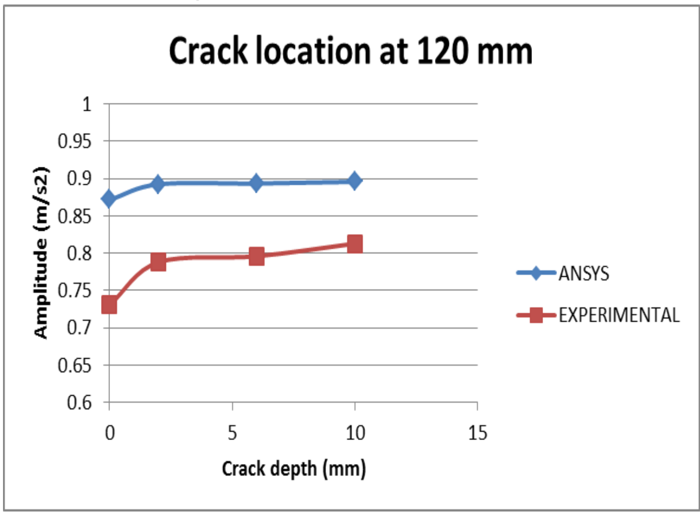

Fig.7. Effect of crack depth on frequency at CL 120mm

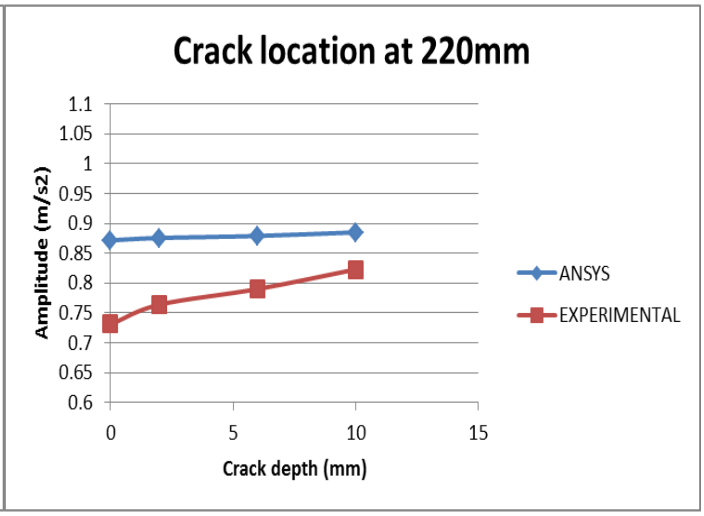

Fig.8. Effect of crack depth on frequency at CL 220mm

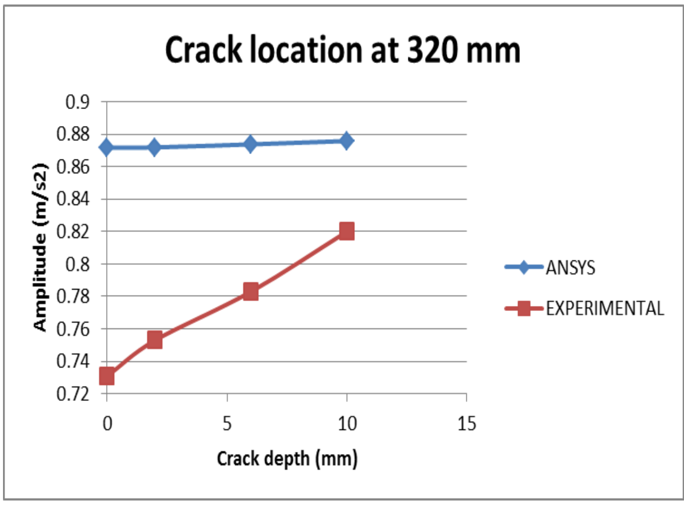

Fig.9. Effect of crack depth on frequency at CL 320mm

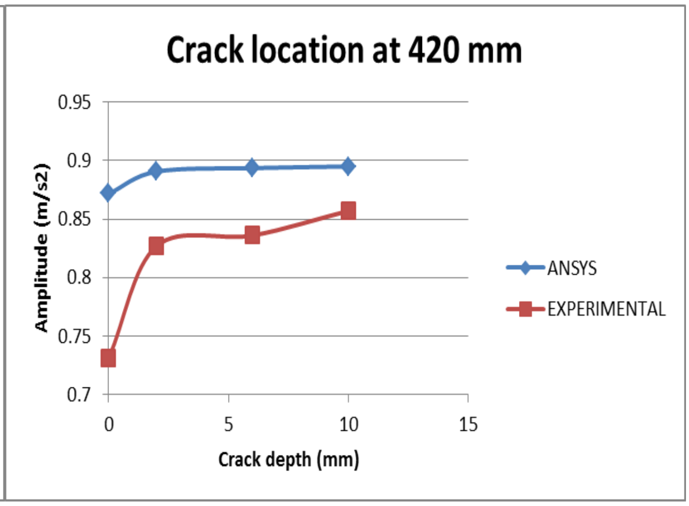

Fig.6. Effect of crack depth on frequency at CL 420mm

3. RESULT AND DISCUSSION

The vibration results of the beam included the effect of crack size, crack location. The method studied to evaluate the natural frequency of beam with crack effect, by using ANSYS Program Version 11. Above graphs shows ANSYS and experimental results for natural frequency and its amplitude and how natural frequency as well as its amplitude changes with crack depth 2mm, 6mm, 10mm for different crack position 120mm, 220mm, 320mm, 420mm. Natural frequency decreases with increase in crack depth for same crack position because of stiffness of beam decreases. Amplitude increases with increase in crack depth for same crack position.

4. CONCLUSIONS

1] The crack causes decrease in the natural frequencies of the beam.

2] The crack also causes effect on the stiffness of the beam, which affect the frequency of the beam. So, as the crack depth increasing, the stiffness of beam will decrease, due to which the natural frequency of the beam is decreasing.

3] If crack position is near the middle of the beam, it has more effect on the stiffness and natural frequency of beam as compared to other positions of cracks (near to the ends of the beam), i.e. natural frequency of beam when the crack in the middle position, it has a lower frequency of beam as compared to other positions of cracks on beam.

4] Amplitude increases as crack depth increases.

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