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ANALYSIS OF CRACK IDENTIFICATION IN BEAM USING FINITE ELEMENT METHOD

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ABSTRACT

Crack in any structure changes the dynamic behaviour of the structure and by examining this change location and severity of the crack can be identified. Non-destructive testing (NDT) methods are used for detecting the location and severity i.e. crack size but these techniques are costly and time consuming. Modal parameters like natural frequency, mode shape can be used to detect the crack in beams. The present work is aimed for detection of open transverse crack in a Euler Bernoulli beam. The crack considered is an open crack and the analysis is made for linear behaviour of the beam. Finite element method is adopted for the dynamic analysis of the beam. Additional flexibility coefficients of the cracked beam element are computed using 6-point Gaussian quadrature and theories of fracture mechanics. The total flexibility matrix is obtained by adding the additional flexibility coefficients to the intact element flexibility matrix. Then from the total flexibility matrix, overall flexibility matrix is obtained. Stiffness matrix of the cracked element is derived from the overall flexibility matrix of the element for the analysis of an Euler Bernoulli beam. The first four natural frequencies and the corresponding mode shapes of vibration are obtained by dynamic analysis solving the Eigen value problem using a FORTRAN code. These natural frequencies are used for the crack detection. 3D graphs of normalized frequency (cracked beam frequency/intact beam frequency) in terms of crack depth and crack location are plotted. The intersection of these contours gives the crack depth and crack location..

Keywords: *FORTRAN, Non-destructive testing (NDT), Gaussian quadrat, intact beam frequency and contour.*

I. INTRODUCTION

Civil structures in its lifetime are subjected to various dynamic loads like earthquake load, seismic load etc. which may act separate or in combination of these loads and hence an early detection of cracks are very important as these may lead to catastrophic failure leading to heavy loss of life and property. Crack identification methods are mainly based on changes in natural frequency or mode shapes. NDT methods are once used for the crack detection but these methods requires the location of damage before using these techniques and the damage part should be accessible which makes the work very time consuming in case of pipelines and long beams. These drawbacks have led to the development of global vibration based damage detection methods. In crack some materials are removed during the loading which leads to decrease in stiffness and increase in damping and a reduction in the natural frequency and these shifts are used for locating the crack and its severity.

The use of global vibration based damage detection methods instead of Nondestructive testing is due to the fact that natural frequency of a beam can be measured from any location on the beam offering scope for the development of a fast and global Nondestructive evaluation technique. These have led to considerable saving in time, labour and cost making it very effective. In this study Euler Bernoulli beam have been used with both ends free. The crack assumed is a transverse and open. All the numerical analysis of the beam has been done with suitable numerical models with the help of the computer programme.

II. LITERATURE REVIEW

J.K.SINHA et al. [1] (2002) have devoloped a simplified approach to model cracks in beams undergoing transverse vibration which uses EulerBernoulli beam elements with modifications of flexibility near the cracks and this developed model was inturn used to estimate the crack size and location

H.NAHVI et al. [2] (2005) have proposed an approach to identify crack location and depth in a cantilever open cracked based on measured frequencies and mode shapes of the beam. The crack is identified by plotting contours of normalised frequency with normalised crack depth and location and by finding the intersection of contours with constant modal frequency planes

CHAUDHARI et al. [3] have modelled the crack in the beam of constant thickness and linear varying depth as a rotational spring and used frobenius method to detect the crack location and depth based on measured natural frequenci.

III. METHODOLOGY

Comparison study

For comparing the results with Sinha et al [1] (2002) an aluminium beam was taken with the following properties:

—Length of the beam = 1832mm
—Width of the beam = 50mm
—Depth of the beam = 25mm
—Young's Modulus of the beam = 69.79GPa
—Density of the beam = 2600Kg/
—Poisson's ratio = 0.33
—No of elements = 16
—Boundary conditions of the beam = Free-Free
—DOF at each node=2(rotation & translation)

The natural frequencies for the intact and cracked beam for various crack locations and crack depths were found out using the FORTRAN code and were tabulated. These frequencies are then divided by the intact beam frequencies to get required normalised frequencies. Normalised frequencies are then used to plot contours for different modes. Experimental normalised frequency is calculated. Contours corresponding to this normalised frequency are retrieved using MINITAB 16 software. Intercection of these normalised frequency cotours gives the location and depth of the crack.

Table 1 Normalized frequency for varying crack depths and locations for first mode

L1/L	RCD=0.0	RCD=0.1	RCD=0.3	RCD=0.5	RCD=0.7
0.1	1	0.999302	0.99307	0.977385	0.939285
0.2	1	1.000081	0.999865	0.999109	0.996642
0.3	1	0.999857	0.998207	0.993657	0.979471
0.4	1	0.999244	0.993302	0.977162	0.928987
0.6	1	0.999244	0.993301	0.97717	0.92903
0.7	1	0.999864	0.998212	0.993536	0.978788

Table 2 Normalized frequency for varying crack depths and locations for second mode

L1/L	RCD=0.0	RCD=0.1	RCD=0.3	RCD=0.5	RCD=0.7
0.1	1	1.000196	0.999064	0.996139	0.989145
0.2	1	0.999652	0.996144	0.986484	0.95792

0.3	1	1.000209	0.989182	0.964287	0.898516
0.4	1	0.999441	0.994442	0.981281	0.945923
0.6	1	0.999438	0.99444	0.981331	0.946184
0.7	1	0.99875	0.989183	0.964274	0.898469

Table 3 Normalized frequency for varying crack depths and locations for third mode

L1/L	RCD=0.0	RCD=0.1	RCD=0.3	RCD=0.5	RCD=0.7
0.1	1	1.000554	1.000492	1.000089	0.998559
0.2	1	0.998814	0.989856	0.966996	0.910656
0.3	1	0.999698	0.99632	0.987908	0.968117
0.4	1	0.999978	0.997692	0.99142	0.974036
0.6	1	0.999969	0.997686	0.991567	0.974838
0.7	1	0.999712	0.99633	0.98767	0.966896

Table 4 Normalized frequency for varying crack depths and locations for fourth mode

L1/L	RCD=0.0	RCD=0.1	RCD=0.3	RCD=0.5	RCD=0.7
0.1	1	1.000442	0.998731	0.994027	0.981243
0.2	1	0.999246	0.991773	0.973967	0.937484
0.3	1	1.000426	0.999305	0.996319	0.988261
0.4	1	0.99872	0.988934	0.965137	0.912667
0.6	1	0.998719	0.988933	0.96516	0.912831
0.7	1	1.000481	0.999345	0.99531	0.982238

Table 5 Comparison of results

CRACK PARAMETERS (ACTUAL)	**SINHA ET AL ANALYSIS**	**PRESENT ANALYSIS**
CRACK LOCATION = 275mm CRACK DEPTH = 8mm	CRACK LOCATION =299.64mm CRACK DEPTH = 7.082mm	CRACK LOCATION=201.52mm CRACK DEPTH =9mm
CRACK LOCATION = 275mm CRACK DEPTH = 12mm	CRACK LOCATION =274.8mm CRACK DEPTH =11.68mm	CRACK LOCATION =201.52mm CRACK DEPTH =12.75mm

Table 6 Normalized frequency for varying crack depths and locations for third mode

L1/L	RCD=0.0	RCD=0.1	RCD=0.3	RCD=0.5	RCD=0.7
0.1	1	1.002427	1.002183	1.001087	0.997441
0.2	1	0.997425	0.978903	0.938418	0.869172
0.3	1	0.999701	0.992875	0.978516	0.954934
0.4	1	1.000518	0.995588	0.98355	0.958326
0.6	1	1.0005	0.995576	0.983863	0.960007
0.7	1	0.999732	0.992897	0.97802	0.952417

Table 7 Normalized frequency for varying crack depths and locations for fourth mode

L1/L	RCD=0.0	RCD=0.1	RCD=0.3	RCD=0.5	RCD=0.7
0.1	1	1.002343	0.998618	0.989591	0.970531
0.2	1	0.998995	0.98456	0.956847	0.91771
0.3	1	1.002139	0.999596	0.99359	0.981418
0.4	1	0.997346	0.977722	0.938329	0.87964
0.6	1	0.997343	0.97772	0.938387	0.880056
0.7	1	1.002258	0.999681	0.991368	0.968099

IV. CONCLUSION

1. Vibration behavior of beam is very sensitive to crack location, crack depth and mode number. Frequency decreases largely with the increase in crack depth and mode number but in case of crack location it also depends on boundary conditions.
2. The results slightly deviate from the actual parameters due to variation in the analytical and experimental frequencies which are in turn due to the assumptions about damping.
3. It is also seen that error in crack location is more than the crack depth. We are getting more accurate results in the severity cases which are actually more relevant than location as this helps us to decide whether to repair it or not.

REFERENCES

1. *Sinha J.K., Friswell M.I and Edwards S. "Simplified models for the location of cracks in beam structures using measured vibration data", Journal of Sound and vibration., 251(1) (2002): 13-38.*
2. *NAHVI H., Jabbari M., "Crack detection in beams using experimental modal data and finite element model", International Journal of Mechanical Sciences.,47 (2005):pp. 1477–1497.*
3. *Chaudhari T.D., Maiti S.K.," Modelling of transverse vibration of beam of linearly variable depth with edge crack", Engineering Fracture Mechanics 63 (1999), pp.425-445.*
4. *Lee J, "Identification of a crack in a beam by the boundary element method", Journal of Mechanical Science and Technology.,vol. 24 (3) (2010),pp. 801-804.*