Available online at www.sciencedirect.com
ScienceDirect
Procedia Engineering 194 (2017) 509 – 516
Procedia Engineering
www.elsevier.com/locate/procedia

10th International Conference on Marine Technology, MARTEC 2016

Modal Analysis of Cracked Cantilever Beam by Finite Element Simulation

Md. Shumon Mia[a,*], Md. Shahidul Islam[b], Udayan Ghosh[c]

[a] *Lecturer, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh*
[b] *Professor, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh*
[c] *Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh*

Abstract

Any structure in presence of crack is susceptible to failure depending on the mode of vibration. Failure is due to the resonance formed by the superposition of frequency of periodic force acting on structure and the natural frequency of the structure. To be alert about resonance due to periodic load, it is important to determine natural frequency. In this study of modal analysis, natural frequency and mode shapes of transverse vibration for both un-cracked and cracked cantilever beam has been extracted for first three modes. The analysis has been extended to investigate the effect of crack opening size and mesh refinement. For cracked beam, analysis is performed for various crack depth and crack location. As structural discontinuity problems are difficult to solve analytically, leading commercial Finite Element Analysis software - ”Abaqus” is used to perform all the analysis computationally. For modeling un-cracked beam, hexahedral element is used whereas for cracked beam modeling, both hexahedral and wedge elements are selected for better result. In our study we observed that natural frequency reduces with the presence of crack. The amount of reduction varies depending on crack location, depth and crack opening size. Non-dimensional representation highlights that failure criteria largely depend on mode of vibration. The findings of this study can be applied to predict the structural sustainability under varying loads.

Peer-review under responsibility of the organizing committee of the 10th International Conference on Marine Technology.

Keywords: Modal analysis; natural fequency; cracked beam; FEA; Abaqus

1. Introduction

The modal analysis yields different frequencies of vibration for a number of mode shapes. For a cracked structure, modal analysis is of immense importance as Crack creates discontinuities in a structure. Discontinuities in a structure cause special physical characteristics regarding failure of certain structure. A crack in structural member introduces local flexibility that affects the vibration response.

Cantilever beam is one of the most commonly used structural members in ships and offshore platforms. Moreover this structural mechanism is also found in construction of stadium, bridge, buildings, high rise towers and many more structures. So presence of crack in a single cantilever beam may cause the failure of a vast structure. In the presence of discontinuities it is difficult to perform modal analysis of cantilever beam through analytical approach. Finite Element Analysis (FEA) method is the best to date for solving these problems and in this study ”Abaqus” is used to perform all the analysis computationally. Considering the importance of structural discontinuity an extensive research

* Corresponding author. Tel.:+880 1520 090437
E-mail address: shumon.buet09@gmail.com

Peer-review under responsibility of the organizing committee of the 10th International Conference on Marine Technology.
doi:10.1016/j.proeng.2017.08.178

work has been carried out by naval architects, offshore and ocean engineers, hydro dynamists and mathematicians. H. S. Rane, R.B. Barjibhe and A.V. Patil [1] represented a method based on measurement of natural frequencies for detection of the location and size of a crack in a cantilever beam. Numerical calculations had been done by solving the Euler equation for both un-crack beam and cracked beam to obtain first three natural frequencies of different modes of vibration considering various crack positions for the beam. ANSYS 12 software package had been used for finite element analysis of total 10 models where crack opening size was not mentioned. M Quila, S. C. Mondal and S. Sarkar [2] focused on the theoretical analysis of transverse vibration of a fixed beam and investigated the mode shape frequency and then numerically analysed using ANSYS. A model for free vibration analysis of a beam with an open edge crack had been presented. Variations of natural frequencies due to crack at various locations and with varying crack depths had been studied. A parametric study had also been carried out. But there was insufficient information regarding mesh element type, size and refinement to reproduce their work. M. J. Prathamesh and M. A. Chakrabarti [3] studied on "Free Vibration Analysis of Cracked Beam" in which different boundary conditions were considered. The results obtained by experiments performed by previous studies were compared with those obtained by finite element analysis. The analysis was performed using ABAQUS software. Yet the study lacks information regarding effects of crack opening size and mesh refinement. M. Behzad, A. Meghdari and A. Ebrahimi [4] performed study on "A New Approach for Vibration Analysis of a Cracked Beam". In that paper the equations of motion and corresponding boundary conditions for bending vibration of a beam with an open edge crack had been developed by implementing the Hamilton principle. A uniform Euler-Bernoulli beam had been used in that research. The natural frequencies of beam had been calculated using the newly developed model in conjunction with the Galerkin projection method. The results showed that the natural frequencies of a cracked beam reduce by increasing crack depth. An excellent agreement was found between the theoretically calculated natural frequencies and those obtained using the finite element method. Results were represented non-dimensional graphical form but frequency ratio for varying crack location was not investigated in their paper.

In this study, the natural frequencies of a cracked beam have been investigated in details using Finite Element Method. During the study, natural frequency of both un-cracked and cracked cantilever beam has been observed. For cracked cantilever beam three criteria such as different sizes of crack opening, different crack location and different crack depth have been considered. The effect of mesh refinement has also been studied. Moreover the importance of natural frequency at different mode has been studied. In the end, different cases have been compared and deductive decision has been provided using both dimensional and non-dimensional data compilation.

2. Model geometry and validation

2.1. Approach of study

Natural frequency is the frequency at which a system or structure vibrates when subjected to an initial excitation in the absence of any driving or damping force. To determine natural frequency, thus free un-damped vibration is considered. For any cracked structure analysis, the study of resonance is important as it affects the structure in number of ways. When the frequency of applied load becomes equal to associated natural frequency, the structure vibrates theoretically at infinite amplitude leading to failure. To be alert about structural failure due to periodic load, thus it is important to determine resonant frequency.

Modal analysis is performed to determine frequency of vibration for different mode shapes. A system may undergo vibration with different mode shapes depending upon the constraints imposed on it. For modal analysis, a steel cantilever beam of length 3m, width 0.25m and depth 0.2m is considered. Table 1 represents model dimensions and properties of the material used. It is assumed that crack have uniform depth across the width of the cantilever beam. An open edge crack, perpendicular to the longitudinal axis, is present in the cantilever beam. For the study on the behaviour of crack three crack opening sizes 2 mm, 4 mm and 10 mm are considered at first. By analysing the result of crack opening, a certain crack opening is determined for further modelling. Crack is positioned at 0.5m, 1m, 1.5m, 2m and 2.5m from the fixed end for the analysis. For every crack position, crack of varying depth such as 0.05m, 0.075m, 0.1m, 0.125m and 0.15m are taken. Considering these factors, the effect of crack on a cantilever beam is investigated. For all cases, data of first three modes of vibration are taken under consideration.