Harmonic Analysis of Vibration of Double Cracked Cantilever Beam by Using FEM

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Abstract:- Cracks in vibrating component can initiate catastrophic failures. The presences of cracks change the physical characteristics of a structure which in turn alter its dynamic response characteristics. Therefore there is need to understand dynamics of cracked structures. Crack depth and location are the main parameters for the vibration analysis. So it becomes very important to monitor the changes in the response parameters of the structure to access structural integrity, performance and safety. In the current investigation theoretical and finite element method are adopted for receiving vibration signatures (Natural frequencies and mode shapes) cantilever of double cracked cantilever beam structure containing transverse cracks. The presence of cracks a severe threat to the performance of structures and it affects the vibration signatures. The presence of a crack in a structural member introduces a local flexibility that affects its dynamic response. Finite element analysis is carried out by using commercially available software ANSYS to find the relation between the change in natural frequencies and mode shapes for the cracked and un-cracked cantilever beam. Based on convergence study a higher order 3-D, 10-node element having three degrees of freedom at each node, SOLID 187 elements is used in analysis. The effect of crack in the mode shape of beam is analyzed at the vicinity of the crack though magnified view and it is found that the steeper change in the mode shapes at vicinity of crack. These changes in mode shapes and natural frequencies will be helpful in prediction of crack location and its intensity.

I. Introduction

Health monitoring and analysis of damage in the form of a crack in structures like beam are important not only for leading safe operation but also retraining system performance. When a structure suffers from damages, its dynamic properties can change. Cracks are a potential source of catastrophic failure in mechanical systems, civil structures and in aerospace engineering. To avoid the failures which are caused by cracks, a number of researchers have performed extensive investigations over the years to develop structural integrity monitoring techniques.Most of the techniques are based on vibration measurement and analysis because vibration based methods can offer an effective and convenient way to detect cracks in structures. Cracking structures may be dangerous due to their dynamic loadings. So crack detection plays an important role for structural health monitoring applications. Crack diagnosis in vibrating structures has drawn a lot of attention from the science and engineering community in the last three decades. The presence of cracks in a structure, if unetected for longer period of time will lead to the failure of the system and may cause loss of life and loss of resources.Utilization of the dynamic response of the member is one of the techniques, which has been widely accepted for crack diagnosis in different engineering systems. The present chapter emphasizes the various techniques that are being used for fault diagnosis. Engineering structures plays a vital role in the lives of a modern community.They are normally designed to have longer life period. The failure or poor performance of engineering structures may lead to disruption of transportation system or may result in loss of lives and property. It is therefore, very important to ensure that the structural members perform safely and efficiently at all times by monitoring their structural integrity and undertaking appropriate remedial measures. It is required that structures must safely work during its service life. But, damages initiate a breakdown period on the structures. Cracks are amongst the most encountered damage types in the structures. Cracks in a structure may be hazardous due to static or dynamic loadings, so that crack detection plays an important role for structural health monitoring applications. Beam type structures are commonly used in construction and machinery industries. In first phase of the work two transverse surface cracks are included in developing the analytical expressions in dynamic characteristics of structures. These cracks introduce the new boundary conditions for the structures at the crack locations. These new boundary conditions are derived from strain energy equation using castiligiano's theorem. Presence of crack also reduces stiffness of the structures which is derived from stiffness matrix. The detailed analyses of crack modelling and stiffness matrices are presented in subsequent sections. Euler-Bernoulli beam theory is used for the dynamic characteristics of beams with transverse cracks. Modified boundary conditions due to the presence of crack have been used to find out the theoretical expressions for natural frequencies and mode shape for the beams.

LITERATURE REVIEW When any structure suffers from the damages, its dynamic properties can change, especially; crack damage can cause a stiffness reduction, with an inherent reduction in natural frequencies, an increase in modal damping, and a change of the mode shapes. For vibration analysis of cracked beams and possible crack detection, the fracture mechanics procedure is generally preferred. According to the given procedure the crack occurring in a beam would reduce the local stiffness at the location of crack. In using the fracture mechanics model, the local stiffness at the crack section is being calculated using Castigliano's second theorem as applicable to fracture mechanics formulations. The calculated local stiffness is then modeled by a flexural spring for the bending vibration of a cracked beam. To establish the Vibration equations, the crack is represented by two structures connected by flexural spring.

THEORY OF CRACK

Physical parameters affecting Dynamic characteristics of cracked structures:-

Remarkably 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 Added to this presence of a cracking structures modifies its dynamic behavior. The following aspects of the crack greatly influence the dynamic response of structure.

The position of crack.

The depth of crack.

The orientation of crack.

The number of crack

CLASSIFICATION OF CRACK

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 originate 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 general 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.

MODES OF FRACTURE: -

The three basic types of loading that a crack experiences are

Mode I corresponds to the opening mode in which the crack faces separates in direction normal to the plane of the crack and the corresponding displacements of crack walls are symmetric with respect to the crack front. Loading is normal to the crack plane, and tends to open the crack. Mode I is generally considered the most dangerous loading situation

Mode II corresponds to in-plane shear loading and tends to slide one crack face with respect to the other (shearing mode). The stress is parallel to the crack growth direction.

Mode III corresponds to out-of-plane shear, or tearing. It has been observed that the presence of cracks in structures or in machine members cause operational problem as well as premature failure. A number of researchers throughout the world are working on structural dynamics and particularly on dynamic characteristics of structures with crack. The dynamic characteristic comprises of natural frequencies; the amplitude responses due to vibration and the mode shapes. Due to presence of crack the dynamic characteristics of structure changes e.g. there is a reduction in natural frequencies, an increase in modal damping.

FINITE ELEMENT MODELLING AND SIMULATION

The finite element method has been established as a powerful numerical tool because of its broad spectrum of generality and its ease of applicability to rather more complex and difficult problems showing greater efficacy in its solution than that of any other existing similar techniques. This advantage of the method over others has led various research organizations and modern industries to Endeavour the development of general purpose software packages and other in-house codes for solving practical problems of more complex nature. In an effort to make the method more powerful and to address more complicated problems, the finite element analysis programs themselves become extremely complex and computationally involved. These programs are available as black box modules which are to be used with the help of CAD programs. These conventional programs cannot easily be modified to perform a desired task necessitating redesign and rebuild of finite element libraries to suit one's need. Hence there is a requirement for finite element analysis programs to be easily modifiable to introduce new analysis procedures, and new kinds of design of structural components or even emerging technology of new materials whenever needed. In the present investigation, Ansys12 is used to find the natural frequency of the laminated plate with different boundary condition.

FINITE ELEMENT ANALYSIS:-

The finite element analysis is a useful numerical technique that utilizes variation and interpolation methods for modelling and solving boundary value problems such as the one described in this current chapter. The finite element analysis is very systematic and can be useful for model with complex shape. So, the finite element model can be suitably employed for solving vibration based problems with different boundary conditions. Commercial finite element packages are available to address the practical problems. During finite element analysis, the structure is approximated in two ways. First step devotes to dividing the structure into a number of small parts. The small parts are known as finite elements and the procedure adopted to divide the structure is called as discretization. Each element on the structure has usually associated with equation of motion and that can be easily approximated. The each element on the finite element model has end points, they are known as nodes. The nodes are used to connect one element to other. Collectively the finite element and nodes are called as finite element mesh or finite element grid. In the second stage of approximation the equation of vibration for each finite element is determined and solved. The solution for each finite element brought together to generate the global mass and stiffness matrices describing the vibrational response of the whole structure. The displacement associated with the solution represents the motion of the nodes of the finite element mesh. This global mass and stiffness matrices represent the lumped parameter approximation of the structure and can be analysed to obtain natural frequencies and mode shapes of damaged vibrating structures.

MODELLING AND SIMULATION IN ANSYS

The finite element analysis is brought out for the cracked cantilever beam shown in fig 4.2 to locate the mode shape of transverse vibration at different crack depth and crack location. The dimensions of the cracked beams of the current research are as follows. Length of the Beam (L) = 800mm;

Width of the beam (W) = 38 mm;

Thickness of the Beam (H) = 6mm;

Relative crack depth (ς_1 =a1/H) = Varies from 0.25 to 0.5;

Relative crack depth (ς_2 =a2/H) = Varies from 0.25 to 0.5

Relative crack location (β_1 =L1/L) = Varies from 0.625 to 0.875;

Relative crack location (β2 =L2/L) = Varies from 0.125 to 0.9375.

CONCLUSION AND SCOPE FOR FUTURE WORK

Following conclusions are based on above discussions supported in the form of graphical and tabular representation. The crack location and its size strongly influence the mode shapes and natural frequencies of the cracked structures. The noteworthy changes in mode shapes are observed near crack location. The positions of the cracks in relation to each other affect significantly the changes in the natural frequencies vibrations in the case of an equal relative depth of the cracks. When the cracks are located near to each other, the change in the natural frequency tends to increase. The natural frequency of the structure having single crack tends to merge when the crack location is shifted toward the free end for the cantilever. And for case having two cracks, 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. In the case of two cracks of different depths, the larger crack has the most significant effect on the natural vibration frequencies. This is evident for the first natural vibration of a cantilever beam. For further more modes of vibration this is not so clear, because the influence of a crack location at a node is negligible. These changes in mode shapes and natural frequencies will be advantageous in prediction of crack location and its intensity and can further be extended to any multi crack system. Good agreement between theoretical and numerical results is observed.

SCOPE FOR FUTURE WORK

Theoretical and finite element analysis can be estimated for stepped cracked beam. Theoretical and finite element analysis can be valued for composite cantilever beam. Vibration signatures can be used to crack identification of multiple cracked beam using artificial intelligent techniques.

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