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Simply Supported Fibre Glass Composite Beam fault-Crack investigation Based on Natural Frequencies-A Review

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ABSTRACT

Composite beams and beam like elements are important constituents of many structures and used widely in high speed machinery, aircraft and light weight structures. Crack is a damage that often occurs on members of structures and may cause serious failure of the structures. The influence of cracks on dynamic characteristics like natural frequencies, modes of vibration of structures has been the subject of many investigations. However, the parametric studies like effect of geometry, crack location and support conditions on natural frequencies of composite beam are scarce in literature. In the present work, a numerical study using finite element is performed to investigate the free vibration response of composite beams. The finite element software ANSYS is used to simulate the free vibrations.

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I. INTRODUCTION

Beams of different materials like aluminium, iron, steel, and fiber reinforced composite material are widely used in structural purposes in civil, mechanical and other engineering applications. Crack/damage is such an important phenomenon which needs to be studied closely for the safety of structure. The presence of the crack in the structure reduces the stiffness of the structure which in turn reduces the natural frequency of it. Thus dynamic characteristics of the structures are changed. The number of cracks present in the structure, the positions of those cracks and depths of the cracks are important parameters to change the natural frequencies of it. Detection of crack is necessary to ensure that the structure is free from any defect or not.Various techniques are adapted by different authors for the prediction of the crack location and the depth and size of crack. The finite element method is considered as a mathematical tool for the analysis of complicated structures. It is observed in this study that many authors used this method for the modeling of the structure for the analysis. The commercial software package ANSYS is used frequently for the analysis. ANN and fuzzy logic are used also for the prediction of the crack location and size, depth of the crack. In this study, an attempt has been taken to discuss different research papers on the detection and prediction of cracks in different structures by non destructive methods. This study will help any scholar to collect information of some research papers related with cracks in structures.

II. LITERATUREREVIEW

According to **Ostachowicz**and **Krawczuk**(1991) presented a method of analysis of the effect of two open cracks upon the frequencies of the natural flexural vibrations in a cantilever beam. There are types of cracks were considered: doublesided, occurs in the case of cyclic loadings, and single-sided, which in principle occur as a result of fluctuating loadings. It was also assumed that the cracks occur in the first mode of fracture. [3]

Patil and Maitihave developed method for prediction of location and size of multiple cracks based on measurement of natural frequencies has been verified experimentally for slender cantilever beams with two and three normal edge cracks. The analysis is based on energy method and representation of a crack by a rotational spring. [1]

T.D. Chaudhari, S.K. Maiti have modelled of transverse vibration of a beam of linearly variable depth and constant thickness in the presence of an `open' edge crack normal to its axis has been proposed using the concept of a rotational spring to represent the crack section and the Frobenius method to enable possible detection of location of the crack based on the measurement of natural frequencies. The method can also be used to solve the forward problem.

A number of numerical examples are presented involving cantilever beams to show the effectiveness of the method for the inverse problem. The error in the prediction of crack location is less than 2% and size is around 10% for all locations except at the end. Crack sizes 10±50% of section depth have been examined.

[2] **Meng Zhang &JukkaPekkaMatinlinna** as described in paper , Fiber reinforced composites (FRCs) are more and more widely applied in dentistry to substitute for metallic restorations: periodontal splints, fixed partial dentures, endodontic posts, orthodontic appliances, and some other indirect restorations. In general in FRCs, the fiber reinforcement provides the composite structure with better biomechanical performance due to their superior properties in tension and flexure. Nowadays, the E-glass fiber is most frequently used because of its chemical resistance and relatively low cost. Growing interest is being paid to enhance its clinical performance. Moreover, various techniques are utilized to reinforce the adhesion between the fiber and the matrix. Oral conditions set special requirements and challenges for the clinical applications of FRCs. The biomechanical properties of dental materials are of high importance in dentistry, and given this, there is on-going scientific interest to develop E-glass fiber reinforced composite systems. FRCs are generally biocompatible and their toxicity is not a concern. [4]

V.D.Wakchaure et al. as described in paper, “Experimental Investigation of Crack Detection in Cantilever Beam Using Natural Frequency as Basic Criterion” Crack changes the dynamic behaviour of the structure and by examining this change, crack size and position can be identified. Nondestructive testing (NDT) methods are used for detection of crack which are very costly and time consuming. Currently research has focused on using modal parameters like natural frequency, mode shape and damping. To detect crack in beams. In this paper a method for detection of open transverse crack in a slender Euler–Bernoulli beam is presented.

Experimental Modal Analysis (EMA) was performed on cracked beams and a healthy beam. The first three natural frequencies were considered as basic criterion for crack detection. To locate the crack, 3D graphs of the normalized frequency in terms of the crack depth and location are plotted. The intersection of these three contours gives crack location and crack depth. Out of several case studies conducted the results of one of the case study is presented to demonstrate the applicability and efficiency of the method suggested. [5]

Dinesh R. Satputeet al. as described in paper, ‘Vibration Analysis of Multiple Cracked Shaft’, Crack in component if undetected may lead to catastrophic failure of the component. The problem of damage and crack detection in structural components has acquired important role in past few years. For multiple cracked structures the problem of crack sizing and location becomes more complex. The proposed work is on vibration analysis of multiple cracked shafts, beams. An Euler Bernoulli beam fixed at one end with two transverse cracks is considered. The vibration characteristics of the shaft are studied using Experimental Modal Analysis and Finite Element Analysis. The mode shapes and natural frequencies of the beams are studied and their variation with change in position and depth of the crack is also studied. The study shows good agreement of the results obtained using Finite Element Analysis and Experimental Modal Analysis.

III.PROPOSED WORK

In the recent decades, fiber reinforced composite materials are being used more frequently in many different engineering fields. The automobile, aerospace, naval, and civil industries all use composite materials in some way. Composite materials are gaining popularity because of high strength, low weight, resistance to corrosion, impact resistance, and high fatigue strength. Other advantages include ease of fabrication, flexibility in design, and variable material properties to meet almost any application.

To avoid structural damages caused by undesirable vibrations, it is important to determine:

1-Natural frequencies of the structure to avoid resonance;

2- Mode shapes to reinforce the most flexible points or to determine the right positions to reduce weight or to increase damping

During operation, all structures are subjected to degenerative effects that may cause initiation of structural defects such as cracks which, as time progresses, lead to the catastrophic failure or breakdown of the structure. Thus, the importance of inspection in the quality assurance of manufactured products is well understood. Cracks or other defects in a structural element influence its dynamical behaviour and change its stiffness and damping properties. Consequently, the natural frequencies of the structure contain information about the location and dimensions of the damage (Krawczuk, 1995).

That is the case for methods based on vibration responses that allow one to obtain meaningful time and/or frequency domain data and calculate changes in the structural and modal properties, such as resonance frequencies, modal damping and mode shapes, and use them with the objective of developing reliable techniques to detect, locate and quantify damage. Hence, the vibration based damage identification method as a global damage identification technique is developed to overcome these difficulties. Present topic deals with the vibrational analysis of composite simply supported beam and results are validated by using finite element analysis (Ansys).

IV.METHODOLOGY

The analysis is done using Finite Element Method and the simulation is done using ANSYS. The advantage of using the FEM methodology is that unlimited number of stiffeners can be added to the model, which can be placed at any direction inside the plate element. The formulation accepts eccentric and concentric stiffeners of different crosssections.

V. FINITE ELEMENT METHOD

The **finite element method (FEM)** (its practical application often known as **finite element analysis** (FEA) is a numerical technique for finding approximate solutions to partialdifferential equations (PDE) and their systems, as well as (less often) integral equations. Insimple terms, FEM has an in built algorithm which divides very large problems (in terms of complexity) into small elements which can be solved in relation to each other. FEM solvesthe equations using the Galerkin method with polynomial approximation functions. The solution is obtained by eliminating the spatial derivatives from the partial differential equation. This approximates the PDE witha system of algebraic equations for steady state problemsa system of ordinary differential equations for transient problems.

These equation systems are linear if the corresponding PDE is linear and vice versa. Algebraic equation systems are solved using numerical linear algebra methods. The ordinary differential equations that arise in transient problems are numerically integrated using techniques such as Euler's method or the Runge-Kutta method. In solving PDE’s, the major problem is to create an equation that approximates the equation to be analyzed, but is numerically stable, meaning that errors in the input and intermediate calculations do not accumulate and cause the resulting output to be meaningless. There are many ways of doing this, which have their respective pros and cons. The finite element method is considered to be the best way for solving PDE’s over complicated domains (like cars and oil pipelines), but when the domain changes for example in a moving boundary solid state reaction when the desired precision varies over the entire domain, or when the solution is not smooth. For example in a frontal car crash simulation where we need more accurate results in the front of the car and hence we can reduce the simulation cost in the rear end. Another instance is in weather prediction (which is done numerically), where it is more important to have accurate predictions over highly developing nonlinear phenomena (unpredictable natural calamities which happen, like cyclones) rather than relatively calm environment.

Geometric Non-Linearity:

Structures whose stiffness is dependent on the displacement which they may undergo are termed geometrically nonlinear. Geometric nonlinearity is responsible for stiffening of a loaded clamped plate, and buckling behaviour in slender structures and components etc. It is necessary to take these effects into account for the computer simulation to predict the behaviour accurately.

Material Non-Linearity:

Material Nonlinearity refers to the ability for a material to exhibit a nonlinear stress-strain (constitutive) response. Elasto-plastic, hyper-elastic, crushing, and cracking are good examples. Material non-linearity can also include temperature and time dependent effects such as visco-elasticity or viscoplasticity. Material nonlinearity occurs due to some form of internal decomposition, characterized by a gradual weakening of the structural response as an increasing force is applied.

The analysis is done in a numerical way by the ANSYS program, a finite element package, which enables us to solve the linear and the nonlinear PDE’s and thus the modulus of elasticity of the beam material is obtained . ANSYS is modelling and analysis software which helps in the modelling and analysis of required models, a FEM tool. It is used to analyze complex problems in mechanical structures, thermal processes, electrical fields, magnetic, and computational fluid dynamics. ANSYS provides a rich graphics environment, which is used to display results of analysis that re performed.

Forward problem analysis

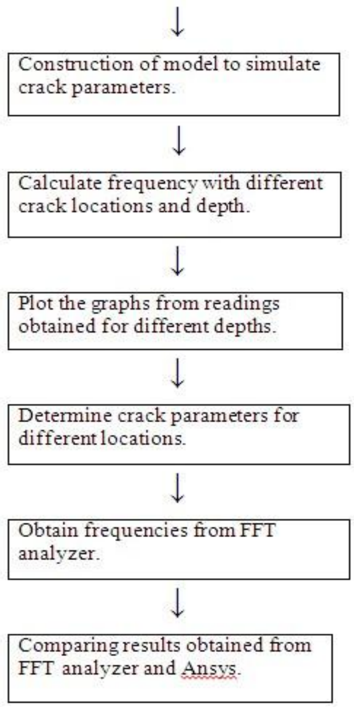
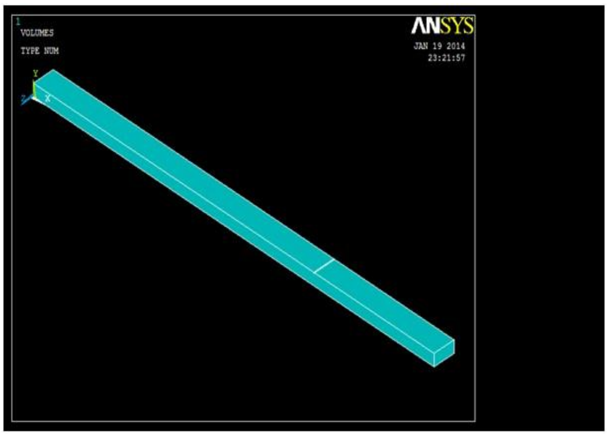


Fig.1: forward problem analysis

The ANSYS 14.0 finite element program was used for free vibration of the cracked beams. A8 node three-dimensional structural solid element under BRICK 185 element. Cantilever boundary condition was considered by constraining all degrees of freedoms of the nodes located on the left end of the beam. The subspace mode extraction method was used to calculate the natural frequencies of the beam.



VI. RESULTS AND CONCLUSIONS

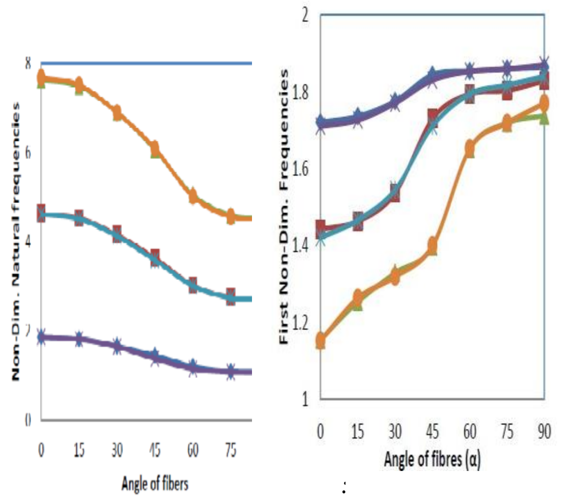


Fig.2: Composite beam- Ansys Model

The presented method has been applied for the free vibration analysis of an intact and cracked composite cantilever beam. Free vibration analysis of a cantilever cracked composite beam has been examined by Krawczuk&Ostachowicz (1995) using finite element method. In addition, the three natural frequencies for various values of orientation of fiber.

The following conclusions can be drawn from the present investigations of the composite beam with crack beam finite element having transverse open crack i.e. v-notch. This element is versatile and can be used for static and dynamic analysis of a composite beam. The in-plane bending frequencies decrease, in general, as the fiber angle increases; the maximum occur at $\alpha = 0°$and decrease gradually with increasing the fiber angle up to a minimum value obtained for $\alpha = 90°$. In case of composite beam with crack, as the angle of fibers (α) increases the value of the natural frequencies also increases. The most difference in frequency occurs when angle of fibers is zero degree. The nondimensional natural frequencies is also depends upon the volume fraction of the fibers. The flexibility due to crack is high when the volume fraction of the fiber is between 0.2 and 0.8 and maximum when the fiber fractions is nearly 0.45. Decrease in the natural frequencies become more intensive with the growth of the depth of crack. The increase of the beam length results in a decrease in the natural frequencies of the composite beam. Boundary conditions have a remarkable influence on the natural frequencies. The natural frequencies for the clamped-clamped support are higher compared to clamped free support condition. The first natural frequency is maximum at crack locations $L1/L = 0.1$ and $L1/L = 0.9$ and minimum at $L1/L = 0.5$. While the second natural frequency is minimum at crack locations $L1/L = 0.3$ and $L1/L = 0.7$. The effect of cracks is more pronounced near the fixed end than at far free end. It is concluded that the first, second and third natural frequencies are most affected when the cracks located at the rear of the fixed end, the middle of the beam and the free end, respectively.

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