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A Review on Dynamic Analysis of Composite Materials with and without Damping

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ABSTRACT *Composite Materials have an extensive use in several areas sector like aerospace, automobile and railroad sectors. The structures made of composite materials often subjected to severe undesirable vibrations. These vibrations may be significantly minimized through appropriate design features by active or passive damping treatments. This paper presents a state of the art review of research methodologies adopted by different researchers around the globe on the dynamic analysis of composite materials, with and without damping and the outcomes.*

KEYWORDS: Dynamic analysis, Composite materials, active damping, passive damping

1. INTRODUCTION:

The composite materials are used in mainly important sectors like aerospace, automobile and railroad sectors. Often these composite structures are subjected to severe vibrations which are undesirable in many industries. These vibrations must be minimized by appropriate design features through active and/or passive damping treatments in order to improve damping performance and reliability levels of structures and systems. Passive damping treatments in composites as a result of the application of embedded visco-elastic materials which have greater advantages in terms of energy efficiency and reliability of machines & structures compared to active systems. Presently, there are a few research works concerning noise and vibration control related to aircraft & plate.

The aim of this review is to analyze different methodologies adopted by the authors for the dynamic analysis of the composite structures and the associated advantages and disadvantages in them. This survey will be helpful for readers to set their research motivations, in this particular area.

2. SOME BASIC THEORIES OF LAMINATED COMPOSITE PLATES

Analysis of the plates rely upon the basic theories and a wide range of laminated composite plate theories have been developed and considerable amount have been reported also as obserbed from an exhaustive literature survey.

A comparison of various laminated composite plate theories have been reported by Liu and Li (1996). Shear deformation theory, Layer-wise theory, Generalized Zig-Zag theory, Quasi layer-wise theory, have been discussed by the authors. It was summarized that Layer-wise theory gives a very good result for distribution of stress in both global and local distribution. Reddy and Robbins (1994) have presented equivalent single layer and layer-wise theories with their finite element models. The authors have approached to find out the most suitable mathematical model with maximization of solution economy without compromising with the solution accuracy. A review on stress based refined shear deformation along with displacement theories of both isotropic and anisotropic laminated plate has been presented by Ghugal and Shimpi (2001), along their advantages and disadvantages. A comprehensive review on shear deformation of plate and shell theories has been highlighted by Reddy and Arciniega (2004). Analysis of laminated composite beams using layer wise displacement theories is focused by Tahani (2007) in his paper. He focused two laminated beam theories for beams with general lamination are devolved in his first theory, an existing layer wise laminated plate theory is adapted to laminated beams. The second theory is used in the development of plate and shell theories. This

theory can also be used in devolving simpler theories such as classical, first and higher order shear deformation laminated beam theories. For assessment of accuracy of these theories, analytical solution for statics bending and free vibration devolved and compare three dimensional finite element analyses for angle ply laminates.

Laminated plate theory according to (Zhang and Yang, 2008) is broadly of two types

(a) Equivalent single layer (ESL) theories, which includes

- Classical lamination theory (CLT)
- The first-order shear deformation theory (FSDT)
- Higher-order shear deformation theories (HSDT)]
- Layer-wise lamination theory (LLT)

(b) Continuum-based 3D elasticity theory.

CLT is based on Kirchoff plate theory and is the simplest one, with the disadvantage that shear deformations have been neglected in it. Thin and moderately thick plate may be used with FSDT, which shows a balance between computational efficiency and accuracy. In this approach the local effects cannot be predicted properly. To overcome this deficiency various HSDT have been developed, whereas LLT assumes displacement in each layer. Inter-laminar stress of composite laminated plate can be predicted using continuum based 3D elasticity theory.

3. MODELING AND ANALYSIS OF LAMINATED COMPOSITE PLATES

Modeling followed by analysis of the laminated composite plate is performed after careful study of the various theories involved, and then choosing the right theory for the problem. Lights have been thrown on several modeling and analysis techniques, by various researchers around the globe and a few them are highlighted here.

Effect of fiber orientation in laminate geometry and its dynamics analysis has been performed by Adam and bacon (1973). Flexural properties of anisotropic fiber composite beam has been analyzed by Adam and Maheri (1994) and the same author analysis adding damping in composite material (2003). Alijani et al. (2013) have focused in an analysis of nonlinear vibration of laminated and sandwich rectangular plates with free edges. Analysis and identification of the multiple parameters of damped mechanical systems have been presented by Adhikari (2000), in his research, where attention has been focused on viscously and non-viscously damped multiple degrees of freedom in linear vibrating system.

Damping modeling of unidirectional composites and laminates has been performed using Ritz method by Berthelot (2006) for describing the flexural vibration of beam & plates. The influence of the beam width as well as influence of frequency has been considered in this analysis, taking into account the laminar effect, unlike to the several two dimensional theories that have been compared earlier, for predicting the specific damping capacity of fiber composite laminate, without considering the laminar effect. Crane and Gillespie (1992) have presented an analysis on modeling of the damping which was implemented using Finite Element Method on mode analysis theory and strain energy method. The influence of fiber orientation on natural frequency and damping loss factor for different modes are analyzed. The result indicates that natural frequency decreases with increase in fiber orientation. Qiao and Yang (2007), in their research, have performed impact analysis of a manufactured Fiber glass Reinforced Plastics (FRP) honeycomb sandwich system with sinusoidal core geometry in the plane and extending vertically between face laminates. In the analysis a higher order impact sandwich beam theory has been adopted by the authors, to carry out the free vibration and impact analysis of the FRP honeycomb sandwich system and the full elastic field under impact can be predicted from the analysis. Pradeep et al.(2007) have performed an analysis on the vibration and thermal buckling behavior of sandwich beams with composite facing and visco-elastic core. Sandwich plate and beam element have been compared in this analysis and composite laminate is modeled as an equivalent

single layer, with a steady state temperature field assumption. Nonlinear analysis for dynamics response of a truss core sandwich plate has been performed by Zhang et al. (2014). In the analysis nonlinear dynamic behavior of a simply supported 3 dimensional Kagome truss core sandwich plate, subjected to transverse and in plane excitation, have been investigated. The governing equation of motion for the truss core sandwich is derived by using the von Karman type equation for the geometric nonlinearity and third order shear deformation theory.

Fenza (2011) has performed both modeling and prediction of visco-elastic damping materials properties for practical use in aeronautical applications. The aim of his research was to identify, define and validate a procedure for experimental analysis to capable to characterize the behavior of structures with embedded visco-elastic damping treatments, as a function of temperature. Trindade and Benjeddon (2002) have performed a comparative performance analysis of hybrid active passive damping treatment using visco-elastic and piezoelectric material, and have drawn conclusion on the advantages and drawbacks of each damping treatment. The authors have presented a detailed parametric and comparative analysis for the hybrid active (piezoelectric) and passive (viscoelastic) damping characteristics. A six node, plane stress mixed finite element model (Ramtekkar and Desai, 2002) has been devolved by using Hamilton energy principal for the natural vibration of laminated composite beams. Continuity of the transverse stress and displacement field has been enforced through the thickness of the laminated beam in the formulation for modeling. Natural frequencies of laminated composite beams obtained through the formulation obtained have been shown in good agreement with data of literature. Diaceno et al.(2013) have proposed a Finite Element Reduction strategy method for composite sandwich plates with visco-elastic layers. The authors have emphasized on a general condensation strategy specially adopted for case of visco-elasticity damped structure, in which a constant (which is frequency and temperature independent) reduction basis, with static residue, has been associated to the applied loads and viscoelastci force is used for the analysis.

4. SUMMARY AND FUTURE SCOPE

Based on an exhaustive literature review it was observed that there is still a limited research on the dynamic analysis of the laminated composite plates in both without and with damping. Further an analysis can be performed to investigate the use of viscoelastic material to the dynamic properties of the same, in without and with damped environment.

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