Engineering Universe for scientific Research and management
ISSN (Online): 2319-3069
Vol. XIII Issue II
February 2021

A REVIEW FINITE ELEMENT VIBRATION OF SANDWICH PLATE

Akhilesh Singh, Prof. Suresh Gupta
Department of Mechanical Engineering, Millennium Institute of Technology Bhopal.

ABSTRACT

In this paper Sandwich panels comprising composite face sheets and a lightweight core, such as polymer foams or balsa wood, are extensively employed in marine structures as they provide superior quasi-static bending stiffness and strength to monolithic beams. The present work deals with static and dynamic response of sandwich beams and sandwich plates consisting of a viscoelastic core layer and face layers subjected to two different boundary conditions. The problem is analysed using three-dimensional finite element methods and is modelled in ANSYS software. Static and dynamic response of the beam is studied by varying the parameters of the core layer such as its geometry. The sandwich plate subjected to point load is analysed statically and dynamically using finite element method under two different boundary conditions, simply supported and clamped- clamped conditions.

KEYWORDS: ***Static; dynamic; mode shape; ANSYS; sandwich***

1. INTRODUCTION

Sandwich structures are composite constructions of alloys, plastics, wood or other materials consisting of a core laminated and glued between two hard outer sheets (skins). The core is in general lightweight foam or solid core, honeycomb, web core, tubular or corrugated/truss core. Foams are usually plastic or ceramic, even the foamed metal; honeycomb, web or corrugated cores are metals or glass-reinforced plastic. Synthetic organic adhesives (epoxies, phenolic or polyesters) are employed to assemble the sandwich components. Facing sheets are usually made from high-strength materials. In all cases of construction, the primary loads are carried by the outer sheets, and the transverse shear loads by the core. Most sandwich structures have superior structural performance. The core separates and stabilizes the outer sheets against buckling under edgewise compression, torsion or bending. Other considerations such as heat resistance or electrical requirements dictate the choice of suitable materials. Sandwich structures have a high ratio of flexural stiffness to weight, resulting in a higher buckling resistance, lower lateral deformations, and higher natural frequencies.

The lack of damping in structural components has led to numerous mechanical failures over a seemingly infinite multitude of structures. For accounting the damping effects, lots of research and efforts have been done in this field to suppress vibration and to reduce the mechanical failures. Since it was discovered that damping materials could be used as treatments in passive damping technology to structures to improve damping performance, there has been a flurry of on-going research over the last few decades to either alter existing materials, or develop entirely new materials to improve the structural dynamics of components to which a damping material could be applied. Vibration control of machines and structures incorporating viscoelastic materials in suitable arrangement is an important aspect of investigation. The use of viscoelastic layers constrained between elastic layers is known to be effective for damping of flexural vibrations of structures over a wide range of frequencies. The energy dissipated in these arrangements is due to shear deformation in the viscoelastic layers, which occurs due to flexural vibration of the structures. Multi-layered cantilever sandwich beam like structures can be used in aircrafts and other applications such as robot arms for effective vibration control. These members may experience parametric instability when subjected to time defendant forces.

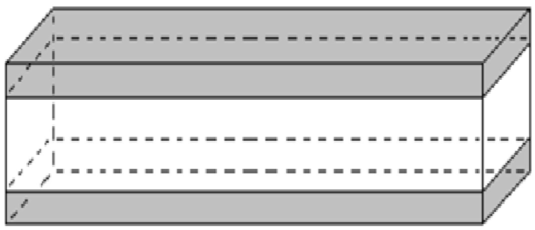

Fig.1. 3-layer sandwich beam

The energy dissipated in these arrangements is due to shear deformation in the viscoelastic layers, which occurs due to flexural vibration of the structures. Multi-layered cantilever sandwich beam like structures can be used in aircrafts and other applications such as robot arms for effective vibration control. These members may experience parametric instability when subjected to time defendant forces. Viscoelastic materials are generally polymers, which allow a wide range of different compositions resulting in different material properties and behavior. Thus, viscoelastic damping materials can be developed and tailored fairly efficiently for a specific application Viscoelastic damping is exhibited in many polymeric and glassy materials and this internal damping mechanism is very important for damping augmentation to reduce vibration and noise in structures. The damping arises from relaxation and recovery of the polymer network after it has been deformed. Because viscoelastic materials exhibit both viscous and elastic characteristics, they hold unique properties. For example, in addition to undergoing an instantaneous displacement, when subjected to a constant force, they also undergo creep over a period of time. Alternatively, the force required to maintain a given deformation decreases over a period of time. This phenomenon is called relaxation. The relaxation function is the stress response to a unit-step strain input. The stress-strain relationship for a viscoelastic material under cyclic loading takes on the form of an ellipse shown in Figure.2

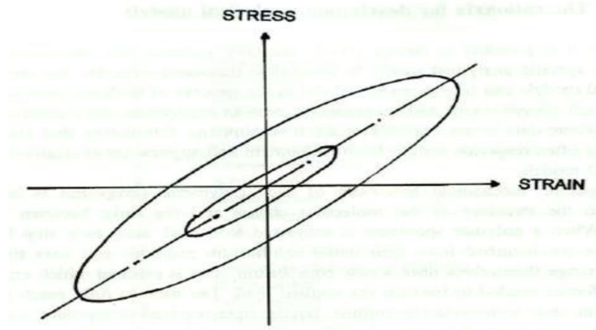

Fig.2 Stress-Strain hysteresis loop for linear viscoelastic material

2. MODELING OF VISCOELASTIC MATERIALS

Modeling of viscoelastic materials unlike structural components which exhibit fairly straight-forward dynamic response, viscoelastic materials are somewhat more difficult to model mathematically. Because most high load bearing structures tend to implement high strength metal alloys, which usually have fairly straight-forward stress-strain and strain-displacement relationships, the dynamics of such structures are simple to formulate and visualize. An engineer or analyst need only take into account the varying geometries of these structures and the loads which are applied to them to accurately model the dynamics because the material properties of the structure and its components are generally well known. However, difficulty arises when viscoelastic materials are applied to such structures. This difficulty is mainly due to the strain rate (frequency), temperature, cyclic strain amplitude, and environmental dependencies between the viscoelastic material properties and their associated effect on a structure’s dynamics (Jones, 2001, Sun, 1995). Additionally, many viscoelastic materials and the systems to which they are applied exhibit nonlinear dynamics over some ranges of the aforementioned dependencies, further complicating the modeling process (Jones, 2001). Typical applications and viscoelastic material characteristics Many polymers exhibit viscoelastic behavior. Viscoelasticity is a material behavior characteristic possessing a mixture of perfectly elastic and perfectly viscous behavior. An elastic material is one in which there is perfect energy conversion, that is, all the energy stored in a material during loading is recovered when the load is removed. Thus, elastic materials have an in phase stress-strain relationship. Figure 1.6a illustrates this concept.

Contrary to an elastic material, there exists purely viscous behavior, illustrated in Figure 1.6b. A viscous material does not recover any of the energy stored during loading after the load is removed (the phase angle between stress and strain is exactly π/2 radians). All energy is lost as 'pure damping.' For a viscous material, the stress is related to the strain as well as the strain rate of the material. Viscoelastic materials have behavior which falls between elastic and viscous extremes. The rate at which the material dissipates energy in the form of heat through shear, the primary driving mechanism of damping materials, defines the effectiveness of the viscoelastic material. Because a viscoelastic material falls between elastic and viscous behavior, some of the energy is recovered upon removal of the load, and some is lost or dissipated in the form of thermal energy. The phase shift between the stress and strain maximums, which does not to exceed 90 degrees, is a measure of the materials damping performance. The larger the phase angle between the stress and strain during the same cycle (Figure the more effective a material is at damping out unwanted vibration or acoustical waves.

3. FINITE ELEMENT METHOD

The Finite Element Method is essentially a product of electronic digital computer age. Though the approach shares many features common to the numerical approximations, it possesses some advantages with the special facilities offered by the high speed computers. In particular, the method can be systematically programmed to accommodate such complex and difficult problems as non-homogeneous materials, nonlinear stress-strain behavior and complicated boundary conditions. It is difficult to accommodate these difficulties in the least square method or Ritz method and etc. an advantage of Finite Element Method is the variety of levels at which we may develop an understanding of technique. The Finite Element Method is applicable to wide range of boundary value problems in engineering. In a boundary value problem, a solution is sought in the region of body, while the boundaries (or edges) of the region the values of the dependent variables (or their derivatives) are prescribed. There are two differential Finite element approaches to analyze structures, namely Force method in which the number of forces (shear forces, axial forces & bending moments) is the basic unknown in the system of equations and displacement method in which the nodal displacement is the basic unknown in the system of equations. The fundamental concept of finite element method is that is that a discrete model can approximate any continuous quantity such as temperature, pressure and displacement. There are many problems where analytical solutions are difficult or impossible to obtain. In such cases finite element method provides an approximate and a relatively easy solutions. Finite element method becomes more powerful when combined rapid processing capabilities of computers.

The basic idea of finite element method is to discretize the entire structure into small element. Nodes or grids define each element and the nodes serve as a link between the two elements. Then the continuous quantity is approximated over each element by a polynomial equation. This gives a system of equations, which is solved by using matrix techniques to get the values of the desired quantities. Selection of materials in designing the structural and/or mechanical components play an important role and is fixed based on the strength, stiffness, cost and other mechanical properties such as hardness, toughness, wear resistance etc.. Materials selected in view of the above requirements may not have internal damping capacity. When the structures are subjected to harmonic loads of high frequencies, conventional damping techniques such as providing external dashpots, arranging dynamic vibration absorbers may not have control on the dynamic response of the structures resulting in failure at resonance frequencies.

Arrangement of soft-core material that requires more energy to deform provides internal damping of structures known as sandwich treatment. Sandwich treatment will reduce the amplitude of oscillation depending upon the location, volume and Mechanical properties of the core layer in the structure. It is also important to study the effect of sandwich treatment on static response of the structure in order to confirm the safe design. The objective of the present research problem is to study the static and dynamic response of sandwich beam, consisting of a viscoelastic core layer and face layers, (where in one case the face layers are structural steel which is an isotropic material and in the other case the analysis is carried out for carbon epoxy composite material) with a) simply supported and b) clamped-clamped boundary conditions. Static and dynamic response of the beam is studied by varying the parameters of the core layer such as its geometry and damping coefficient.

The analysis is also carried out for sandwich plates, where structural steel and viscoelastic materials are used. The layer arrangement is done in two different ways. In one arrangement the core layer is viscoelastic material with 0.02x0.02m slot at its center, the top and bottom faces and the slot of viscoelastic layer are structural steel. In the next arrangement the viscoelastic material of 0.02x0.02m is positioned at the center of the middle layer. For both the arrangements, Static and dynamic response is studied by varying the parameters of the core layer such as its geometry and damping coefficient.

4. CONCLUSION

The static deflection is increasing with value for beam subjected to clamped- clamped and simply supported boundary conditions for same loading. The model frequency values of the beam increased with t2/h value. A hierarchical FEM for free vibration analysis of sandwich plate with parabolic fibers based on the Reddy's high shear deformation theory. The element shape functions were expressed in terms of hierarchical trigonometric functions. The equations of motion of free vibration of thick sandwich plates are obtained by the mean of the Lagrange's equation. The convergence studies were carried out for simply supported and clamped plates and comparisons were made that the hierarchical finite element give very for sandwich plate with parabolic fibers with a reasonably small number of polynomial orders. The effects of thickness ratio, boundary conditions, orientation angle, and material properties on natural frequencies of parabolic fiber composite sandwich plates are presented and discussed for the first time. Not only the natural frequencies are influenced by fiber-orientation angle but the mode shape of composite sandwich plates is also influenced.

REFERENCES

[1] Kar, R.C. and Hauger,W., "Stability of a sandwich beam subjected to a nonconservative force" Computer and structures 46 (1993), pp. 955-958.

[2] Ray,K. and Kar, R.C., "Parametric instability of a sandwich beam under various boundary conditions", Computers and structures 55 (1995), pp. 857-870.

[3] Ray,K. and Kar, R.C., "The parametric instability of partially covered sandwich Beams", Journal of Sound and Vibration 197 (1996), pp. 137-152.

[4] Ray,K. and Kar, R.C., "Parametric instability of a dual cored sandwich beam", Computers and structures 61 (1996), pp. 665-671.

[5] Ray,K. and Kar, R.C., "Parametric instability of a symmetric sandwich beam with higher order effects", Computers and structures 60 (1996), pp. 817-824.

[6] Lin, C.Y., and Chen, L.W., "Dynamic stability of a rotating beam with a constraineddamping layer", Journal of sound and vibration 267 (2002), pp. 209-225.

[7] Trompette, P., Boillot, D., and Ravanel, M.A., "The effect of boundary conditions on the vibration of a viscoelsticlly damped cantilever beam", Journal of Sound and Vibration 60 (1978), pp. 345-350.

[8] Mace, M., "Damping of beam vibrations by means of a thin constrained viscoelastic layer: Evaluation of a new theory", Journal of sound and vibration 172 (1994), pp. 577-591.

[9] Gorrepati, M. and Rao, M.D., " Analysis of modal parameters of adhesively bonded double-strap joints by the modal strain energy method", Journal of Vibration and Acoustics, Trans of ASME 118 (1996), pp. 28-35.

[10] Chen, Q. and Chan, Y.W., "Integral finite element method for dynamical analysis of elastic-viscoelastic composite structures", Computers and structures 74 (2000),pp. 51- 64.

[11] Nayfeh, S.A., "Damping of flexural vibration in the plane of lamination of elsticviscoelastic sandwich beams", Journal of Sound and Vibration 276 (2004), pp. 689-711.