OPEN ACCESS

International
Journal
Of Modern Engineering Research (IJMER)

Damping Of Composite Material Structures with Riveted Joints

T. Subramani[1], K. Udhaya Kumar[2]

[1]Professor & Dean, Department of Civil Engineering, VMKV Engg. College, Vinayaka Missions University, Salem, India.

[2]PG Student of Structural Engineering, Department of Civil Engineering,VMKV Engg.College,Vinayaka Missions University, Salem, India

Abstract: *Vibration and noise reduction are crucial in maintaining high performance level and prolonging the useful life of machinery, automobiles, aerodynamic and spacecraft structures. It is observed that damping in materials occur due to energy release due to micro-slips along frictional interfaces and due to varying strain regions and interaction between the metals. But it was found that the damping effect in metals is quite small that it can be neglected. Damping in metals is due to the micro-slips along frictional interfaces. Composites, however, have better damping properties than structural metals and cannot be neglected. Typically, the range of composite damping begins where the best damped metal stops.In the present work, theoretical analysis was done on various polymer matrix composite (glass fibre polyesters) with riveted joints by varying initial conditions. Strain energy loss was calculated to calculate the damping in composites. Using FEA model, load variation w.r.t time was observed and the strain energy loss calculated was utilised in finding the material damping for Carbon fibre epoxy with riveted joints. Various simulations were performed in ANSYS and these results were utilised to calculate the loss factor, Rayleigh's damping constants and logarithmic decrement.*

Keywords: *Material damping, Energy balanced approach, Damping mechanism, Structural damping factor.*

I. Introduction

Damping capacity is an extent of a material's ability to dissipate elastic-strain energy during mechanical vibration or wave propagation. Complications involving vibration arise in many regions of mechanical, civil and aerospace engineering. The damping of a structural component or element is often a significantly overlooked criterion for good mechanical design. Numerous mechanical failures over a seemingly infinite multitude of structures occurred dueto lack of damping in structural elements.

For accounting the damping effects in a structural material, lots of researches and studies have been done in the field to suppress the vibration and to minimize the mechanical failures. Since it was found that damping materials can be utilised in treatment in passive damping technology to mechanical components and structures to increase the damping performance, there had been a commotion on the on-going research and studies over the last few periods to either alter the existing materials and components, or to develop an entirely new type of material to improve the structural dynamics of components for which damping concept could be applied.

Composite structures are generally polymers, which give various ranges of different compositions which result in different material properties as well as behaviour. Hence, composite damping structures and materials can be developed and tailored quite efficiently for a specific purpose and application. Problems involving vibration and damping occur in many regions of mechanical, civil and aerospace engineering.

Engineering composite structures and materials are generally fabricated using a variety of connections which include bolted, riveted, welded and bonded joints etc. The dynamics of mechanical joints is a topic of special importance due to their strong effect on the performance of the structural material. Moreover, the inclusion of the above mentioned joints play a significant role in the overall system behaviour, particularly the damping level of the components and structures. However, determining damping either by analysis or by experiment is never easy and straightforward keeping in view of the complexity of the dynamic interaction of components. The estimation of damping in beam-like structures using passive damping approach is very essential in problem solving addressed by the present research

II. Composites

Composite materials are naturally occurring materials or synthetically prepared from 2 or more constituent materials with considerably different physical or chemical properties or both which remain isolated and dissimilar at the macroscopic or microscopic scale within the completed structure. The elements are assorted in such a way so that they can retain their distinctive physical state and which are not solvable with each other nor a new chemical compound is formed. One element is known as reinforcing state which is embedded in another phase called matrix. The most visible applications are pavement in roadways in the form of either steel and aggregate reinforced Portland cement or asphalt concrete.

Most of the fibres are utilised as the reinforcing state and are even tougher than the matrix and this matrix is utilised in holding the fibres intact. Examples: Aluminium‘s matrix implanted in boron fibres and an epoxy matrix implanted with glass or carbon fibres. These fibres may be long or short, directionally aligned or randomly orientated, or some sort of mixture, depending on the intended use of the material. Commonly utilised materials for the matrix are polymers, metals, ceramics, carbon and fibres are carbon (graphite) fibres, aramid fibres and boron fibres.

Fibre-reinforced composite materials are further classified into the following:

a) Continuous reinforced fibre.
b) Discontinuous reinforced aligned fibre.
c) Discontinuous fibre-reinforced random oriented.

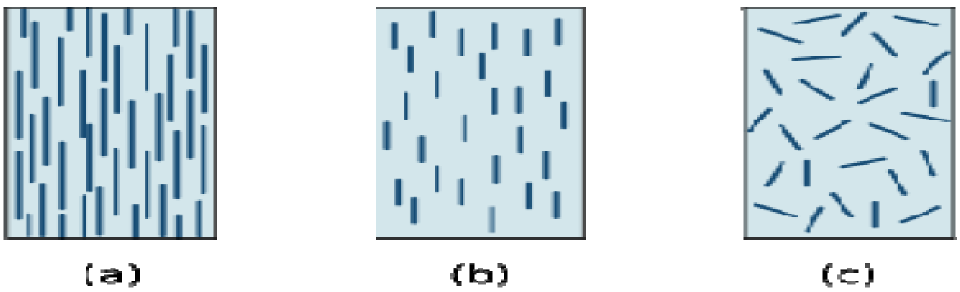


Fig 2 Types of Fibre Reinforced Materials

Composites utilised in this work are Carbon epoxy fibre are shown in figure 2.

Carbon fibre is made up of extremely thin fibres of carbon. It is utilised as an reinforcing agent for many polymer products; the resulting composite material is commonly known as Carbon fibre epoxy. Uses for regular carbon-fibre include applications in the fields of automotive engineering and also aerospace engineering, like Formula One. The toughest and most costly of these essences, carbon nanotubes, are enclosed in some principally polymer baseball bats, car parts and also golf clubs where economically they are available.

Epoxy is a polymer used for thermosetting which is formed by reaction of an epoxide "resin" with polyamine "hardener". Epoxy has a widespread variety of applications, including fibre-reinforced plastic materials and universal purpose adhesives. The uses for epoxy materials are for outer layers which include adhesives, coatings and materials using such composite as those using carbon fibre and fibreglass reinforcements (although polyester, vinyl ester, and other thermosetting resins are generally utilised for glass-reinforced plastic).

The damping rising due to the interactions in-between fibres and matrix can be very huge and are very complex in nature because of many properties of composites which affect the interactions. For example, length, fibre orientation, and interface all affect the damping properties. But the effect of length on damping can be neglected, since it is very small. Damping is generally more when the orientation of fibres is off the axis by 5 to 30 degrees.

III. Modeling and Analysis of the Composite with Rivets

3.1 MODELLING

As discussed earlier, the geometry and the structure of the composite material play an effective role in the reduction in damping. In this paper, a model was prepared using CATIA V5R17.The model prepared was a standard case in which 2 composite laminates were joined using a riveted joint and was discussed thoroughly. An assembled view of this model is shown in figure 3.1.

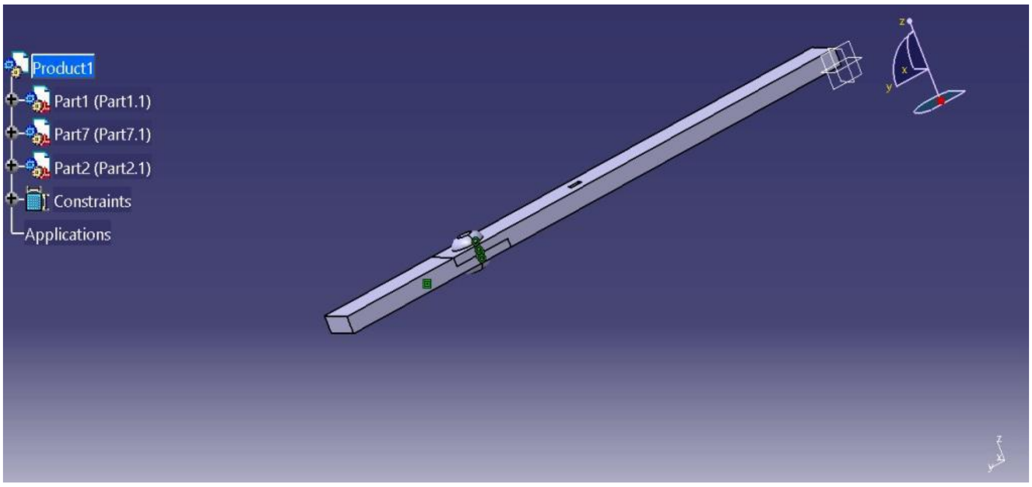


Figure 3.1: Model designed on CATIA V5R17

3.2 HARMONIC RESPONSE ANALYSIS

It is a technique utilised to determine the steady state response of a linear structure to loads that varies sinusoidal with time. The mode superposition method calculations factored mode shapes (eigenvectors) from modal analysis to calculate the structures response. Hence it is known as harmonic response analysis as shown in figure 3.2

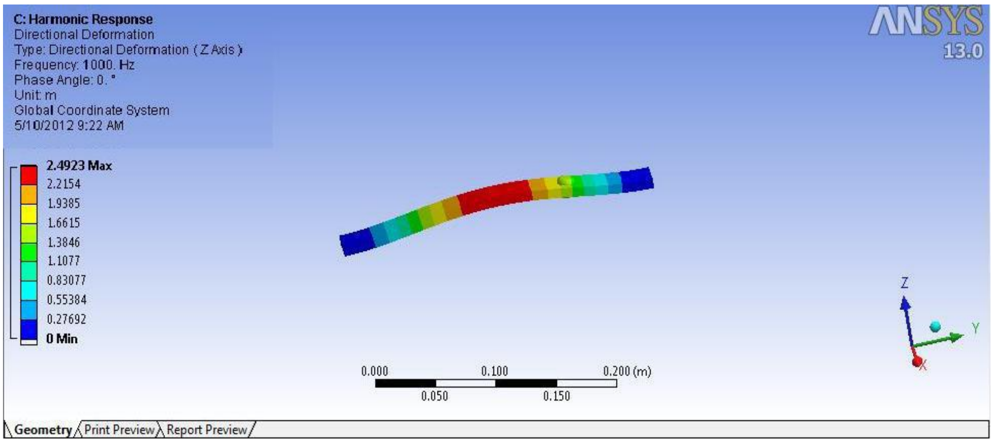


Figure 3.2: Harmonic response analysis of ANSYS model

IV. Modeling of Vibration Damping In Composite Structures

Composite damping or energy dissipation property of vibrating composite structures, refers to a complex physical dynamic nature that is amenable to rheological modal analysis. In a broad class of composite structures, the distinguishing characteristic of the damping mechanism is its strong dependence on the eigen frequencies such that it exhibits little damping at high frequency level. In contrast to the dynamic nature of isotropic materials, a further complication arises in composite domain due to the mutual effects of various parameters, such as code number, degree of isotropism (volume fraction), boundary conditions as well as the vibrating mode number on the damping and stiffness distributions.

As an example, the decreasing of volume fraction of the ber enhances energy dissipation by increasing the loss associated with matrix composite. It might be expected that the natural frequencies of vibrating composite structures and in sequence the damping capacity, can be altered by changing the layer's orientations and stacking sequence, so that the damping nature as a function of frequencies of composites should be further studied. At the present time, it is still difficult to determine accurately the modal characteristics of composite structures (particularly damping parameters) by an analytical approach.

The experimental confirmation prediction is therefore at very least desirable and can be used to form analytically the mathematical model. In turn it can be used to more clearly understand the effect of parameters controlling the dynamics of composite states. Recently, a mathematical model representing the damping capacity of the composite was established. Based on the student distribution approximation of the measured values of damping in the fundamental mode, the modal relationships between the fundamental frequencies and the damping factors were developed in equivalence to the uniform mass damping of isotropic structures.

In the present work, an attempt has been made to improve the convergence characteristics of the model within a wide range of frequencies for different code numbers at two levels of volume fraction. Basically, a weight factor (a) has been introduced for correlating and updating the mathematical model to the experimental data throughout the utilization of the curve fitting response function. This has resulted in generalized quasi-rectangular hyperbolic relationships between the loss factors and the natural frequencies with the confidence level at 99.5%. These results permit the uncoupling of simultaneous equations of motion of composite structures with the lowest residual errors.

In the experimental work, cantilever composite beams made from fiber reinforced plastic FRP are considered as the object of the study for their simplicity and for extensive applications. Various specimens made from three plies, Fig. 1, are utilized for two levels of volume fraction (a) a weakly composite 15% and (b) an average composite 45%.

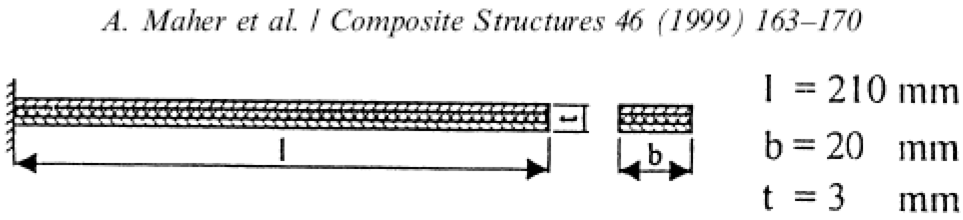


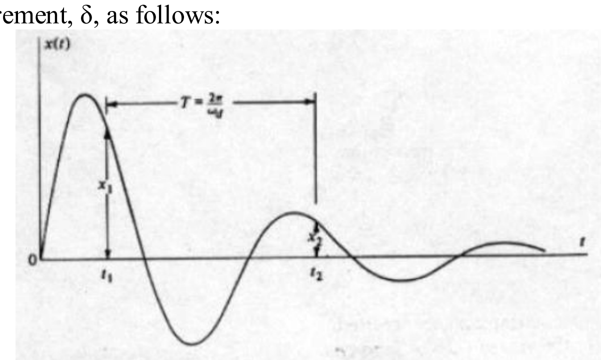
Fig. 4 layered beam model.

In order to evaluate accurately the influences of code number on the damping capacities and natural frequencies, twelve specimens of unidirectional cross-ply and angle-ply laminate have been fabricated in the laboratory by using hand lay up technique. Numerically the first four natural frequencies at the two levels of volume fraction are computed by the use of the modified formula MFM and listed in the second column of Tables 1 and 2. For the sake of verification, the experimental results of the natural frequencies and the loss factors for the first four natural modes are listed in the third and fourth columns in these tables, respectively.

To highlight the unpredictable nature of the damping parameters, various curves representing mutual relationships of modal parameters were plotted in Figs.. The close agreement of the results of the proposed mathematical and experimental models proves the efficient applicability of the proposed models for deeply understanding the dynamic nature of vibrating damping composite structures.

IV. Conclusion

- From modal analysis reported modal frequency = **591.87 Hz**
- From harmonic response model, Maximum strain energy = **8.68 X 10-5 J.**
- In transient analysis, the directional deformation along z axis with an impulsive force of **100 N** applied, the values of maximum deformation fluctuate and tend to converges to **9.42X 10-10.**
- $\omega = 2\pi f$ = **3718.82 rad/sec.**
- logarithmic decrement, δ, as follows:



X1 and X2 are two consecutive displacements one cycle apart $\delta = \ln(x1/x2)$ = **6.3 X 10-3**, X1 and X2 are taken from the values of the table

$$\xi = \frac{\delta}{\sqrt{(2\pi)^2 + \delta^2}}$$

ζ = 1.04X 10-3.

α = 2δω = **7.471 s-1** and β = 2δ/ω = **5.59 x 10-7** s

- Energy released = πcωx2 =**1.95 x 10-5** J.
- Loss factor (ε) =1/2π (energy released per cycle / maximum strain energy) = **0.0358**

REFERENCES

[1]. Cochardt, A.W., 1954, A method for determining the internal damping of machine members, ASME, Journal of Applied Mechanics, Vol. 76, No. 9, pp. 257-262.

[2]. Goodman, L.E. and Klumpp, J.H., 1956, Analysis of slip damping with reference to turbine-blade vibration, ASME, Journal of Applied Mechanics, Vol. 23, pp. 421–429.

[3]. Beards, C.F., 1992, Damping in structural joints, The Shock and Vibration Digest, Vol. 24, No. 7, pp. 3-7.

[4]. Ruzicka, J. E., ―Structural Damping‖. ASME, New Jersey (1959).

[5]. Lazan, B. J., ―Damping of Materials and Members in Structural Mechanics‖. Pergamon Press, London (1968)

[6]. Nashif, A. D., Jones, D. I. G. and Henderson, J. P., ―Vibration Damping‖. John Wiley & Sons, Inc., New York (1985).

[7]. Jones, D. I. G., ―Handbook of Viscoelastic Vibration Damping‖. John Wiley & Sons, Inc., New York (2001).

[8]. Sun, C. T., Lu, Y. P., ―Vibration Damping of Structural Elements‖. Prentice Hall PTR, Englewood Cliffs, NJ , (1995).

[9]. Beards, C. F., ―Structural Vibration Analysis: Modeling, Analysis, and Damping of Vibrating Structures‖. Halsted Press, Chichester (1983).

[10]. Ungar, E. E., "Structural Damping", Chapter 12 in Noise and Vibration Control Engineering: Principles and Applications, Leo. L. Beranek (Editor). John Wiley & Sons, Inc.,(1992).

[11]. Mead, D. J., ―Passive Vibration Control‖. John Wiley & Sons, New York (1999).

[12]. Bert, C.W., ―Composite materials: A survey or the damping capacity of fibrereinforced composites in damping applications for vibration control‖, AMD-Vol. 38. (1980).

[13]. Nashif, A.D, Jones, D.I.G and Henderson, J.P. Vibration Damping, Wiley, New York, (1985).

[14]. Chandra, R., Singh S.P, and Gupta.K Damping studies in fibre-reinforced composites—a review. Composite Structs, 46(1), 41-51, (1999).

[15]. Gibson, R.F., Chaturvedi, S.K. and Sun, C.T., ―Complex moduli of aligned discontinuous fibre-reinforced polymer composites‖, J. Mater Sci., Vol. 17. pp. 3499-3509 (1982).

[16]. Gibson, R.F., Chaturvedi, S.K. and Sun, C.T., ―Internal damping of short-fibre reinforced polymer matrix composites‖, Comput. Struct 20, pp. 391—401, (1985).