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Study on the Damping characteristics of epoxy-Cloisite 30B filled hybrid metal fiber composites

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Abstract

Light weight metal fiber reinforced composites are nowadays being increasingly used in aerospace structures due to their high strength to weight ratio. In this work, an attempt has been made to study the damping behavior of epoxy-Cloisite 30B filled hybrid aluminium metal fiber composites at different impact velocities by mixing small percentage of Cloisite 30B material in the epoxy resin system. It is observed that the damping factor determined by impact by drop weight method increases with the addition of Cloisite 30B for a constant impact velocity and that the damping property is higher at higher impact velocities. The damping factor increases at a faster rate upto 3% of Cloisite 30B loading and thereafter for higher additions it increases only marginally.

Keywords: epoxy, metal fiber laminates, cloisite 30B, damping factor

1. INTRODUCTION

Hybrid metal fiber composites are a class of composite structure that are made up of metal sheets bond to both sides of composite. In the present study we have utilisedAluminium sheets as the metal and Glass Fiber Reinforced in epoxy resin and Cloisite 30B as the composite. These structure reflect the good properties of composite as well as metal [1]. Metal like Aluminium are light weight and good stiffness to specific weight, are more ductile and have better impact strength. Composites have good corrosion resistant behaviour as well as fatigue strength and stiffness. In applications such as aerospace structures such light weight material couldbe used in place of solid metal like aluminium preserving the strength to weight. More specifically these hybrid metal fiber composite when used as structures could withstand tensile and impact stresses in a better way.When these materials are used in aerospace the fuel cost will get reduced over a long period of time as the weight structure is very less [2].

Generally aerospace structures are subject impact due to birds hitting the body, tools dropped by the maintenance workers, hitting the structure by service cars, tyre bursting, debris of runways and ice rains. The impact behavior is to a greater extent depends on the damping characteristics of the structural material [3]. In turn, the damping characteristics are influenced by aluminium layer thickness, the amount of glass fiber used, the angle of fiber direction and the type of resin as well as the velocity of the impacting mass.

Generally, the metal fiber composite structure is mostly made up of metal sheets on the outer faces of the composite layer and therefore the metal layers are one more than the composite layer [4]. Lot of research has been carried out by many researchers in order to find out the influence of the volume percentage of fiber, the type of fiber material, the direction of placing the fibers and the aluminium metal thickness on both sides of the composite.

F. AshenaiGhasemi et al. [5] studied about the effect of low velocity impact on hybrid laminates composed of Aluminium/Steel and Glass/Carbon fiber epoxy. They observed that parameters such as layer sequence of metal layers, different types of aluminium metal layers and the E11/E22ratio of composite material predominantly affected the hybrid laminates.

Early research by A.Vlot [6] to study the influence of low and high velocity impact on aluminium fiber epoxy laminates of glass, aramid and carbonshowed that the amount of impact energy necessary for glass fiber laminates to initiate the first crack on the non impacted side of outer aluminium sheet was greater carbon and aramid fiber laminates. The glass fiber hybrid laminate exhibited aluminium or fiber critical mode. When compared to monolithic aluminium, the dent depth of hybrid laminate was found by them to be lower. Further, the area of damage after the impact was observed to be greatly lesser than plain glass fiber or carbon fiber laminates. As the glass fiber has more tensile strength, the tensile strength of aluminium glass fiber hybrid laminates markedly increased with increasing rate of strain because of the reason that glass fiber is strain rate dependent.

The influence of bonding of fiber matrix over the impact property of aluminium-carbon fiber reinforced panels were done by G. D. Lawcocket al. [7]. Impact tests were done for three range of velocity of impact like quasi static, low and high. It was found by them that although that the crack length of the back face and indentation that was permanent after impact were lower, the area covered by the damage was greater for laminates that had poor fiber/matrix bonding for a given impact energy. It was also observed that due to increase in fiber/matrix splitting in the layer of the composite, the fiber laminates that were untreated exhibited more residual strength after impact.

G. S. Langdon and L. A. Rowe [8] carried out tests on Steel/Aluminium alloy-GFRP hybrid laminates by subjecting them to blast loading. They observed that similar to that the blast loaded laminates showed They found that the steel-composite interface showed large inelastic deformation like that of Aluminium-GFRP laminates and failed due to debonding. Also, Aluminium-GFRP laminates showed a higher non-dimensional displacement than that of Steel-GFRP panels.

S. Mckown et al. [9] carried out experiments to find out the influence of scaling on laminates made up of Aluminium alloy-polypropylene. They noted that the scaling did not affect the tensile and flexural strength. At the same time scaling was found to control the impact force and damage threshold energy.S. H. Song et al.[10] carried out detailed study on the impact behavioral characteristics of carbon fiber reinforced aluminium laminates. Through both experimental and numerical studies, it was shown by them that the specimen impacted by 2.35 J energy did not exhibit any critical damage occurred on and that the laminate could absorb about 64% of the impact energy. At an impact energy of 9.40 J it was observed that a shear crack on the aluminum metal as well as fiber and matrix failures were observed on the CFRP layers. The amount of impact energy absorbed by the laminate was about 83%.

The influence of hygrothermal aging on the mechanical strength characteristics of metal fiber hybrid structures consisting of Aluminium and or E-glass/epoxy (GE) composites were studied by Moslem Najafi et.al.[11]. Both type of structures were subjected to Hygrothermal aging simulation in distilled water for 5 weeks at a steady temperature of 90 °C. They observed that the hybrid metal fiber laminate structure exhibited less water absorption after hygrothermal aging treatment than that of neat glass-epoxy laminate. They attributed this due to the protective action of aluminium layers. They also found that due to hygrothermal aging, the flexural properties of both the FML and GE laminates were affected and at the same time the impact strength of neat glass-epoxy laminates was reduced than that of hybrid aluminium fiber hybrid composite.

KartikBalakumar et.al [12] carried out experiments to find the influence of input variables on the low velocity impact strength of metal fiber laminates. They considered the input parameters such as residual velocity of impactor and the shape and size of the impactor. It was found that the geometry of impactor had a predominant role in affecting the impact strength succeeded by the thickness of metal fiber laminate. The arrangement of configuration of fiber was less important than the direction of fiber placement on the low velocity impactperformance of the hybrid laminate structure.

E.V.Prasad et.al [13] studied the effects of different parameters such as aspect ratio, side-to-thickness ratio, ply orientation, and boundary conditions on the dynamic behavior of the FMLs. A finite element (FE)-based formulation was established for the plate using the first-order Reissner–Mindlin theory, including both fibers and metals of different material properties in alternate layers. A four-node isoparametric quadratic element with five degrees of freedom per node was adopted in the analysis.A set of experiments was conducted to get natural frequencies of vibration for glass FML (GFML) plates using Bruel and Kjaer (B&K) Fast Fourier Transform (FFT) analyzer with PULSE platform. They observed that increasing the aspect ratio can increase the natural frequency of the FML plate, while the increase in the side-to-thickness ratio decreases the natural frequency of vibration. They also found that the boundary conditions can significantly affect the natural frequency of the FML plates due to the restraint effect at the edges.

Sinan Maras et.al [14] studied about the vibration properties of FML composite beam subjected to fixed-free boundary condition numerically. Four cases depending on the number and location of Al and prepreg have been investigated. FML composites were produced with 6 and 8 layers. In addition, lower and upper layers of the composites were made of aluminium sheet while inner layers were composed of carbon prepregs. Experimental results were obtained with the PULSE vibration measurement system, a computer-based multichannel analysis system**.** The beams have clamped-free boundary conditions. They found that the natural frequencies decrease when the number of Al layers increased, but increased when the position of Al layers changed from surface towards mid-plane. It was also observed that, the natural frequencies changed with a change in orientation angle of fibers and a change in the position of prepreg layers from surface towards mid-plane resulted in the decrease in natural frequencies.

Although many researchwork have been done on metal fiber laminates it is found that only a little information is available on the effect of the resin composition used in the metal composite laminate for the purpose of matrix as well as bonding the metal with the composite over the damping characteristics. Therefore, this paper discusses on the experiments carried out to find how the damping characteristicsof epoxy-Cloisite 30 B filled hybrid Aluminium - fiber composites changed at various impact velocities.

2. EXPERIMENTAL

The description of materialsused in the preparation of test specimens are given below.

1) Aluminium alloy sheets – AA 1050 H 14;

2) E-glass fiber reinforced in epoxy resin

3) Epoxy resin as adhesive. (LY 556 and HY 951)

4) Cloisite 30B particles of size 2 to 13 micrometer, organically modified with methyl, tallow, bis-2-hydroxy ethyl quaternary ammonium salt.

For testing the characteristics of damping, square shaped specimens of size 300 × 300 mm have been fabricated. The sheet thickness of aluminium is 0.4mm for the outer layers and the thickness of the inner glass fiber epoxy mixed with Cloisite 30B layer is 1.7mm. For such a configuration the metal thickness ratio works out to 0.32. The volume percentage of fiber in the matrix is 35%. The specimen was fabricated using hand layup technique. Three specimens for each impact velocity were made using a mold that was made of acrylic that corresponded to the shape of the specimen. The surface of Aluminium was cleaned of dirt and other scales by means of wiping with acetone. A sheet of aluminium is placed inside the mould. The epoxy resin is mixed with 1/2/3/4/5% of weight Cloisite 30B by way of mechanical shear mixing for about one hour at room temperature. After shear mixing the resin –Cloisite mixture is sonicated for 5 hours. Thereafter, hardener (HY 951) is mixed by stirring for about 25 minutes. This mixture is then applied to the aluminum surface as a coating. The E-glass fibers are placed in unidirectional orientation over the coated aluminium surface. The outer aluminium sheet was carefully aligned over the fibers . Using an acrylic sheet coated by wax the mold cavity was closed. The system was left to curing for about six hours at room temperature. Then the specimens were subjected to impact in a drop weight testing machine and the velocity of impact was kept below 11 m/s to ensure low velocity impact. The specimens were tightly clamped on all sides of the fixture. The specimens were impacted by a steel indenter. The impactor weight was 4.91 kg. Two different velocities 3.2 and 4.1 m/s. were used. Apneumatic actuator attached in the machine was used to prevent multiple strikes by the indenter due to rebounding after the first impact. An accelerometer attached under the specimen and also connected to dynamic signal analyzer was used to measure the amplitude- time response. The damping factor for each velocity of impact was found using logarithmic decrement method. The damping factor ζ is found by the relation $\zeta = \delta / (4\pi^2 + \delta^2)^{1/2}$and theamplitude reduction factor δ iscalculated by using $\delta = [1/n] [\ln (x/x^n+1)]$. In case of n=1, $\delta = \ln (x1/x2)$.

3. RESULTS AND DISCUSSION

Table 1 shows the damping property of the Cloisite 30B filled epoxy Glass Fiber aluminium hybrid laminates for different weight percent Cloisite 30B loading for two different impact velocities.

Table 1. Variation of damping factor for different Cloisite 30B loading and impact velocities.

S.No	% of Cloisite 30 B loading	Impact Velocity (3.20 m/s)	Impact Velocity (4.10 m/s)
1	0	0.03286	0.03915
2	1	0.04212	0.04683
3	2	0.05316	0.06031
4	3	0.06185	0.07188
5	4	0.06754	0.08136
6	5	0.07196	0.08713

It is observed that mixing of Cloisite 30B has resulted in the increase of damping factor (Figure-1) for both the impact velocities.

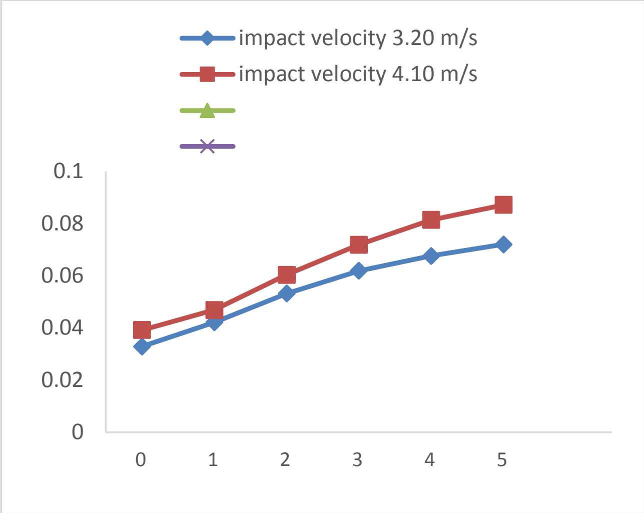

Figure 1. Variation of damping factor for different Cloisite 30B loading and impact velocities.

For an impact velocity 3.20 m/s and 0% Cloisite 30B addition the damping factor is 0.03286. The damping factor increases to 0.07196 for 5% addition of Cloisite 30B and this is about 2.18 times than that of pure epoxy without addition of Cloisite 30B indicating that addition of Cloisite 30B in the epoxy Glass Fiber aluminium hybrid laminates greatly reduces the vibration. Also, that the damping factor for impact velocity 4.10 m/s is more than that for an impact velocity of 3.20 m/s. This is attributed to the reason that the contact time between the impactor and the specimen is more in case of low velocity impact when compared to higher velocity of impact. Hence the amount of impact energy absorbed becomes more for low velocity of impact resulting in conversion of more energy into vibration resulting in low damping factor. At higher velocity of impact, due to lower contact time, more energy is used for penetration of the impactor which results in less amount of energy available for vibration of the systemand therefore the amount of damping increases.It is also observed that the damping factor increases at a greater rate upto addition of 3% of Cloisite 30B. Thereafter, for more addition of Cloisite 30B, only a marginal increase in damping factor is observed.

4. CONCLUSIONS

The effect of adding Cloisite 30B with epoxy resin on the damping characteristics of hybrid Aluminium-Glass Fiber laminates was studied for two different low impact velocities. Results of the experiments indicated that with an increase in the percentage of Cloisite30B in the epoxy resin increases the damping property of the hybrid structure. It is also found that when the impact velocities is more, the damping factor is found to be more. It is alsoobserved that the damping factor increases at a greater rate upto addition of 3%of Cloisite 30B.Thereafter, for more addition of Cloisite 30B, only a marginal increase in damping factor is observed.

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