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Study on the Mechanical Characteristics of hybrid metal-fiber panels with resin-Cloisite 10A mixture.

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Abstract

Hybrid metal-fiber panels made up of Aluminium-Glass Fiber epoxy resin panels nowadays are being increasingly used in aerospace structures due to their high strength to weight ratio. In this research an attempt has been made to increase themechanical strength of Aluminium-Glass Fiber epoxy resin Panels as well as specific strength by introducing a small percentageof Cloisite 10A material in the epoxy resin system. These panels were tested for ultimate tensile strength, flexural strength and interlaminar shear strength for various weight percentage (0, 1, 2, 3, and 4) addition of Cloisite 10A in the epoxy resin matrix. The results show that there is improvement in all the above mechanical properties due to the addition. However, beyond 2% Cloisite 10A addition, the properties decreases drastically.

Keyword: Mechanical strength; epoxy resin; metal fiber panels;

1. INTRODUCTION

Aluminium-Glass Fiber epoxy resin panels are made up of glass fiber reinforced plastic bonded to thin aluminium sheets on either side. These panels have the better properties of the metal as well as fiber [1]. Aluminium possess better ductility, specific stiffness and impact and damage tolerances and fiber reinforced plastic has high specific strength, better corrosion and fatigue resistances. When these panels are used to replace monolithic aluminium, weight reduction is obtained and at the same time the strength to weight ratio is not reduced. These panels are used in structural parts of aerospace and automobile structure [2] where tensile strength is important, resulting in reduced fuel cost because of the weight reduction. In the Aluminium-Glass Fiberepoxy resin panels, the aluminium layers form the outer layer on both sides. Between thesealuminium layers there may be a number of alternate FRP and aluminium layers, with the ratio between the number of aluminium and FRP layers as (n+1)/n where n denotes the number of FRP layers [3]. Many studies have been made on metal-FRP composite panels with respect to parameters such as the thickness of metal layer, type of fiber in the FRP, orientation of fiber, thickness of FRP layers and fiber volume fraction in the FRP, that influence the mechanical properties of the sandwich panels. Khalili et al [4] carried out an experimental study on the mechanical properties of steel/aluminium GFRP laminates. They have shown that the characteristics of metal fiber hybrid laminates is superior to that of plain GFRP and this facilitates such hybrid laminates for using aerospace. Glyn Lawcock et al [5] studied the effect of differences in adhesive bonding between aluminium and carbon fiber reinforced metal laminates during mechanical property testing. They observed that there has been no difference in the tensile strength and elastic modulus. However, the reduced interfacial bond strength between aluminium and composite layer decreased the interlaminar shear strength by 10%. Kawai et al[6] subjected aluminium-GFRP panels to tensile loading and studied about the off-axis inelastic and fracture behavior. They found that an increase in off axis angle from 0 to 90 degrees resulted in reduction of elastic modulus by 25%. They also found that for off axis angle greater than 5 degree ,transverse cracks developed in the FRP layers before the hybrid laminate fracture. Gresham et al [7] studied the drawing behavior of metal composite sandwich structures. It was found that a low blank holder force (2 kN) increased the likelihood of wrinkling. At a higher blank holder force of 14 kN wrinkling was found to be almost nonexistent and the laminates had a tendency to fail due to tearing or fracture. Carrillo et al [8] studied about the scaling effects in the tensile behavior of hybrid aluminium composite laminates. They found that the normalized elastic modulus isindependent of the scaling effect and remained constant. They also found that in the 1D and 3D scaled samples, a small decrease in tensile strength from 160 to 153 MPa has been observed with increasing scale size and the strength of 2D scaled samples increased from 150 to 160 MPa with increasing scale size. Wu et al [9] studied about the tension test specimens of laminated hybrid composites made of aluminium and aramid fibers. They carried out tension test on straight sidedas well as dogbone shaped specimens. They observed that the straight sided specimen had 3% lower ultimate tensile strength than the dogbone shape specimen. Remmers et al [10] studied the delamination buckling of metal fiber composite laminates and showed that the laminates aresensitive to delamination buckling which occurs when a partially delaminated panel is subjected to a compressive force. Alderliesten et al [11] studied about the fatigue and damage tolerance ofthe aluminium-glass fiber epoxy hybrid laminates. They found that the crack growth resistance isexcellent due to the mechanism of delamination and fiber bridging in hybrid laminates. MoslemNajafi et.al.[12] studied about the influence of hygrothermal aging on mechanical strength ofmetal and fiber panels and E-glass/epoxy (GE) composites. They carried out Hygrothermal agingsimulation on both specimen types in distilled water at a constant temperature of 90 °C for 5weeks. They found that the specimens showed a better lower water absorption after hygrothermalaging compared to the glass/epoxy composites because of the protective role of aluminum layers. They also found that the hygrothermal aging affected the flexural properties of both the metal fiber and GE laminates and that a lower level of decrease in impact strength was noticed. Sivakumar Dhar Malingam et.al [13], investigated the tensile and impact properties of hybridkenaf/glass reinforced metal laminates (FMLs) with different fiber orientations and stacking configurations. FMLs were formed by sandwiching the annealed aluminum 5052 sheets to the composite laminates using hot press molding compression technique. The tensile test wasperformed at a quasi-static rate of 2 mm/min with reference to ASTM E8 whereas Charpy impact test was conducted using impact pendulum tester according to ASTM E23. They found that there was improvement in tensile and impact strength in hybrid FMLs compared to kenaf fiber reinforced FMLs. Fiber orientation of ±45° reduced the tensile strength but increased the impact strength of FMLs in comparison with fiber orientation of 0°/90°. Further, hybrid FMLs incorporated with a fiber stacking sequence of glass/kenaf/glass showed superior characteristic in tensile and impact performance. In this research an attempt has been made to study the behavior in the mechanical properties such as elastic modulus, tensile strength, flexural strength, interlaminar shear strength of Aluminium-Glass Fiber epoxy resin panels as well as specific strength by introducing a small percentage of Cloisite 10A material in the epoxy resin system.

II. EXPERIMENTAL

The materials used in the fabrication of the test specimens were:

1. Aluminium alloy sheets – AA 1050 H 14;
2. E-glass fiber reinforced in epoxy resin
3. Epoxy resin as adhesive. (LY556 and HY 951)
4. Cloisite 10A particles of size 2 to 10 micrometer, a nano clay organically modified with Quaternary dimethyl, dehydrogenated tallow, ammonium salt with CEC of 90meq/100g.

The thickness of aluminium sheet in both the outer layers of the specimen are 0.4mm each and the thickness sandwiched GFRP layer is 1.7mm resulting in a total specimen thickness 2.5mm and the fraction of aluminium thickness as 0.32. The volume fraction of fiber in the GFRP layer is kept at 35%. The specimen for the tensile testing is made to dog bone shape. As there are no specific ASTM standards for such metal-FRP hybrid sandwich systems, the specimen size was fixed between the aluminium and FRP ASTM standards. The specimen for flexural testing was made according to ASTM D 790 with a support span length of 40mm and spanlength to depth ratio of 16, width 12.7 mm for three-point bending configuration mode and at a crosshead speed of 5 mm/min. The specimen for interlaminar shear strength testing was made according to ASTM D 2344 with a support span to thickness ratio of 4 and width 5mm for short beam shear mode. All the specimens for the above three types of strength testing were made by hand layup method. An acrylic mold, as per specimen shape was made. The surface of aluminium was cleaned by using acetone. The aluminium sheet was kept in the mold. Epoxy resin with Cloisite 10A (weight percentage 1,2,3 and 4) was mixed by mechanical shear mixing for one hour in ambient temperature and this was followed by sonication for six hours. Then the hardener was mixed and stirred for 20 minutes. This mixture is applied over the aluminum surface. Unidirectional E-glass fibers were placed in the mixture. Finally, outer aluminium sheet was placed and the mold cavity was closed by wax coated acrylic sheet. This setup was left curing for six hours at room temperature. Specimens with different percentage of Cloisite 10A in the resin were made by varying its weight percentage in the epoxy resin system. The specimens were tested for tensile properties in a universal tensile testing machine (SIMADZU make) with a crosshead speed of 1 mm/min at room temperature. Flexural test was carried out in a three point bending configuration at a crosshead speed of 5mm/min. Interlaminar shear strength testing was carried out in the short beam shear mode configuration.

III. RESULTS AND DISCUSSIONS

Table-1 shows the effect of Cloisite 10A addition on the tensile, flexural strength andinterlaminar shear strength of Aluminium-Glass Fiber epoxy resin panels.

Table 1. Variation of mechanical properties

S.No	Cloisite 10Ading %	Elasticmodulus (GPa)	Ultimate Tensile Strength (MPa)	Flexural strength (MPa)	InterLaminar Shear Strength(MPa)	Specific Stiffness(E/ρ)	Specific strength (UTS/ρ)
1	0	39.5	372	556	43	0.01845	0.1738
2	1	40.3	396	612	46	0.01910	0.1876
3	2	41.5	455	718	51	0.01966	0.2156
4	3	40.4	410	640	48	0.01914	0.1943
5	4	38.8	380	580	44	0.01838	0.1800

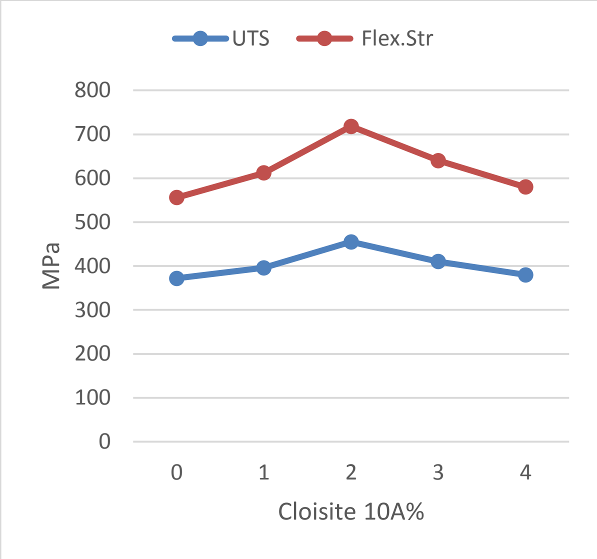

Figure 1. Variation in UTS and flexural strength for different weight % Cloisite 10A

It is observed that the elastic modulus increases upto 2% addition of Cloisite 10A (Figure-1) and then it decreases for increase beyond 2%. Similar trend has been observed in the properties such as ultimate tensile strength, flexural strength and interlaminar shear strength. There is an increase of 5%, 22%, 29% and 18% in the elastic modulus, ultimate tensile strength, flexural strength and interlaminar shear strength respectively between epoxy without Cloisite10A and 2% Cloisite 10A addition. It is also observed that the specific stiffness and the specificstrength increases 6.5% and 3.5% respectively upto 2% Cloisite 10A addition.

IV. CONCLUSIONS

Aluminium-Glass Fiber epoxy resin panels with resin modification by Cloisite 10A was successfully prepared. They were tested for ultimate tensile strength, flexural strength andinterlaminar shear strength for various weight percentage of Cloisite 10A (0, 1, 2, 3, 4) in the epoxy resin matrix. The results show that there is improvement in all the above mechanical properties due to the addition. However, beyond 2% addition, the properties decrease drastically.

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