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Fibre Metal Reinforced Laminates

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***Abstract*: FML laminates play an important role in aeronautical and they are used in varieties of engineering applications. The fibre metal reinforced laminates are used in most of the areas due to their tensile strength and impact resistance. FML shows high yield strength and fatigue resistance than compared to the other fibre laminates. The FML properties are examined and their mechanical properties are studied.**

***Keywords*: carbon fibre, aluminium alloy, mechanical properties.**

1. Introduction

The FML materials are used in many aeronautical applications due to their outstanding properties. FML is an advanced hybrid material system consisting of metal layers bonded with fibre-reinforced polymer layers.

These materials are used because of the excellent strength with low weight. Many of the sandwich materials deals with the glass fibre and aluminium. The carbon fibre used in various aerospace applications and their related fields. The FML is formed by stacking the layers of the aluminium with the carbon fibre. These have a magnificent properties like overall reduced weight, corrosion resistance and environment friendly. The aerospace material are prone more to the crack growth properties, which should be prevented. These FML have the ability to increase the fatigue resistance in the aerospace industry.

The FML combines the advantages of both metallic materials and fibre reinforced matrix systems. These materials have high strength and impact resistance and are easy to recondition, they also have characteristic stiffness. The normal alloys have low bearing strength, impact resistance and reparability than FML. These materials are created by sandwiching the metals on one other. These aluminium usually bonds with the aluminium metal more than compared to the other reinforced laminates. The mechanical properties of the FML are studied by various tests. The various impact loading test are used to check their tensile strength and their resistance is checked by the plastic and elastic deformation. The FML are materials with high strength and stiffness-to-weight ratio and they are also used in various fields such as aerospace, aircraft, ship, etc. Since the FML has higher more advantages than synthetic and glass fibres they are mostly fabricated in the form of the GLARE. GLARE is the material consisting of alternating layers of thin metal sheets and thin composite layers. High stiffness of carbon fibre provides more efficient crack bridging aluminium layers than aramid fibre and glass fibre. The good impact resistance is provided by the presence of aluminium layer. This good impact resistance along with the combination of high stiffness and strength gives GLARE a greater advantage as an application for structures in aircraft, helicopter, space, robot, laminated pipe, drive shaft, etc. The fibre-metal laminates could be the only option from a safety standpoint for large parts of the new generation of large aircraft. A new design philosophy based on an increased level of safety compared with today's standards.

We have analysed the mechanical response of carbon fibre composite sandwich panels with pyramidal truss cores. Thus the failure modes and structure analysis have been studied. Cantwell have studied the carbon fibre aluminium foam sandwich with short aramid fibre interfacial toughening. Reyes have studied the low velocity impact behaviour of glass fibre reinforced plastics aluminium sandwich composite materials. Khalili examined the mechanical properties of Aluminium Laminates and Afaghi-Khatibi researched the mechanical behaviour of fibre reinforced metal laminates. They have also studied the fracture behaviour of fibre reinforced metal laminates. From the above research studies, it has been came to conclusion, that the carbon fibre reinforced laminates are one of the important class of materials and are used in many applications.

Thus, carbon fibre reinforced aluminium laminates are fabricated and their mechanical properties are evaluated.

2. Experimental

A. Materials

The carbon fibres are used for the fabrication of composite materials. These fibres are purchased in the online markets in India. For fabrication epoxy is using for the bonding of the metals. The properties of the aluminium is listed below, the specifications of the fibre are also listed below.

B. Aluminium 7XXX

Appropriately alloyed and treated, aluminium can resist corrosion that are caused due to various factors like salt, water and by a large range of many chemical and physical agents. The corrosion characteristics of aluminium alloys are examined.

Aluminium surfaces can be highly reflective. Radiant energy, visible light, radiant heat, and electromagnetic waves are efficiently reflected on the other hand anodized and dark anodized surfaces may be absorbent or reflective. The reflectance of polished aluminium, over a broad range of wave lengths makes it as a candidate for a variety of decorative and functional uses.

Aluminium shows excellent electrical and thermal conductivity, but certain aluminium alloys are developed with high degrees of electrical resistivity. For example, these alloys are used in electric motors with high torque. Aluminium is often selected for its electrical conductivity, which is nearly twice that of copper on an equivalent weight basis. The high conductivity and mechanical strength requirements can be met the by use of high voltage, long-line, aluminium steel-cored reinforced transmission cable. The thermal conductivity of aluminium alloys, about 50 to 60% that of copper, is advantageous in evaporators, heat exchangers, electrically heated appliances and utensils, and radiators and automotive cylinder heads.

Aluminium is non ferromagnetic which is an important property in the electrical and electronics industries. It is non pyrophoric, which is also an important property in applications involving inflammable or explosive-materials handling or exposure. Aluminium is also non-toxic and is routinely used in containers for food and beverages. It has an attractive natural finish appearance, which can be bright and shiny or soft and lustrous. It can be virtually any colour or texture.

C. Physical properties of aluminium

Alloys in which zinc is the principal alloying element, used in aircraft structural components and other high-strength applications. The 7xxx series are the strongest aluminium alloys, with yield strengths ≥500 MPa possible.

D. Chemical properties of aluminium

Alloys in which zinc is the principal alloying element. Other alloying elements such as copper and magnesium may be specified.

E. Carbon fibre

Carbon fibres are fibres which are about 5–10 micrometres in dia and composed mostly of carbon atoms. Carbon fibres have various advantages including properties such as high stiffness and tensile strength, high chemical resistance and temperature tolerance and low weight and thermal expansion. These properties have made carbon fibre very popular in civil, aerospace engineering, military, and motorsports. Carbon fibre are expensive when compared with glass fibres or plastic fibres.

To produce a carbon fibre, the carbon atoms are bonded together in crystals that are more or less aligned parallel to the long axis of the fibre as the crystal alignment gives the fibre high strength-to-volume ratio.

Table 3
Properties of carbon fibre

FIBRE	Carbon fibre fabric
GSM	200

Carbon fibres are combined with other metals or fibres to form composites. When impregnated with a plastic resin and baked it forms carbon-fibre-reinforced polymer which has a very high strength-to-weight ratio, and is extremely rigid although somewhat brittle. Carbon fibres are also composited with other materials, such as graphite, to form reinforced carbon-carbon composites, which have a very high heat tolerance.

F. Epoxy resin

Epoxy is either any of the basic components or the cured end products of epoxy resins, as well as a colloquial name for the epoxide functional group. Epoxy resins, also known as polyepoxides, are a class of reactive prepolymers and polymers which contain epoxide groups. Epoxy resins may be reacted either with themselves through catalytic homopolymerisation, or with a wide range of co-reactants including polyfunctional amines, acids, phenols, alcohols and thiols. These co-reactants are often referred to as hardeners or curatives, and the cross-linking reaction is commonly referred to as curing. Reaction of polyepoxides with themselves or with polyfunctional hardeners forms a thermosetting polymer, often with favourable mechanical properties and high thermal and chemical resistance. Epoxy has a wide range of applications, including metal coatings, use in electronics/electrical components/LEDs, high tension electrical insulators, paint brush manufacturing, fibre-reinforced plastic materials and structural adhesives.

Table 4
Properties of epoxy resin

RESIN	Epoxy
TYPE	Bisphenol
HARDENER	Aromatic amine hardener

G. Fabrication

In the fabrication process, carbon fibre is used as reinforced fibre material, epoxy resin is used as a matrix and aluminium (AA67075-T6) is used as sandwich plate. The aluminium sandwich carbon fibre laminate is fabricated by means of hand

Table 1
Physical properties of aluminium

Materials	Density Kg/m^3	Elastic Modulas Gpa	Yeild Strength Mpa	Tensile Strength Mpa	Shear Strength Mpa	Poissions Ratio
AL7XXX	2800	73.3	503.3	572.3	10	0.3

Table 2
Chemical properties of aluminium

Materials	Al	Zn	Cu	Mn	Mg	Cr
AL7XXX	90	5.6	1.6	-	2.5	0.23

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lay-up technique at room temperature. The schematic illustration of the aluminium sandwich carbon fibre reinforced plastic composite specimen is presented in Fig. 1.

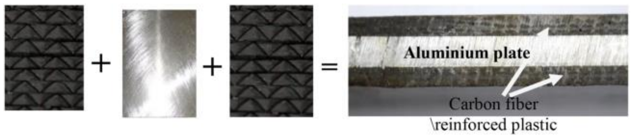

Fig. 1. Schematic illustration of aluminium sandwich carbon fibre reinforced composites

The Sandwich of Aluminium/Carbon is processed using hand layup technique at the room temperature and the volume fraction of 55:45 ratio is maintained throughout the process to complete one laminate using bi-directional layer of carbon fibre and aluminium sandwich. Carbon fibre and adhesive has not been bonded properly on the plane surface of the aluminium. Therefore, the inverted roots are made on the aluminium plate in order to fabricate the sandwich composites to avoid the debonding and to have a strong bonding between fibre and aluminium. The specimen is made to the size of 300mm × 300mm × 10mm (l × b × t).

3. Mechanical properties

A. Tensile test

FML is fabricated into required shape and size. The edges are finished by using emery paper. The process of tensile testing involves fixing the fabricated material in the machine using proper fixing equipment and the tensile load is applied until the fracture occurs. The tensile force is recorded with respect to the increase in gauge length. The tensile test is carried out on the universal testing machine. The experiment is repeated for several times and the results are presented below.

Fig. 2. The specimen (a) Before tensile test, (b) After the fracture

The tensile strength analysis for the FML structure for different specimen is presented in Fig. 3. This figure indicates the variation between 555-572. The variation is caused due to the variation that has taken place during the fabrication process.

This shows the typical curve obtained for tensile strength. The curve indicates that, the tensile strength carrying capacity increases up to certain extent and after that there is a sudden fall in load later, it moves as a straight line as shown.

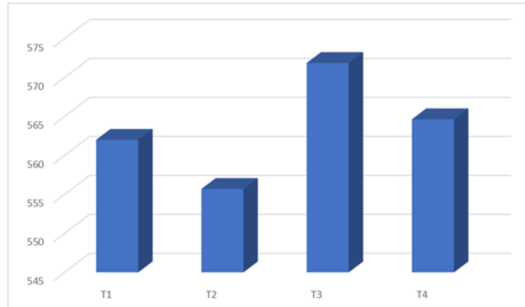

Fig. 3. Tensile strength observation

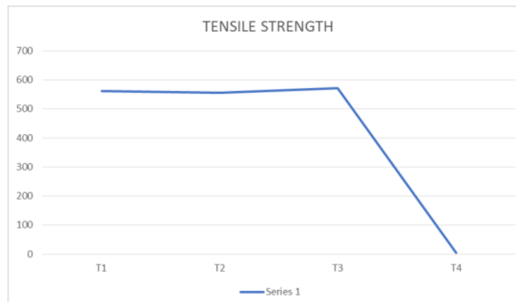

Fig. 4. Tensile strength graph

B. Flexural test

The flexural test is carried out using flexural specimen. Experiments are conducted by using the most common test method used for composite materials that is three point flexural tests. The cross head position is used to measure the displacement of the specimen. The displacement and the flexural strength are measured. The specimen prepared for conducting the flexural test and the fractured specimen after the testing are presented in Fig. 5. The experiments are carried out at a temperature of around 25 °C with 50% humidity.

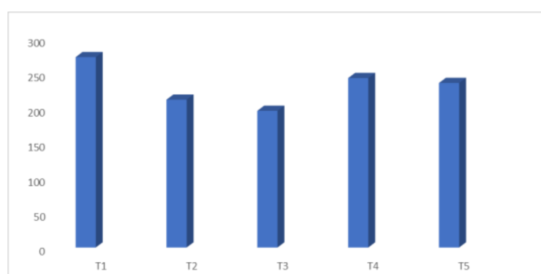

Fig. 5. Flexural test observation

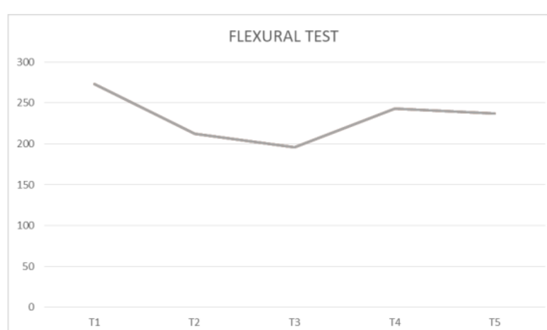

Fig. 6. Flexural test graph of aluminium

This graph shows the flexural strength for fibre metal reinforced laminates.

C. Impact test

Fig. 7. The specimen (a) Before testing (b) After testing

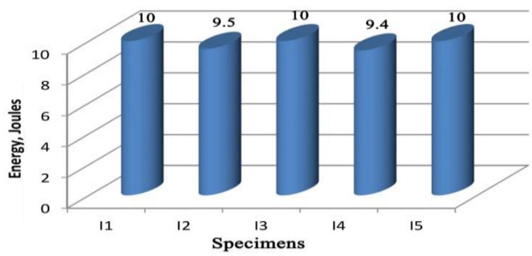

Fig. 8. Impact test observation

The required dimension of test specimen for the impact test was prepared. In the testing process, the energy is applied by means of an impact load until the fracture occurs on the specimen while the specimen is fixed in the impact testing machine. The energy required for breaking the materials can be measured by using impact test.

4. Result, discussion and conclusion

Thus, carbon fibre reinforced Fibre Metal Reinforced Laminates are fabricated and their mechanical properties are evaluated. Based on the experimental investigation and analysis, the following conclusions are drawn:

- The tensile strength, flexural strength and the impact strength are observed for different specimen. The tensile strength increases up to certain limit, and then falls due to the variation of metal-fibre laminate.
- The flexural strength also shows some drastic changes in the FML laminates

Overall, the FML shows excellent resistance properties and it can be used in the aerospace and other industrial applications due to their high tensile and flexural strength. These FML are easy to fabricate and shows far more physical properties than the other corresponding metals.

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