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EXPERIMENTAL ANALYSIS OF FIBER METAL LAMINATE WITH ALUMINIUM ALLOY FOR AIRCRAFT STRUCTURES

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ABSTRACT

The objective is to examine the methods of testing on FIBER/METAL LAMINATE (FML) WITH ALUMINIUM ALLOY to obtain empirical estimates of Load capacity under various loads.FML is the combination of metal and polymer composite laminates. The main objective is Weight reduction and improved damage tolerance characteristics. Mechanical properties of FML shows improvements over the properties of both aluminum alloys and composite materials individually. Moisture absorption in FML composites is slower when compared with polymer composites. Load tests are of interest because such tests are commonly used to determine the suitability of a fiber used in aircraft components. This analysis has focused on experimental obstacles to the reliable determination of post-crack load capacity.

KEYWORDS: FMl,Carbon Fibre,Aluminium Alloy 6061,Mechanical properties.

INTRODUCTION

A Fibre Metal Laminate (or FML) is one of a class of metallic materials consisting of a laminate of several thin metal layers bonded with layers of composite material. This allows the material to behave much as a simple metal structure, but with considerable specific advantages regarding properties such as metal fatigue, impact, corrosion resistance, fire resistance, weight-savings and specialised strength properties. Being a mixture of monolithic metals and composite materials, FMLs belong to the class of heterogeneous mixtures. Fibre metal laminates are hybrid composite materials built up from interlacing layers of thin metals and fibre reinforced adhesives. Taking advantage of the hybrid nature from their two key constituents: metals (mostly aluminium) and fibre-reinforced laminate, these composites offer several advantages such as better damage tolerance to fatigue crack growth and impact damage especially for aircraft applications. Metallic layers and fibre reinforced laminate can be bonded by classical techniques, i.e. mechanically and adhesively. Adhesively bonded fibre metal laminates have been shown to be far more fatigue resistant than equivalent mechanically bonded structures. Traditionally, composites have also been fabricated by similar methods. However, infusing liquid resin into dry fabric layers solely by vacuum pressure to produce high quality materials has proven to be a more cost effective process for preparing composites. This process, known as Fabrication of Fibre/Metal Laminate involves the fabrication of a composite material consisting of layers of Aluminum and carbon fibre bonded together by compression moulding process along with epoxy resin as hardener.

LITERATURE REVIEW

Different persons have discussed the Fiber Metal Laminate with various combination of materials in various methods and process. They are as Follows.

B.J.JENSEN says two types of fiber metal laminates were prepared by vacuum assisted resin transfer molding. Both methods provide for through the thickness infusion by either the insertion of resin flow pathways or by utilizing a metal deposited layer with porosity. The VAR TMFMLs provide good mechanical properties that can be optimized by proper selection of metal foil, fiber, resin and size and

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distribution of the pathways. The VAR TMPCLs allow the incorporation of a plasma deposited metal layer that can improve functional properties like electrical and thermal conductivity.

Prasanth Banakar describes that the objective of this research was to gain a better understanding of Mechanical properties of epoxy resin composites reinforced with carbon fiber. The effect of fiber orientation of fiber metal laminates has been investigated and experimentation was performed to determine property data for material specifications, the laminate were obtained by hand lay- up process. The laminates were cut to obtain ASTM standards. The investigation deals with the testing of tensile and flexural strength on a universal testing machine.

F.D. Moriniere presents a theoretical and experimental comparative study on the low-velocity impact behavior of GLARE Fiber-Metal Laminate (FML). Using the Classical Laminate Theory and the First-order Shear Deformation Theory, an analytical model was developed to predict the impact behavior of FMLs. Delamination onset and contact increase during perforation were taken into account. New generic expressions were derived for strain energy and contact force. Absorbed energy, impact force, maximum deflection and impact velocity were predicted within 5% of test results. GLARE 5-2/1-0.4 is 72% more resistant than its monolithic 2024-T3 aluminum counterpart of the same thickness. Because GLARE is made of thin high strength layers that can undergo large deformation, this hybrid material is an ideal candidate for impact prone structures. This general understanding will support the development of high-energy absorbing FML concepts.

M.Vasumathi describes that she replaced a portion of carbon fibre by natural jute fibre to provide pollution-free environment and the analysis for mechanical performance is done.Flexture Stresses of CAJRALL and CAJRMAL are directly proportional and the Flexure modulus is inversely proportional to the number of layers. The microstructure study reveals that the predominant failure mechanisms in axially loaded CAJRMAL specimen are found to be fibre pull out and delamination between layers and in impact loaded specimens, it is matrix cracking. Since magnesium is 1.55 times less heavy than aluminium and also not much difference is observed from the results of the mechanical response of CAJRMAL.

MATERIALS AND METHODS

Materials

The material considered for this analysis are given in the table below with some of their properties:

Table 1. Material with Properties

Material	Properies
Carbon Fiber	330GSM, Unidirectional
Glass Fiber	600GSM, Bidirectional, Woven Roven Mat
Aluminium Alloy 6061	Thickness - 1mm Density – 0.98 lb/in^3 Melting point – 1090^{o}F
Matrix	Resin – LY556 Hardener – HY951

Fabrication of Composites:

Two laminates with different proportions and additional layers of Carbon/Glass fiber and Aluminium alloy 6061 sheet are fabricated using Compression moulding at room temperature. By considering the desity, specific gravity and mass the weight fraction of the fiber is determined. The fibers and Aluminium are weighed and sliced with dimension of 300*300 mm. The fabrication was done at room temperature by hand lay-up technique. The required resin and hardener were mixed at the ratio of 10:1. The mixture is continuously stirred. To prevent the bonding of the laminate the mould surface must be smooth enough. The aluminum alloy sheet is cleaned and dryed using ordinary thinner before using it in the laminate. The made mixture is uniformly brushed over the plies of Carbon/Glass and aluminum alooy 6061 plate. The air inside the laminate is squeezed out manually using a roller. Then the laminate is placed inbetween the plates of Compression mould of same size. The laminate is cured at room temperature for two days.

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Fig 1. Laminated Slabs

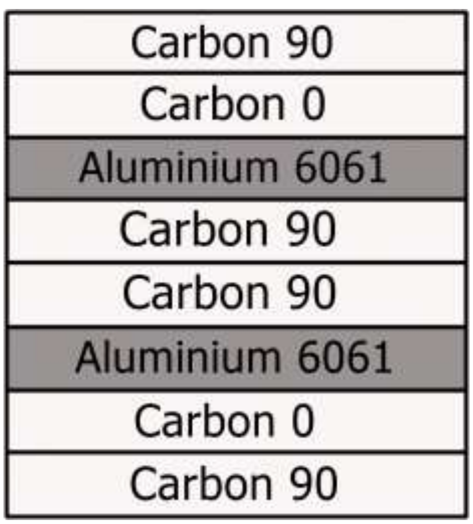

Fig 2. Laminate (i) with 8 Layers

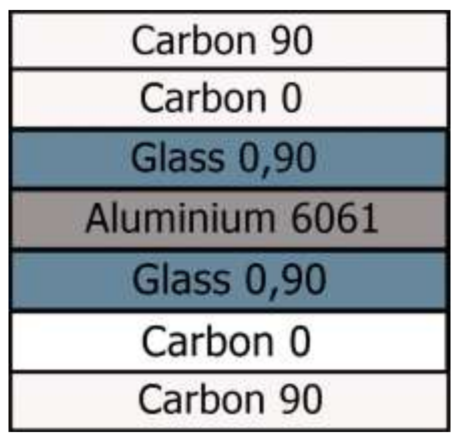

Fig 3. Laminate (ii) with 7 Layers

Specimen Preparation:
The Laminates slabs are removed from the Compression moulding and subjected for the specimen cutting according to ASTM standards. The test specimens were cut using Water Jet cutting. Two specimens are cutted for each mechanical testing.


Fig 4. Water jet cutting on Laminate


Fig 5. Cut Specimen

EXPERIMENTAL ANALYSIS

Tensile test :

As per ASTM D3039 standard, Tensile testing of the specimens with the stacking order (i) and (ii) were carried out by using the Universal Testing Machine. The UTM has a maximum load capacity of 50KN. The Specimen is mounted vertically in the grips of the jaws of the UTM. The testing machine is connected to a computer system which monitors and records the test results. For each specimen the breaking load is recorded.


Fig 6. Tensile Test in UTM


Fig 7. After Tensile Test in UTM

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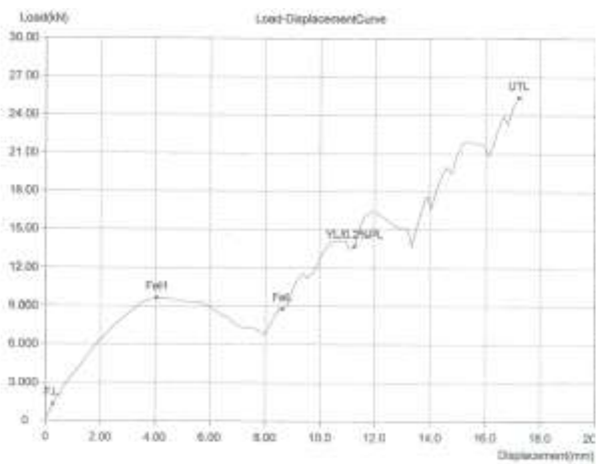

Fig 8. Graph for (i)- 1

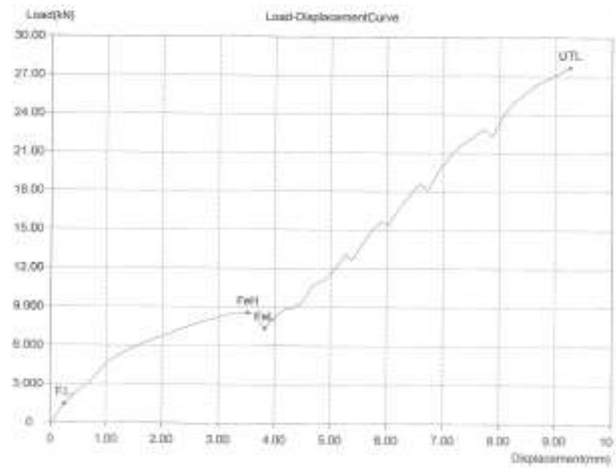

Fig 9. Graph for (i)- 2

Note : Laminate (i) is having Two layers of Aluminum and Glass fiber.
Laminate (ii) is having single layer of Aluminum.

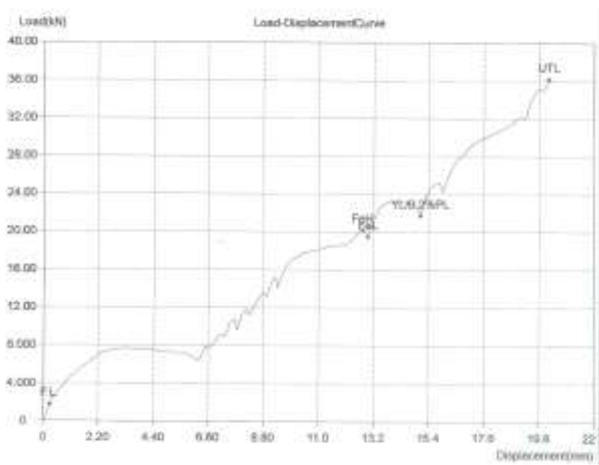

Fig 10. Graph for (ii)- 1

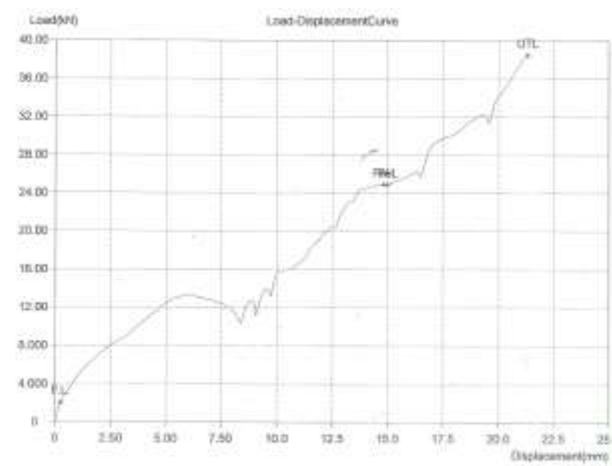

Fig 11. Graph for (ii)- 2

Note : Laminate (i) is having Two layers of Aluminum and Glass fiber.
Laminate (ii) is having single layer of Aluminum.

Table 2. Results for Tensile Test

Specimen	(i)-1	(i)-2	(ii)-1	(ii)-2
Ultimate Tensile Strength(Mpa)	198	211	239	268

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Flexural Test :

The important part of the characterization of any material is the Flexural testing. This test gives information about the behavior of the materials at real conditions. As per ASTM D790 standard the Flexural test is done by using three point bending method using an Universal Testing Machine (UTM). The flexural stress is calculated by using formulae. From the graph the Ultimate breaking load is obtained.

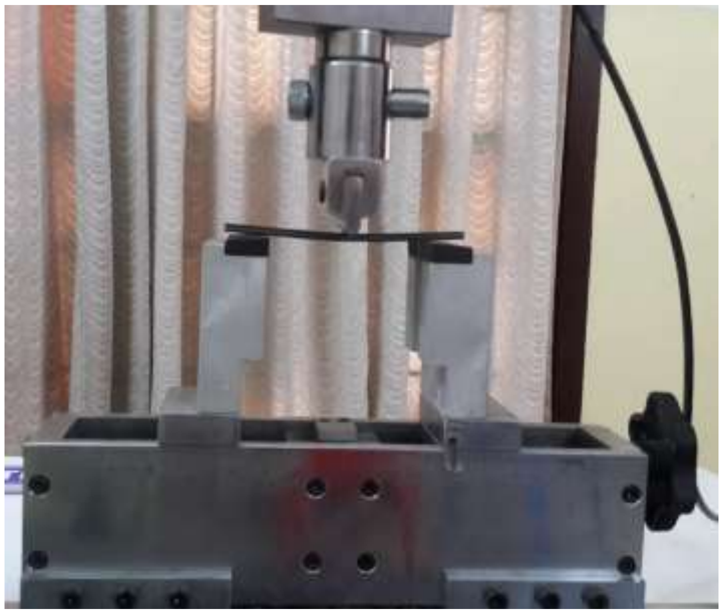

Fig 12. Flexural Test in UTM

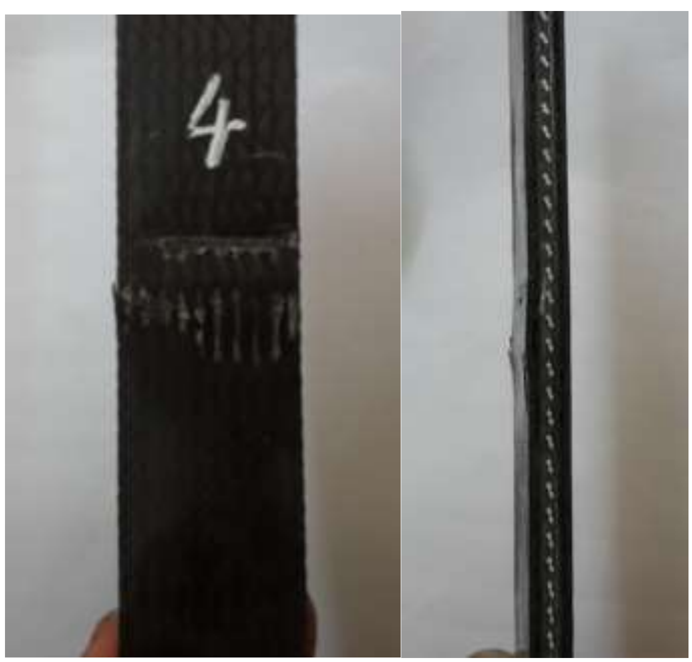

Fig 13. After Flexural Test in UTM

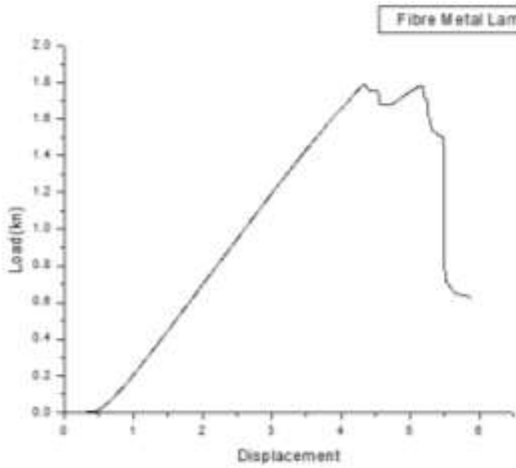

Fig 14. Graph for (i)

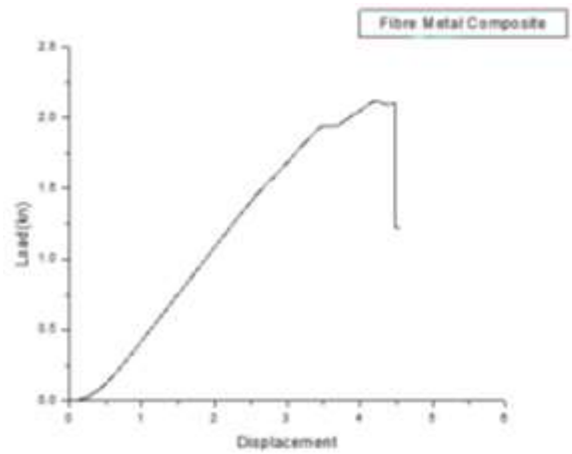

Fig 15. Graph for (ii)

Note : Laminate (i) is having Two layers of Aluminum and Glass fiber.
Laminate (ii) is having single layer of Aluminum.

Table 3. Results for Flexural Test

Specimen	For (i)	For (ii)
Load at Peak	2.102 KN	1.790 KN
Deflecction at Peak	4.884mm^2	6.226mm^2
Flexural Stress	350.33N/mm^2	417.840N/ mm^2

Compression Test :

As per the ASTM D 3410 standard the specimen cut.To avoid buckling of the specimen fixture is made at both sides and both ends to get enough grip during the test. The compression test is done usin Universal Testing Machine (UTM).

Fig 16. Cut Specimen with Al Fixtures

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Fig 17. Cut Specimen with Al Fixtures

Table 4. Result for Compression test

Specimen	For (i)	For (ii)
Load at peak	357..040KN	268.509KN
C.H. Travel at peak	1.482mm	8.673mm
Compressive strength	3570.400N/mm^2	2685.090 N/mm^2

CONCLUSION

The FML of CARALL laminates were tested with two different types of layers and fibers.The FML (ii) has more tensile strength than (i).Carbon fiber with 90^o is used as top and bottom layer for both the laminates. As this increases the impact strength rupture of the specimens gets delayed. Materials can be combined to form new hybrid ones having enhanced properties. However there are several factors that should be considered when designing a new hybrid material such as extreme internal stress, galvanic corrosion, voids and volatile contents. And more over technological difficulties, availability, and costs are also important issues. In general materials will not be used when the price is exceptionally high or the manufacturing technologies are not feasible. This laminate can be used in parts of aeroplane when it is necessary the use of highly compression resistant material.

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