International Conference on Innovative Research in Engineering, Management and Sciences
International Journal of Scientific Research in Computer Science, Engineering and Information Technology
© 2019 IJSRCSEIT | Volume 4 | Issue 9 | ISSN : 2456-3307

Characterization of Aluminum-E-Glass Fibre - Epoxy Reinforced Fibre Metal Laminates Composites

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ABSTRACT

Fiber Metal Laminates (FMLs) are hybrid materials consisting of layers of thin metal sheets and fibres in sandwich pattern. These are best known and extensively used in the Aerospace applications. Aiming this objective, new lightweight FML has been developed by hand layup technique using thin aluminium and E-glass fibres. Tensile tests had been carried out in accordance to ASTM standards to witness the quality of the specimens. From the experimental work, load v/s. displacement and assessing the strength it is observed that the mechanical properties of woven roving mat with aluminum type FML composite proved to be possessing 11.5% higher than the rest of the specimens characterized.

Keywords: Chopped Strand Mat (CSM), Fiber Metal Laminates (FML), Glass Fiber reinforced aluminum

I. INTRODUCTION

Post World war-II scenario witnessed plenty of changes in the area of material research. Owing to the process of depletion of traditional metals, such as steel, cast iron, aluminium, zinc, copper, magnesium, titanium and their alloys, new technologies are being evolved by material and design engineers, by inventing a new category of materials named metal fibre composites, which are formed by combining different materials for the high end applications. A Fibre Metal Laminates (FML) are a family of relatively new hybrid materials comprising thin aluminum sheets with pre-impregnated synthetic fibres. The technique was originally developed at the Delft University of Technology. It consisted of thin sheets of aluminum, bonded with fibre adhesive layers. This laminated structure behaves much the same as a simple metal structure, but with considerable specific advantages with regard to properties, such as metal fatigue, impact, corrosion resistance, fire resistance, weight savings and specialized strength properties and have significant properties that are useful in the aviation field [5-6]. Glass fiber reinforced epoxy and aluminum alloy is considered as hybrids composite Fiber–metal laminates. These types of material have applications in aircraft structures such as the upper fuselage of aircrafts [1-3]. Fibre Metal Laminates are well-known by their superior damage tolerance and their relatively limited crack propagation rates [3, 4]. Machinability and durability related to many metal of superior fatigue properties are the advantages of such systems [4-6]. These specific materials are currently found an extensive use in the wide range of load bearing engineering applications. Fiber metal laminates are a family of highly fatigue and impact resistant laminated composite materials. They offer the structural designer a damage tolerant, light-weight and cost-effective replacement for conventional aluminum alloy sheets or composites in advanced transport structural applications [7]. Many authors have reported GLARE composites and their applications but ultra thin aluminum foil composites are scarce in the literature. Therefore the present work explores the compatibility and characterization of ultra thin aluminum metal & E-glass fibre composites subjected characterization tests and results are discussed.

II. Specimen Preparation and Experimentation

- **Materials and Test Methods**

The fibre metal laminates consists of thin aluminum foils bonded together with appropriate E-glass (CSM, WR)/ in epoxy matrix layers. The volume fraction of fibre to matrix maintained to be 60:40. Glass fibre (220 GSM) supplied by Vitrotex Saint Gobain Bangalore and blended with CY219 Huntsman epoxy system. The tensile properties of prepared composites are tested according to ASTM D3039 standard and shown in Table 1.

Table1. Specimen Details

Sl. No.	Lay-up	Thickness (mm)	Weight (gm)
1	AlF: Epoxy	3	11 gm
2	AlF:CSM:Epoxy		18
3	AlF:WR:Epoxy		21

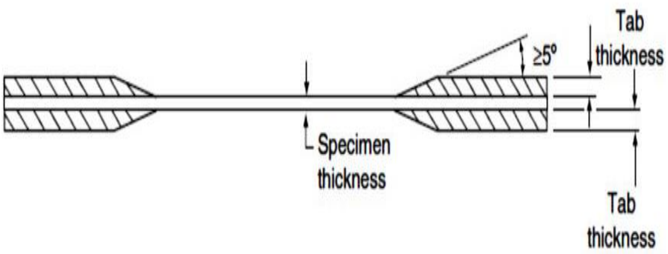

Fig.1 Fibre Metal Laminate Specimen

III. Results and discussion

The tensile properties, such as tensile strength, modulus, and elongation of the FML composites were determined by static tension tests in accordance with ASTM D3039 and the values tabulated in Table.2.

Table. 2: Tensile Test Values

Specimen ID	Yield Strength (MPa)	Ultimate Strength (MPa)	Elongation (%)	Modulus (MPa)
1	196	214	2.9	33.8
2	267	496	3.8	50.8
3	298	579	4.1	57.4

The Fig.2 to Fig.5 exhibits the load versus deflection behavior of the various specimens. It is observed that a plateau region with downward tendency suggests the material deformation at a constant pace before the fracture. All the three samples (bare aluminum thin foil specimens) deliberately showed the same pattern with 1.9 mm maximum deflection. Fig.2 represents the load-deflection behavior of bare al foils.

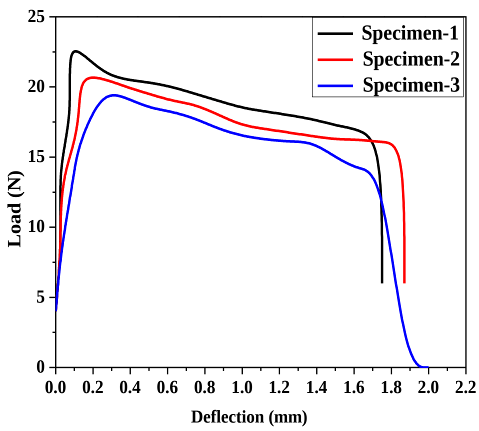

Fig.2 FML: Load V/s Deflection Plot

The tensile tests conducted on FML with epoxy showed slightly varied pattern. It is observed gradual rise in the load values and a shorter plateau region suggesting the mixed behavior (ductile & brittle). Fig.3 represents the load-deflection behavior of bare al foils in epoxy matrix system. The maximum deflection of 1.3 mm i.e., 31% drop in the stretch of the specimens noted and is shown in below figure 3.

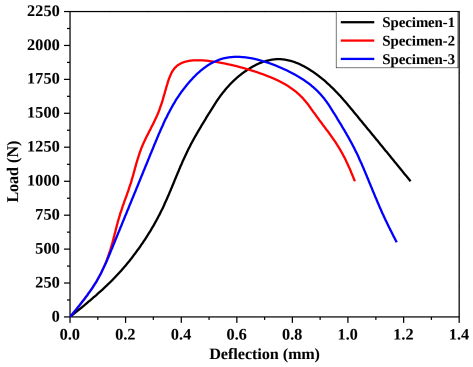

Fig.3 FML + Epx: Load V/s Deflection

Figure 4 and Figure 5 indicates the load deflection behavior of the FML composites with chopped strand mat (CSM) and woven roving (WR) mats. The behavior in both the cases seems to be similar indicates the integrity of the combination of the fibres and aluminum foils during the test.

The WR FML composites showed 74% increased strength than the bare foil FML's. But it is observed that only a mere of 7% variation in the load carrying behavior of the fibre reinforced FML's with the change of fibres. No much changes observed in terms of elongation and modulus.

The Fig.4 and Fig. 5 represents the load-deflection behavior of FML's with varying fibre types.

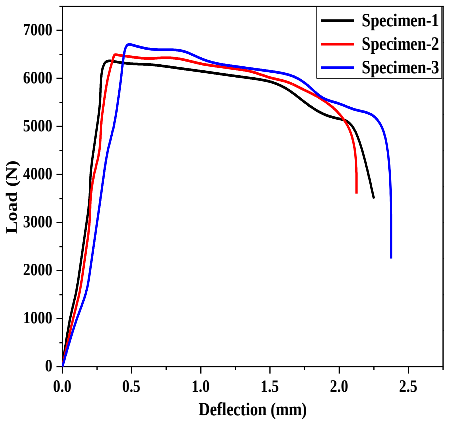

Fig.4 CSM+Al FML: Load V/s Deflection

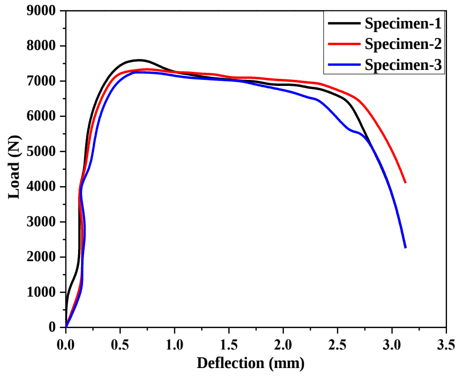

Fig.4 WR+Al FML: Load V/s Deflection

Tensile failure of these FML's laminates involves the release of a large amount of elastic energy by breaking fibers and by debonding. The delamination also found to occur at metal fibre interface. Tensile failure is accompanied by partial disintegration of the fibre layer, which fractures into large fragments upon failure. Inspection of the peeled FML specimens revealed that about 75% of the delamination area was at the fiber/adhesive interfaces, and the remainder was at the adhesive/aluminum primer interface. The results showed in the study indicate that there can be substantial improvements with combining thin aluminum foils in composites.

IV. CONCLUSION

- Fibre metal laminated composites comprising of thin aluminum foils with varied E-glass fibre architecture were successfully characterized and the following conclusions were drawn.
- The load-deflection and the failure behavior observed witnessed ductile and ductile brittle combinations.
- The specimens showed an increase of 70% load bearing capacity with the fibre impregnation.
- There is an increase of 41% modulus shows good compatibility.
- The test specimens revealed 63% increase in ultimate tensile strength and 34% increase in yield strength suggests flawless synthesis of the FML composites.

The Viability of FML fabrication procedure is proved and the quality of interfaces between two different E-glass fibre architectures with thin aluminum foil found to be good.

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