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Mechanical Behaviour of Basalt/Carbon/Aluminium Fiber Metal Laminates – An Experimental Study

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ABSTRACT

Tailorable nature of composites plays a vital role in the development of advanced functional graded engineering materials. Especially sandwich composites made with fiber reinforcement and metal core (Al or Steel) grabs significant attention among worldwide material researchers due to its excellent mechanical, thermal and damping characteristics. Applications of metal core fiber laminates are inevitable in the various engineering industries like automobile, aviation and structural components due to its remarkable strength to weight ratio. The present investigation focusing on the study of mechanical behaviour of carbon/basalt fiber reinforced vinyl ester matrix composites with the aluminium core plate. Hybrid composite fabricated by open mould process, tensile, impact and flexural tests were done as per ASTM standards. Results obtained through various experiments were reported for analysis with scanning electron microscopic images.

Index Terms: *Fiber Metal Laminates*, Vinyl Ester, Fiber Reinforced Composites, Carbon, Basalt, Aluminium Plate, Polymer Composites.

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I. INTRODUCTION

Modern engineering materials made up of fiber reinforced metal sandwich structures receives special attention among industries due to its admirable properties such as design flexibility, room temperature processing, and strength to weight ratio [1]. Most of the automobile sectors using fiber metal configurations for fabricating components like bonnets, floorings, and frames [2]. Sinmazcelik achieved reasonable impact and fatigue resistance by adhesive bonded Aramid Reinforced Aluminium Laminates [3]. Carrillo investigated the impact and flexural behaviour of fiber metal laminates fabricated with propylene matrix and revealed that fabricated FMLs shows better reliability than other similar grade composites (made by conventional thermosets) [4].

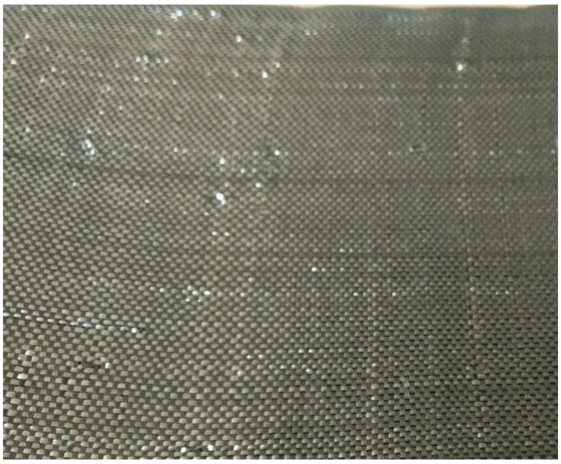
Hu developed PMR Titanium/carbon polyimide FMLs and anodized in order to achieve better bonding between polyamides and titanium, surface hardness. He reported that excellent bonding behaviour of proposed FMLs possess superior mechanical properties in both room and elevated temperatures [5]. Santhosh et al. prepared Glass Laminated Aluminium Reinforced Epoxy (GLARE) composites by using open compression moulding process and reported that higher reinforcement of metal laminates possess enhanced mechanical properties and very minimal crack formation/propagation [6]. Chai reported aluminium reinforcement in the epoxy matrix fiber metal laminates greatly improves mechanical, thermal, electrical properties and reliability [7]. Ali investigated corrosion and mechanical behaviour of carbon fiber- titanium/epoxy FMLs and revealed that titanium greatly holds the mechanical properties of FMLs during various load conditions [8].

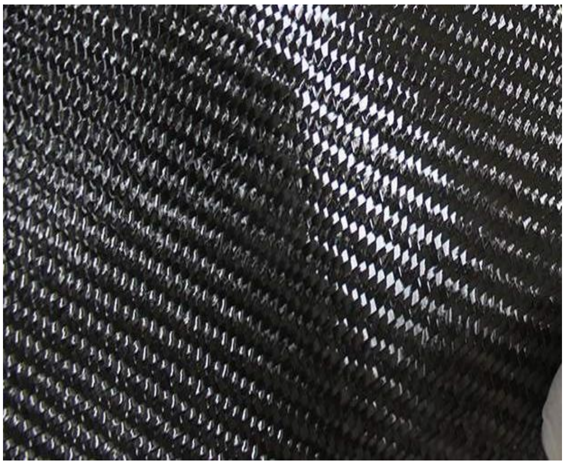
Weight and volume fraction of reinforcements and polymer matrix greatly influence the mechanical behaviour of fiber metal laminates, generally higher volume of reinforcement improves flexibility and higher volume of matrix enhances corrosion and impact resistance [9, 10]. Fabrication of polymer matrix composites by using hand layup or open moulding technique remarkably improves fatigue and impact responses. At the same time by altering the stacking sequence of fiber laminates and metal plates significantly improves mechanical properties [11, 12]. The above studies clearly indicates that there is a reasonable studies in fiber metal laminates were already done and still there is an opportunity for mechanical behaviour study of hybrid fiber metal laminates (two or more fiber reinforcements). This proposed work focuses on tensile, impact and flexural behaviour study of carbon/basalt hybrid FMLs fabricated via open mould technique. The experimental results were presented for the discussion.

II. MATERIALS AND METHODS

Materials

In this proposed work bi-directional carbon and basalt fabrics supplied by Hindustan composites, Mumbai was utilized as a dispersed phase. Aluminium metal core plate (30mm x 30 mm x 2 mm) and vinyl ester continues phase (Derakane momentum 411–350) were supplied by bharth metals, Chennai and CF composites, Mumbai respectively. The properties and images of reinforcement and metal plates as mentioned by the supplier is depicted in the table.





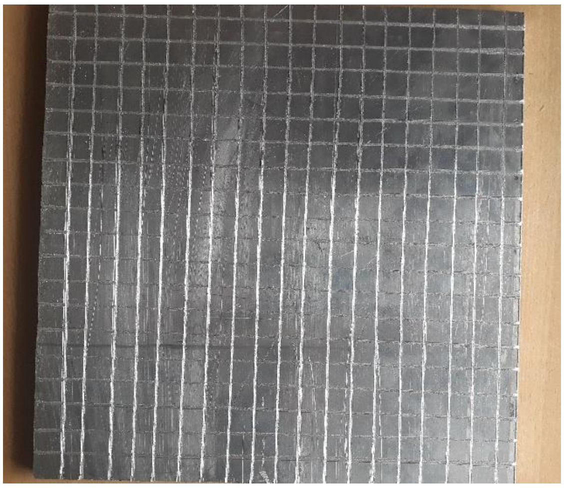


Figure 1 a) Basalt Fiber, b) Carbon Fiber, c), Grooved Aluminium Plate

Table 1 Properties of Fiber Reinforcement Materials

Fiber	Specific Gravity	Max Temp. of Application (ºC)	Elongation at Break (%)	Elastic Modulus (GPa)	Tensile Strength (MPa)
Carbon	1.80-1.90	550	2.5	150-180	2750-3400
Basalt	2.65-2.8	650	3.1 -6	93-110	3000-4840

Table 2 Properties of Aluminium Metal Plate

Material	Modulus of Elasticity, GPa	Tensile strength MPa	Yield Strength MPa	Fatigue Strength, MPa	Poisson ratio	Density, g/cc
Aluminium	68.50	520	295	115.8	0.33	2.81

Fiber Metal Laminate Fabrication

The fiber metal laminates with the stacking sequence B-C-B-C-B-C-Aluminium Plate-B-C-B-C-B-C is fabricated via open mould process. The volume fraction of the matrix is maintained 30 percent throughout the laminate, basalt and carbon fibers were used in the equal volume fraction of 35:35 percentages. Open mould fabrication is the most commonly adopted technique for fiber laminate fabrication and well known for its easy and low-cost manufacturing.

The fiber metal laminates were fabricated and allowed to cure in the room temperature for 24 hours under compression load. After room temperature curing process laminates were cured in the hot air oven (50^0C) for 2 hours under vacuum pressure. After the curing process the laminates were marked/designed for its dimensions as per ASTM standards and specimens were prepared by using a saw cutter. Finally, the specimens were edge prepared by using emery sheets. Fabricated carbon/basalt/aluminium laminate is shown in figure 2

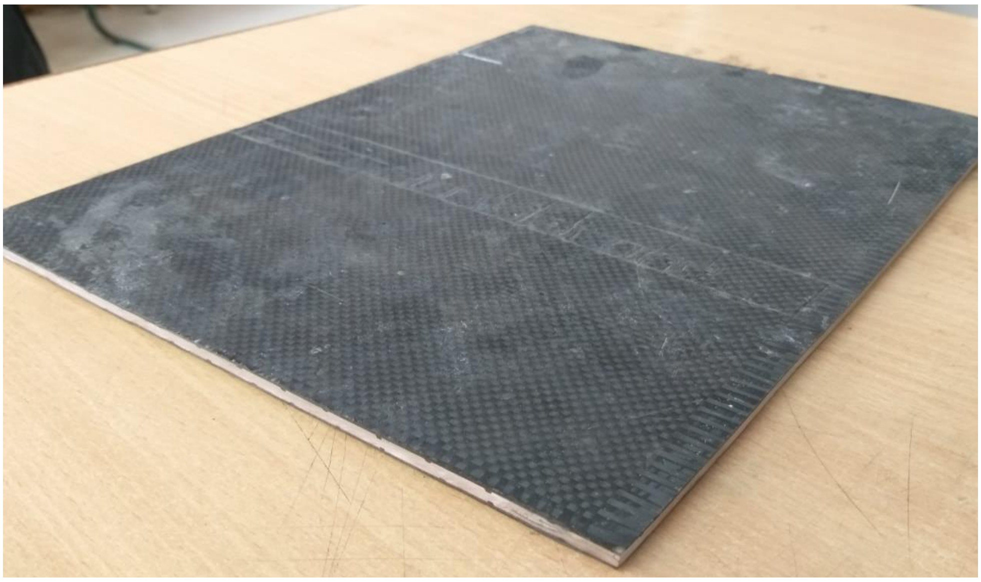


Figure 2 Fabricated Carbon/Basalt/Aluminium Fiber Metal Laminate

Specimen Preparation and Testing

Tensile test specimens were prepared as per ASTM D638 and tests carried out by using instron 3360 universal tensing machine. Izod impact test specimens and flexural three-point bending test specimens were prepared as per ASTM D790-10 and ASTM 790 (Instron 4486 UTM) respectively. For each tests three samples were prepared and average of results represented in the graph. Figure 3 (a) and (b) shows the tensile and flexural test machines.

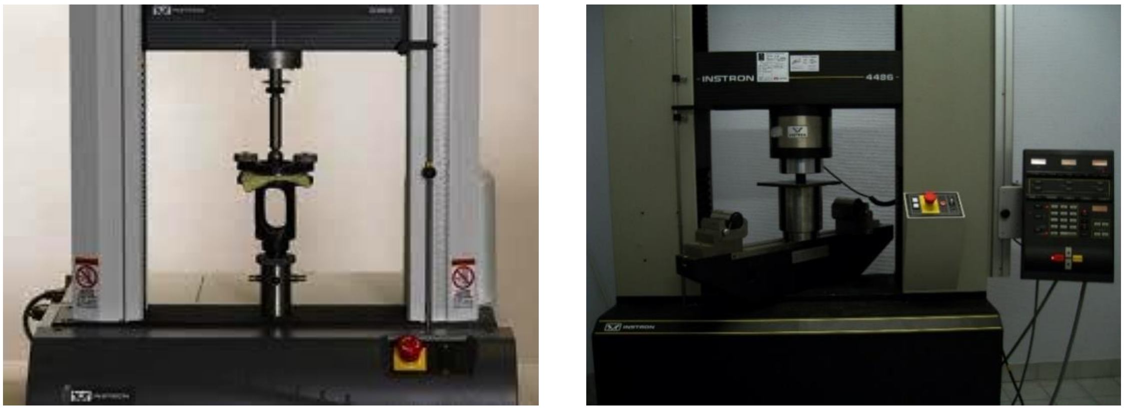


Figure 3 Instron 3360 and Instron 4486 Testing Machines

III. RESULTS AND DISCUSSION

The results obtained from various experiments like tensile, flexural and impact tests were presented for the discussion. Figure 4 and 5 represents stress-strain and load-displacement relationship of prepared hybrid laminate.

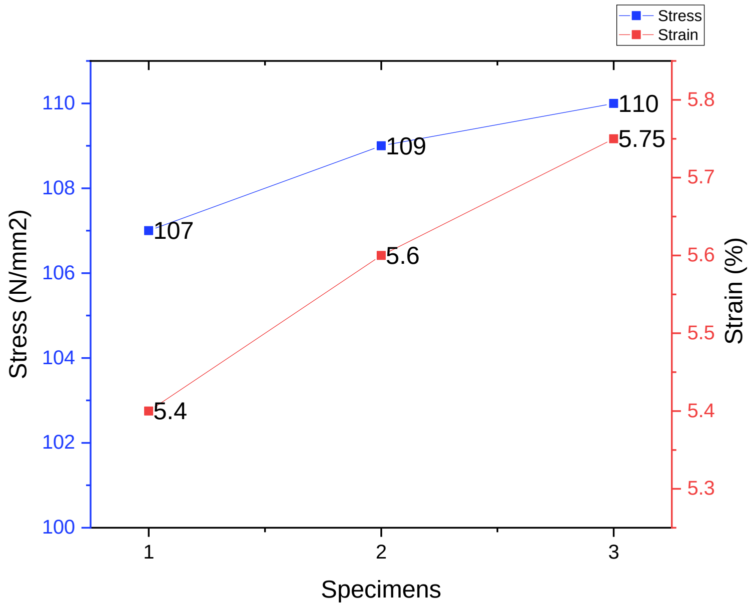


Figure 4 Stress vs. Strain Curve (Tensile test)

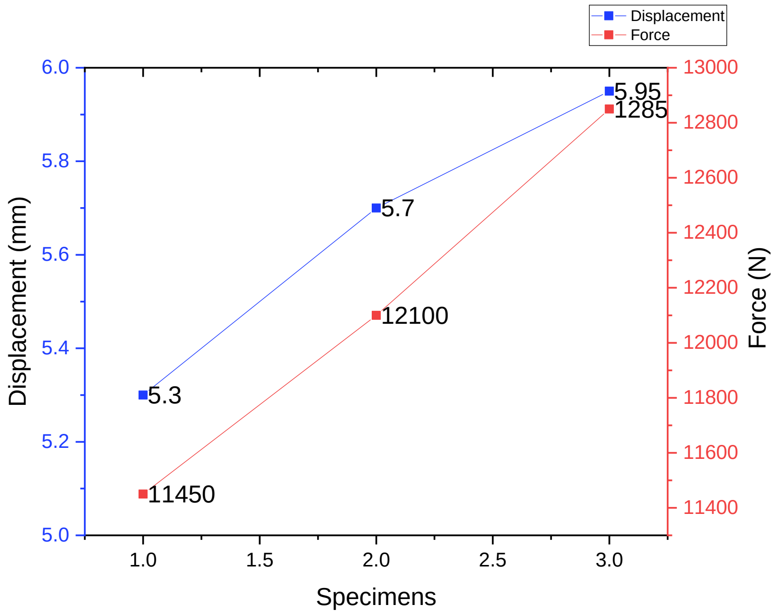


Figure 5 Load vs. Displacement Curve (Tensile test)

Results indicates that the strain respect to the corresponding stress increases gradually over a span of time. The tensile behaviour of fiber metal laminates was decided based on the elongation of fiber followed by aluminium core plate. The aluminium core supports the hybrid configuration for maximum tensile modulus. Elongation at break of the fiber plate seems very low when compared to aluminium metal.

Flexural behaviour of fabricated fiber metal laminate samples was represented in the figure 6 and 7. The flexibility of the fiber laminates greatly improved because of the metal reinforcement. The load-displacement diagram indicates that maximum load requires for the displacement and shows higher strain to the applied load. Carbon and basalt reinforcement possess significant improvement in the flexibility of the hybrid configuration.

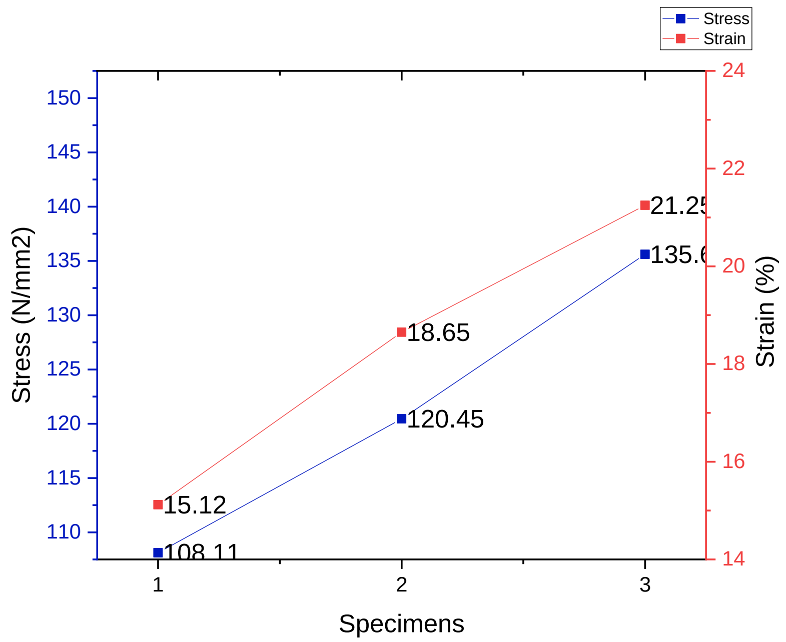


Figure 6 Stress vs. Strain Curve (Flexural test)

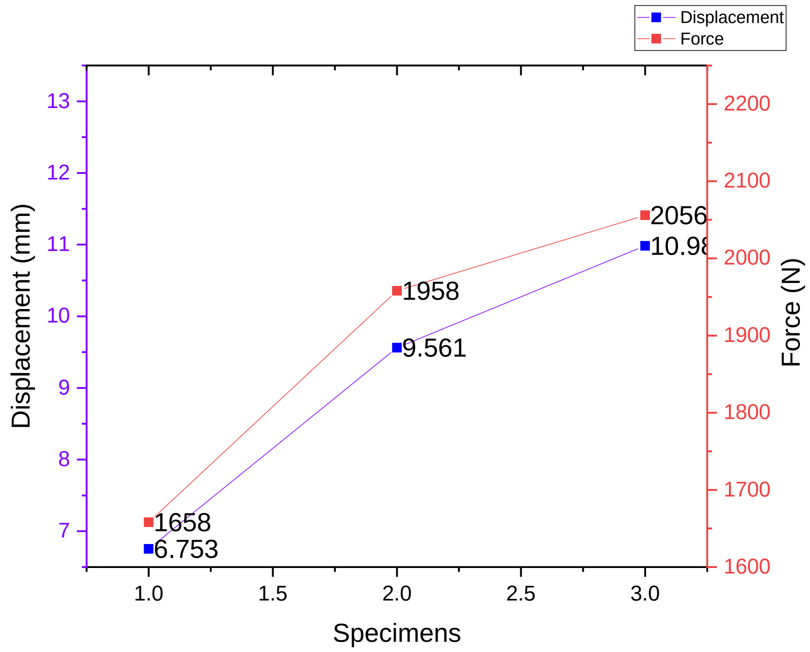


Figure 7 Load vs. Displacement Curve (Flexural test)

Figure 8 depicts the results obtained from a low-velocity izod impact test. It's clearly visible from the impact test is that metal core likely bends than fiber materials. At the same time, some minor delamination's occurs between the metal and fiber laminate.

Fiber metal laminates show enhanced energy absorption ratio than unreinforced fiber metal laminates. Here fiber supports flexibility and metal holds the reliability of the composite configuration. Similarly, figure 8 (a) and (b) represents the SEM images of voids, fiber pull-outs and delamination's of fractured tensile specimens.

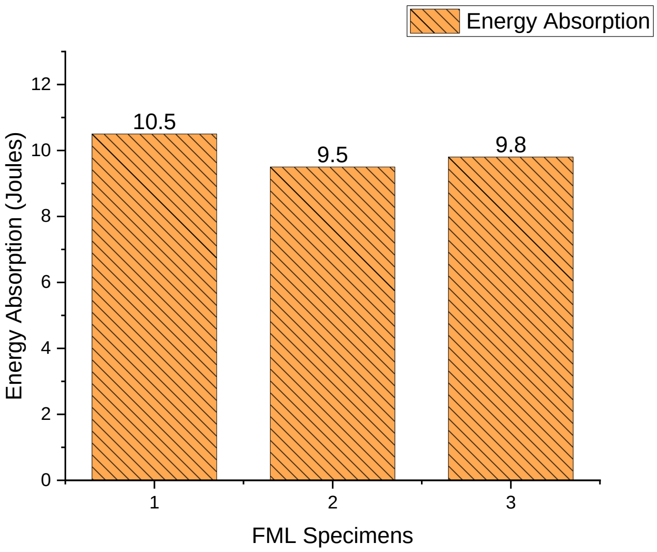


Figure 8 Izod Impact Test Results

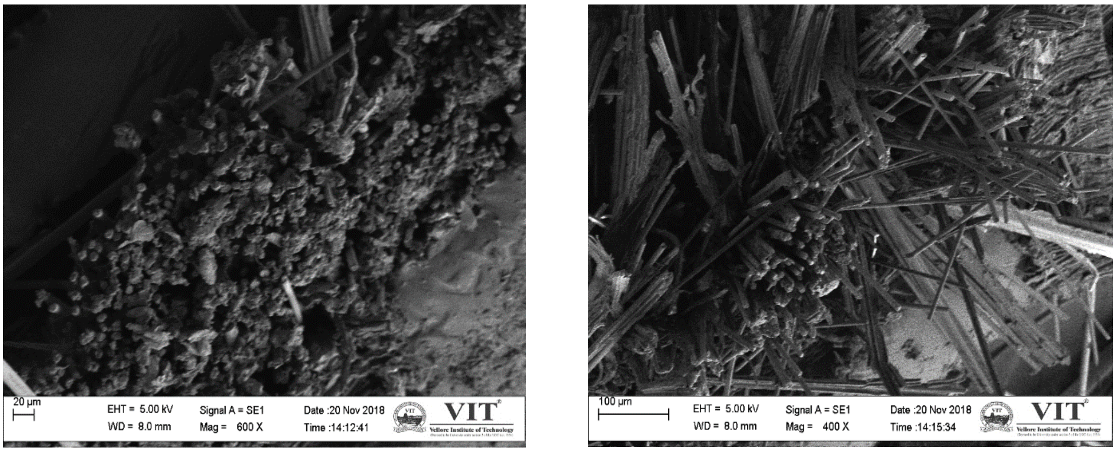


Figure 9 Scanning Electron Microscopic Images of Fractured Surface

IV. CONCLUSION

The proposed high strength aluminium/carbon/basalt reinforced fiber metal vinyl ester laminates was fabricated with open mould process and its mechanical properties were studied. The experiments reveals the following outcomes.

- Fiber metal laminates possess enhanced tensile properties than pure fiber laminates.
- Enhanced flexural behaviour obtained by combining fiber and metal together.
- FMLs possess great energy absorption behaviour than pure fiver or metal parts. The energy of the FMLs are up to 30-40 percentage higher than the traditional polymer composites.
- Microstructural analysis exposes the presence of tear, delamination, voids and fiber pull-outs in the fractured samples.

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