International Journal of Materials Science
ISSN 0973-4589 Volume 14, Number 1 (2019), pp. 1-9

http://www.ripublication.com

Fabrication and Characterization of Basalt/Kevlar/Aluminium Fiber Metal Laminates for Automobile Applications

M.S. Santhosh[1], R. Sasikumar[2], T. Thangavel[3], A. Pradeep[4], K. Poovarasan[5], S. Periyasamy[6], T. Premkumar[7]

[1] *Junior Research Fellow, Selvam Composite Materials Research Laboratory, Tamilnadu, India.*

[2] *Professor & Director Research, Selvam College of Technology, Tamilnadu, India.*

[3] *Assistant Professor, Mechanical Department, Paavai Engineering College, Tamilnadu, India.*

[4, 5, 6, 7] *UG Scholars, Mechanical Department, Paavai Engineering College, Tamilnadu, India.*

Abstract

Sandwich fiber metal laminates (FMLs) grabs significant growing attention among disparate engineering industries such as defense, aerospace and commercial vehicle manufacturers, due to its improved mechanical, thermal and electrical properties. Over the past few decades, FMLs were used as an impeccable identical for classical fiber composites like carbon and E-Glass. This prospective work interrogates mechanical behaviour of Basalt/Kevlar/AA 8090 reinforced FML fabricated by hand layup - compression moulding process. The low-velocity impact, flexural and tensile behavior of fabricated FMLs were calculated by various mechanical testings done as per ASTM standards. Fractured surface of the FML also analyzed by scanning electron microscopic images for understanding the fracture behavior of the proposed outcome.

Keywords: Fiber metal laminate, Basalt, Kevlar, Al 8090, Flexural, Low velocity impact, compression moulding.

1. INTRODUCTION

Fiber reinforced composites has a significant impact in production of engineering materials. It occupies huge percentage in the total fabrication due to its admirable mechanical properties like strength to weight ratio and cost-effectiveness. Recent researchers focusing on use fiber reinforced metal laminates for various automobile applications such as bonnets, frames, and floorings [1]. Carrillo developed self-reinforced poly propylene matrix FMLs to carry out flexural and impact tests and expressed that FMLs shows better stability and reliable than other conventional fiber thermoset matrix laminates [2]. Aramid Reinforced Aluminium Laminate (ARALL) fabricated by adhesive bonding possess more fatigue and impact resistance than similar kind of mechanically joined structures [3].

Hu fabricated PMR polyimide carbon/Titanium FMLs and reported that anodization induces surface roughness on the titanium which possess better bonding between metal and polyamides. Due to the rigid bonding, proposed FMLs shows better mechanical properties in both room and elevated temperature working environments [4]. Santhosh fabricated GLARE composites by compression moulding technique and reported that higher of fiber metal volume fraction (up to 70%) possess better mechanical properties and minor crack propagation [5]. Ali experimentally studied mechanical and corrosion behaviour of titanium-carbon fiber/epoxy FML and carbon fiber/epoxy composites and expressed that the mechanical property reduction in Titanium FML is very minimal when compared to CF/E composites [6].

Aluminium sheets in the FMLs improves stiffness of the laminates and provides reasonable ductility over entire structure [7]. Weight fraction of reinforcement and matrix material plays vital role in the superior mechanical properties of fiber composites. Impact energy absorption behaviour of the composites were greatly improved by altering stacking sequence and use of filler material [8, 9]. Fatigue and impact behaviour of the FMLs fabricated by using hand layup compression moulding varies with respect to different stress and loading conditions also the maximum energy absorption depends on the ratio of energy dissipation [10, 11].

The above studies clearly shows that fiber reinforced metal laminates especially Kevlar and basalt are widely used in various domains of engineering to obtain ultimate material performance. In this proposed research Basalt/Kevlar/Al 8090 FMLs were fabricated by compression moulding process and its tensile, flexural and low velocity impact behaviour studies were done. Fracture surface analysis also done by SEM analysis.

2. MATERIALS AND METHODS

2.1 Materials

In this present work basalt and Kevlar fiber hybrid laminates and aluminium 8090 metal plates were used for fabricating FMLs. Basalt and Kevlar fibers were supplied by Hindustan composites ltd, Maharashtra. Epoxy resin matrix LY 556 (density - 0.9 g/cm3, viscosity - 1.25x104 cP) and hardener W152 LR (density - 1.2 g/cm3, viscosity 1.30x104 cP) were supplied by Aishwarya polymers, Coimbatore, Tamilnadu. The properties of fiber reinforcement and aluminium metal plates as mentioned by supplier were depicted in table 1 and 2 respectively.

Table 1: Properties of Fiber Reinforcement Materials

Fiber	Specific Gravity	Max Temp. of Application (°C)	Elongation at Break (%)	Elastic Modulus (GPa)	Tensile Strength (MPa)
Kevlar	1.75-1.95	400	0.5-1.5	230-800	2900-3450
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
Al 8090	70.05	420	315	105.6	0.33	2.70

2.2 Composite Fabrication

The Kevlar/basalt/Al 8090 composite sandwich was fabricated by room temperature hand layup followed by compression moulding method with the volume fraction ratio of 60:40. The unidirectional FML laminates are arranged in the laminate sequence of K-B-K-B-AA8090-B-K-B-K. Kevlar and basalt fibers are alkaline pre-treated and surface of aluminium plates were grooved inversely in order to achieve good bonding between fiber and Al plates. FML with the dimension of 300mm x 300mm x 5mm were fabricated and surface smoothened by abrasive machining process. Similarly test specimens for mechanical testing were cut as per ASTM standard by using saw cutter. Fabricated fiber metal laminate is depicted in figure 1.

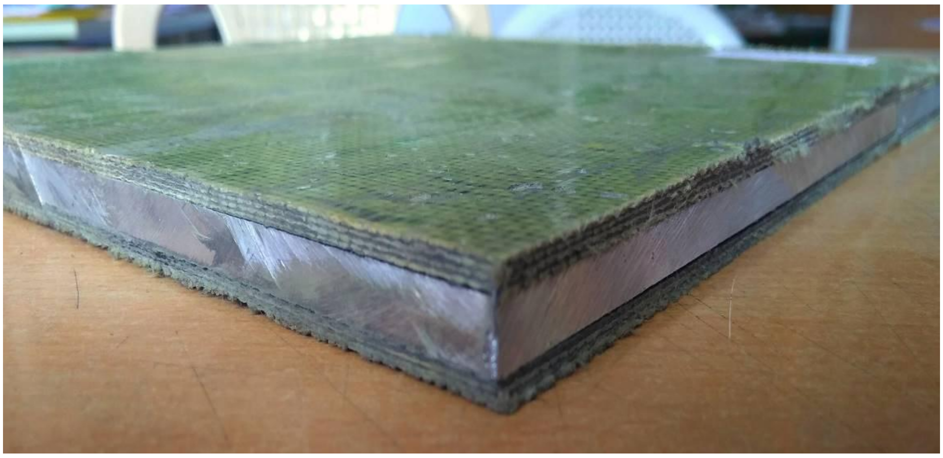

Figure 1: Fabricated Sandwich Composite

2.3 SPECIMEN PREPARATION AND TESTING

Three tensile test specimens were prepared for testing as per ASTM standard to get accurate results. Tensile tests were done repeatedly for all the three specimens in FIE 11/98- 2450 make universal tensile testing machine. Three point bending flexural test was carried out in the Instron 4486 UTM with the specimen dimension of 80mm x 13mm x 5mm (ASTM 790). Similarly izod impact tests were done in the AIT-300N impact pendulum testing machine (ASTM D256). For each testing three specimens were tested and the results were reported. Figure 2 shows the prepared tensile, flexural and izod test specimens.

Figure 2: Tensile, Izod and Flexural test specimens - Before test

3. RESULTS AND DISCUSSION

The results obtained through various experiments like tensile, flexural and impact tests were presented for the investigation. Figure 3 represents tensile results of the specimens. Three samples were tested to acquire the average tensile strength of the FML specimens.

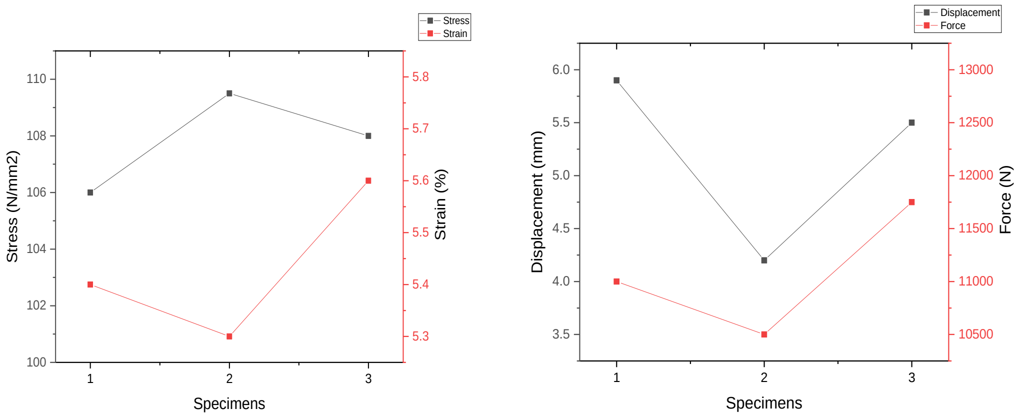

Figure 3: Tensile Results - a) Stress-strain curve, b) Load-displacement curve

Stress strain relationship curves clearly indicates that the gradual increase in strain rate for the corresponding stress levels. It has been identified that specimen 2 possess lower strain values because of the moderate bonding of fiber and metal laminate in that particular region. Similarly the force – displacement curve indicates that fiber metal laminates shows better resistance towards applied force.

Figure 4 and 5 represents flexural and impact test results of the specimens respectively. The proposed FML possess excellent impact and flexural properties than any other fiber reinforced polymer laminates. It is due to the combination of kevlar and basalt fibers, where Kevlar is well known for its impact resistance and energy absorption and basalt fiber is for better mechanical and thermal properties.

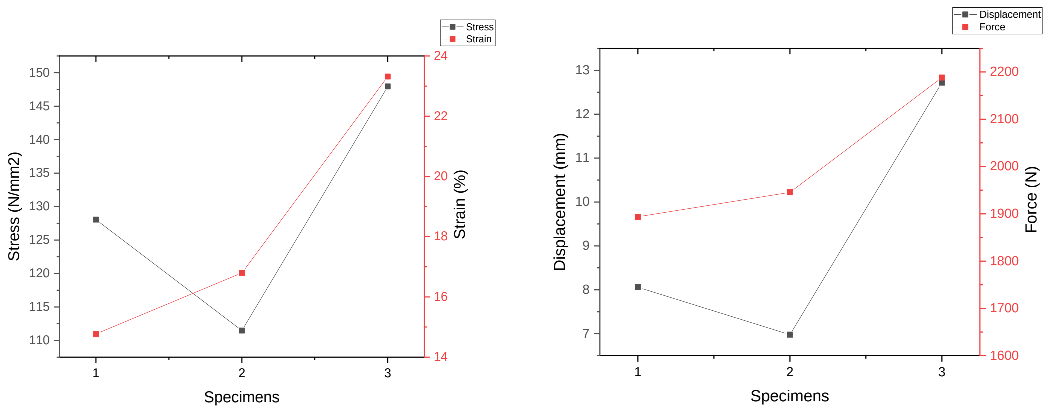

Figure 4: Flexural Results - a) Stress-strain curve, b) Load-displacement curve

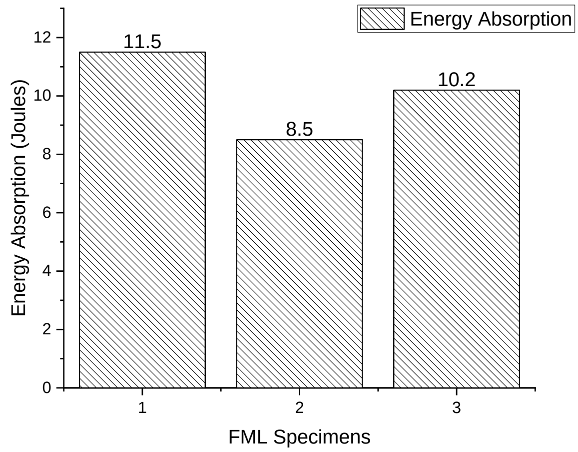

Figure 5: Izod Impact test results

Scanning Electron Microscopic Analysis

The SEM images of fractured specimen surfaces were shown in figure 6. It represents that the bonding between metal and fiber laminates are rigid enough to form uniform stress concentrations in FML.

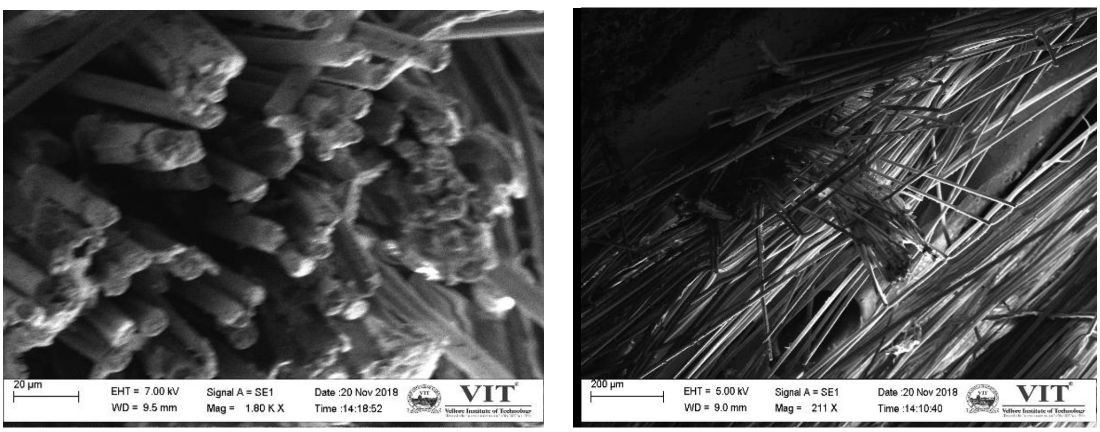

Figure 6: SEM Images of Fractured Surfaces

Microstructure SEM analysis reveals that delamination's and pull outs present in the fractured samples. Mostly minor de bonding and fiber pull outs occurred between fiber and metal. The damage tolerance of metal gets improved with the fiber usage. Equivalently the energy dissipation and absorption behaviour of kevlar/basalt fibers protects the metal plate from the fracture.

4. CONCLUSION

In this proposed research kevlar/basalt/Al 8090 reinforced metal laminates were prepared by hand layup compression moulding to study its mechanical properties. From the experimental results the following outcomes has been obtained.

- FML shows great tensile modulus and strength with the increasing stress conditions than conventional fiber reinforced polymer matrix laminates.
- The inverted groove technique and alkaline pre-treatment of fibers moderately enhances fiber and metal bonding.
- Flexural and impact properties are intensively great in the FMLs due to the hybrid reinforcement of basalt and kevlar fibers.
- SEM microstructure analysis clearly indicates the delamination, de bonding, cracks and pit formations of the fractured samples.
- The fabricated hybrid sandwich structure is preferably suitable for high strength commercial automobile applications like floorings, frames and bonnets.

ACKNOWLEDGEMENT

We thank the management of Selvam College of Technology for their deliberate support to carry out this research at Selvam Composite Material Research Laboratory (SCMRL), Namakkal, Tamilnadu, India.

REFERENCES

[1] Straznicky PV, Laliberte JF, Poon C, Fahr A. “Applications of fiber-metal laminates”, Polymer Composites, Vol. 21, 558–67, 2000.

[2] Carrillo JG, Cantwell WJ. “Mechanical properties of a novel fiber–metal laminate based on a polypropylene composite”, Mech Mater, vol. 41, 828–38, 2009.

[3] Sinmazçelik T, Avcu E, Bora MO, Coban O. “A review: Fibre metal laminates, background, bonding types and applied test methods”, Mater Des, vol. 32, 3671–85, 2011.

[4] Hu YB, Li HG, Cai L, Zhu JP, Pan L, Xu J, et al. “Preparation and properties of Fibre- Metal Laminates based on carbon fibre reinforced PMR polyimide”, Compos B Eng, vol. 69, 587–91, 2015.

[5] Santhosh M. S, Sasikumar R. “Influences of Aluminium / E-Glass Volume Fraction on Flexural and Impact Behaviour of GLARE Hybrid Composites”, Journal of Engineering Sciences, Volume 6 (1), 2019. DOI: 10.21272/jes.2019.6(1).c2.

[6] Ali A, Pan L, Duan L, Zheng Z, Sapkota B. “Characterization of seawater hygrothermal conditioning effects on the properties of titanium-based fiber-metal laminates for marine applications”, Compos Struct, vol. 158, 199–207, 2016.

[7] Chai GB, Manikandan P. “Low velocity impact response of fibre-metal laminates – A review”, Compos Struct, vol. 107, 363–81, 2014.

[8] Gonzalez-Chi PI, Flores-Johnson EA, Carrillo-Baeza JG, Young RJ. “Micromechanical analysis of the kink-band performance at the interface of a thermoplastic composite under tensile deformation”, Polym Compos, vol. 31, 1817–21, 2010.

[9] M.S. Santhosh, R. Sasikumar, L. Natrayan, M. Senthil Kumar, V. Elango and M. Vanmathi. “Investigation of mechanical and electrical properties of Kevlar/E-glass and Basalt/E-glass reinforced hybrid composites”, International Journal of Mechanical and Production Engineering Research and Development, Vol. 8(3), 591-598, 2018.

[10] Takamatsu T, Matsumura T, Ogura N, Shimokawa T, Kakuta Y. “Fatigue crack growth properties of a GLARE3-5/4 fiber/metal laminate. Engineering Fracture Mechanics”, vol. 63(3), 253-272, 1999.

[11] Sadighi M, Parnanen T, Alderliesten RC, Sayeaftabi M, Benedictus R. “Experimental and Numerical Investigation of Metal Type and Thickness Effects on the Impact Resistance of Fiber Metal Laminates”, Applied Composite Materials, vol. 19(3), 545-559, 2012.

[12] Alireza Golshahr, Elango Natarajan, M. S. Santhosh, R. Sasikumar, S. Ramesh, Rajkumar Durairaj. “Multiwall Carbon Nanotube Reinforced Silicone for Aerospace Applications”, International Journal of Mechanical and Production Engineering Research and Development Vol. 8, Issue 4, 743-752, 2018.

[13] Chang PY, Yeh PC, Yang JM. “Fatigue crack initiation in hybrid boron/glass/aluminium fiber metal laminates”, Materials Science and Engineering A, vol. 496, 273-280, 2008.

[14] Parnanen T, Vanttinen A, Kanerva M, Jokinen J, Saarela O. “The Effects of Debonding on the Low-Velocity Impact Response of Steel-CFRP Fibre Metal Laminates”, Applied Composite Materials, vol. 23(6), 1151-1166, 2016.

[15] Cortes P and Cantwell WJ. “The prediction of tensile failure in titanium-based thermoplastic fibre-metal laminates”, Composites Science and Technology, Vol. 66(13), 2306-2316, 2006.

[16] Khalili SMR, Mittal RK and Kalibar GS. “A study of the mechanical properties of steel/aluminium/GRP laminates”, Materials Science and Engineering A, vol. 412, 137-140, 2005.

[17] Carrillo JG and Cantwell WJ. “Scaling effects in the tensile behaviour of fiber-metal laminates”, Composites Science and Technology, vol. 67(7-8), 1684-1693, 2007.

[18] R.D. Hemanth, M. Senthil Kumar, Ajith Gopinath and L. Natrayan, “Evaluation of Mechanical Properties of E-Glass and Coconut Fiber Reinforced with Polyester and Epoxy Resin Matrices”, International Journal of Mechanical and Production Engineering Research and Development, vol. 7, Issue 5, 13-20, 2017.

[19] Iaccarino P, Langella A and Caprino G. “A siplified model to predict the tensile and shear stress-strain behaviour of fibre-glass/aluminium laminates”, Composites Science and Technology, vol. 67(9):1784-1793, 2007.

[20] Reyes G, Kang H. “Mechanical behavior of lightweight thermoplastic fiber–metal laminates”, J Mater Process Technol, vol. 186, 284–90, 2007.

[21] Po-Yu Chang, Po-ChingYeh, Jenn-Ming Yang. “Fatigue crack initiation in hybrid boron/glass/aluminum fiber metal laminates”, Materials Science and Engineering: A, vol. 496, Issues 1–2, 273-280, 2008.