

EXPERIMENTAL INVESTIGATION OF FIBERGLASS REINFORCED ALUMINIUM

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Abstract – In the present work, an experimental investigation on fiberglass reinforced aluminium has been carried out. Fiberglass reinforced aluminium is a hybrid composite material. Composite materials are made by combining two materials in which one material is reinforced (fiber) and other material is matrix. The combination of fiber and matrix provide superior characteristics. Here, we are performing various tests on Fiber Metal Laminates (FMLs) which is a type of hybrid composite material in which we use fiberglass as fiber fragment and aluminium.

Key Words: Hybrid composites, Fiber Metal Laminates, fiberglass, composite materials, structural composite.

1. INTRODUCTION

Composite materials are made by combining two materials where one of the materials is reinforced and other material is matrix. The combination of the fiber and resin (matrix) provide superior characteristics compare to the each material alone. Composite products are ideal in applications where high performance is required such as aerospace, race cars, boating, industrial applications, in defense application, etc. Now a day, hybrid fiber composite materials are used in wide range of applications. So we are working on Fiber Metal Laminates in which we are making Fiberglass reinforced aluminium. In most of industrial and structural applications the important parameters in material selection are specific strength, weight and cost. Fiber Metal Laminates (FML) is a family of hybrid composite structure formed from the combination of metal layers sandwiching a fiber-reinforced plastic layer. The metal currently being used is either aluminium, magnesium or titanium and fiber-reinforced layer is either glass fiber, carbon fiber, aramid fiber reinforced composite. Hybrid nature from two different constituents (Metal and fiber) gives excellent mechanical properties like high corrosion resistance, outstanding strength to weight ratio compared to conventional composites. These laminates consist of thin high strength metal sheets bonded together with alternating unidirectional composite layers. These layers are aramid, carbon or glass fibers reinforced in an epoxy resin. We are using fiberglass and aluminium. In this present study we are producing the fiberglass reinforced aluminium and going to perform number of tests.

1.1 Fiber Metal Laminates

Aluminium based FML's mainly classified into followings:

ARALL: It is aramid reinforced aluminium composite,

GLARE: It is fiberglass reinforced aluminium composite,

CARALL: It is carbon fiber reinforced aluminium composite.

Here, we carry out experimental investigation on GLARE.

2. LITERATURE REVIEW

Tamer Sinmazçelik et al. discussed the classification of Fiber Metal Laminates and performed various surface bonding treatments like mechanical, chemical, dry surface treatments, etc to improve bonding between the metal surfaces and fiber layers. Mechanical properties of FMLs are being enhanced by improving the interface bond between composite and metal plies, [1].

Leslie Lamberson et al. performed high velocity impact test on high performance fiberglass panels. Thin phenolic laminates of plain-weave glass cloth impregnated with synthetic thermosetting resins, one melamine and the other epoxy, were impacted by a 1.6 mm diameter nylon sphere using combustion less two-stage light-gas gun. The resulting impact and ejector was captured using high-speed imaging, and the perforation characteristics and damage zone were examined post-mortem using optical microscopy. Both composites had a fiber volume fraction of an estimated 56% and identical fibers weave so that the role of the matrix on impact performance could be comparatively investigated, [2].

O. Laban et al. applied chemical treatments, surface treatments like, etching and anodizing, plasma, etc on fiberglass/aluminium laminates for improving fracture toughness of the laminates. This paper shows that surface roughness also an important factor which affects the bonding of the layers, [3].

Amal A.M. Badawy et al. investigated the impact behavior of glass fibers reinforced polyester (GFRP) by using notched Izod impact test specimen. The experimental program was carried out on unidirectional laminate of GFRP in directions 0, 45 and 90 in addition to cross-ply laminate. The effect of fiber volume fraction, Vf % (16%, 23.2% and 34.9%) was

considered. The impact specimens were tested after exposure to temperatures of -10°C, 20°C, 50°C and 80°C for exposure time of 1 h and 3 h. Test results showed that the effect of exposure temperature and fiber volume fraction on impact strength of GFRP composite depends on the parameter controlling the mode of failure, i.e. matrix or fiber. The failure characteristic changed from fiber pull-out to fiber breakage with increasing the exposure temperature, [4].

S.K.Singh et al. carried out experimental investigation on the E-glass fiber composite with epoxy resin and nanoclay in which natural ingredient nanoclay is added in the epoxy resin by stirring for reinforcement of glass fiber polymer. Various tests were carried out on the composite shows that by adding proper amount of nanoclay in epoxy resin can improve the performance of the composite, [5].

Aniket Salve et al. performed various test like bending test, tensile test, drop weight test on Fiber Metal Laminates. And also the carried out numerical modeling of it, [6].

M. Sadighi et al. carried out on the glass fiber metal laminates in which simultaneous and two successive repeated impacts were carried out on the composite. Results shows that glass fiber laminates offer better energy absorption than carbon fiber metal laminates. The inspection of the impact damage is carried out by visual inspection and by ultrasonic C scan, [7].

Ming-mingXu, Guang-yan Huang et al. performed high velocity impact on the Carbon Fiber Reinforced Polymers (CFRP) and Carbon Fiber Reinforced Laminates (CARLL). They used 2/1 and 3/2 lay up of 0.8mm thick carbon fiber composite and 0.8 mm thick Al 2024 T3. The results shows that the CARLL has better resistance to penetration compare to CFRP. It also shows that in the test of flat nose high velocity impact, the performance of CARLL is better compare to the Al 2024T3 having same thickness around 8% higher, [8].

B. Yu et al. performed the experiments on Carbon Fiber Reinforced Polymer (CRFP) and aluminium plates. This paper shows the performance of the CFRP plates and aluminium alloy plates against the ballistic and Quasi-static loading. In the experimental set up aluminium alloy (AA1050A) plates are placed in front of the CFRP plates in order to protect it from the impact by spherical projectiles, [9].

BB Liao and PF Liu performed Finite element analysis of dynamic progressive failure properties of GLARE hybrid laminates under low velocity impact. In this paper they did finite element analysis of GLARE under low velocity impact. It shows how much amount of energy GLARE can withstand, [10].

From the research papers in this classification, it is observed that some work done on the Carbon Fiber Reinforced

Polymers (CRFP) and also carbon fiber reinforced metal laminates in which manufacturing and testing methods of both material as well as comparison of the performance of both material, etc. And also lots of work has been carried out on Fiberglass Reinforced Polymers (FRP). We observed that there is some work done on the Fiberglass Reinforced Aluminium. So, we are focusing on fiberglass reinforced aluminium for strength based application and also there is less work done on the comparative study of different patterns of the fiberglass reinforced aluminium. So we are focusing on the above criteria.

3. EXPERIMENTAL WORK

From the literature we concluded that we are focusing on fiber reinforced aluminium for strength based application, as well as we are considering the different patterns which could be produced on the fiberglass reinforced aluminium.

So we are going to produce the mainly two types of pattern and also varying the thickness of aluminium metal sheets. After that we will carry various tests like impact test, bend test on the number of specimens comparing the performance of the specimens based on their pattern as well as on the thickness of the metal sheets.

In this present study we carried out impact and bend test in which dimensions of specimens are 150*150 mm & 150*50 mm respectively.

3.1 Hybrid Composites Preparation

The hybrid composite material used for this study is prepared by hand layup process. In which mixer of resin and hardener added layer by layer. After that fiber metal laminate is placed into the vacuum bags so that uniform pressure can be applied and also air can be eliminated for proper bonding. Then after specimens are subjected to curing process, it takes 2-3 days. After that specimens are ready for testing.

Here we use three different thickness of aluminium (0.5mm, 0.75mm&1mm). And had two main two patterns first one is fiber faced and second one is metal faced in which we added number of fiber layers and metal layers.

- Fiber faced specimens:

- 1 (F-F-Al-F-F)

- 2 (F-F-Al-F-F-Al-F-F)

- 3(F-F-Al-F-F-Al-F-F-Al-F-F) in which 'F' represents fiberglass layers and 'Al' represents aluminium metal layers.

- Metal faced specimens:

- 1 (Al-F-F-Al)

- 2 (Al-F-F-Al-F-F-Al)

- 3 (Al-F-F-Al-F-F-Al-F-F-Al)

3.2 Testing & Analysis

- **Drop weight test:** We carried out low velocity impact test on the fiberglass reinforced aluminium. Drop weight test set up is shown in the figure.

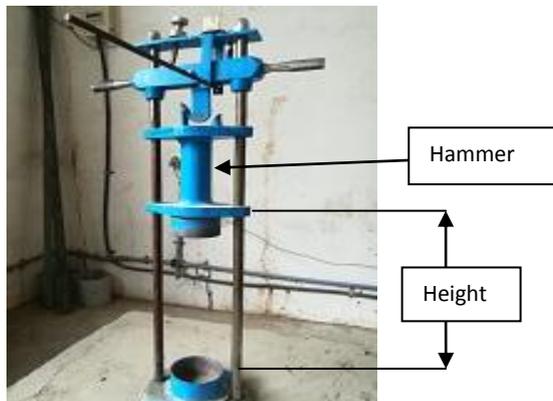
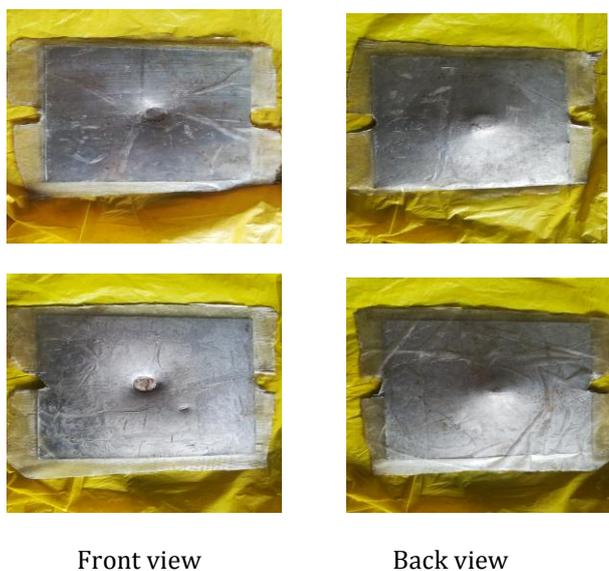


Fig-1 Drop weight (Impact) test setup

We used a rigid cylindrical object having dimensions of 3mm length and 2 mm diameter to concentrate the impact into small area. In the set up mass of hammer is 15 kg and height between the hammer to the contact point is 35 cm. So, the impact energy can be calculated by conversion of potential energy into kinetic energy.

Here, energy in the terms of kinetic energy (K.E) = 51 J & velocity before the impact $v = 2.61$ m/sec.

- **Analysis:**
Samples of specimens after impact test:



Front view

Back view

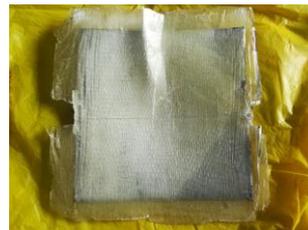


Front view



Back view

Fig-2 Metal faced samples



Front view



Back view

Fig-3 Fiber faced samples

Above are some pictures of specimens which were tested. From the inspection of all the specimens, we observed that in metal faced specimens energy is absorbed by the upper and bottom layers of metal where as in fiber faced specimens energy absorbs along the fiber principal direction, here we used unidirectional fiberglass due to that energy dissipated in all directions. Specimens having thick aluminium sheets have better performance compare to the thin aluminium sheets.

As we add the number of metal layers and fiberglass layer, the capacity to withstand the impact force of specimens increases. In the metal faced layers performance of the specimens improved with the addition of metal layers

compare to the fiber faced layers. And also thickness of the metal sheets also affects the performance. More the thickness better the performance of specimens.

We also observed that delamination mainly occurred in the fiber faced specimens as shown in the figure. It occurred because the damage done by impact is more concentrated at interface bond between the metal and fiber layers in fiber faced specimens. Delamination did not occur in metal faced specimens of 1mm & 0.75mm thickness of metal sheets.



Fig-4 Delamination of fiber faced specimens



Fig-5 Delamination of metal faced specimen

But in Metal faced specimens having 0.5 mm thickness of metal sheets delamination occurred as shown in figure. It is due to the thickness of metal layers.



Generally in metal faced specimens bottom and top metal layers absorb the impact energy but in this case (Fig-5) thickness of metal layers is 0.5 mm so it could not withstand the impact energy.

- In some literature reviews two successive impacts were carried out [7]. So we also carried out two impacts on a couple of specimens. Effect of the second impact on the specimens is shown below.



Front view



Back view

Fig-6 Effect of second impact on metal faced specimen Pattern (Al-F-F-Al)



Front view



Back view

Fig-7 Effect of second Impact on fiber faced specimens Pattern (F-F-Al-F-F)

As shown in the Fig-6 & Fig-7 Metal faced specimens are more durable than fiber faced specimens. Second impact on metal faced specimen did not affect much on it compare to fiber faced specimen. It is observed that fiber faced specimen was bended due to the amount of impact force and the bottom layer of it slightly tear off as shown in the figure. Where in metal faced specimen interface bond between metal layers and fiber layers is little bit of damaged.

- In the literature review amount of impact energy is 17.5 J & maximum amount of Impact energy is 26 J. [7], [8]. In this present study we carried out two successive impacts having 51 J of force each.

So, in this present study we observed that performance of metal faced specimens is better compare to the fiber faced specimens.

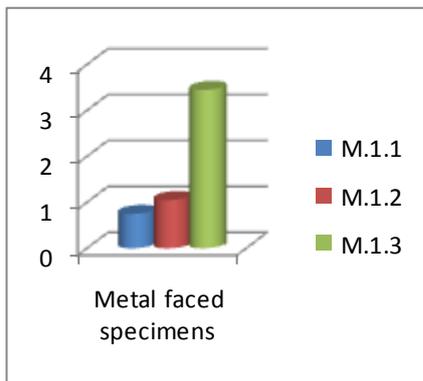
- **Bend test:** Main aim of doing bend test to find out that the Fiberglass reinforced aluminium can be used where high bending strength is required.

M.1.1	M.5.1	M.7.1
M.1.2	M.5.2	M.7.2
M.1.3	M.5.3	M.7.1
F.1.1	F.5.1	F.7.1
F.1.2	F.5.2	F.7.2
F.1.3	F.5.3	F.7.3

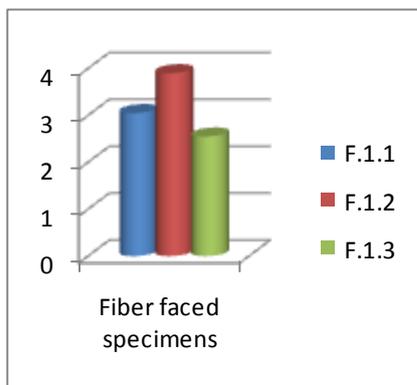
Table-1 Bend test specimens

Where, M= Metal faced, F= Fiber faced, (.1, .5, .7) = Thickness (1mm, 0.5mm, 0.75mm). And 1, 2&3 denotes the various patterns shown in section 3.1

- Bending strength in kilo Newton of specimens having metal layers thickness of 1mm



(a)

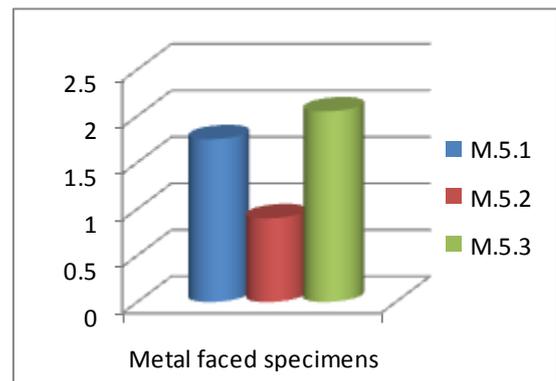


(b)

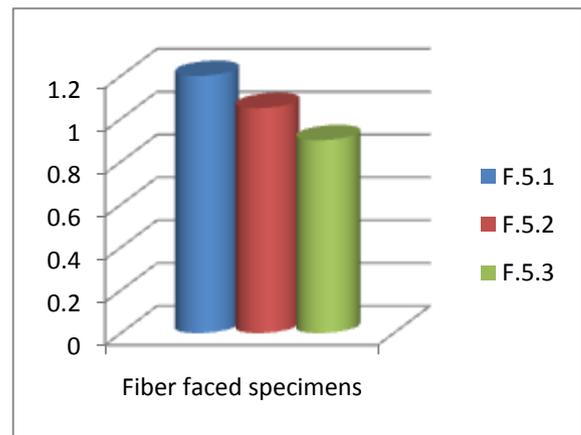
Fig-8 Bending strength (in kN) of specimens having metal layer thickness 1.0 mm

We observed that bending strength of Metal faced specimens is very low compare to the fiber faced specimens as mentioned in above charts. F.1.3 specimen has low strength compare to the other two specimens in chart (b) it may be caused due to the improper bonding between the fiber layers and metal layers.

- Bending strength (in kN) of specimen having 0.5mm thickness of metal layers:



(c)

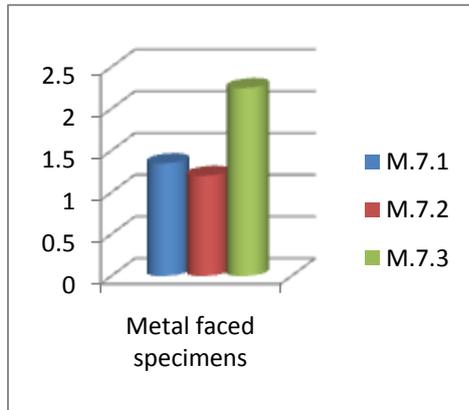


(d)

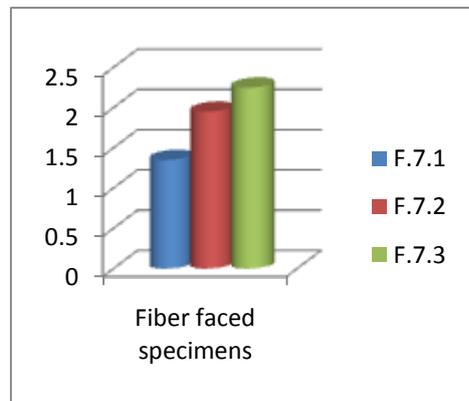
Fig-9 Bending strength (in kN) of specimens having metal layer thickness 0.5 mm

Thin layer of metal sheets does not affect the bending strength of Fiberglass reinforced aluminium.

- Bending strength (In kN) of specimens having metal layers thickness 0.75mm



(e)



(f)

Fig-10 Bending strength (in kN) of specimens having metal layer thickness 0.75 mm

By the analysis of the results of bend test, we can say that bending strength of Fiberglass reinforced aluminium is depends on the thickness of the metal layers. More the thickness of metal sheets better the bending strength. From the charts a, b, c, d, e & f we can say that specimen having metal layers of 1mm thickness have better bending strength in which fiber faced specimens have better strength compare to metal faced specimens. As we reduces the thickness of metal sheets bending strength of metal faced and fiber faced specimens comparatively became same.

4. CONCLUSION

- By performing the impact test on different specimens, we observed that metal faced specimens have better energy absorption capacity compare to fiber faced specimens.

- There is no 100% penetration in any specimens for single impact test. It shows that Fiberglass Reinforced Aluminium can with stand more than 50J force. In this study Fiber reinforced aluminium withstand much more energy compare to other research papers [7, 8].
- We observed that FRA's performance was improved by adding the number of fiber and metal layers. We observed that specimen having pattern (Al-2F-Al-2F-Al-2F-Al) in which metal layer of 1 mm thickness is used has better performance compare to others.
- Bending strength of the Fiber faced specimens is more comparing to the Metal faced specimens. And also thickness of the metal sheet is affects bending strength of Fiberglass reinforced aluminium. Specimens having metal layers of 1.0 mm thickness have better bending strength compare to specimens having thickness of 0.5 mm & 0.75 mm.

REFERENCES

- [1] Tamer Sinmazçelik, EgemenAvcu, Mustafa Özgür Bora a, OnurCuban "Fiber metal laminates, background, bonding types and applied test methods" Materials and Design 32 (2011) 3671–3685
- [2] Leslie Lamberson "Investigations of High Performance Fiberglass Impact Using Combustion less Two-Stage Light-Gas Gun" Procedia Engineering 103 (2015) 341 – 348.
- [3] O. Laban, E. Mahdi "Enhancing mode I inter-laminar fracture toughness of aluminum/fiberglass fiber-metal laminates by combining surface pre-treatments" International Journal of Adhesion and Adhesives 78 (2017) 234–239.
- [4] Amal A.M. Badawy "Impact behavior of glass fibers reinforced composite laminates at different temperatures" Ain Shams Engineering Journal (2012) 3, 105–111
- [5] S.K.Singh, S.Singh, S.Sharma "Strength degradation of mechanical properties of unidirectional E-glass fiber with epoxy resin composite" Procedia Materials Science 5 (2014) 1114 – 1119
- [6] Aniket Salve, Ratnakar Kulkarni and Ashok Mache "Fiber Metal Laminates (FML's) - Manufacturing, Test methods and Numerical modeling" IJETS.6.2016.10.2.1060
- [7] M. Sadighi, M. YarmohammadTooski, and R.C. Alderliesten "An experimental study on the low velocity impact resistance of Fibre Metal Laminates under successive impacts with reduced energies" Aerospace Science and Technology S1270-9638(16)30303-0
- [8] Ming-mingXu, Guang-yan Huang, Yong-xiang Dong, and Shun-shan Feng "An Experimental Investigation into The High Velocity Penetration Resistance of CFRP and

CFRP/Aluminium Laminates" Composite Structures
S0263-8223(17)32911-2

- [9] B. Yu, V.S Deshpande, and N.A. Fleck "Perforation of Aluminium Alloy-CFRP Bilayer Plates under Quasi-static and Impact Loading by" International Journal of Impact Engineering S0734-743X(18)30157-X
- [10] BB Liao and PF Liu "Finite element analysis of dynamic progressive failure properties of GLARE hybrid laminates under low velocity impact " in Journal of composite materials