Processing of 45 Degree Stitched Mat GLARE Laminate and Analyzing Tensile and Flexural Properties

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Abstract- *Combining the suitable properties of metals and fiber reinforced composites, as the idea behind the application of new types of materials called fiber metal laminates (FMLs). In this article, the effect of volume percentage of fiber determines the mechanical properties such as tensile and flexural tests have been investigated and experimentation was performed. Aim of this paper is to compare the four different types of layers such as 2/1, 3/2, 4/3, 5/4 in 45degree stitched mat GLARE laminate. Essential quality of this 45degree orientation may lead superior resisting to tensile and flexural properties. The laminates were obtained by hand layout technique and specimens were cut off from wire cutting as per ASTM standards. The experimental work was done by AUTOGRAPH -50KN Computer controlled UTM. From the experimental work, tensile and flexural tests were taken and graphs were plotted between stress vs. strain and load vs. deflection. In addition to that, 4/3 layer of 45 degree GLARE laminate had superior strength than that of the other layers.*

Keywords- GLARE Laminate, FML, Mechanical Properties, Computer controlled UTM, ASTM standards.

I. INTRODUCTION

Fiber–metal laminates (FMLs) which consist of alternating layers of unidirectional fiber reinforced plastic (UD FRP) laminate and thin metal sheets have potential advantages over monolithic metal alloys not only in weight saving in the design of structural components but also in its damage tolerance [1–6]. GLARE is a "Glass Laminate Aluminium Reinforced Epoxy" FML, composed of several very thin layers of metal (usually aluminum) interspersed with layers of glass-fibre "pre-preg", bonded together with a matrix such as epoxy. The uni-directional pre-preg layers may be aligned in different directions to suit the predicted stress conditions. Although GLARE is a composite material, its material properties and fabrication are very similar to bulk aluminum metal sheets. It has far less in common with composite structures when it comes to design, manufacture, inspection or maintenance. GLARE parts are constructed and repaired using mostly conventional metal material techniques. GLARE parts are constructed and repaired using mostly conventional metal material techniques. Within the FML family, GLARE composed of UD GFRP laminate and thin sheets of aluminum alloy has proved to be superior to monolithic aluminum alloys, especially in resistance to the growth of cracks in the aluminum-alloy layers under tensile fatigue loading conditions. Owing to the fiber bridging effect from the GFRP layers [5]. The fatigue crack propagation in the aluminum-alloy layers was found to be 10–100 times slower than in the monolithic aluminum alloy [1]. It has also been confirmed that GLARE exhibits higher impact resistance as well as excellent fatigue resistance [6]. The mechanical properties of a unidirectional GLARE-2 laminate in the fiber direction contribute to weight saving over the aluminum alloy by roughly 6% in the design based on bending stiffness and by 17% in the design based on yield strength. Because of its optimized performance, GLARE has now been applied to the fuselage skin structures of commercial aircrafts.

II. EXPERIMENTAL WORKS

Four types of layers were fabricated in 45^0 stitched mat laminates, Glare2/1 Glare3/2 Glare4/3 and Glare 5/4. Glare 5/4 woven roving 45^0 stitched mat laminates consisting of five 0.3 mm thick aluminum sheets supplied by JSK Industries and four 1600 gms/m2 E-glass 45^0 stitched mat supplied by Goa Glass fibre Ltd. Epoxy resin plies were fabricated using a hand-layup technique. Hand-layup technique was chosen as it was ideally suited to manufacture low volume with minimum tooling cost [12]. The nominal weight fraction of fibers in GFRP was kept constant at 60%.
The plies were laminated in such a way that the warp and weft directions were parallel to the edges of the laminates. The plates were then post-cured in an oven at 100°C for 4 hours after they had been cured under 15 kPa pressure for one day at room temperature [15]. These laminates were then cut up to 250x25 mm for tensile specimens and 127x12.7mm for flexural specimens as per standard ASTM D3039 and D790 [16,17] respectively. The processing of glare laminate was i)

hand abrasion by 200 grit Aluminium oxide papers, to create a roughness, ii) Etching in acetone, iii) Washing by dilute alkaline solution unto 5mins at 60˚c to 70˚c, iv) rinsing in hot water and Etching aluminium sheets in sulfochromic solution (FPL-Etch) based on ASTM D2674 [18] and D2651 [19] standards.

A. TENSILE TEST

Tensile specimens are 250 mm long and 25 mm width of the specimen and similarly 2/1 – 1.9mm, 3/2 – 3.1mm, 4/3 – 4.5mm and 5/4 – 5.65mm thick with a gauge length of 200 mm were prepared [16]. Tensile tests were performed on an Autograph-AGIS-Shimadzu-50KN capacity universal testing machine at a crosshead rate of 5 mm/min, which corresponds to a strain rate of 0.2% per second. Tensile properties were determined from these specimens [8]. Fig. 8 and Fig. 9 show the specimen before and after tensile testing.
Specimens are mounted on the grips of a universal testing machine and gradually loaded in tension while recording load. The ultimate strength of the material can be determined from the maximum load carried before failure and also various failure modes were analysed.

After that, the stroke was monitored with displacement transducers then the stress-strain response of the material can be determined, from which the tensile strain, modulus of elasticity were derived [16].

B. FLEXURAL TEST

The test method for conducting the test usually involves a specified test fixture on a universal testing machine. Details of the test preparation, conditioning, and conduct affect the test results. The flexural test specimens are 127mm length and 12mm width taken from ASTM standard and 2/1 – 1.9mm, 3/2 – 3.1mm, 4/3 – 4.5mm and 5/4 – 5.65mm thick with a gauge length of 100 mm were prepared. The three point bending flexural test provides values for the modulus of elasticity in bending flexural stress, flexural strain and the flexural stress-strain response of the material. The flexural properties of the glass fibre aluminium laminate composites were determined according to ASTM D790 test standard specifications. The average flexural properties determined from 3 specimens test on each type of layer.

Properties of composite materials are governed by the adhesion between fibre and matrix. Beside this, the interface bond between composite ply and metal ply governs same properties of FMLs. The main advantage of a three point flexural test is the ease of the specimen preparation and testing. However, this method has also some disadvantages the results of the testing method are sensitive to specimen and loading geometry and strain rate. Specimens are mounted on the grips of a universal testing machine and gradually loaded in tension while recording load. The ultimate strength of the material can be determined from the maximum load carried before failure and also various failure modes were analyzed.

C. SCANNED ELECTRON MICROSCOPE ANALYSIS

A scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that can be detected and that contain information about the sample's surface topography and composition. The electron beam is generally scanned in a raster scan pattern, and the beam's position is combined with the detected signal to produce an image. SEM can achieve resolution better than 1 nanometer. Specimens can be observed in high vacuum, in low vacuum, and (in environmental SEM) in wet conditions. Magnification in a SEM can be controlled over a range of up to 6 orders of magnitude from about 10 to 500,000 times. Unlike optical and transmission electron microscopes, image magnification in the SEM is not a function of the power of the objective lens. SEMs may have condenser and objective lenses, but their function is to focus the beam to a spot, and not to image the specimen. Provided the electron gun can generate a beam with sufficiently small diameter, a SEM could in principle work entirely without condenser or objective lenses, although it might not be very versatile or achieve very high resolution. In a SEM, as in scanning probe microscopy, magnification results from the ratio of the dimensions of the raster on the specimen and the raster on the display device. Assuming that the display screen has a fixed size, higher magnification results from reducing the size of the raster on the specimen, and vice versa. Magnification is therefore controlled by the current supplied to the x, y scanning coils, or the voltage supplied to the x, y deflector plates, and not by objective lens power.In SEM analysis, our uses were before test and analysis for tensile test and then after test for tensile test. Learn from this method the FML structure has breaking and surface of the FML layer. In this analysis only we have to know the surface of fiber with aluminium laminate.

III. RESULT AND DISCUSSION

The results were evaluating the strength between glare fiber metal laminate and to compare the material properties like tensile and flexural and discuss about the strength comparison graphs and which is the best layer among from the results. From table.3 readings for tensile strength to compare the all layers like GLARE 2/1, 3/2, 4/3, 5/4 the maximum stress withstand that layer GLARE 4/3. Where as, layer 2/1 have 197.368N/mm^2 then layer 3/2 have the maximum stress like 56.2477N/mm^2. Similarly layers were 4/3 and 5/4 having like that maximum stress 307.284N/mm^2 and 121.164N/mm^2 To compare all layers the 4/3 layer was best one because the 5/4 layer strength was much better than 4/3 layer but the 5/4 layer has 4 layer of fiber so that the deflection was increasing similarly load will decreasing. So the 4/3 layer was best in withstanding load.

From fig.14 load vs deflection for GLARE 2/1, 3/2, 4/3, 5/4 comparison of tensile test. The graph have maximum load or ultimate load were found easily. So, to compare all the layers of glare and which one was best among these layers were found. From fig.15 stress vs strain for GLARE 2/1, 3/2, 4/3, 5/4 comparison of tensile test. The graph has maximum stress or ultimate stress was found easily. So, to compare all the layers of glare and which one was best among these layers were found. And this stress vs strain curve has maximum yield point and maximum bending load were found. When this graph has found the deflection of the specimen. Here the deflection was increasing the load will decreasing. When the specimen goes to the failure or the specimen was broken.
From table.4 readings for flexural strength to compare the all layers of the maximum load withstand that layer was 5/3 GLARE. Where as, layer 2/1 have 197.368N/mm^2 then layer 3/2 have the maximum stress like 56.2477N/mm^2. Similarly layers were 4/3 and 5/4 having like that maximum stress 307.284N/mm^2 and 121.164N/mm^2.

From fig.16 load vs deflection for GLARE 2/1, 3/2, 4/3, 5/4 comparison of flexural test. In this graph has find the maximum bending load, for all layer to compare the best was 5/4 having resist maximum bending load. Because the 5-aluminium layer and 4 fiber layer so it will reach its yield point was very slow. Then 5/4 layer has increasing load and decreasing deflection. So in this flexural test the best layer has 5/4 GLARE.

IV. FIGURES AND TABLES

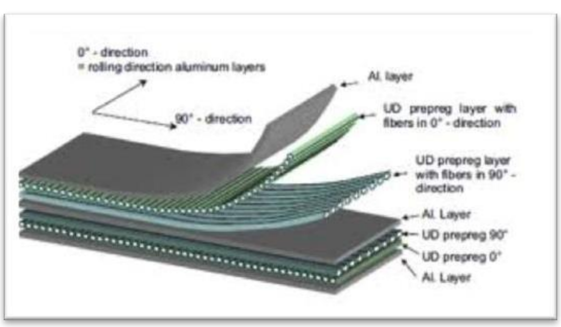

Fig.1 Fiber Metal Laminate

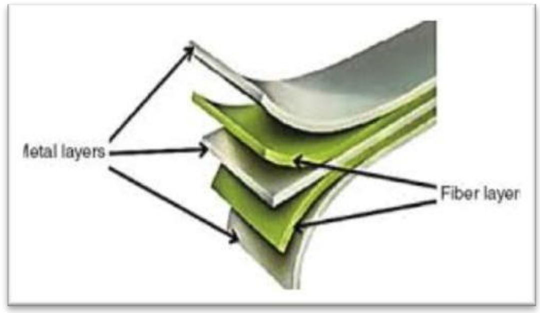

Fig. 2 Aluminim sheet with fiber

Fig. 3 Aluminium sheet cleaning with Acetone

Fig. 4 Aluminium sheet cleaning with hot water

Fig. 5 Preparation of sodium hydroxide solution

Fig. 6 Preparation of Epoxy resin

Fig. 7 Applying epoxy resin on fiber

Fig.8 Specimen before tensile test

Fig. 9 specimen after tensile test

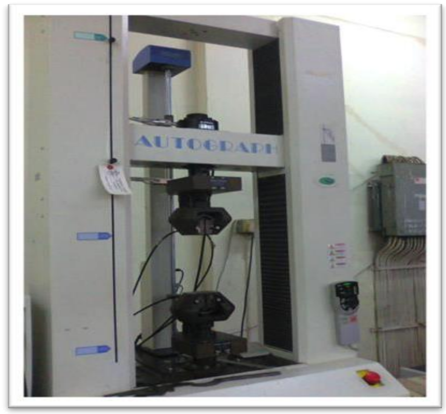

Fig. 10 Universal testing machine

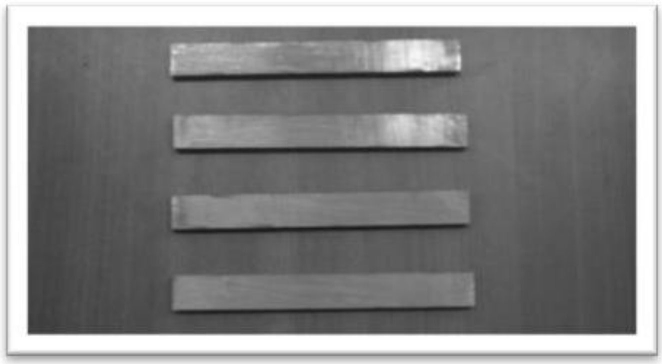

Fig. 11 specimen before flexural test

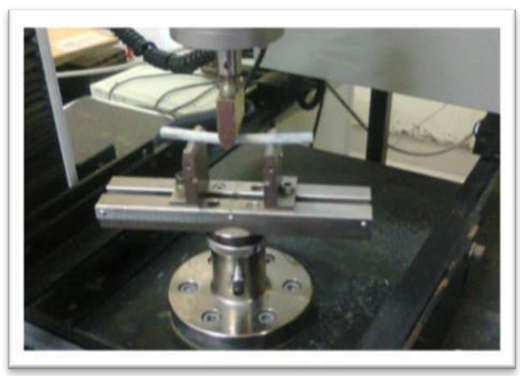

Fig. 12 During flexural test

Fig. 13 Specimen after flexural test

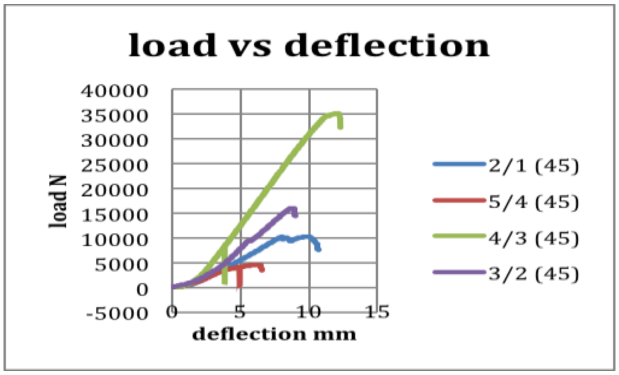

Fig. 14 load vs deflection for tensile test

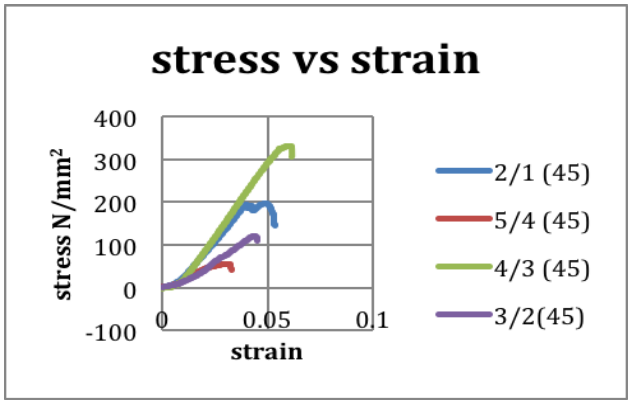

Fig. 15 stress vs strain for tensile test

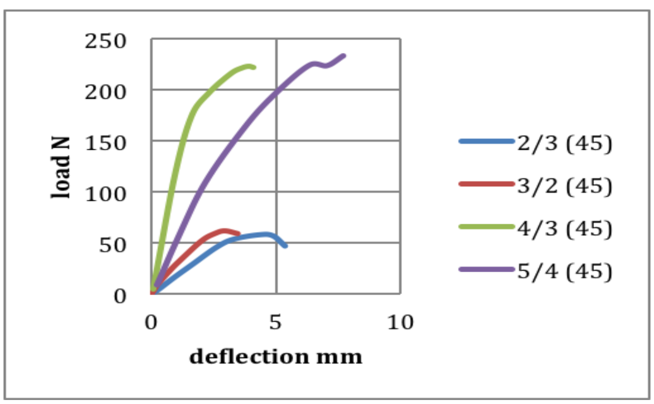

Fig. 16 load vs deflection for flexural test

TABLE I DIMENSIONS OF TENSILE SPECIMEN

Layer	Width (mm)	Thickness (mm)	Gauge length (mm)
Glare 2/1	27.5	1.9	200
Glare 3/2	26.2	3.1	200
Glare 4/3	23.5	4.5	200
Glare 5/4	23.5	5.65	200

TABLE II DIMENSIONS OF FLEXURAL SPECIMEN

Layer	Length (mm)	Thickness (mm)
Glare 2/1	127	1.9
Glare 3/2	127	3.1
Glare 4/3	126.8	4.5
Glare 5/4	127.7	5.65

TABLE III READINGS FOR TENSILE SPECIMEN

Layer	Maximum force (KN)	Maximum stress (N/mm^2)	Maximum strain (%)
Glare 2/1	10.3125	197.368	4.9355
Glare 3/2	4.568	56.2477	3.197
Glare 4/3	32.4953	307.284	5.5765
Glare 5/4	16.4836	121.164	4.4105

TABLE IV READINGS FOR FLEXURAL SPECIMEN

Layer	Maximum breaking load (KN)	Deflection (mm)
Glare 2/1	57.9344	4.3184
Glare 3/2	62.0753	2.9497
Glare 4/3	223.3340	3.8697
Glare 5/4	233.4856	7.6703

V. CONCLUSION

- The experiment results were analyzed for various layers of FML
- Increase in volume of fibre percentage in aluminum tends to decrease the tensile strength. Maximum load required to fracture, increase in thickness of the specimens.
- The maximum load absorption and strain rate were obtained as a result.
- By the result analysis and comparison of layers were done.
- The best among the layer were tested and found to be GLARE 4/3

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