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A STUDY ON THE FABRICATION OF GLASS LAMINATE ALUMINUM REINFORCED EPOXY AND THE BEHAVIOR OF THE MATERIAL UNDER DIFFERENT LOADING CONDITIONS

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ABSTRACT
FMLs (Fiber metal laminates) are the new kind of material developed for the need to create superior light weight structures with exceptional properties. The first generation FMLs used thermosetting resins but as the demand increases over the years, new types of FMLs are being fabricated using new types of materials and resins which are more lightweight and efficient when compared to previous generation FMLs. Because of their light weight, robust, economical properties the fiber metal laminates are finding their application in wide variety of industries. Better strength to weight ratio, stiffness to weight ratio are main reasons for the expansion of the application of FMLs in different fields. Because of their improved mechanical properties like fatigue resistance, low specific weight, good thermal, acoustic and electrical resistance they are good material for advanced aerospace and automotive structural applications. Adhesive bonding between the composite layers is the important factor which has to be considered in the manufacturing of these types of laminates.
In this study three types of glass-fiber reinforced aluminum laminates were manufactured with different glass fiber orientation using hand layup technique based on ASTM standards. Then tests such as Tensile, flexural, hardness are conducted to study the behavior of the material under different loading conditions.

INTRODUCTION
Composite material is the macroscopic blend of two or more materials, having a distinguishable interface at the intervals of each layer. Bonding of layers with considerably different chemical and physical properties leads to a new type of composite with the properties dissimilar to that of original materials used. This is known as the principle of combined action. The resulted composites have applications in various fields because these materials are lighter, stronger, tougher and cheaper than conventional metals.

COMPOSITES
Because of the enhanced mechanical and chemical properties of the composite materials the demand for composite materials has increased among various other industries other than aerospace industry. Thus use of composite materials has been shifted from aerospace industry to other commercial products in recent times. The main reasons for composite material uses are.

- To reduce weight of the structure.
- To increase the impact strength and toughness of the structure.
- To increase damping.
- To increase strength, stiffness and stability.
- To reduce overall cost.
- To decrease thermal expansion.
- To increase the wear resistance.
- To reduce corrosion.

Composites have found its applications in many fields because of their mechanical properties like high strength to weight ratio, low weight, resistant to wear etc, hence lots of research have been made on these type of materials, which gave raise to various types of composite materials. These composites have found its uses in Military, aerospace, automotive and sports industries etc.

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MATERIALS AND METHODS
SELECTION OF MATERIAL

Materials which have been used in the manufacturing of this FML composite are Aluminum 2024, E-glass woven fiber, LY 556 Epoxy resin and Aradur HY 951 hardener

Aluminum 2024: 2024aluminum is used in the project. This alloy is selected because it poses good mechanical properties. Aluminium 2024 is the alloy of aluminum, and the copper is used as the fundamental alloying material. It is mainly used in the fields where the material should be strong as well as light in weight and the material should be resistant to fatigue. Aluminum 2024 is extruded commonly, and also available in the forms of sheet and plate.

Glass fiber: The glass fiber used in this project is E glass fiber and is a alumino borosilicate glass with less than one percent of alkali oxides and it has a tensile strength of 3445Mpa compressive strength of 1080Mpa, density 200 g/m^2

Epoxy: The epoxy used in this study is Araldite LY556 epoxy is a thermosetting matrix which is a pale yellow clear liquid it has low viscosity and the reaction time of the epoxy can be varied by using accelerators. The key properties of the epoxy are excellent impregnation to fibers and good mechanical properties and thermal properties, resistant to chemical actions up to 80^0 C. the viscosity of the epoxy at 25^{0}C is 10000-12000 Mpa, density of the epoxy at 25^{0}C is 1.15-1.2 g/cm^3, flash point of the epoxy is less than 200^{0}C.

Hardener: Hardener used in this study is Aradur HY951 which is mixed with the epoxy with the ratio of 10:1 ie (10 parts of resin and one part of hardener). The important properties of the hardener are good mechanical and electrical properties and good resistance to chemical actions.

METHODOLOGY: Following steps are followed to carry out this project

1. Preparing the aluminum sheets and glass fiber by preparing the surface of aluminum sheets.
2. Mixing LY 556 epoxy and Hardener HY 951 at the ratio 10:1 respectively.
3. Applying the resin mixture to the glass fiber and then aluminum sheets and glass fibers are laid on top of another until the required thickness of composite material is achieved.
4. Applying the necessary load on top of the composite material to remove the excess resin and trapped air from the composite material
5. Then the composite is allowed to cure for about 24 hours to achieve the proper bond between the layers.
6. Conduct mechanical test. And results are analyzed.

The above steps are represented in the form of flow chart below

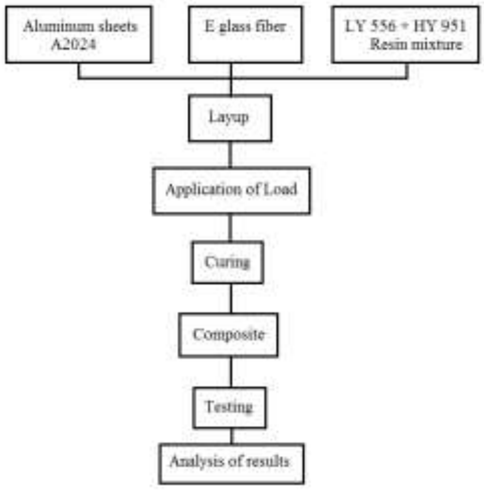

Fig 1: Glass laminate aluminum reinforced epoxy composite flow chart.

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RESULTS AND DISCUSSION

RESULTS AND DISCUSSIONS

Strength of the composite material depends on the composition of the composite material itself and the types of layers used in the fiber metal laminates. And also the orientation of the glass fibers in the composite plays an important role in determining the strength of the composite. The strength of the composite also depends on the bonding strength between the laminates, in order to have good adhesion between the laminates the surface of the metal sheets should be properly treated. All these factors affect the mechanical properties of the composite material.

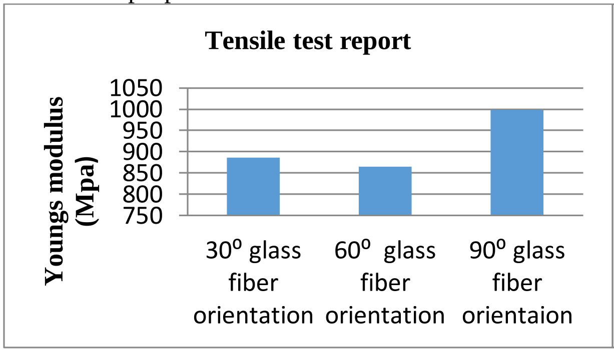
Tensile, flexural and hardness tests are conducted on GLARE to study following mechanical properties of the composite.

- Tensile properties
- Flexural properties
- Hardness of the composite

MECHANICAL PROPERTIES OF GLARE

6.1.1 Tensile strength of the GLARE

Tensile strength is the mechanical property of the material which can be measured by conducting tensile test on the specimen. In order to conduct the tensile test on the GLARE. Three types of GLARE specimens with different glass fiber orientation are fabricated they are 90^0 GLARE, 30^0 GLARE and 60^0 GLARE. All these specimens are fabricated according to ASTM standards and are subjected to tensile test to the study the mechanical properties of the material.



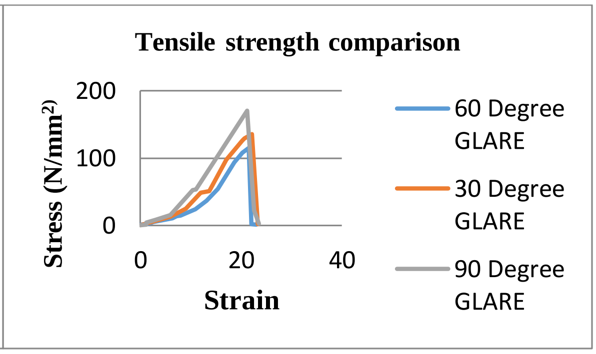


Fig 2: Comparison of young's modulus of different orientation. Fig 3: Comparison of tensile strength of GLARE specimens

From the fig 2 the young's modulus of 90^0 GLARE is higher which is 998.99 MPa when compared to other two specimens and the specimen with the lowest young's modulus is 60^0 GLARE with the tensile modulus of 865.35 Mpa. The young's modulus of 30^0 GLARE is 865.35 MPa. It is evident from the graph that the 90^0 GLARE is 11.32% stronger when compared to 30^0 Glare specimen. And 90^0 GLARE is 13.37% stronger when compared to 60^0 GLARE.

From the fig 3 it can be understood that the 90^0 GLARE has the highest tensile strength than the other two orientations. The tensile strength of the 90^0 GLARE is 170.52 Mpa which is 20.63% stronger than 60^0 GLARE specimen having a tensile strength of 135.34 Mpa. And the GLARE 90^0 specimen is 32.48% stronger than 30^0 GLARE specimen with the tensile strength of 115.12 Mpa.

From both the Graphs 2 and 3 it is observed that the 90^0 GLARE showed the highest strength than 60^0 and 30^0 GLARE specimens. The 90^0 GLARE can withstand the peak load of 16.50KN, load at the yield is 12 KN and fractures at the load of 0.3KN. While 60^0 GLARE can withstand the peak load of 13.86 KN, the yield load of 12 KN and the specimen fractures at 180N. And finally the 30^0 GLARE can withstand the peak load of 13.06 KN and the specimen breaks at 13.03KN. The fact that the 90^0 GLARE shows higher strength because of the orientation of the glass fiber along the length of the specimen.

Similar observations are made by the researchers.

Ban. Bakir et.al. Have investigated the effect of fiber orientation on the glass reinforced composites, they prepared three types of composites with different fiber orientations and found out that that the 90^0 specimen has greater tensile strength compared to other orientation. And after examination on the specimens they concluded

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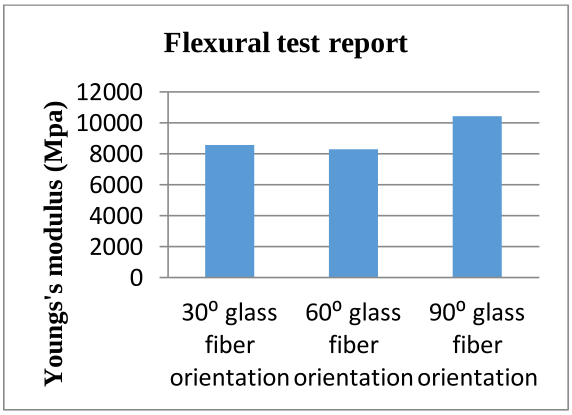
that the 90^0 specimens were stronger because the propagation of crack is perpendicular to the direction of application of load while for other orientations the crack propagation was irregular and crack propagates in different direction to the application of load.

Flexural strength of the GLARE

Flexural strength is a mechanical property, which measures the bending strength of the composite material. To conduct the bending test three types GLARE specimens are manufactured they are 90^0,30^0,60^0 GLARE. All these specimens are manufactured according to ASTM standards and are subjected to flexural test to study their behavior.



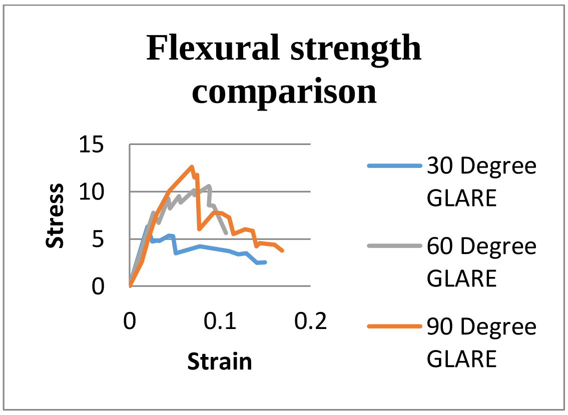


Fig 4: Comparison of flexural modulus of different specimens. ***Fig 5: Comparison of flexural strength of GLARE.***

From the fig 4 it can be observed that the Flexural modulus of 90^0 GLARE is higher, which is 10439.89 MPa when compared to other two orientations, and the specimen with the lowest young's modulus is 60^0 GLARE with the flexural modulus of 8288.492 Mpa. And the flexural modulus of 30^0 GLARE is 8591.91 MPa. It is evident from the graph the 90^0 GLARE is 20.6% stronger when compared to 30^0 GLARE specimen. And 90^0 GLARE is 17.7% stronger when compared to 60^0 GLARE.

From the fig 5 it can be observed that the 90^0 GLARE has the highest Flexural strength than the other two orientations. The flexural strength of the 90^0 GLARE is 12.628 Mpa which is 16.03% stronger than 60^0 GLARE having a flexural strength of 10.6 Mpa. And the 90^0 GLARE is 49.74% stronger than 30^0 GLARE having a flexural strength of 6.346 Mpa.

From both the Graphs 4 and 5 it can be observed that the 90^0 GLARE has the highest flexural strength than 60^0 and 30^0 GLARE. The 90^0 GLARE can withstand the peak load of 1245 N and fractures at the load of 362.859N. While 60^0 GLARE can withstand the peak load of 1049.3 N and the sample fractures at 578.613 N. And finally the 30^0 GLARE can withstand the peak load of 617.8 N and specimen fractures at 490.35N. it can be concluded from the above findings the 90^0 GLARE shows higher flexural strength because of the orientation of the glass fiber along the length of the specimen.

Hardness of the GLARE

Hardness of the material is the mechanical parameter of that material which shows how resistant the material is to the permanent deformation when they are subjected to compressive forces. To study the hardness of the GLARE, three types of specimen with different glass fiber orientation are manufactured. And they are cut into 20mm x 20mm strips for testing the hardness of the GLARE composite using Rockwell hardness tester.

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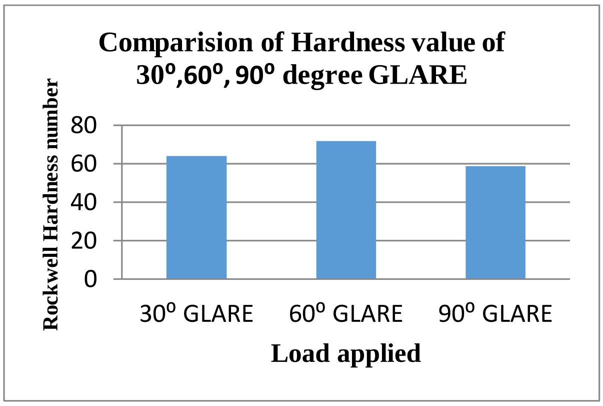

Fig 6: Hardness value of 30^0 GLARE for different loads.

Fig 6 shows the Hardness of the GLARE at 30^0, 60^0, 90^0 orientations. The hardness value of 60^0 GLARE is maximum than other two GLARE specimens which is 71.66 RHN. The lowest hardness value is obtained for 90^0 GLARE which is about 58.66. And the hardness of 64 RHN is obtained for 30^0 GLARE. From the graph it has been observed that 60^0 GLARE is 10.68 percent harder than 30^0 GLARE. And 60^0 GLARE is 18.14 percent harder than 90^0 GLARE.

From the graph it is evident that the difference in the hardness values of the specimen are only minor. From the results it can concluded that the effect of fiber orientation on hardness of GLARE specimens is negligible. The difference in the hardness value of the GLARE specimens can be attributed to the presence of voids, poor adhesion etc.

CONCLUSION

In this project GLASS LAMINATE ALUMINUM REINFORCED EPOXY COMPOSITE was manufactured and mechanical properties are studied. Three types of GLARE with different glass fiber orientation are manufactured and are subjected to tensile, flexural and Hardness tests to study their mechanical behavior. And following conclusions are drawn.

- GLARE specimens are manufactured using hand layup technique.
- Adhesion between the layers plays an important role in determining the strength of the composite.
- In order to have strong bond between the layers of the composite surface of the aluminum sheets have to properly prepared. Surface finish on the layers affect the bonding between the layers.
- It has been studied that the orientation of the glass fiber within the composite has the significant effect on tensile, hardness and flexural strength of the GLARE.

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