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MATERIAL PROPERTIES OF GLASS LAMINATE ALUMINIUM REINFORCED EPOXY

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ABSTRACT

Fibre Metal Laminates (FMLs) are a relatively new type of material developed for high performance lightweight structures with excellent properties under tensile, flexure and impact conditions. The first generation of FMLs was based on thermosetting matrices, typically epoxy resins. Recently, new types of FMLs are emerging as a result of the demand for more efficient and lightweight materials for use in the automotive and aerospace industries. This study characterizes the mechanical properties of a new type of GLARE based on three types of binding resins and two types of fibres to make a composite with aluminium. This GLARE FML is manufactured in a simple compression-molding process, allowing it to subsequently be re-shaped according to operational requirements.

I.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 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. Fibre Metal laminates (FMLs) are hybrid composite structures based on thin sheets of metal alloys and plies of fibre reinforced polymeric materials. The fibre bar metal composite technology combines the advantages of metallic materials and fibre reinforced matrix systems. Metals are for instance isotropic, have a high bearing strength and impact resistance and are easy to repair, while full composites have

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excellent fatigue characteristics and high strength and stiffness. These material systems are created by bonding composite laminates plies to metal plies. The concept usually applied to aluminium with aramid and glass fibres, but also can be applied to other constituents. Figure 1.1gives a classification of FML based on metal plies. The most commercially available FMLs are ARALLI, based on aramid fibres and GLARE1 based on high strength glass fibres.

II.METHODOLOGY FOR PREPARING GLARE

The steps involved for the making of the GLARE are:

SURFACE TREATMENTS FOR ADHESIVE BONDING

All the treatments for modification of metal surfaces can be grouped as:
1. Mechanical.
2. Chemical.

Solvent degreasing is important, because it removes contaminant materials which inhibit the formation of the chemical bonds. However, solvent degreasing, while providing a clean surface, does not promote the formation of acceptable surface conditions for longer term bond durability. The degreasing stage usually makes use of chlorinated solvents such as trichloroethylene,1,1,1-trichloroethane, erchloroethylene, or dichloromethane, or alternatively, non-chlorinated solvents including methyl ethyl ketone, methanol, isobutanol, toluene or acetone. All aluminium alloy sheets were initially degreased prior to further surface pre-treatment steps. The first step in the fabrication of baseline test specimens was methyl ethyl ketone (MEK)-wiping of aluminium substrates with lint-free tissues to degrease the surface.

MECHANICAL TREATMENT

As a preliminary preparation step in the multi-stage schedules, mechanical abrasion has been used to produce a macro-roughened surface, different roughness level of the surface textures and to remove an undesirable oxide layer, respectively. This method typically involves abrasive scrubbing of the substrate surface with sand paper. This mechanical treatment would introduce physicochemical changes which yield a wettable surface and modify the surface topography, i.e., a macro-roughened surface.

CHEMICAL TREATMENT

The most commonly applied chemical treatments are based on a chromic–sulphuric acid etch. This treatment consists of immersion of the substrate in a solution of sulphuric acid and potassium dichromate. Typically, chemical treatment, i.e., acid etching, is an intermediate production step between degreasing, alkaline cleaning, and electrochemical treatment. Three classical acid-etching solutions were introduced to modify the metallic surfaces: chromic–

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sulphuric acid (CAE), Forest Product Laboratory (FPL), and sulfo-ferric acid (P2) etches. The most effective etches incorporate mixed chromic and hydrofluoric acids. However, non-chromated acid etchants have been demonstrated to provide good adhesion results. Early experiences in bonding techniques demonstrated that surface treatment prior to bonding is the single most critical step which cannot be disregarded, even for tertiary-loaded structures, since it is essential to achieve long-term service capability. A particular surface treatment tends to modify the substrate surface by delivering the following features: free from contamination; wettable with either primer or adhesive; highly roughened; and mechanically and hydrolytically stable.

BONDING

Bonding procedures of the GLARE are:

1. Measure and mix the epoxy resin with hardener as per requirement. Stir well until the mixture gets smooth and less viscous. Do not let it harden until it is used. So stir in a spiral way until it loses its hardenability.
2. In a table, cover up with a smooth surface such as glass and add wax all over it. The wax is used for non-sticking purpose and fix a thin lamination sheet with the dimensions should be more than the aluminium sheet. Also apply the wax on the lamination sheet.
3. Place the aluminium sheet on the surface of the lamination sheet. With the help of a paint brush, fill the surface of the aluminium sheet with epoxy resin mixture. Cover all the edges properly and do not mix it with the wax.
4. Take the E Glass fibre (CSM or Woven) and place it on the resin applied aluminium surface. Then again apply the resin on the fibre completely. For mixed GLARE, the first fibre placed is woven and CSM is place above it, then it is placed with aluminium sheet upon it. Each surface is applied with the epoxy resin mixture except the first and top surface of the GLARE.
5. For the normal type 3/2 GLARE the first sheet is aluminium, then covered with resin and fibre (either CSM or Woven), apply resin on the fibre, then upon it aluminium sheet. Again apply resin and place fibre and at last apply the resin on the fibre and place the top aluminium sheet. This is the way of doing for the other type of GLARE.
6. Cover the top of the aluminium sheet with waxed lamination sheet. Do not let the resin to come out.
7. Place the finished laminates in the die according to their size. Tight up the die with bolts and nuts.
8. Remove the die after 24 hours. At this time the epoxy will get setted and bind the aluminium sheets and fibre together.

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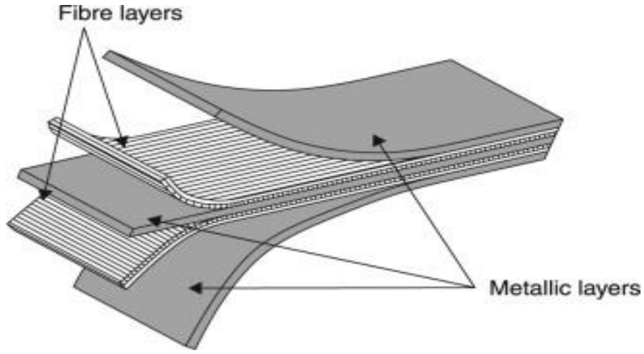

Figure- Lay-up of Metal and Fibre.

I. MATERIAL PROPERTIES

ALUMINIUM (AL 6061)

Aluminium / Aluminium alloys are sensitive to high temperatures. They tend to lose some of their strength when exposed to high temperatures of about 200-250°C. However, their strength can be increased at sub-zero temperatures. They also have good corrosion resistance. Aluminium / Aluminium 6061 alloy is the most commonly available and heat treatable alloy.

The following datasheet gives an overview of Aluminium / Aluminium 6061 alloy.

CHEMICAL COMPOSITION

The following table shows the chemical composition of Aluminium / Aluminium 6061 alloy.

ELEMENTS	CONTENT (%)
Aluminium / Aluminium, Al	97.9
Magnesium, Mg	1
Silicon, Si	0.60
Copper, Cu	0.28
Chromium, Cr	0.20

PHYSICAL PROPERTIES

The physical properties of Aluminium / Aluminium 6061 alloy are outlined in the following table.

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PROPERTIES	METRIC	IMPERIAL
Density	2.7 g/cm^3	0.0975 lb/in^3
Melting point	588°C	1090°F

MECHANICAL PROPERTIES

The mechanical properties of Aluminium / Aluminium 6061 alloy are tabulated below.

PROPERTIES	METRIC	IMPERIAL
Tensile strength	115 MPa	16680 psi
Yield strength	48 MPa	6962 psi
Shear strength	83 MPa	12038 psi
Fatigue strength	62 MPa	8992 psi
Elastic modulus	70-80 GPa	10153-11603 ksi
Poisson's ratio	0.33	0.33
Elongation	25%	25%
Hardness	30	30

MACHINABILITY

Aluminium / Aluminium 6061 alloy has good machinability in harder T4 and T6 tempers. It can be machined in annealed temper.

FORMING

Aluminium / Aluminium 6061 alloy can be easily formed and worked in the annealed condition. The standard methods are used to perform bending, stamping, deep drawing, and spinning operations.

WELDING

Aluminium / Aluminium 6061 alloy has excellent weldability. Thinner sections can be welded using gas tungsten arc welding technique. Heavier sections can be welded using gas metal arc welding technique. Alloy 4043 filler wire can be used to achieve good result, but it will affect T 6 properties.

E GLASS FIBRE CSM

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E-Glass or electrical grade glass was originally developed for stand-off insulators for electrical wiring. It was later found to have excellent fibre forming capabilities and is now used almost exclusively as the reinforcing phase in the material commonly known as Chopped Strand Mats of fiberglass.

E GLASS FIBRE WOVEN

E-Glass Woven is made from continuous glass fibre roving which are interlaced into heavy weight fabrics. Or we can say that Woven Roving is a bidirectional fabric made by interweaving direct roving in plain weave pattern. It is compatible with most resin systems. With Woven Roving as a general rule estimate the resin/reinforcement ratio at 1:1 by weight. Woven Roving is available in a variety of weaves, weights, widths and finishes to suit a wide range of applications.

II. DESIGN OF FML

In the design of fibre metal laminates, the design might changes according to the place of applications. The place where these composites are used, requires a very distinct set of properties. So the design considerations are made as per the requirement. Fibre metal laminates (FMLs) are materials that have composite layers sandwiched between metal layers. These composite layers typically consist of fibres embedded in an adhesive system.

Glass Laminate Aluminium Reinforced Epoxy (GLARE) is a very popular FML, especially in Europe. For this report, some background research was first conducted to study GLARE, which included its history, construction, features and properties. Next, an experimental investigation was carried out to determine how this material behaves mechanically and to compare its properties to conventional aircraft grade aluminium alloys. Microscopy examination and tensile testing provided important information about the material

III. LITERATURE SURVEY - COMPOSITE MATERIALS

1. Y.D DWIVEDI**,** conducted the experiment on cost effective composite materials

An increase in the application spectrum of composite materials necessitates cost effective high quality rapid processing in order to meet stringent design as well as market requirements. Material selection has become one of the major problems in aviation. The objective of the current study is to compare the bending strength of Glass Fibre Reinforced Polymer (GFRP) with the conventional material of aviation industry (ie., aluminium). The deflection test was performed on standard bending test equipment by applying the concentrated loads on the cantilever specimens, which were made of Glass Fibre Reinforced Polymer fabricated by hand layup technique and the Aluminium specimen was made and supplied with the test equipment. On performing the bending test it is observed that aluminium shows promising results where high modulus of elasticity is considered and the GFRP is found to be the cheap and best material where lower weight is considered and young’s modulus of material is of low importance.

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IV. NEW FABRICATION

The arrangement are differently vary from the previous type of composite materials. Three different configurations we used.

3/2 LAYER
Al alloy
Epoxy/ Glass
Al alloy
Epoxy/ Glass
Al alloy

Figure- construction of 3/2 layer

4/3 LAYER
Al alloy
Epoxy/ Glass
Al alloy
Epoxy/ Glass
Al alloy
Epoxy/ Glass
Al alloy

Figure-4/3 construction layer.

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5/4 LAYER
Al alloy
Epoxy/ Glass
Al alloy
Epoxy/ Glass
Al alloy
Epoxy/ Glass
Al alloy
Epoxy/ Glass
Al alloy

Figure- 5/4 construction layer.

V.

VI. RESULT

TENSILE TEST RESULT

The tensile strength are provided here in Mpa

GLARE	**3/2 SEQUENCE**	**4/3 SEQUENCE**	**5/4 SEQUENCE**
CSM EPOXY	76.3719	80.8163	85.2617
WOVEN EPOXY	125.7619	135.47	150.1646
MIXED EPOXY	80.8526	88.7874	94.6612

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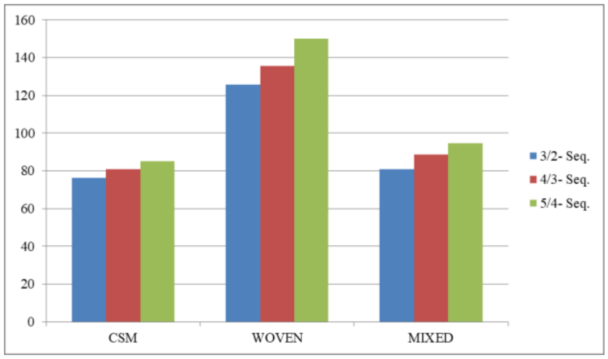

Figure-1. Bar Chart for Tensile Test Result

FLEXURAL TEST RESULT
The bending strength are provided here in Mpa

GLARE	3/2 SEQUENCE	4/3 SEQUENCE	5/4 SEQUENCE
CSM EPOXY	624.372	686.8163	722.2617
WOVEN EPOXY	788.762	868.47	912.1646
MIXED EPOXY	652.853	712.7874	742.6612

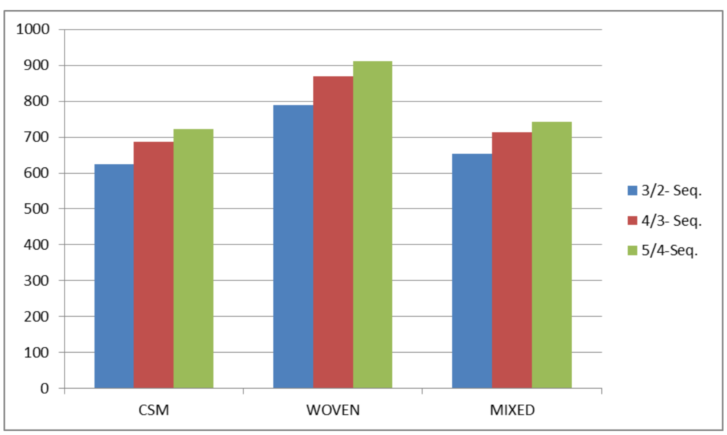

Figure-2. Bar Chart for Flexural Test Result

VII. APPLICATIONS

APPLICATION

- Marine vehicles

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- Road Vehicles for high speed and low weight.
- Aerospace application.

VIII. ADVANTAGES AND DISADVANTAGES

ADVANTAGES

1. Lightweight: High static strength of GLARE contributes to weight saving over the aluminum.
2. High strength: It is apparent that the GLAREs reinforced with unidirectional glass fiber have anisotropic properties. This glass fiber contributes to increase in static strength and elastic modulus in the longitudinal direction along which the glass fiber is oriented. On the other hands, the aluminum sheets control overall mechanical properties of GLAREs in the transverse direction.
3. GLARE reduced the overall structural member weight by 20-50%.
4. GLAREs are good in corrosion and fatigue resistance.
5. GLARE Composites have lower assembly costs because it requires very few fasteners, bolts etc.

DISADVANTAGES

1. GLARE have high recurring costs.
2. GLARE have higher materials costs.
3. GLARE have very expensive repairs and maintenance.
4. GLARE needed isolation to prevent adjacent aluminium part galvanic corrosion.
5. GLARE will delaminate eventually, if not manufactured properly.

IX. CONCLUSION

The specimens are compared with each other on basis of the results provided, they are:

1. The GLARE made with Woven Fibre has the highest flexural and tensile strength out of the three variants and the three sequences.
2. The GLARE made with Mixed Fibres holds the second position in this test.
3. The GLARE made with CSM Fibre has the least strength among the three types and sequences.

There are many variables that can be altered to improve GLARE properties. Those variables include but are not limited to different adhesives, different types of fibreglass, other metals and improved fabrication processes. This opens up countless possibilities for improvement

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