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Comparison of Fiber Metal (Aluminium) Laminates of Chopped Glass Fiber And 45^0 Stitched Glass Fiber Mat by Analyzing Tensile and Flexural Properties

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Abstract: *In Air craft industries there is a research for low density material with higher mechanical properties and introducing fibre metal laminates called FML. In this article I have been processing 2 types of FML namely Chopped fibre laminated with Aluminium sheet and 45^0 stitched Mat glare laminated with Aluminium sheet by handmade. The hand made FML is done by 4 different types of layers such as 2/1, 3/2, 4/3 and 5/4 orientation in both type. The specimens were cut by suitable water jet cutting /Electric discharge machine wire cutting for flexural and tensile properties testing as per ASTM standards. The experimental work was done by AUTOGRAPH 50 KN computer controlled Universal testing machine at Central Institute of Plastic Engineering and Technology Chennai. From the tensile and flexural tests were taken and graphs were plotted between stress, strain, load and deflection. In the graph it clearly shows the 45^0 stitched glass fibre mat FML was superior than chopped fibre glass mat FML and also found the increase in thickness was reducing the strength and not in proportionate strength.*

Keywords: *Aluminium, 45^0 Stitched Glass fibre mat, Epoxy resin, Metal Matrix, Fibre metal laminates (FML).*

I. Introduction

A composite material is a material in which two or more distinct materials are combined together but remain uniquely identifiable in the mixture. Different materials can be combined on a macroscopic scale, such as in alloying of metals, but the resulting material is macroscopically homogeneous, that is the components cannot be distinguished by naked eye and essentially act together. The advantage of composite material is that, if well designed, they usually exhibit the best qualities of their components or constituents and often some qualities that neither constituent possesses. Composite materials have a long history to usage. Straw was used by the Israelites to strengthen mud bricks.

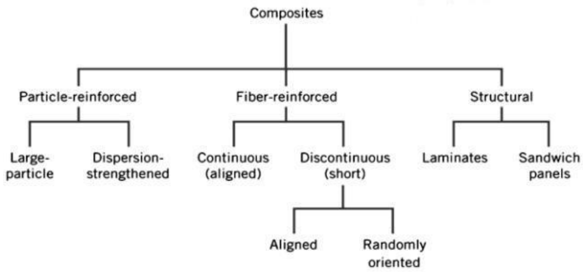


Figure 1.types of composites

LAMINATED COMPOSITE MATERIALS

Laminated composite material consists of layers of at least two different materials that are bonded together. Lamination is used to combine the best aspects of the constituent layers and bonding materials in order to achieve a more useful material. The properties that can be emphasized by lamination are strength, stiffness,low weight, corrosion resistance, wear resistance, beauty or attractiveness, thermal insulation.

The different types of glass are supplied in several different configurations including:

- Fibreglass rovings
- Sheet moulding compound
- Woven rovings
- Chopped strand mat

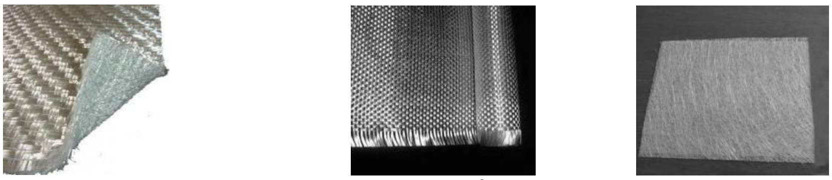


Figure 2 .types of Fibre mat

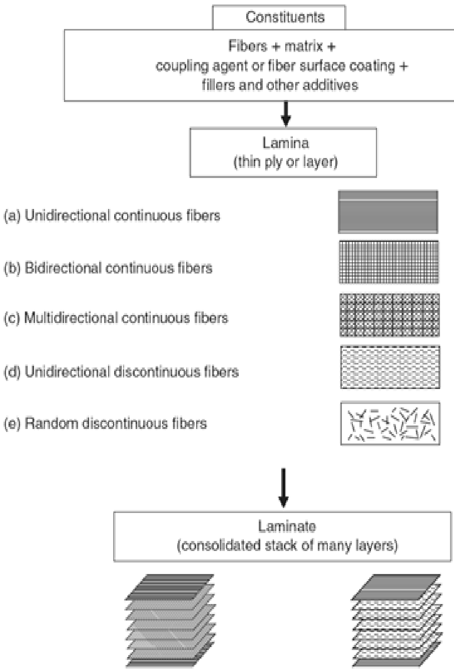


Fig. 3 Basic building blocks in fiber- reinforced composites

The commonly accepted types of composite materials are

(1) Fibrous composite materials
(2) Laminated composite materials
(3) Particulate composite materials
(4) Combination of some or all of the first three types

MATRIX

The role of matrix in a fiber reinforced composite is

- To transfer stresses between the fibers
- To provide a barrier against an adverse environment
- To provide the surface of the fibers from mechanical abrasion

The matrix plays a minor role in the tensile load carrying capacity of a composite structure. However, selection of a matrix has a major influence on the inter-laminar shear as well as in plane shear properties of the composite materials.
Type of Matrix

The various types of matrices are as follows:
1) Polymer matrix
2) Metal matrix
3) Ceramic matrix

METAL MATRIX

Metal matrix has advantage over polymeric matrix in application requiring a long-term resistance to serve environments, such as high temperature. The yield strength and modulus of most metal are higher than those for polymer, which is an important consideration for application requiring high transverse strength and modulus as well as compressive strength for the composite. Another advantage of using metals is that they can be plastically deformed and strengthened by a variety of thermal and mechanical treatments. However, metals have a number of advantages namely they have high specific gravity, high melting points and a tendency towards corrosion at the fiber/matrix interface.

The two commonly used metal matrixes are based on aluminum and titanium. Both of these metals have comparatively low specific gravities and are available in a variety of alloy form.

Fibre Metal Laminates

A Fiber Metal Laminate (or FML) is one of a class of metallic materials consisting of a laminate of several thin metal layers bonded with layers of composite material. This allows the material to behave much as a simple metal structure, but with considerable specific advantages regarding properties such as metal fatigue, impact, corrosion resistance, fire resistance, weight-savings and specialised strength properties. Being a mixture of monolithic metals and composite materials, FMLs belong to the class of heterogeneous.

Fiber metal laminates (FMLs) are hybrid composite structures based on thin sheets of metal alloys and plies of fibre reinforced polymeric materials. The fiber/metal composite technology combines the advantages of metallic materials and fiber 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 excellent fatigue characteristics and high strength and stiffness. The fatigue and corrosion characteristics of metals and the low bearing strength, impact resistance and reparability

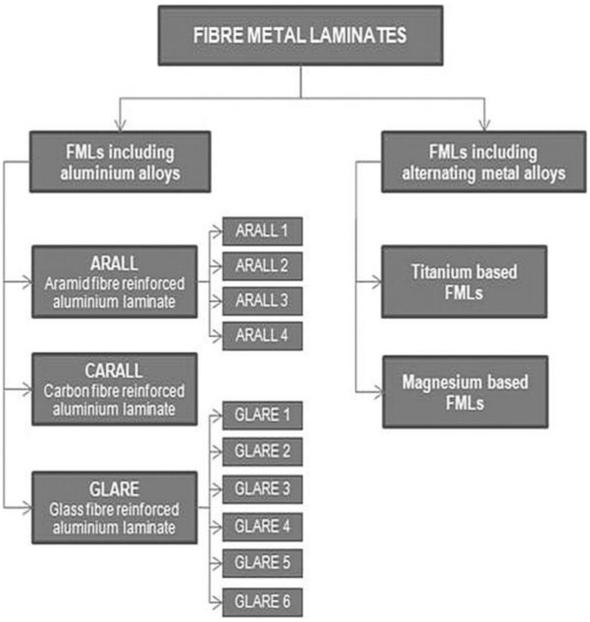


Fig 4 Classification of FMLs based on metal plies

GLARE

Glare laminates belong to fiber metal laminates family, they consist of alternating layers of unidirectional glass fiber reinforced pregregs and high strength aluminium alloy sheets. At first, they were developed for aeronautical applications as an improvement of ARALL with advanced glass fiber and introduced at the Technical University of Delft in Netherlands in 1990. Later, a partnership between AKZO and ALCOA started to operate in 1991 to produce and commercialize GLARE Fig. schematically illustrates a cross-ply GLARE laminate. The biggest differentiation of GLARE compared to ARALL is that GLARE consists of glass fibers instead of aramid fibers. This diversity gives superior properties to GLARE laminates

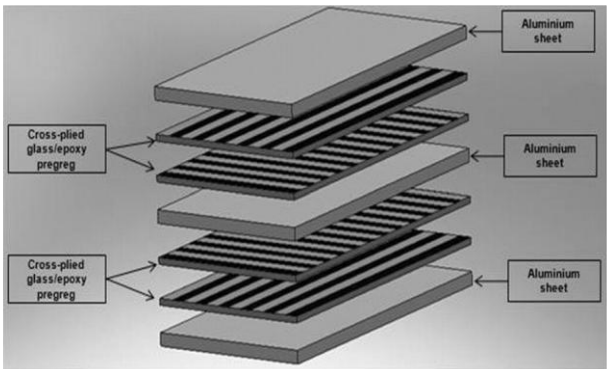


Fig 5 Schematic illustration of a cross-ply GLARE laminates

Production of FMLs

To produce FMLs, as for polymeric composite materials, the most common process involves autoclave processing. The overall generic scenario for production of FMLs involves about five major activities.

II. Experimental Details

Introduction

A new class of lightweight Fiber Metal Laminate (FML) has been developed for structural applications. The combination of metal and polymer composite laminates can create a synergistic effect on many properties. The mechanical properties of FML show improvements over the properties of both aluminum alloys and composite materials individually. Fiber metal laminates having growth in use of structural applications like automotive, marine, space structures and military use in the aircraft industry because of their significant weight reduction in structural design, high tensile and compressive strengths, good fatigue and corrosion resistance properties. Polymer composites are susceptible to mechanical damages when they are subjected to efforts of tension, flexural, compression which can lead to material failure. Therefore it is necessary to use materials with higher damage tolerance & carryout an adequate mechanical evaluation. Damage tolerance of epoxy polymeric composites can be enhanced by improving the interlaminar properties by matrix reinforcement with fiber. Tensile and flexural strength of fiber metal laminates purely depend on the thickness of the layers. The experimental study to determine the tensile, flexural properties and failure mode of the glass fiber epoxy aluminium laminates.

Properties of 45^0 Woven Rover

S. No	Property	unit	Specification		Test method	Observed values
			LSL	USL		
1	Loss in ignition	WI %	0.4	0.8	ISO 1887	0.63
2	Moisture current	WI %	0.00	0.2	ISO 3344	0.23
3	Mass per unit area	GSM	752.00	848.00	ISO 3374	800

Table 1 properties of 45^0 woven rover

III. FML Preparation

DIMENSION OF ALUMINIUM SHEET

Length: 127mm and 300mm
Breadth: 100mm, 25mm and 13 mm
Thickness: 0.3mm

For our convenient made the piece into 300*200mm and cut after finishing all the works.

3.3.2 DIMENSION OF 45^0 WOVEN ROVER MAT

Length: 300mm
Breadth: 200mm

Figure 6 45^0 woven rover mat

Surface Treatment of Aluminium Sheet

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. All aluminium alloy sheets were initially degreased prior to further surface pre-treatment steps. The first step in the cleaning of test specimens was acetone, NaOH cleaning treatments and Ferric sulphate with H_2SO_4 cleaning.

Scratching Of Aluminum Surface

Bonding strength of aluminium sheet is only increased by increasing the frictional effect of the surface which contact with the resin. So that scratches the surface with the use emery sheet. After that contaminant of aluminium powder particles are removed under the following process.

Acetone Cleaning

The following steps are followed for cleaning the aluminium sheet by the use of acetone.

1. ¼ litre of acetone is poured in the washing tray.
2. Next sheet of aluminium is dipped in the tray and rinsed.
3. Process continues until colour of acetone become lightly blackly.
4. Next the sheet is rinsed with hot water to remove the content of acetone.

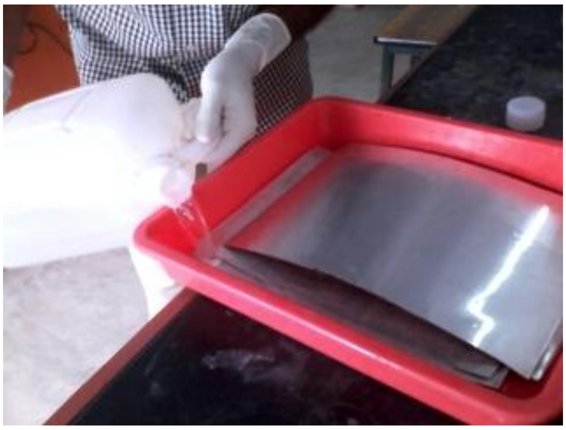


Figure7 shows Acetone cleaning

NaOH CLEANING

After finishing the above process, the next step is to clean the sheet with the NaOH chemical. It is in the form of white granules.

1. 4 gram of NaOH is soluble in the 1 litre of distilled water.
2. Heat this solution up to 60-65^0c and poured into the washing try containing aluminium sheet.
3. Rinse the sheet until solution become to create white bubbles.
4. Next the sheet is rinsed with hot water to remove the content of NaOH.

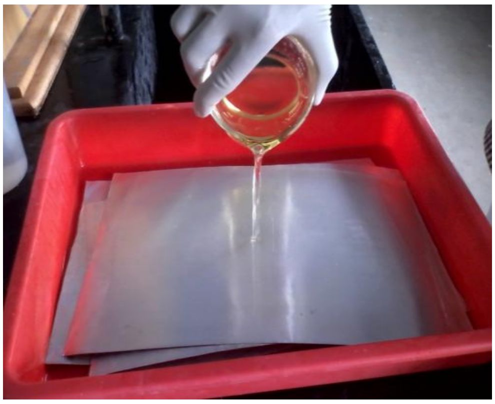


Figure 8 NaOH cleaning

Ferric Sulphate with H_2SO_4 Cleaning

Due to the above treatments, the white NaOH particle is precipitated in surface of the aluminium sheet. So that ferric sulphate cleaning is essential to remove the NaOH contaminant.

1. 18 gram of ferric sulphate (powder in form) is added in the distilled water. Stir until all the powder diluted in the water.
2. 120ml of H_2SO_4 is added in the 400ml of distilled water.
3. Mix this two solution and heat up to temperature of 65-70^0c, the colour of the solution is light yellowish.
4. Rinse the sheet with this solution and wash in hot distilled water and dry the sheet for 1 hour for further process.

Figure 9 Prepared ferric sulphate solution

Resin name: epoxy hardener					
S. no	Test	Test method	Specification	Test value	Unit
1	Appearance	Visual	Colorless to mild yellow clear liquid	Mild yellowish clear liquid	
2	Viscosity @25^0c	ASTM D-1652	24-30	27	Cp
3	Specific gravity @25^0c	ASTM D-4052	0.95-0.99	0.90	g/ml
4	Amine value		300-350	315	Mg of KOH /gm
5	Hydrogen	ASTM D -1652	76-80	77	Eq.m.mol/ gm

Table 2 Properties of resin

IV. Production of FML

RESINS

A material, generally polymer, which has an indefinite and often high molecular weight and a softening or melting range and exhibits a tendency to flow when it is subjected to stress. Resins are used as the matrices to bind together the reinforcement material in composites. The two classes of resins are the Thermoplastics and thermosets. A thermoplastic resin remains a solid at room temperature. It melts when heated and solidifies when cooled. The long chain polymers do not chemically cross link. Because they do not cure permanently, they are undesirable for structural application. Conversely, a thermosetting resin will cure permanently by irreversible cross-linking at elevated temperatures. This characteristic makes the thermoset resin composites very desirable for structural applications. The most common resins used in composites are the unsaturated polyesters, epoxies, and vinyl esters; the least common ones are the polyurethanes and phenolics .

3.5.2 EPOXY RESINS

Epoxy resins are a range of compounds. They are long-chain compounds, which can be cross-linked with various other chemicals to give thermosetting compounds, crosslinking takes place without the liberation of water. One of the constituents of epoxy resin is epichlorhydrin. Most epoxy resins are based on the reaction between epichlorhydrin and a chemical, which is usually referred to as bisphenol . The epoxies used in composites are mainly the diglycidyl ethers and amines. The material properties and cure rates can be formulated to meet the required performance.

Epoxies are generally found in marine, automotive, electrical and appliance applications. The high viscosity in epoxy resins limits it use to certain processes such as molding, filament winding, and hand lay-up. The right curing agent should be carefully selected because it will affect the type of chemical reaction, pot life and final material properties. Although epoxies can be expensive, they may be worth the cost when high performance is required.

Resin name: liquid epoxy resin					
S.no	Test	Test method	Specification	Test value	Unit
1	Appearance	Visual	Colorless to mild yellow clear liquid	Mild yellowish clear liquid	
2	Viscosity @25^0c	ASTM D-1652	11000-14000	11980	Cp
3	Density @25^0c	ASTM D-4052	1.16-1.17	1.164	g/ml
4	Non volatile content	Rpm 104B	100	100	%
5	Epoxy equivalent weight	ASTM D-1652	182-192	187	g/eq

Table 3 Properties of resin

V. Properties of Resin

RESIN PREPARATION

After finishing sheet preparation prepare the resin.

1. Mix epoxy and hardener in 2:1 ratio in the bowl.
2. Procedure is continue until it become lousy and oily

Figure 10 -Resin preparation

APPLICATION OF RESIN:

1. Resin is applied with the help of brush along the fibre and the aluminium sheet.
2. Pattern is formed in the form of sandwich manner.
3. Then it kept in the moulding table to allow the weight for one day.
4. So that bonding strength will increased.

Figure 11 -Apply of Resin

CURING PROCESS

1. The specimen is now subjected to internal stress due to loading.
2. To remove the internal stress the specimen is now cure under the oven.
3. At the temperature of 100^0c for 4 hour.

1. Preparation of tools and materials. During this step, the aluminium layer surfaces are pre-treated by chromic acid or phosphoric acid, in order to improve the adhesive bonding between metallic layer and fibre reinforced laminate.
2. Material deposition, including cutting, lay-up and debunking.
3. Cure preparation, including the tool cleaning and the part transferring in some cases, and the vacuum bag preparation in all cases.
4. Cure, including the flow-consolidation process, the chemical curing reactions, as well as the bond between fiber/metal layers.
5. Post stretching, after the hot-curing (200 _C) cycle in the autoclave, the fibre metal laminates carry a residual stress system over the thickness of the material with a small tensile stress in the aluminium sheets and compression in the fibres, this situation adversely effects fatigue resistance of FMLs. Post stretching operation after curing cycle can reverses the residual stress system and solves this problem.

VI. Inspection, usually by ultrasound, X-ray, visual techniques and mechanical tests

TENSILE TEST

As per ASTM D3039 standard Tensile specimens 300 mm long and 25 mm width, 4/3 -3.40 mm thick with a gauge length of 100 mm were prepared. Tensile tests were performed on a 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. The strains were recorded with strain gauges. At least four tests were carried out for each case. shows the specimen before tensile Specimens are mounted in the grips of a universal testing machine and monotonically loaded in tension while recording load. The ultimate strength of the material can be determined from the maximum load carried before failure. If the coupon strain is monitored with strain or displacement transducers then the stress-strain response of the material can be determined, from which the ultimate tensile strain, tensile modulus of elasticity, Poisson's ratio, and transition strain can be derived

FLEXURAL TEST

As per ASTM D790 standard Flexural specimens 127 mm long and 12.7 mm width,4/3 -3.40 mm thick were prepared. Specimen rests on two supports and is loaded by means of a loading nose midway between the supports. A support span-to-depth ratio of 16:1 shall be used unless there is reason to suspect that a larger span-to-depth ratio may be required, as may be the case for certain laminated materials Flexural tests were performed on a Autograph-AGIS-Shimadzu-50KN capacity universal testing machine at a crosshead rate of 5 mm/min. The specimen is deflected until rupture occurs in the outer surface of the test specimen or until a maximum strain of 5.0 % is reached, whichever occurs first. Procedure employs a strain rate of 0.01 mm/mm/min and is the preferred procedure for this test method.

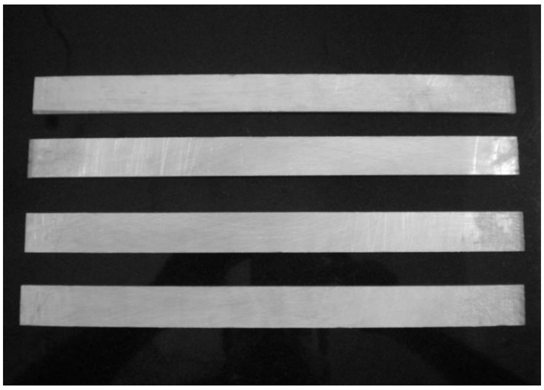


Figure 12 Specimen before tensile testing

Figure 13 Specimen during tensile testing

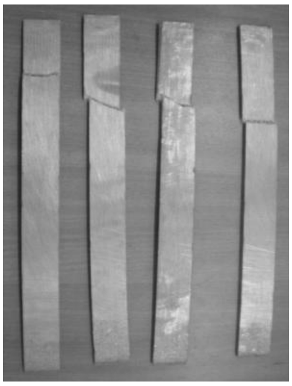


Figure 14 Specimen after tensile testing

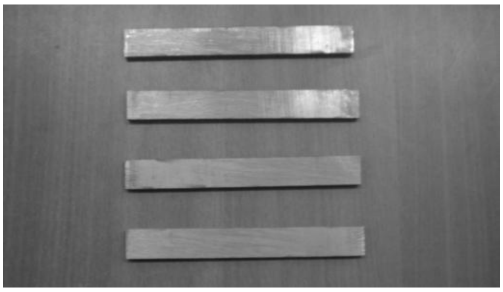


Figure 15 Specimen Before Flexural Testing

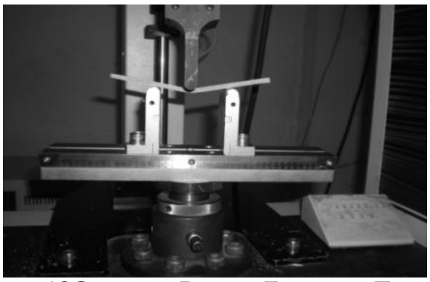
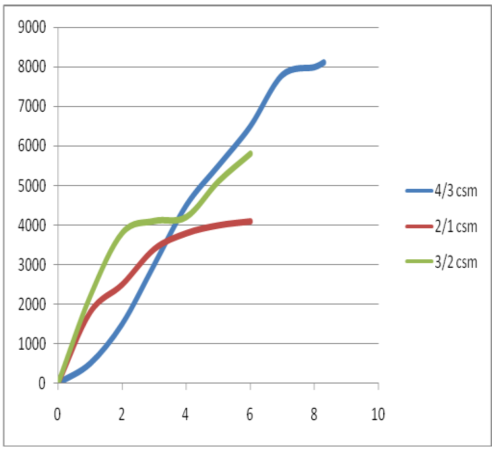
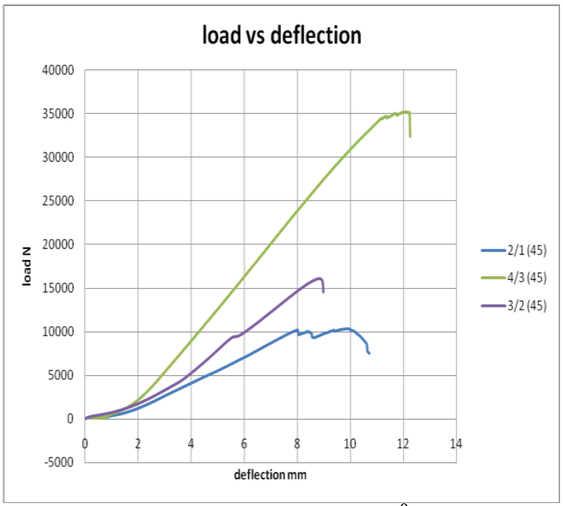


FIGURE 16 SPECIMEN DURING FLEXURAL TESTING

Graph 1 Load vs Deflection for CSM





Graph 2 Load vs Deflection for 45^0 Stitiched Mat

Table 4. Tensile properties of Glare laminates of CSM

Layer	Maximum Breaking Load In N	Maximum Tensile Strength MPa	Deflection in mm
2/1	4250.96	158.58	6.083
3/2	5564.62	148.39	6.28
4/3	8246.31	138.47	7.256

Table 5. Tensile properties of Glare laminates of 45^0

Layer	Maximum Breaking Load In N	Maximum Tensile Strength MPa	Deflection in mm
2/1	9795.66	187.47	4.48
3/2	15944.30	190.085	4.5235
4/3	31593.7	298.759	5.538

VII. Conclusion

The project work gave me a lot of experience and knowledge about composite material's properties and its behavior. .Also it gave the opportunity for finding the methods of manufacturing of Fibre Metal laminates material. During the manufacturing process we have a chance to know the properties of adhesives and it usage. Sintering process gives very good strength and reduce the residual

FMLs consist of metallic alloy and fibre reinforced prepreg. Mostly commercially avaible GLARE, ARALL and CARALL consist various aluminium alloys. Many researches have been trying to use possible metallic alloys such as magnesium, titanium, etc. Instead of aluminium alloys. It is expected that this diversity gives optimum mechanical properties. Same efforts have been examined for engineering polymeric materials to replace fibre reinforced prepreg. Long processing cycle to cure the polymer matrix in the composite plies increases the cycle time of whole production and decreases productivity. New processing methods are investigated for improving the productivity of curing process and decreasing the labour costs of FMLs. These improvements will make FMLs very attractive to various industrial applications (military, automotive and aircraft). Last decades many researchers have been investigating the possibility of using thermoplastic materials instead of thermoset materials as matrix materials in FMLs. By using thermoplastic matrix, FMLs will find new application areas. However low compatibility of thermoplastic matrix with metal surfaces needs to be improved by surface modification methods explaines experimental investigation of tensile and flexural properties of 45^0 woven rover fiber-epoxy-Al laminates is better than Chopped fiber laminates

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