ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Experimental Investigation of Composite Material (Al Alloy+E-Glass FRP) For Application of Aerospace

Mr.Ravipothina
Assistant Professor,
Dept of Mechanical Engineering,
VITS College of Engineering,
Sontyam, Anandapuram, Vizag.

Mr.Sunil Kumar Jena
Assistant Professor,
Dept of Mechanical Engineering,
VITS College of Engineering,
Sontyam, Anandapuram, Vizag.

Mr. P.V.S.Murali Krishna
Associate Professor,
Dept of Mechanical Engineering,
VITS College of Engineering,
Sontyam, Anandapuram, Vizag.

Abstract:

This work investigates that the effects of all angle orientation on three testing properties of a with combined Aluminum alloy and Glass Fiber Reinforced Polymer uni-directionalcomposite laminate experimentally. Laminated Composite materials with Aluminum alloy have characteristics of high modulus, less weight and high strength ratios, excellent fatigue properties, and non-corroding behavior. These advantages encourage the extensive application of composite materials, for example, in aero plane, rocket missile, jet plane and air foil. The understanding of the mechanical behavior of composite materials and Aluminum alloy is essential for their design and application. Although composite materials are often heterogeneous, they are presumed homogeneous from the viewpoint of macro mechanics and only the averaged apparent mechanical properties are considered. For a transversely isotropic composite material, five elastic constants are necessary to describe the linear stress-strain relationship. If the geometry of the material could be considered as two-dimensional,. The most common method to determine these constants is static testing like bending, tensile and compression testing's etc. For composite materials, three types of specimens with different stacking sequences are fabricated.

Key Words:

E-Glass Fiber Reinforced Polymer, Laminated Composite materials.

I.INTRODUCTION:

Naval aircraft are built to meet certain specified requirements. These requirements must be selected so they can be built into one aircraft. It is not possible for one aircraft to possess all characteristics; just as it isn't possible for an aircraft to have the comfort of a passenger transport and the maneuverability of a fighter. The type and class of the aircraft determine how strong it must be built. A Navy fighter must be fast, maneuverable, and equipped for attack and defense. To meet these requirements, the aircraft is highly powered and has a very strong structure.

The airframe of a fixed-wing aircraft consists of the following five major units:
1. Fuselage
2. Wings
3. Stabilizers
4. Flight controls surfaces
5. Landing gear

A rotary-wing aircraft consists of the following four major units:
1. Fuselage
2. Landing gear
3. Main rotor assembly
4. Tail rotor assembly

You need to be familiar with the terms used for aircraft construction to work in an aviation rating.

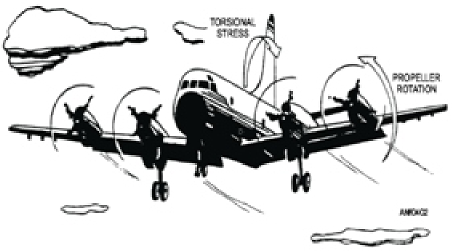


Figure —Engine torque creates torsion stress in aircraft fuselages

The reinforced shell has the skin reinforced by a complete framework of structural members. Different portions of the same fuselage may belong to any one of the three classes. Most areconsidered to be of semimonocoque-type construction. The semimonocoque fuselage is constructed primarily of aluminum alloy, although steel and titanium are found in high-temperature areas. Primary bending loads are taken by the longerons, which usually extend across several points of support. The longerons are supplemented by other longitudinal members known as stringers. Stringers are more numerous and lightweight than longerons.

The vertical structural members are referred to as bulkheads, frames, and formers. The heavier vertical members are located at intervals to allow for concentrated loads. These members are also found at points where fittings are used to attach other units, such as the wings and stabilizers. The stringers are smaller and lighter than long runs and serve as fill-ins. They have some rigidity but are chiefly used for giving shape and for attachment of skin. The strong, heavy long runs hold the bulkheads and formers. The bulkheads and formers hold the stringers. All of these join together to form a rigid fuselage framework. Stringers and long runs prevent tension and compression stresses from bending the fuselage.The skin is attached to the longerons, bulkheads, and other structural members and carries part of the load. The fuselage skin thickness varies with the load carried and the stresses sustained at particular location.

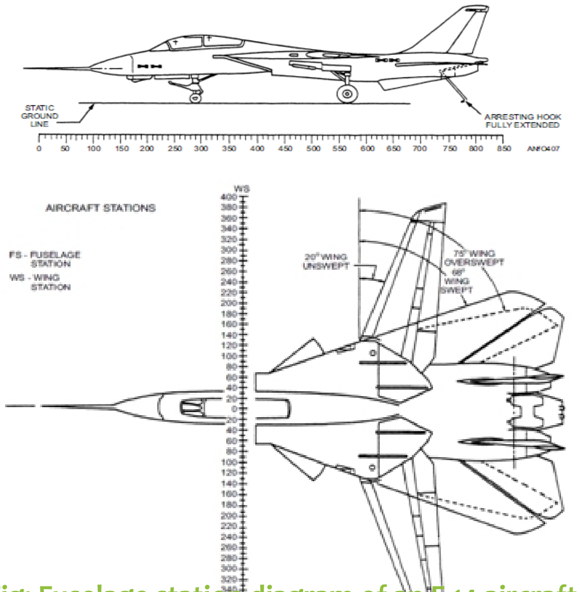


Fig: Fuselage station diagram of an F-14 aircraft

WINGS:

Wings develop the major portion of the lift of a heavier-than-air aircraft.Wing structures carry some of the heavier loads found in the aircraft structure. The particular design of a wing depends on many factors, such as the size, weight, speed, rate of climb, and use of the aircraft. The wing must be constructed so that it holds its aerodynamics shape under the extreme stresses of combat maneuvers or wing loading.Wing construction is similar in most modern aircraft. In its simplest form, the wing is a framework made up of spars and ribs and covered with metal. The construction of an aircraft wing is shown in figure 4-8.

Spars are the main structural members of the wing. They extend from the fuselage to the tip of the wing. All the load carried by the wing is taken up by the spars. The spars are designed to have great bending strength. Ribs give the wing section its shape, and they transmit the air load from the wing covering to the spars. Ribs extend from the leading edge to the trailing edge of the wing.In addition to the main spars, some wings have a false spar to support the ailerons and flaps. Most aircraft wings have a removable tip, which streamlines the outer end of the wing. Most Navy aircraft are designed with a wing referred to as a wet wing. This term describes the wing that is constructed so it can be used as a fuel cell. The wet wing is sealed with a fuel-resistant compound as it is built. The wing holds fuel without the usual rubber cells or tanks.The wings of most naval aircraft are of all metal, full cantilever construction. Often, they may be folded for carrier use. A full cantilever wing structure is very strong. The wing can be fastened to the fuselage without the use of external bracing, such as wires or struts.

A complete wing assembly consists of the surface providing lift for the support of the aircraft. It also provides the necessary flight control surfacesNOTE: The flight control surfaces on a simple wing may include only ailerons and trailing edge flaps. The more complex aircraft may have a variety of devices, such as leading edge flaps, slats, spoilers, and speed brakes.Various points on the wing are located by wing station numbers. Wing station (WS) 0 is located at the centerline of the fuselage, and all wing stations are measured (right or left) from this point (in inches).

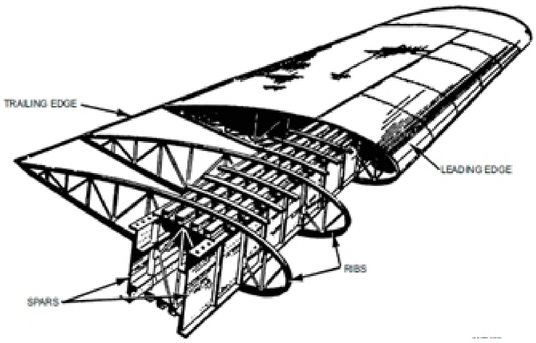


Fig: Two-spar wing construction.

7075 Aluminium Alloy:

It is an aluminium alloy, with zinc as the primary alloying element. It is strong, with a strength comparable to many steels, and has good fatigue strength and average machinability, but has less resistance to corrosion than many other Al alloys. Its relatively high cost limits its use to applications where cheaper alloys are not suitable.7075 aluminium alloy's composition roughly includes 5.6–6.1% zinc, 2.1–2.5% magnesium, 1.2–1.6% copper, and less than half a percent of silicon, iron, manganese, titanium, chromium, and other metals. It is produced in many tempers, some of which are 7075-0, 7075-T6, 7075-T651

Glass fibers:

The glass fibers are divided into three main classes E-glass, S-glass and C-glass. The E-glass is designated for electrical use and the S-glass for high strength. The C-glass is for high corrosion resistance, and it is uncommon for civil engineering application. Of the three fibers, the E-glass is the most common reinforcement material used in civil and industrial structures. It is produced from lime-alumina-borosilicate which can be easily obtained from abundance of raw materials like sand. The fibers are drawn into very fine filaments with diameters ranging from 2 to 13 X 10 m. The glass fiber strength and modulus can degrade with increasing temperature. Although the glass material creeps under a sustained load, it can be designed to perform satisfactorily. The fiber itself is regarded as an isotropic material and has a lower thermal expansion coefficient than that of steel .There are also the other fiber glasses which are used for FRP reinforcement as well as;

1)A-glass, soda lime silicate glasses used where the strength, durability, and good electrical resistivity of E-glass are not required.
2)D-glass, borosilicate glasses with a low dielectric constant for electrical applications.
3)ECR-glass, calcium alumino silicate glasses with a maximum alkali content of 2 wt.% used where strength, electrical resistivity, and acid corrosion resistance are desired.
4)AR-glass, alkali resistant glasses composed of alkali zirconium silicates used in cement substrates and concrete.
5)R-glass, calcium alumino silicate glasses used for reinforcement where added strength and acid corrosion resistance are required.
6)S-2-glass, magnesium alumino silicate glasses used for textile substrates or reinforcement in composite structural applications which require high strength, modulus, and stability under extreme temperature and corrosive environments. Table .1 and .2 show the chemical and mechanical properties of different glass fibers

Table1. Chemical composition of different glass fibers.

	A-glass	C-glass	D-glass	E-glass	ECR-glass	AR-Glass	R-glass	S-2-glass
SiO2%	63-72	64-68	72-75	52-56	54-62	55-75	55-60	64-66
Al2O3%	0-6	3-5	0-1	12-16	9-15	0-5	23-28	24-25
B2O3%	0-6	4-6	21-24	5-10		0-8	0-0.35	
CaO%	6-10	11-15	0-1	16-25	17-25	1-10	8-15	0-0.2
MgO%	0-4	2-4		0-5	0-4		4-7	9.5-10
ZnO%					2-5			
BaO%		0-1						
Li2O%						0-1.5		
Na2O+K2O%	14-16	7-10	0-4	0-2	0-2	11-21	0-1	0-0.2
TiO2%	0-0.6			0-4	0-4	0-12		
ZrO2%						1-18		
Fe2O3%	0-0.5	0-0.8	0-0.3	0-0.8	0-0.8	0-5	0-0.5	0-0.1
F2%	0-0.4					0-5	0-0.3	

Table2. Mechanical Properties Of Different Glass Fibers

	A-glass	C-glass	D-glass	E-glass	ECR-glass	AR-Glass	R-glass	S-2-glass
Density (gr/cm3)	2.44	2.52	2.11-2.14	2.58	2.72	2.70	2.54	2.46
Tensile Strength (MPa) at -196°C		5380		5310	5310			8275
Tensile Strength at 23°C	3310	3310	2415	3445	3445	3241	4135	4890
Tensile Strength at 371°C				2620	2165		2930	4445
Tensile Strength at 538°C				1725	1725		2140	2415
Modulus of Elasticity (GPa) at 23°C	68.9	68.9	51.7	72.3	80.3	73.1	85.5	86.9
Modulus of Elasticity at 538°C				81.3	81.3			88.9
Elongation%	4.8	4.8	4.6	4.8	4.8	4.4	4.8	5.7

E-Glass FRP(Woven Roving Mat grde 610)

Woven Fabrics

Woven fabrics are produced by the interlacing of warp (0°) fibres and weft (90°) fibres in a regular pattern or weave style. The fabric's integrity is maintained by the mechanical interlocking of the fibres. Drape (the ability of a fabric to conform to a complex surface), surface smoothness and stability of a fabric are controlled primarily by the weave style. The area weight, porosity and (to a lesser degree) wet out are determined by selecting the correct combination of fibre tex and the number of fibres/cm2. The following is a description of some of the more commonly found weave styles:

Plain:

Each warp fibre passes alternately under and over each weft fibre. The fabric is symmetrical, with good stability and reasonable porosity. However, it is the most difficult of the weaves to drape, and the high level of fibre crimp imparts relatively low mechanical properties compared with the other weave styles. With large fibres (high tex) this weave style gives excessive crimp and therefore it tends not to be used for very heavy fabrics.

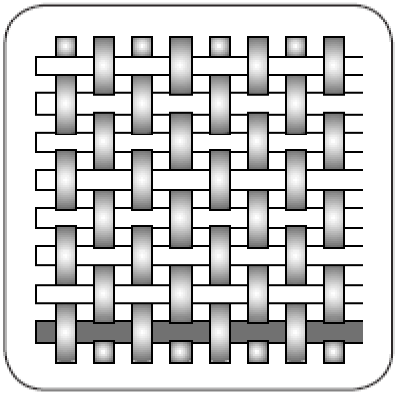
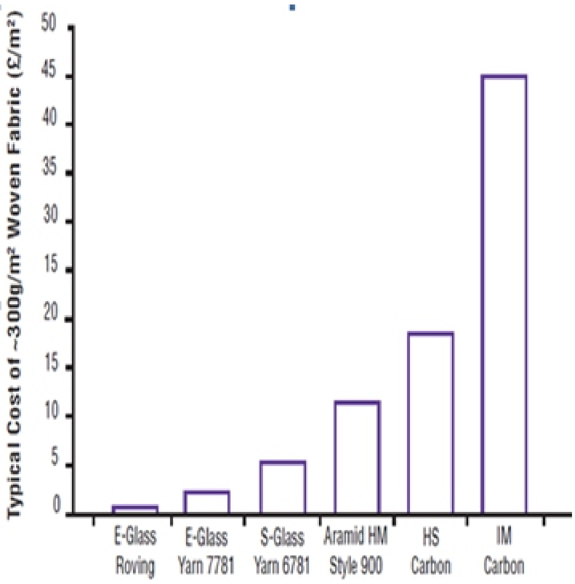


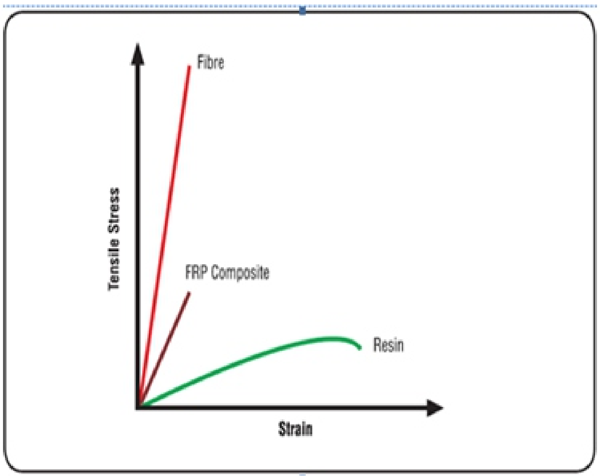
Fig: plain Woven Fabrics



Graph1: Graphical representation of E-glass fiber costs

Resin systems of the matrix:

The resin is another important constituent in composites. The two classes of resins are the thermoplastics and thermosets. A thermoplastic resin remains as 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.

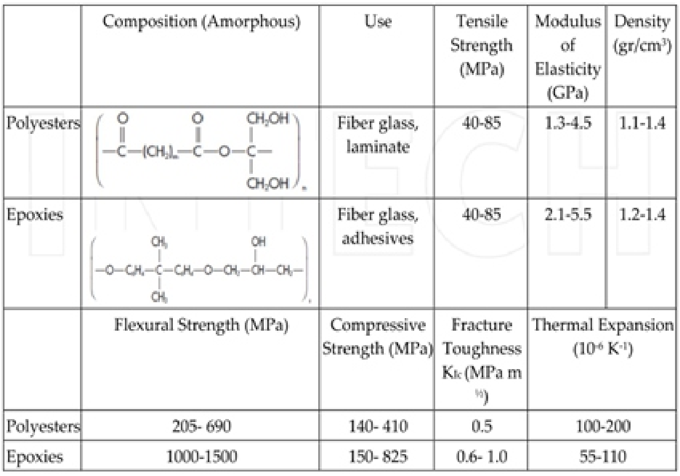


Graph2: Stress and strain relations of resins

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Epoxies :

The epoxies used in composites are mainly the glycidyl 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, it may be worth the cost when high performance is required. Table 6 shows mechanical properties of polyester and epoxy resins.



	Composition (Amorphous)	Use	Tensile Strength (MPa)	Modulus of Elasticity (GPa)	Density (gr/cm³)
Polyesters	$\left(-\overset{O}{\overset{\|}{C}}-(CH_2)_m-\overset{O}{\overset{\|}{C}}-O-\underset{CH_2OH}{\overset{CH_2OH}{C}}-\right)_n$	Fiber glass, laminate	40-85	1.3-4.5	1.1-1.4
Epoxies	$\left(-O-CH_2-\underset{CH_3}{\overset{CH_3}{C}}-CH_2-O-CH_2-\overset{OH}{CH}-CH_2-\right)_n$	Fiber glass, adhesives	40-85	2.1-5.5	1.2-1.4
	Flexural Strength (MPa)	Compressive Strength (MPa)	Fracture Toughness K_{Ic} (MPa m$^{1/2}$)	Thermal Expansion (10^{-6} K^{-1})	
Polyesters	205- 690	140- 410	0.5	100-200	
Epoxies	1000-1500	150- 825	0.6- 1.0	55-110	

Table 3: Mechanical properties of polyester and epoxy resins.

Preparation of aluminium alloy and e- glass FRP:

For the fabrication of GLARE laminates, 1 mm thick and 500mm wide ,500mm length 6061 Aluminium alloy sheets, were used. Due to the surface treatments done on Al surfaces, its final thickness reduced to 0.3±0.02mm. The FRP layers used in this study were 200gr/m2 E-glass plain woven with Araldite LY 5052 epoxy.

The methods used for aluminium alloy and epoxy material laminating was consisted For starting the experiment, take the aluminium alloy sheet with dimensions of 500mm X 500mm, with 1 mm thickness The aluminum alloy sheet clean neatly

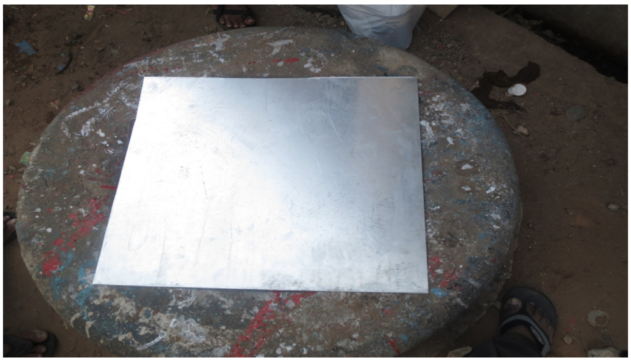


Fig :1mm thickness aluminum alloy sheet

Hand abrasion with 400 and 200 grit aluminum-oxide paper on rolling and its cross direction, respectively, to create macro roughness followed by tissue wiping to remove contaminates,

Fig Grinding process on Al alloy sheet

To prepare a epoxy araldite resin and hardener with the ratio of 1:0.8 and mixed completely in 5 or 6 minutes

Fig Mixed resin and hardner

Fig Eopxy material

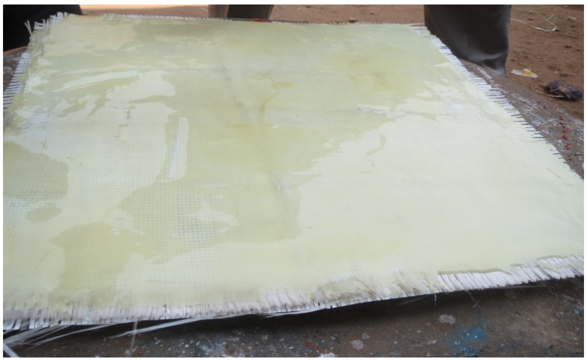
Araldite solution apply on the aluminum surface in the thick of 0.5mm

Fig Pasting proess on aluminium sheet

Then put on the 1st layer wovev roving unidirectional mat and apply araldite solution on that also for the next 2nd layer of woven roving mat.

Fig : Woven roving bonding unidirectionaly

Finally applied the araldite solution on the 2nd layer woven roving unidirectional mat.



Wax applying on the board for the purpose of the keeping on the epoxy material for the dry (for released purpose)and after applying wax pool again apply the poly vinyl alcohol and 5 minutes taken to dry.

Finally composite material put on the board and apply the weight uniformly on material for uniform thickness. To complete procedure we take the material after 2 days for strong adhesion bonding.

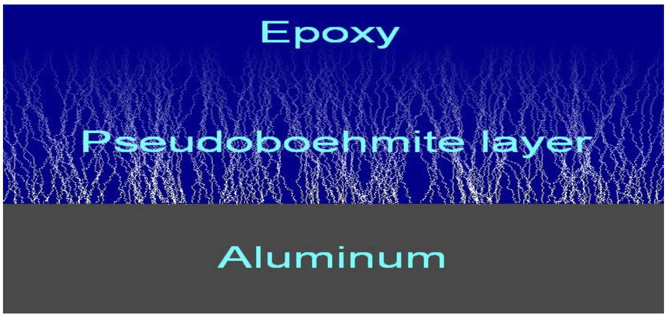


Fig. Schematic of formation of pseudoboehmiteoxy-hydroxide whiskers by immersion of Aluminum in boiling water.

For an optimal adhesion, it is important that the epoxy from FRP layers fully penetrates into the pores of the ALOOH layer . γ-GPS is widely used as a coupling agent for epoxy bonded aircraft repairs . The enhanced durability that the GPS primer can provide is attributable to the two distinct following reactions. The first reaction, is a covalent bond between hydrolyzed GPS and oxidized aluminum surface . The second extensive reaction is between the silanol group and the epoxy group of the γ-GPS molecule in the presence of the aluminum surface .

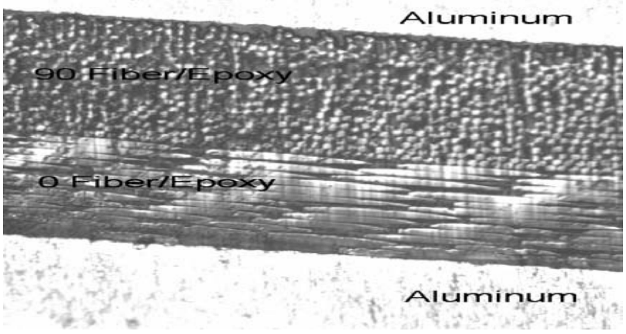


Fig. Microstructure cross section of FML

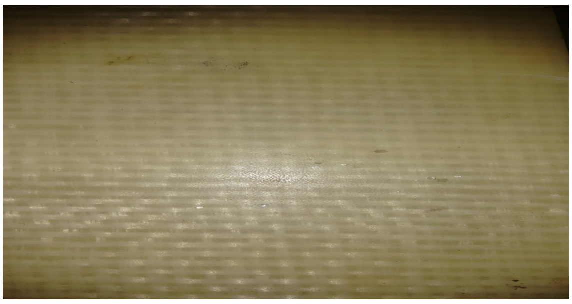


Fig 3.21 Aliuminium with FRP material surface

Fig 3.22 Cross sectional view of aluminium with FRP material

TENSILE TESTING:

After preparing the laminate, in order to find the ultimate tensile strength of the composite laminate conduct the tensile test with UTM, and the specimen is prepared using ASTM standards D3039 The specimen is prepared in dog-bone shape which has a gauge length of 50 mm. The specimens prepared are now tested on the UTM machine and the ultimate tensile strength of the each specimen is determined. As there is a difference in their orientation, each specimen exhibits a definite behaviour during failure

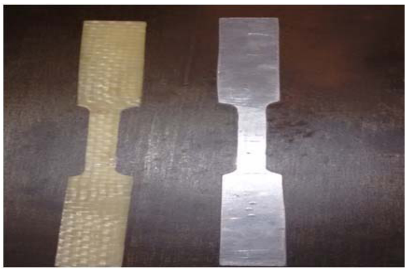


Fig :Tensile speciemens

Mechanical characterization of composite materials is a complex scenario to deal with, either because of the infinite number of combinations of fiber and matrix that can be used, or because of the enormous variety of spatial arrangements of the fibers and their volume content. The foundation of the testing methods for the measurement of mechanical properties is the classical lamination theory this theory was developed during the nineteenth century for homogeneous isotropic materials and only later extended to accommodate features enhanced by fiber-reinforced material, such as in homogeneity, anisotropy, and elasticity. Two basic approaches are proposed to determine the mechanical properties of composite materials: constituent testing and composite sample testing The mechanical tests were carri1ed out in an Universal testing machine. The Universal testing machine is a highly accurate instrument.

Fig 3.23 Tensile test on UTM

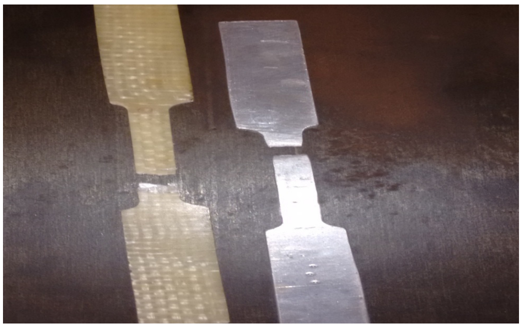


Fig Tensile specimens after rest failure .

COMPRESSION TEST:

After preparing the laminate, in order to find the compression strength of the composite laminate conduct the compression test with UTM, and the specimen is prepared using ASTM standards , The specimen is prepared in rectangular shape which has a length of 100 mm ,wide 100 mm with the specimen has placed in vertical position in UTM. The specimens prepared are now tested on the UTM machine and the compression strength of the each specimen is determined. As there is a difference in their orientation, each specimen exhibits a definite behaviour during failure

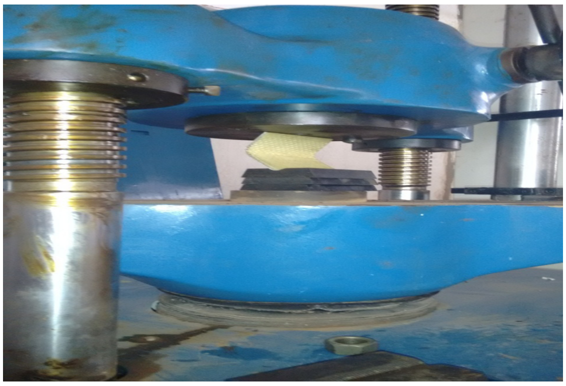


Fig: Compression test on UTM

BENDING TEST:

After preparing the laminate, in order to find the ultimate bending strength of the composite laminate conduct the bending test with UTM, and the specimen is prepared using ASTM standards D3039 The specimen is prepared in rectangular shape which has a length of 100 mm ,wide 100 mm with 20 mandril at 1800 degrees. The specimens prepared are now tested on the UTM machine and the ultimate bending strength of the each specimen is determined. As there is a difference in their orientation, each specimen bending test is satisfactory and no cracks observed.

Fig Bending test on UTM

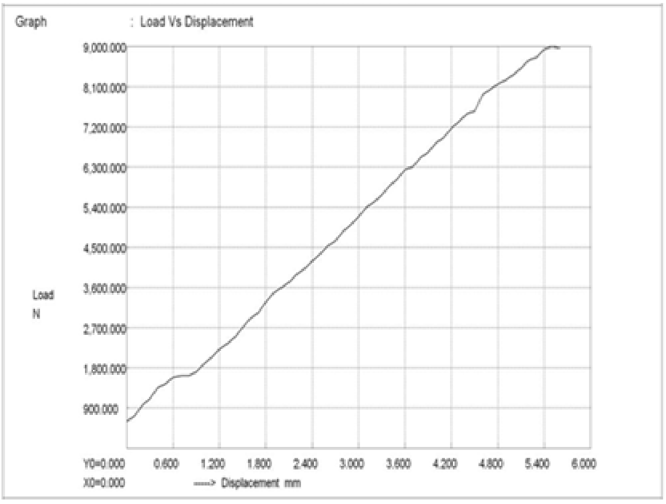
Fig After bending test specimens

S.NO	Nature of test	Aluminum alloy Thickness 3mm	Aluminum alloy 1 mm(thick) + epoxy 2mm thick =3mm
1	Tensile strength(N/mm2)	151.449	272.27
2	% of Elongation (in mm)	14.0	14.0
3	Compression strength(N/mm2)	22.0	22.15
4	Bending	Satisfactory(No cracks observed)	Satisfactory(No cracks observed)

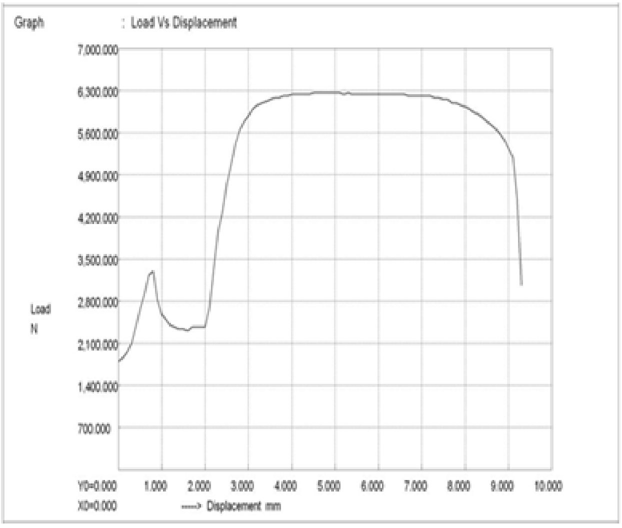
Table: Comparison of mechanical properties of aluminum alloy and aluminum with epoxy material

S.No	Type of material	Weight in kg	specifications
1.	Aluminum alloy (3mm)	2.8	500mmx 500mm
2.	Aluminum alloy (1mm) + Aluminum with epoxy material & resin (2mm)	2.4	500mmx 500mm

Table: WEIGHT COMPERISON OF ALUMN UM ALLOY AND ALUMINUM WITH EPOXY MATERIAL



Graph4: load Vs displacement for Aluminum alloy+ E-glass Frp specimen



Graph4: load Vs displacement for Aluminum specimen

CONCLUSION:

Experiments testing were conducted on bi directional woven rowan mat 610 grade fabric Glass/Epoxy laminate with the Aluminum Alloy composite specimens evaluate the tensile properties and bending properties It is observed from the result that combine Aluminum Alloy and E-Glass fiber 3 mm thickness high strength when compare only with Aluminum Alloy 3mm thickness for the same load, size & shape. In addition, we have conducted failure analysis for and Aluminum Alloy with E-Glass fiber to evaluate different failure modes and recorded. Finally we observe, though combine Aluminum Alloy and E-Glass fiber with have higher strength, stiffness and load carrying capacity than Aluminum alloy. Hence, it is suggested that with is preferred for designing of structures like which is more beneficial for sectors like Aerospace, automotives, marine, space etc.

BIBLIOGRAPHY :

[1] Mallick P.K., Composite Engineering Handbook, 1997, Marcel Dekker Inc., NY, USA.

[2] Gill, R.M., 1973, Carbon Fibers in Composite Materials, Page Bros (Norwich) Ltd, England.

[3] Isaac M. Daniel, Emmanuel E. Gdoutos, Deformation and Failure of Composite Structures, Journal of Thermoplastic Composite Materials 2003; 16;345.

[4] Jean-Marc Scanzi and Bruno Hilaire "All-Thermoplastic Composite Sandwich Panels – Part II: Modeling of Bending Behavior" Journal of Sandwich Structures and Materials 2004; 6; 423.

[5] Topdar, A. H. Sheikh and N. Dhang Finite Element Analysis of Composite and Sandwich Plates Using a Continuous Inter-laminar Shear Stress Model P.Journal of Sandwich Structures and Materials 2003; 5; 207.

[6] Nirmal Saha, Amar Nath Banerjee, "Flexural behavior of unidirectional polyethylene-carbon fibers-PMMA hybrid composite laminates," J. App. Poly. Sci. vol.60, 1996, pp. 139-142.

[7] Y.Li, K.J.Xian, C.L. Choy, Meili Guo, Zuoguang Zhang; "Compressive and flexural behavior of ultra-high-modulus polyethylene fiber and carbon fiber hybrid composites," Comp. Sci. & Tech., vol.59, 1999, pp. 13-18.

[8] Rohchoon Park, Jyongisk Jang; "Stacking Sequence effect of aramid-UHMPE hybrid composites by flexural test method," Polymer Testing, vol. 16, 1997, pp.549-562.

[9] Robert Matteson and Roger Crane, "Flexural testing of steel wire composite beams made with Hardwire unidirectional tape,"NSWCCD-65-TR-2003/48 Nov. 2003 (NASA Technical Report).

[10] P.D.Bradley, S.J. Harris, Strategic reinforcement of hybrid carbon fibers reinforced polymer composites, J. Mater. Sci.12 (1977), pp. 2401-2410.

[11] Dr. Jawad Kadhim Uleiwi, Experimental Study of Flexural Strength of Laminate Composite Material, Eng. & Technology, Vol.25, Suppl.of No.3, 2007, pp 454-466.

[12] WEN-PIN LIN, HSUAN-TEH HU, Parametric Study on the Failure of Fiber-Reinforced Composite Laminates under Biaxial Tensile Load, Journal of composite materials, Vol. 36, No. 12/2002, pp 1481-1503.

[13] Amjad J. Aref and Wael I. Alnahhal, Experimental Evaluation of a Hybrid FRP-Concrete Bridge Superstructure System under Negative Moment Flexural-Loads, Jordan Journal of Civil Engineering, Volume 1, No. 4, 2007, pp 336343.

[14] Slimane Metiche and Radhouane Masmoudi, Full-Scale Flexural Testing on Fiber-Reinforced Polymer (FRP) Poles, The Open Civil Engineering Journal, , 1, 37-50, 2007, pp 37-50.

[15] H. A. Rijsdijk, M. Contant & A. A. J. M. Peijs, Continuous-Glas S-Fib Re-Reinfo Rced Polypropylene Composites" I. Influence Of Maleic-AnhydrideModifiedPolypropylene On Mechanical Properties, Composites Science and Technology 48, 1993, pp. 161-172.

[16] P.N.B. Reis,J.A.M. Ferreira, F.V. Antunes, J.D.M. Costa, Flexural behaviour of hybrid laminated composites, P.N.B. Reis et al. / Composites: Part A 38 , 2007,pp. 1612–1620.

85

[17] M. Davallo, H. Pasdar and M. Mohseni, Effects of Laminate Thickness and PlyStacking Sequence on the Mechanical Properties and Failure Mechanism of Unidirectional Glass-Polyester Composites, International Journal of ChemTech Research, CODEN(USA): IJCRGG ISSN : 0974-4290, Vol.2, No.4, Oct-Dec 2010, pp 2118-2124.

[18] Michel Espinosa Klymus, Rosemary Sadami Arai Shinkai, Eduardo Gonealves Mota, Influence of the mechanical properties of composites for indirect dental-restorations on pattern failure, Stomatologija, Baltic Dental and Maxillofacial Journal, Vol. 9, 2007, pp. 56-60.

[19] S.Benjamin Lazarus, V. Vel Murugan, Experimental Investigation for Mechanical Properties of Chopped Random Fibre Compression Moulded Sunnhemp Polyester Composites, European Journal of Scientific Research,