Experimental Characterization of CFRP for Mechanical Properties with Different Resin Systems

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Abstract

Composites play a vital role in aerospace, land transportation and consumer goods due to their high specific strengths and stiffness's, leading to reduction in the mass of moving objects. Some of the important aerospace hardware such as rocket motor casings makes extensive use of CFRP (carbon fibre reinforced polymer). Judicious choice of the matrix system compatible with new generation high tensile strength carbon fibres like T-700 is crucial in obtaining consistent values of composite strength in tension as well as in shear.

In the present investigation, four different resin matrix systems were used in conjunction with T-700 carbon fibres and specimens derived from UD composites made with each of the resin systems and conforming to relevant ASTM- D series specifications were tested in tension, flexure and shear. Results indicate consistent and enhanced strength properties for CFRP with matrix composition # 4; that is epofine 1555

***Keywords**: CFRP, Epofine, Matrix, T-700.*

I. Introduction:-

Composite materials are widely used in many structural applications like an aerospace, land transportation and consumer goods. Advanced composites using continuous T-700 carbon fibre in multifunctional epoxy resin in a laminate form are becoming popular for structural applications not only the aero space but also in the general engineering. This CFRP composite has high strength and high stiffness compared to other composite materials.

Mechanical performance of carbon fibre reinforced polymer (CFRP) composites depend not only on the properties of reinforcing fibre and matrix, but also on the fibre sizing/matrix interfacial properties(1).Therefore, many scientific efforts have been devoted to modify carbon fibres by a variety methods such- as gas- phase, liquid- phase and continuous anodic oxidation(2-6), and then apply a very thin coating of a prepolymer or resin to the modified carbon fibre surface (7-10)for the purpose of improving the interfacial properties between the carbon fibre and matrix(11,12) and meanwhile to prevent the fibres from damage through the process of manufacture. In addition to that the composite material depends on the properties of its constituents and their distribution and physical and chemical interactions.

Mechanical properties of the composite will depend on the following aspects:

1. Surface treatment of the fibre
2. Percentage elongation of the fibre and matrix
3. Chemistry of the resin dictated by functionality, addition of toughening agent, curing agents and curing conditions.

In this investigation different epoxy resin systems with higher functionality were tried out in conjunction with high performance T-700 carbon fibres. Some of the resins were used along with reactive & non-reactive diluents. Different hardeners were also used to study the effect of these chemicals on the properties of the composites derived from them.

II .Material Preparation:-

Four types of epoxy resin were used in this work.The epoxy LY556(resin#1)was supplied by Hauntsman advaced materials praviate limited,Mumbai.The epoxy LY 556 with 5%reactive diluent(resin#2), Toughed epoxy resin (epoxy resin LY556 is modified with CTBN elastamers,that is resin#3) were supplied by ASL,Hyderabad and Epofine 1555(modified epoxy resin with high elongation (%4), that is resin#4) was provided by fine finish organics pvt Ltd, Mumbai.

Carbon T-700/epoxy resin laminates were prepared by drum winding process. T-700 fibres are passed through a resin bath containing epoxy resin mixed with 10%by weight of hardener HY 5200.The traction for pulling resin wetted fibres which pass through a pay-out eye attached to the longitudinal slide (tool post), is provided by rotating cylindrical mandrel. The resin bath is equipped with in-built servo controlled heating system and the temperature of resin mix is maintained at 40^0c, in order to bring the resin viscosity to around 1000-1500cpa.This enables the volume fraction of fibres to be at around 60%.

The cylindrical drum on which fibres are deposited is rotated at a low speed of 15rpm. Prior to winding, it is covered with a thick HDPE film without any wrinkles what so ever. The gear ratio between the headstock and lead screw is adjusted in such way that the fibre depositing slide moves by 3mm per each revolution of drum. The resulting pattern of fibres will be successive bands of fibre of 3mm width. After the winding is completed, the mandrel kept under rotation for about an hour to ensure that there is no resin collection at the bottom due to gravity.

The green composite (fibre blended with resin before curing) is cut open along the length of drum parallel to its axis. It is then carefully removed from the drum and laid flat on a table top along with the HDPE back-up film and allowed to air-dry for about 24hours to get the required tackiness. The prepag is then cut into the pieces of 300mmx300mm with the help of a template. The 300mmx300mm laminas are placed one by one on die plate up to the required thickness. The punch plate is then assemble to it and clamped with bolts & nuts. The clamping bolts are torqued to a value of 30N-m with the help of a torque wrench. The assembly is placed in a curing

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oven and the composite was cured as per the following general cure cycle. Variations were made to suit the resin systems as recommended by the manufacturer.

Room temperature to 70°C - 3omin

Hold at 70°C – 120 min

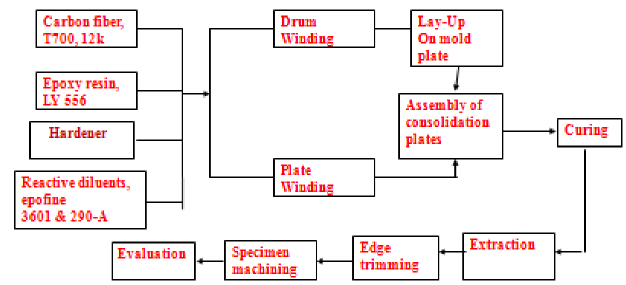
Ramp to 150°C – 30min

Hold at 150°C – 240min

To prepare the laminate, the following process parameters were used

SNo	Parameter/Material	Details
1	Resin/Hardener	LY-556/HY 5200
2	Diluent	EF3601, 290a
3	Tool	Cylindrical/Rectangular Mandrel
4	Process	a)Drum winding b) Plate winding
5	Band width	3.0mm
6	Fibre Tension	0.9kg
7	Distance between Resin bath and mandrel	1.66m
8	Number of processes	a)1 b) 7 to 10
9	Mandrel RPM	15 RPM
10	Resin temperature	45°C
11	Volume fraction	60%

The Process



III .Specimen Preparation and Testing:

Specimens were prepared from composite laminated plates; the manufacturing process is described under the heading “material preparation”. The specimens conform to the requirements lead down in the relevant ASTM specifications listed below.

S.No	Type of test	Relevant ASTM	No.of specimens	Specimen size(mm)
1	UD-Tensile	D-3039	5	250x15x1.0
2	Transverse tensile	D-3039	5	175x25x2.0
3	Flexural	D-790	5	50X25X1.6
4	ILSS	D-2544	5	24X12X6.0
5	In plane shear	D-3518	5	300x25x3.0

A .Test condition:

1. The specimens were tested at a strain rate (displacement) of 2mm/min
2. Co-axiality of the specimen axis and the machine loading axis was ensuring.
3. Two layers of emery cloth were used on either end of the specimen to hold between the grips.
4. Cognizes was taken in respect of the results in which explosive failure within the gauge length was absorbed.

B. Testing:-

In UD- tensile, transverse tensile and In-plane shear the specimen is mountain in the grips of INSTRON universal testing machine and monotonically loaded in a tension while recording the force. The strength can be determined from the maximum loading carried before failure. The maximum displacement can be determined by the strain transducer.

In flexural and short beam shear test, insert the specimen into the test fixture, with the tool slide resting on the reaction supports. Align and centre the specimen such that its longitudinal axis is perpendicular to the loading nose and side supports. Adjust the span such that the span to measured thickness ratio is 4 in flexural and 16 in the in- plane shear. The loading nose should be located equidistance between the side supports.

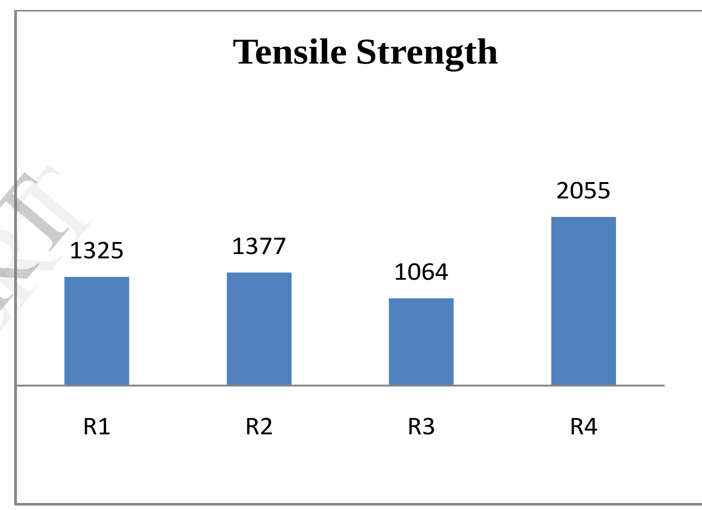
IV. Results:

Observed results in respect of specimen derived from Resin#1(R1), Resin#2(R2),Resin#3(R3)and Resin#4(R4) composite plates are placed in

Table-1: Tensile Properties:

Resin type	Geometry (mm)	Breaking load (KN)	σ (Mpa)	E (Gpa)
R1	250X15X1.0	38.34	1325	137.2
R2	250X15X1.0	45.24	1377	142.1
R3	250X15X1.0	33.13	1064	108.0
R4	250X15X1.0	49.64	2055	134.7

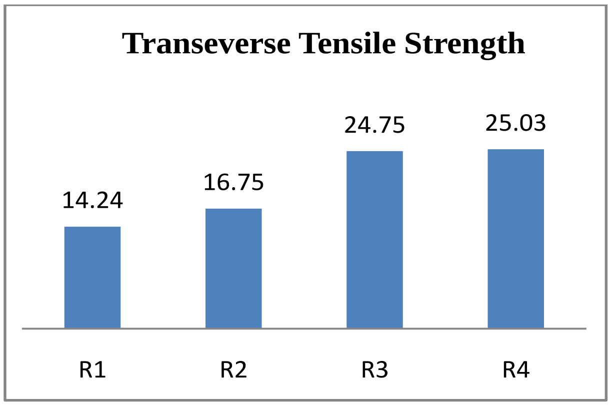
σ=Average value of tensile strength,
E=Young's modulus



Graph-1: Tensile Strength of T-700 CF with different resins

Table-2: Transverse Tensile properties:

Resin type	Geometry(mm)	Breaking load(KN)	σ_f (MPa)	E (Gpa)
R1	175X25X2.0	1.2	14.24	4.96
R2	175X25X2.0	1.12	16.75	5.37
R3	175X25X2.0	1.24	24.75	7.95
R4	175X25X2.0	2.96	25.03	8.44

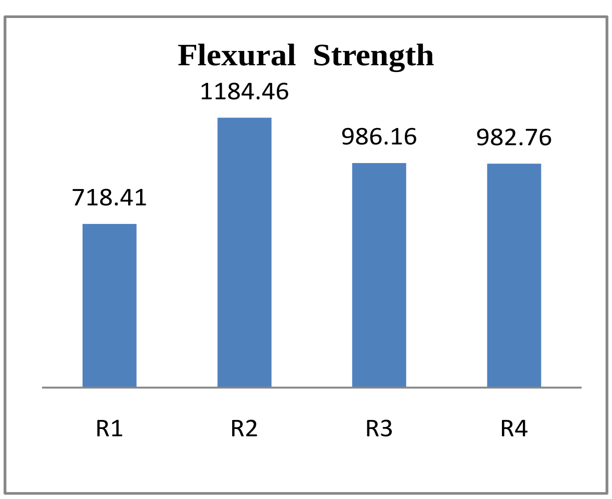


Graph-2: Transverse Tensile Strength of T-700 CF with different resins

Table-3: Flexural properties:-

Res in type	Geometry (mm)	Breaking load(KN)	σ_f (MPa)	E (Gpa)
R1	50x25x1.6	5.0	718.41	32.23
R2	50x25x1.6	1.12	1184.46	103.08
R3	50x25x1.6	4.75	986.16	73.15
R4	50x25x1.6	3.25	982.76	74.11

$\sigma_{f=}$ Flexural strength

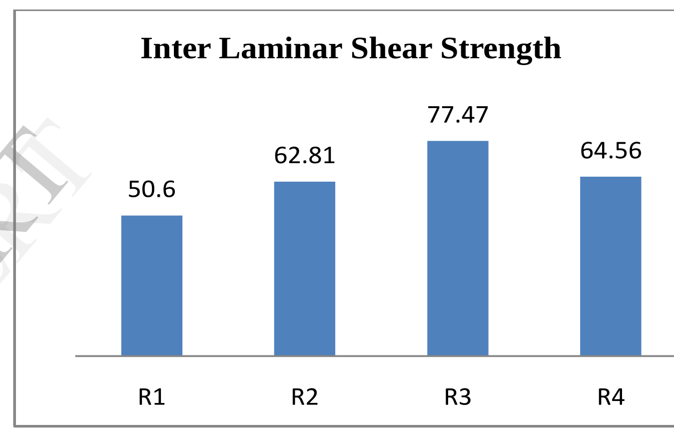


Graph-3: Flexural Strength of T-700 CF with different resins

Table-4: Inter laminar shear properties:

Resin type	Geometry	Breaking load	τ_{12} (MPa)	G_{12} (Gpa)
R1	40x12x6.0	2.9	50.6	3.2
R2	40x12x6.0	3.72	62.81	3.6
R3	40x12x6.0	5.01	77.47	7.8
R4	40x12x6.0	3.07	64.56	4.4

$\tau_{12\,=}$ Inter laminar shear strength
$G_{12=}$ shear modulus

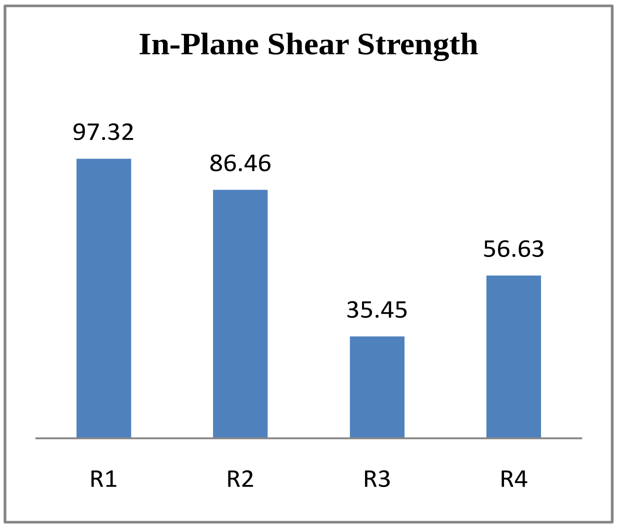


Graph-4: Inter Laminar Shear Strength of T-700 CF with different resins

Table-5: In plane shear properties:-

Resin type	Geometry	Breaking load	τ_{12} (Mpa)	G_{12} (Gpa)
R1	300X25X3	1.5	97.32	3.5
R2	300X25X3	3.45	86.46	3.9
R3	300X25X3	1.98	35.45	8.1
R4	300X25X3	15.04	56.63	4.2

$\tau_{12\,=}$ Inter laminar shear strength



Graph-5 In-Plane Shear Strength of T-700 CF with different resins

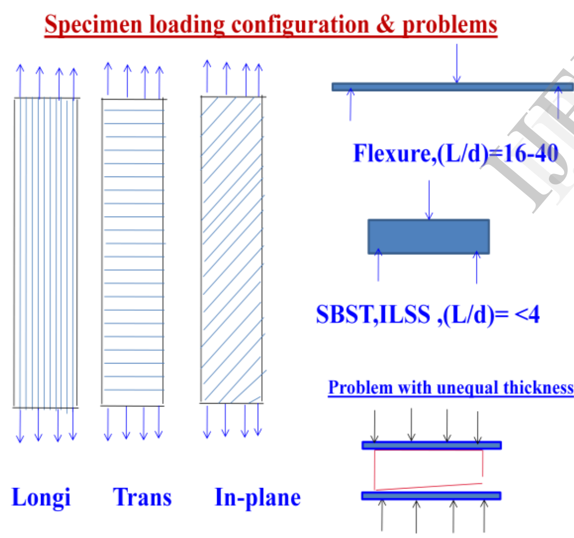


Fig-1: specimen loading configuration

Fig-2: Laminated composite plate

Fig-3: Specimen Failure in Transverse tensile loading

Fig-4: Specimen failure in in-plane shear

Conclusion:-

Among all the resin compositions tried out, Resin#4 is most preferred one since it has given consistent values of tensile strength at an average in excess of 2000Mpa. This resin system is also given reasonable good flexural, transverse tensile, in-plane shear, inter laminar shear stress.

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