Fabrication of FRP Laminates produced by pultrusion process and their Characterization

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Abstract:
pultrusion provides large scope for producing structural members for various applications like aerospace, milit ary, marine, submarine and renewable energy generation. FRP (Fiber Reinforced Poly mer) co mposites are extensively used in airframe structural applications. Glass Fibre Reinforced Poly mer (GFRP) is one of the most commonly used composite materials in composite industry. Higher energy demands across the developed and growing world for usage and replacement of conventional material with composite materials for the engineering applicat ions which is questioned by the end user, unless t he research oriented reliable supporting certificat ion is made available. The mechan ical p roperties like tensile modulus, Flexu ral modulus of GFRP pultruded structures, the mechanical degradation (decrease in the tensile modulus and flexural modulus) will be analyzed and discussed. The pultruded structural composites were subjected to tensile and impact as per ASTMD standards.

Keywords: Pultrusion Process, Co mposite Manufacturing, Resin Bath, UTM .

I. Introduction:

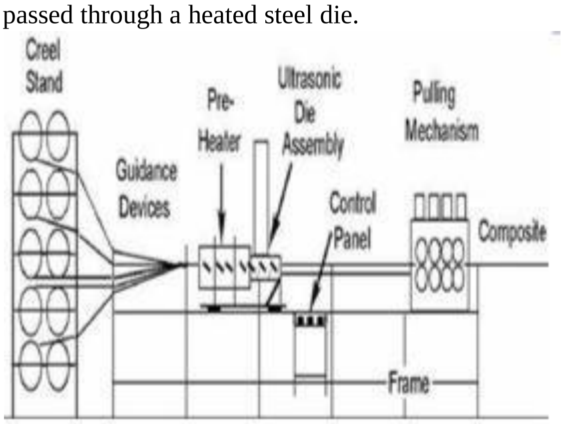
In order to produce high quality pultruded profiles, there are variables such as fibre imp regnation, resin viscosity, pulling speed and curing temperature that have to be considered and these variables are discussed in this study.[1] . The physical and mechanical properties of the test indicated that the properties of phenolic-treated strips have significantly increased as compared to control samples. Dimensional stability (water absorption, thickness swelling and linear expansion) of the phenolic-treated properties were significantly lo wer than control after 5-min pressing time . [2]. A fundamental understanding of the effects of processing parameters and die geometry in a pultrusion process requires a mathematical model in order to min imize the number of necessary experiments. [3].

II. Fabrication of Pultruded Composites:

FRP can be manufactured in a wide variety of methods. These manufacturing processes are selected as per the requirement of end product. FRP drive shafts are made by filament winding. Sheets can be made by casting etc. So me of the manufacturing methods are:

1. Contact Moulding
2. Pultrusion
3. Co mpression Moulding
4. Resin Transfer Mould ing
5. Filament Winding
6. Reaction In jection Moulding

Pultruded FRP sections are usually made by pultrusion process. This process creates continuous composite profile by pulling raw co mposites through a heated die. Pultrusion combines words “pull” and “extrusion” where extrusion is pulling of material such as fiberglass and resin, through a shaping die. Many resin types can be used in pultrusion including polyester, polyurethane and vinyl ester epoxy resins etc. Fiber is wetted or impregnated with resin and is organized and then removed of excess resin. After that the composite is passed through a heated steel die.



Precisely machined and often chromed, the die is heated to a constant temperature, and may have several zones of temperature through-out its length, which will cure the thermosetting resin. The profile that exits the die is now a cured Pultruded Fiber Reinforced Plastic (FRP) composite. This FRP pro -file is pinched and pulled by a “gripper” system. At the end of the pultrusion machine there is a cut-off saw. Pultruded profiles are cut to the specific length and stacked for

delivery. “Pu ltrusion” combines words “Pull” and “Ext rusion”. Extrusion is pulling of material such as Fiberg lass and Resin, through a shaped and heated die.
Some of the Advantages of Pultrusion are increase in Strength, High Fiber Content, Highly Automated, Consistent Quality, High Production, Lo w Labor Required, Low Cost. Conventional pultrusion experiments with a resin bath were carried out in the laboratory using a polyvinyl resin system. For the experiments that were performed at an industrial site, vinyl ester and polyurethane resin systems were used. A resin bath with a capacity of five litres was used for all the conventional pultrusion experiments.
The following section provides an overview of the procedures involved with conventional pultrusion: The E-glass fibre creels located on the creel stand were threaded through eyelets to the guide plates attached on the creel stand; these were then

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passed through a polypropylene guide plate.
Photographs showing the key components of conventional pultrusion process:

(A) E-g lass fibre creels on the creel stand.
(B) Back guide plate.
(C) Dip -type resin bath.
(D) Rovings dipped in the resin bath.
(E) Pre -forming guides.
(F) Pult ruded composite exit ing the die.

The resin bath was secured to the frame of the pultrusion mach ine. After securing the resin bath in position, the fibre rovings were threaded through the plunger, forming plates and the die. In order to pass the dry rovings through the die, one roving was threaded with the help of a brass wire. The remain ing rovings were threaded through the die by “entangling” each additional roving to one of the threaded
rovings at the die entry point, and it was pulled through the die manually. After 20 rovings were threaded in this manner, it was necessary to use the haul-off device (puller). Th is was achieved by binding the threaded rovings with adhesive tape prior to feeding it to the puller. This method allowed the required number o f rovings to be threaded in a continuous manner until the die was packed with the desired number of rovings. Once around forty rovings had been threaded through the die, the roving-pack was coated with a release agent (PAT-672, CRC Ltd) with the introduction of each roving to reduce the frict ion within the die.

Once the die was threaded, it was heated to the required temperature. The co mponents of the resin were weighed and mixed in the required stoichio metric ratio to give a total volume of five litres. The mixing of the components of the resin was carried out with the aid of a mixing blade attached to a power-drill. The filler and IMR were added in small volumes at a time and mixed. The mixed resin system was poured in to the resin bath manually. The “pullers” were started to commence pultrusion. The pultruded composites were labeled and cut at intervals of 1.5 meters. At the end of the pultrusion experiment, the resin remaining in the bath was transferred into small containers and cured prior to disposal. The excess sides of the laminate which are formed because of pressure plate during the fabrication is chopped out and according to the required dimension i.e . A STMD638 standards, the sample pieces are taken out with the help of wood cutting machine as shown below.

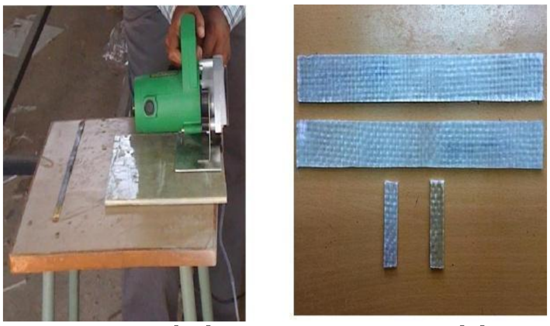

Figure.1: Cutting the laminate in to a required dimension.

Hence the same procedure is carried out for making the making of other co mposite laminates.

III. . Experimentation and Testing:

The presented work is an attempt has been made to study the damage, strength degradation of the chosen laminated composite materials (GFRP) under hydro loading based on combined effect on the parameter of mo is ture results.

Experimentation-1: The numbers of GFRP specimens are exposed to water at room temperature for period of 16 days and every 7 days number of specimens are taken from water bath and tested with tensile test.

Experimentation-2: GFRP specimens are exposed to salt water at roo m temperature water bath tub for 16 days and every 7 days number of specimens are taken fro m the bath and tested with tensile test.

Experimentation-3: The numbers of painted GFRP specimens are exposed to dry environment cond ition and

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tested every 7 days number of specimens are taken and tested with tensile test. There are two stages in the process of familiarizing with plastics. The first is rather general and involves an introduction to the unique molecular structures of

olymers, their physical and transitions which have a marked influence on their behavior. The study of specific p roperties of plastics reveals their application. Besides the relative ease of their mould ing and fabrication, many plastics offer range of important advantages in terms of high strength/weight ratio, toughness, corrosion-resistance, wear-resistance, frictional co-efficient, tensile, flexu ral, comp ression, impact strength and chemical resistance. Due to these qualities, plastics are acceptable as materials for wide variety of engineering applications. It is important therefore, that an engineer be aware of the performance characteristics and significant properties of plastics. Plastics are generally dealt with, in respect of broad categories of properties, namely, mechanical, thermal and chemical. An impo rtant facet of materials development and proper materials selection is testing and standardization. This chapter represents schematically (in simp lified form) a number of standard test methods for plastics, highlighting the principles of the mechanical tests and the properties measured with them. A list of salient features of testing has been stated below.

To assess numerically the fundamental mechanical properties of ductility, malleability, resilience, stress-strain and visco elastic behavior, determine data (i.e . fo rce deformat ion or stress values) to draw up sets of specifications. To determine the surface or subsurface defects in raw materials or processed parts. To check chemical co mposition and to determine the stability of a materials for particu lar applications. In the present work after cutting the laminate of different co mposite specimens are tested in various operations.

IV. Mechanical Properties:

Several unfamiliar aspects of material behavior of plastics needs to be appreciated, the most important, probably being that in contrast to most metals at room temperature, the properties of plastics are time-dependent. Then superimposed on this aspect, are the effects of the level of stress, temperature of material and its structure (such as molecular weight, mo lecular o rientation and density). Properties measured as single values following standard test procedure are therefore useful only as a measure of quality control.

V. Tensile Testing:

Tensile testing, also known as tension testing, is a fundamental materials science test in which a sample is subjected to uniaxial tension until failure. The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under other types of forces. Properties that are directly measured via a tensile test are ultimate tensile strength, maximu m elongation and reduction in area. Fro m these measurements the following properties can also be determined: Young's modulus, Poisson's ratio, yield strength, and strain-hardening characteristics.

Figure.2: Tensile specimen.

Tensile Testing Equipment:

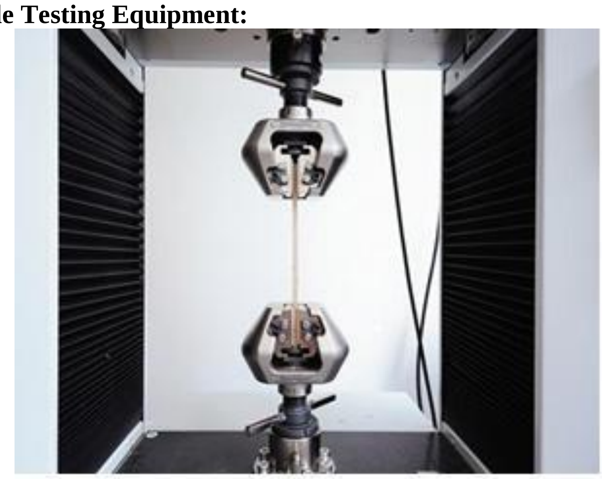

Figure.3: Laminate is fixed between jaws for tensile loading.

The most common testing mach ine used in tensile testing is the universal testing machine. This type of machine has two crossheads; one is adjusted for the length of the specimen and the other is driven to apply tension to the test specimen. There are two types: hydraulic powered and electromagnetically powered machines.

The mach ine must have the proper capabilities for the test specimen being tested. There are three main parameters: fo rce capacity, speed, and precision and accuracy. Force capacity refers to the fact that the machine must be able to generate enough force to fracture the specimen. The machine must be able to apply the force quickly or slowly enough to properly mimic the actual application.

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Specifications of the (Kalpak 060601) Universal Testing Machine:

Model	Universal Testing Machine (UTM)
Kalpak	060601
Load capacity	50 KN
Maximu m speed	500mm/ min
Minimu m speed	0.005mm/ min
Maximu m force at full speed	25KN
Maximu m speed at full load	250mm/ min
Return speed	500mm/ min
Total crosshead travel	1122mm
Total vertical test space	1193mm
Total vertical space	420mm
Space between columns	420mm
Dimensions (H x W x D)	1582mm x 756mm x 707mm
Weight with vertical load cell	141kg
Max power requirement	700VA

inally, the machine must be able to accurately and precisely measure the gage length and forces applied; for instance, a large machine that is designed to measure long elongations may not work with a britt le material that experiences short elongations prior to fracturing.Align ment of the test specimen in the testing machine is critical, because if the specimen is misaligned, either at an angle or offset to one side, the mach ine will exert a bending force on the specimen. Th is is especially bad for brittle materials, because it will dramat ically skew the results. This situation can be min imized by using spherical seats or U-joints between the grips and the test machine. A misalign ment is indicated when running the test if the init ial portion of the stress -strain curve is curved and not linear.The strain measurements are most commonly measured with an extensometer, but strain gauges are also frequently used on small test specimen or when Poisson's is being measured. Newer test machines have digital time, force, and elongation

Measurement systems consisting of electronic sensors connected to a data collection device (often a computer) and software to manipulate and output the data. However, analogy mach ines continue to meet and exceed ASTM, NIST, and ASM metal tensile testing accuracy requirements, continuing to be used today.

Process:

The test process involves placing the test specimen in the testing machine and applying tension to it until it fractures. During the application of tension, the elongation of the gauge section is recorded against the applied force . The data is man ipulated so that it is not specific to the geometry of the test sample. The elongation measurement is used to calculate the engineering strain (ε)

$$\varepsilon = \frac{\Delta L}{L_0} = \frac{L - L_0}{L_0}$$

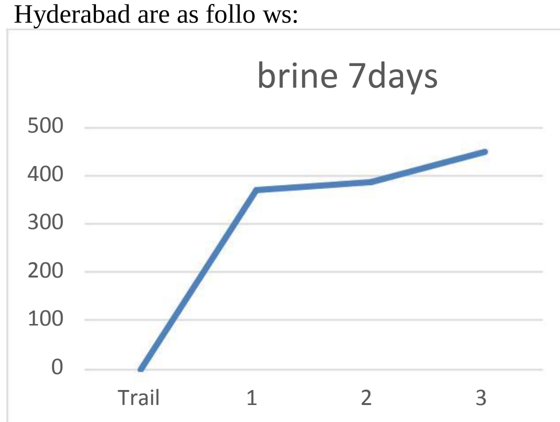
Where L is the change in gauge length, $L0$ is the initial gauge length, and L is the final length. The force measurement is used to calculate the engineering stress, σ, using the following equation:

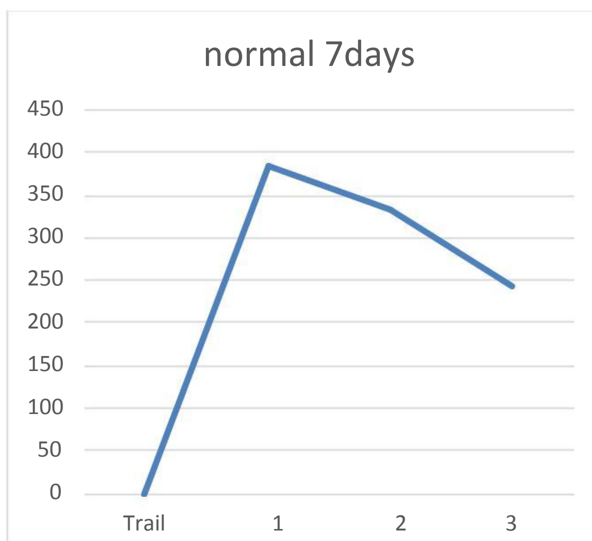
$$\frac{F}{A}$$

Where 'F' is the force and A is the cross -section of the gauge section. The machine does these calculations as the force increases, so that the data points can be graphed into a stress - strain curve.

VI. . Results and Conclusion:

In the above said Tensile test (UTM) and Morphology (SEM) has been done and the results obtained were furnished in the form of Data Sheets and the output screen shots and the results were published by performing these testing in the BHARATH TECHNICA L LA BS and O.U (Physics Depart ment) Hyderabad are as follo ws:





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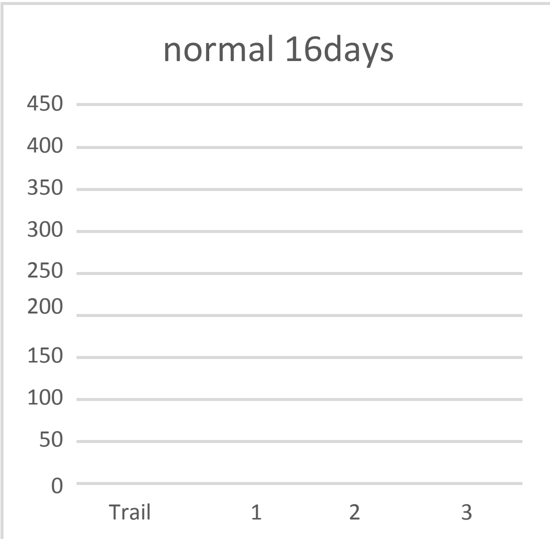

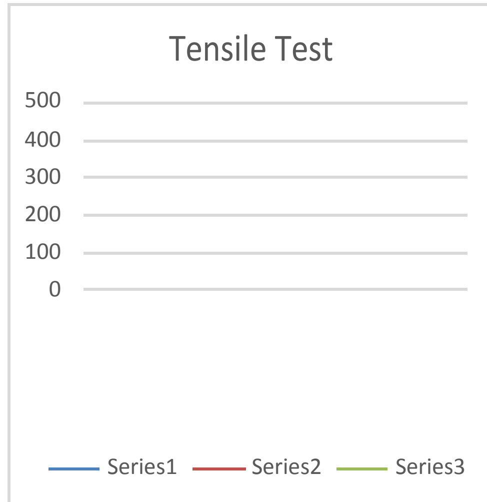

VII. Tensile Test Report For Graphs (units: N/mm²):

Tensile Test					
Trail	**brine 7 days**	**normal 7 days**	**dry**	**brine 16days**	**normal 16 days**
1	372.19	384.38	393.08	381.54	347.69
2	386.48	333.02	401.85	431.99	401.45
3	451.44	242.48	457.51	398.7	411.627

Specimens With Brine Solution for 7 days								
Trail	**Load at Yield**	**Elongation at yield**	**Yield Stress**	**Load at Peak**	**elongation at peak**	**tensile strength**	**load at break**	**elongation at break**
1	41.82	15.4	274.035	56.8	17.3	372.19	0.76	18.91
2	44.36	21.38	285.167	60.12	24.16	386.48	3.76	26.88
3	54.28	28.93	348.868	70.24	33.94	451.44	70.24	31.16

specimens with noraml water for 7 day								
Trail	**Load at yeild**	**Elongation at yield**	**Yield Stress**	**Load at Peak**	**elongation at peak**	**tensile strength**	**load at break**	**elongation at break**
1	46.52	10.62	307.036	58.24	12.11	384.38	58.24	12.02
2	41.28	13.73	261.258	52.62	15.41	333.02	4.78	15.34
3	28.12	12.88	182.317	37.4	14.24	242.48	3.7	16.57

specimens under dry condition for 7 days								
		Elongation at		**Load at**	**elongation at**	**tensile**	**load at**	**elongation at**

Trail	Load at yeild	yield	Yield Stress	Peak	peak	strength	break	break
1	47.9	27.24	307.862	61.16	28.41	393.08	2.52	28.44
2	43.36	7.05	281.855	61.82	6.84	401.85	12.56	6.84

specimen with Brine solutions for 16 days

Trail	Load at yeild	Elongation at yeild	Yeild stress	Load at peak	Elongation at peak	Tensile strength	Load at break	Elongation at break
1	45.86	15.31	293.979	59.52	17.64	381.54	9.5	21.15
2	34.38	6.21	215.323	68.88	11.35	431.99	3.6	15.16
3	22.96	12.01	147.48	62.02	18.4	398.7	11.98	21.52

specimen with normal water for 16 days

Trail	Load at yeild	Elongation at yeild	Yeild stress	Load at peak	Elongation at peak	Tensile strength	Load at break	Elongation at break
1	34.1	9.49	217.989	54.34	14.54	347.69	2.78	14.87
2	31.1	6.62	206.232	60.54	11.65	401.45	0.66	12.19
3	26.02	6.16	169.471	63.2	12.38	411.627	63.2	11.9

VIII. Acknowledgment:

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