



Preparation and Properties of Glass Fibre Pultruded Composites

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Abstract

The paper presents the preparation and properties of glass fibre reinforced unsaturated polyester resin produced via pultrusion method. Solid rod profile was used as the geometry for investigation. The percentage of glass fibres used was kept at 70% by weight of matrix. Compression and flexural tests were performed in order to study the mechanical properties of the composites. Morphological study was done by using light microscopy. Morphological evaluation on the fracture specimens show that failure was induced by crack formation in the interface layer between fibre and matrix. Consequently, fibre arrangement (direct or twisted) also plays a major role in dictating the direction of crack propagation.

Key-word: - Glass fibre, Pultrusion, Pultruded composites

1. Introduction

Fibre reinforced polymer (FRP) provides another alternative to traditional materials thus significantly improve the performance and durability of new or deteriorated constructed facilities. In addition to their high strength and weight ratio, corrosion resistance and high fatigue strength, FRPs can be easily bonded to reinforced concrete members (Larry McCuaig et. al, 2008). Another peculiarity is the possibility of changing the material properties designing the volume ratio of the fibres to resin and choosing the type and orientation of the fibres (Marisa Pecce, 2002). Nowadays, FRP composites are widely being used as part of construction materials (Adam C.Berg, 2006, A.H. Al-Saidy, 2007, Lawrence C. Bank, 2007)

Pultrusion is a process that combines different forms of reinforcement layers, such as roving, woven and non-crimp fabrics, and mat performs, with a resin matrix such as polyester or vinylester (Woong-Ryeol Yu et. al, 2008). The typical cross-sections of pultruded composites are I, channel, angle and box, but if desired, custom shapes also can be produced. Pultruded composites can be very stiff competitor to the traditional materials when cost analysis is evaluated on life span rather than initial cost basis. However, the reliability of pultruded composites under some circumstances such as the resistance towards the mechanical testing is well being discussed among the authors (David W.Palmer ,1998, Ninoslav Pesic, 2003, Francesca Ceroni, 2006) because their mechanical properties depend on the fibres orientation.

Glass fibre is a reinforced plastic material which is composed of a woven material that is embedded with glass fibres which are randomly laid across each other and held together with a binding substance. Glass fibre is combined with resin to form an extremely strong and durable composite. Glass fibre composites have been used in a variety of application like aerospace, automotive, sports, ships and constructional work. Because of their several advantages such as relatively low cost of production light weight, easy to fabricate and superior strength to weight ratio (Ishan Khani & Anshuman, 2018)

This paper is focused on the preparation and properties of glass fibre reinforced polyester composite using pultrusion method. Rod profiles have been produced after a series of experiments. Flexural test, compression test, and morphological assessment were examined on the rod profiles pultruded composites.

2. Experimental

2.1 Materials

Glass fibres in roving form were used in this experimental. The properties of the glass fibre and unsaturated polyester resin can be obtained from Table 1 and Table 2.

2.2 Preparation of pultruded composites

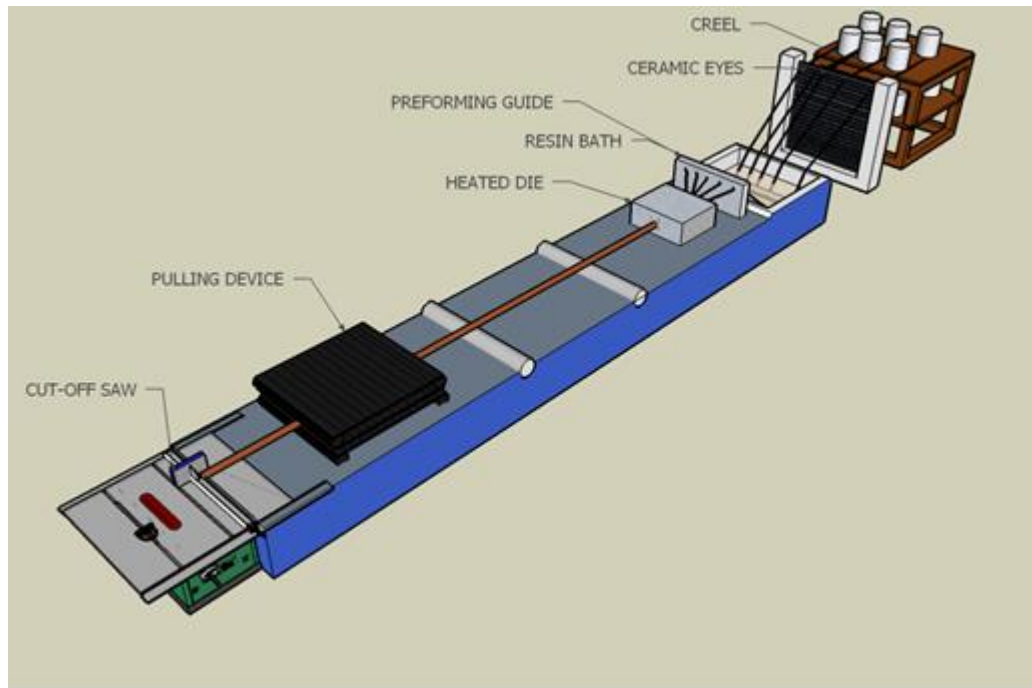


Figure 1: Thermoset Pultrusion Machine

The composites were prepared using a thermoset pultrusion machine. A thermoset pultrusion machine typically consists of a creel, guidance devices, resin bath, preforming guide, heated die, pulling device and cut-off saw (Figure 1) was used in this experiment. Details of the constituents used in the preparation of the glass fibre composites are given in Table 3 respectively. The parameter used for pultrusion processing is given in Table 4.

Glass fibre rovings are placed on a creel merely of bookcase-type shelves and equipped with roving guider to lead the strands to the resin bath. Roving guider is used to insure the strands do not scrape across one another as this will generate considerable static and cause “fuzz balls” to build up in the resin bath, raising its viscosity (Raymond W.Meyer, 1985).

Then, the fibre is guided to the resin bath containing unsaturated polyester resin to wet it out. Usually the resin bath containing a set of adjustable slots at the exit end to remove excessive resin from the reinforcement. Preforming guide is functioning to gentle and bend the impregnated reinforcements to form the shape and to minimize the amount of excess resin present during the cure cycle. Directly after passing the performing guide, the glass fibre is then pulled to be cured by electrically heated die. The pultrusion process is driven by a pulling device which is placed at the end of the pultrusion line. Finally, a cut-off saw is used to cut the desired length of the pultruded composites. The average diameter of all composites rod is 12.7 mm.

2.3 Material characterization

2.3.1 Compression

Compression test were performed using Instron 8802 following the standard method using for compression properties (ASTM D 695-02a). The diameter and length of the specimen was 12.7mm and 25.4mm respectively. The crosshead speed was set to 1.3mm/min. Three specimens from each type of composites were tested.

2.3.2 Flexural

Three-point flexural test of pultruded composites were carried out using Instron 5582. This test was done according to the standard method using for flexural properties (ASTM D 4476-03). Specimens were cut into two parts so that the cross section of each part is smaller than a half-round section and the span was 100mm. The crosshead speed for flexural test was set to 3mm/min. Three specimens were prepared for the glass fibre composites.

2.3.3 Morphological assessment

The composites were observed with a Rax Vision optical microscope and fibre length was measured by direct analysis of the micrographs using JVC color video camera model TK-C921EG. The samples were grinded using sandpaper and followed by polishing with alumina paste.

3. Results and discussions

3.1 Compression properties



Figure 2 : Load-Displacement Extension Curve Under Compression

Figure 2 a load-displacement curve glass fibre reinforced pultruded composites. In this loading case, glass fibre composites show a linear portion before sudden drop occurred. The non-linearity and sudden drops for glass fibre composites are associated with matrix cracking and rod buckling within the materials. Despite the separation of the outer matrix layers from the fibre, kink bands on the surface which was started from the interior of the composites also were detected. A kink band of rods usually started from microbuckling which cause the short fibre fragments and it became longer from the triggering point, forming a gradually widened kink band. Then, the kink band propagates steadily along an inclined direction until it meet the composites surface (Wen-Shyong Kuo et al, 2000).

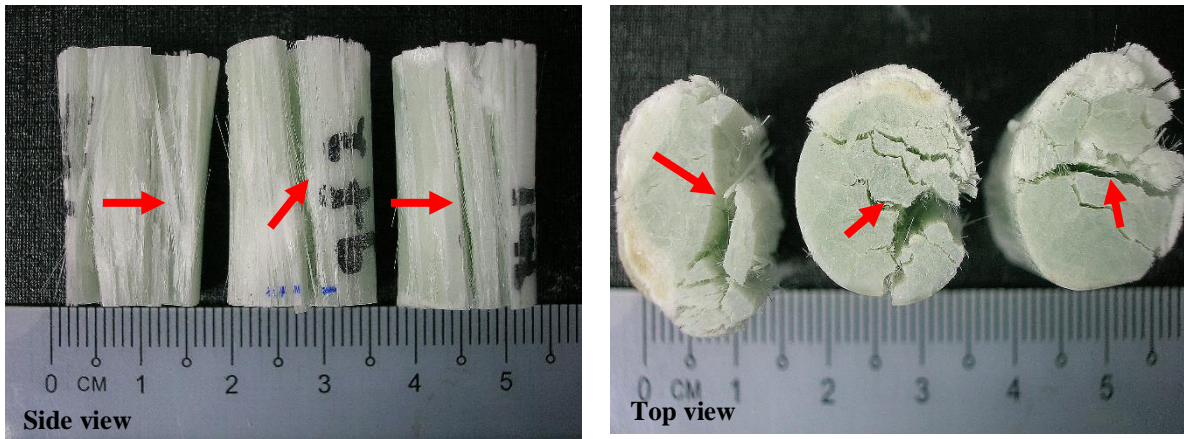


Figure 3 : Failure mechanisms of glass fibre reinforced composites

Figure 3 illustrate the failure mechanisms of the three specimens for the glass fibre of composites. Photographs were taken after the composites were failed at a load of nearly 59 kN. Catastrophic failures were experienced by the glass fibre composites as shown in Figure 3. Glass fibre composites begin to fail from the centre of the rod specimens and propagate width-wise on either side. The good interfacial bonding between glass fibre composites and matrix contributes to this catastrophic failure. Glass fibre and matrix were fractured together and it is shows in Figure 2 where glass fibre composites had a sudden drop of curve after the loads reach the maximum.

3.2 Flexural properties

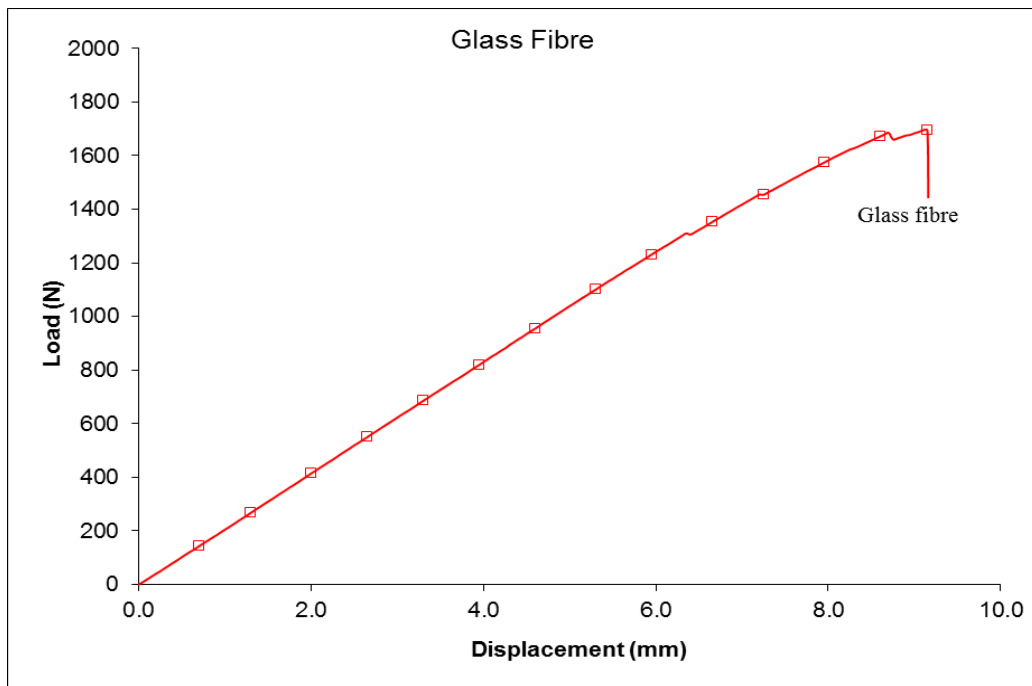


Figure 4 : Load-Displacement Curve Under Flexure Loading

The flexural properties of the glass fibre composites were obtained by three points bending tests. The ultimate load before glass fibre composites failing were recorded at 1.7 kN a respectively. Flexural modulus of a composite is mainly controlled by the volume fibre fraction rather than the matrix with most of the stress being taken by the outer fibres (Andres Carlsson et al, 1998).

Figure 4 shows load-displacement curve of flexural for fibre glass composites. It is clear that glass fibre composites show high elasticity and lower extensibility due to the inherent property of glass fibre. It can be seen from the curve in Figure 4 for glass fibre composites that it is linear up to some value and then follows a non-linear path to the peak load before dropping suddenly. This behavior shows the existence of various damage mechanisms such as tension, compression shearing etc. take place simultaneously. The upper and bottom surface of the specimen under flexural test is subjected to compression and tension and axisymmetric plane is subjected to shear stress.



Figure 5: Failure Mode for Glass Fibre Reinforced Composites under Flexural Loading

Typical pictures of failure mechanisms observed for glass fibre composites are presented in Figure 5 respectively. Failure occurs at the compressive surface under the loading cylinder by matrix cracking and rod buckling. For the composites, no fibre pull-in and fibre pull-out were detected because the rod specimens were buckle beforehand. Moreover, when using flexible yarn as a basic reinforcement, the nature of the crimp and inconsistent would preclude the possibility of yarn pull-in and pull-out (Wen-Shyong Kuo et. al, 1998). A longer specimen used in this experiment provides larger interfacial areas for transfer shear stress and the specimens are more likely to damage in the form of rod buckling. From the observations, the rod buckling occurs at the middle of the specimens as pointed by the arrows in the pictures where the compressive stress is the highest before form a kink band along the specimen width.

4. Morphological assessment

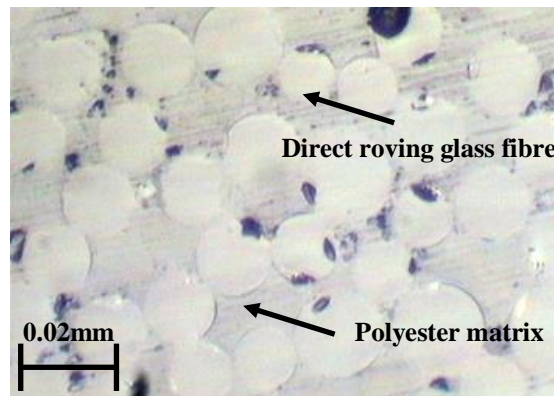


Figure 6 : Upper Cross-Section of Glass Fibre Pultruded Composite Surface

Figure 6 shows the polished cross-sectional of glass fibre reinforced composites. The photos were taken by using electronic microscope. The shape of glass fibre remains in round-shape after being pultruded. In this case, the properties of glass fibre and the shape of the fibre remain unchanged after pultrusion process.

5. Conclusions

From the mechanical properties study, it is concluded glass fibre pultruded composites exhibit high strength in terms of compressive and flexural tests. The pultrusion process produces stronger components with exceptional strength, dimensional stability, and rigidity. It also enables the creation of profiles of customized shapes and virtually any size. Pultruded fiberglass composites have unique characteristics to suit a wide range of applications in various industries such as transportation, construction, communication and tool manufacturing.

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Ishan Khan1 & Anshuman Bhadri2 A Study Of Fiberglass Material With Different Compositions Volume 5 I Issue 3 I July – Sept 2018 International Journal Of Research And Analytical Review

List of Table

Table 1

Properties	Unit	Value
Tex	g/km	4400
Density	g/cm ³	2.5
Diameter	µm	5-25
Tensile strength	Mpa	2500-3500
Specific strength	UTS/density	1000-1400
E-modulus	Gpa	70.0
Specific modulus	E/density	28
Elongation	%	2.5

Table 2

Properties	Unit	Value	Standard
Viscosity at 23 °C			
Brookfield RVT 2/10 rpm	Mpa s	1200	ISO 2555
Density	Kg/dm ³	1.2	ISO 2811
Reticulation at 23 °C			
Operational time	min	20	
Young modulus	Mpa	4000	ISO 527
Tensile stress at break	Mpa	61	ISO 527
Tensile strain at break	%	2.5	ISO 527

Table 3

Properties	Unit	Value
Percentage of matrix	%	70
Percentage of fibre	%	30
Number of glass fibre roving	nos	40
Mould dimension	mm	1000 x 200 x 200
Density of composite	g/cm ³	1.97

Table 4

	Pulling speed (mm/min)	Temperature (°C)
Glass fibre pultruded composites	350	135