MECHANICAL CHARACTERIZATION OF LOCALLY DEVELOPED COMPOSITE MATERIALS USING VARTM SYSTEM

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ABSTRACT

The world of composite materials is constantly improving by the introduction of new materials with improved characteristics. In this paper, using a locally developed Vacuum Assisted Resin Transfer Moulding (VARTM) system, a composite material specimen (using a local cotton fabric laminated with vinyl ester resin KrF1001) has been developed. The mechanical properties of the developed specimen have been tested with and without reinforcement with vinyl ester resin. The results reflect that the developed composite material specimen acquired significant enhancement in mechanical properties such as tensile strength, modulus of elasticity and break elongation. The specimen is found ductile in nature.

Key words: *Mechanical characterization, composite materials, VARTM system, tensile strength, modulus of elasticity, break elongation*

1. INTRODUCTION

Composite materials have been used to solve technological problems since long, however, significant attention from industrial side started in 1960s with introduction of polymer-based composites. Since then composite materials have been in common practice in the field of engineering. The increased awareness regarding the product performance and the competition in the global market for the light materials also boosted the increased applications of composite materials. The advantages such as low weight, resistance to corrosion and low maintenance cost, made composite materials an attractive alternative to traditional materials such as wood, steel and concrete. In addition, the extensive reaction of composites to harsh environmental conditions reduce the cost associated with expensive maintenance compared to wooden and steel members [1].

The development of biodegradable polymer as thermoplastics stretch (TPS) materials gained much interest in recent years, in particular because of their biodegradability, low cost and wide availability. Nevertheless, TPS has two main limitations; one the poor mechanical properties (i.e. low strength, low flexure strength and low stiffness) compared to advanced fabric reinforced plastic composites, and other the high water absorption rate [2-4].

The fabric-reinforced composite materials exist in two main categories; namely particle reinforced and continuous reinforced materials. The continuous reinforced materials often constitute a layered or laminated structure, whereas the particle reinforced composites are made from agricultural waste. The latter type is a potential field of composites, but is inferior in mechanical properties compared to commercially available composite materials. Fabrics for advanced composites are glass fabric, which possess high strength in humid environment, however, degrade under elevated temperature [5-7].

The continuous glass fibbers (the first type of fibbers used in advanced composites) are made by pulling molten glass (at a temperature of about 1300°C) through 0.8-3.0 mm diameter dies and 3-19 mm high-speed stretching [8]. Hybrid composites are made from rubber, wood and coconut shell in combination with textile fabric reinforced with polymer resin. These hybrid composites possess enhanced mechanical properties like tensile strength, modulus of elasticity, impact strength and flexural strength [9].

Natural fabric such as cotton in advanced composite material with polyester resin offers an interesting alternative to petrochemical products. Cotton is mainly used as low cost reinforcement fabric in composites for interior parts of automotive industries and low load bearing structures [10-12].

This paper examines the locally developed composite material prepared with potential use of cotton fabric (CF) with Vinyl ester (VE) resin KrF1001. For this composite material, the cotton fabric was used as reinforcement agent and vinyl ester resin as matrix material. The sample specimen was prepared using locally developed Vacuum Assisted Resin Transfer Moulding (VARTM) system. The scope of this study was to investigate the mechanical properties (such as tensile strength, Young's modulus and tensile elongation) of the proposed composite material through experiments.

The paper is structured like Section 2 describes the methodology, Section 3 presents the results and Section 4 concludes the work.

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2. METHODOLOGY

2.1. Development of VARTM System

VARTM is a special method used in modern industries to form material. Products made by VARTM system are applicable from home decorative piece to a complex space shuttle advance technology. For present study, VARTM was locally developed in the mechanical engineering department laboratory, Quaid-e-Awam University of Engineering, Science and Technology, Nawabshah Pakistan. The developed VARTM system is shown in Figure 1.

Figure-1: Locally developed VARTM system. (a) VARTM system, (b) Acrylic sheet mould, (c) Compressor (vacuum pump), and (d) Pressure gauge.

The developed simple mould has dimensions of 152.4 mm length, 152.4 mm width and 1 mm thickness. In this way, the cavity in the mould has square shape of 152.4 X 152.4 mm^2 with thickness of 1 mm. The molten material in this cavity can be poured with the help of vacuum pump to get the final solid shaped material.

2.2. Preparation of Composite Material

For the development of composite material, VE and CF (plain 2/2 weave, $0/90^0$ oriented) were used. In the first stage, VE was used as matrix material. In the next stage, for the preparation of VE specimen "hardener" was used as reactant agent. When hardener mixed with VE resin, in reaction liquid shaped material changed into solid shape. In the mixture, the amount VE resin taken was 96-99% and hardener 0.5-2%. In the third stage, for the preparation of cotton VE composite, methyl ethyl ketone peroxide (MEKP) was added as catalyst with resin. Again the amount of VE resin was 96-99% and catalyst 0.5-2% in the mixture.

In last, the CF was used as the reinforcement material laid on a waxed surface (bottom transparent acrylic plate of mould). Next, a square frame of sealing sheet fixed on all edges of the same bottom plate, then covered with upper transparent acrylic plate and tightened the sandwich mould using vices. In this way, a composite sheet specimen of dimensions 152.4 X 152.4 X 1 mm^3 has been developed through VARTM process. For testing purpose, from the developed composite sheet, three strips of size 152.4 mm long, 25.4 mm wide and 1 mm thick, were sheared as shown in Figure 2.

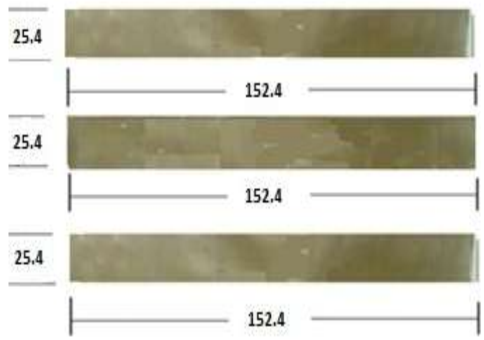

Figure-2: Three sheared strips from developed composite sheet for testing. The dimensions are in mm.

2.3. TEST SETUP

The mechanical properties of the developed composite specimen have been examined by conducting standardized tests using a standard SSTM-20KN UTM machine shown in Figure 3. During the test, following three properties have been analysed:

- Tensile Strength (GPa)
- Modulus of Elasticity, MOE (GPa)
- Tensile Elongation (%)

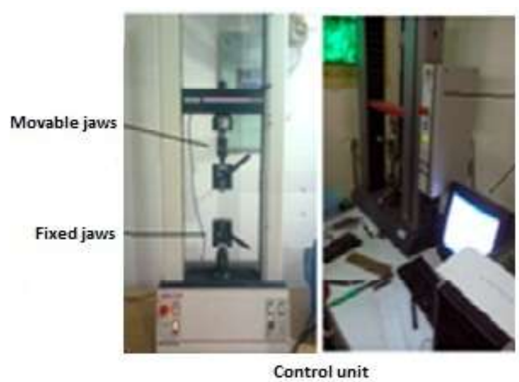

Figure-3: Standard SSTM-20KN UTM machine.

3. RESULTS

3.1. CF Reinforcement Agent Test

The CF specimen was cut into three pieces of size 152.4 mm long, 25.4 mm wide and 0.27 mm thick. Then three consecutive tests for CF specimens were conducted through standard SSTM-20KN UTM machine to analyse their mechanical properties. Summary of achieved results is given in Table 1.

Table 1: Tensile test results for CF reinforcement material

Cotton Fabric 0/90^0	Strip 1	Strip 2	Strip 3	Mean
Tensile Strength (GPa)	1261.81	1261.76	1262.00	1261.86
Modulus of Elasticity (GPa)	86.38	80.81	86.38	84.52
Tensile Elongation (%)	7.46	6.96	7.47	7.30

3.2. COMPOSITE MATERIAL SPECIMEN TEST

Again using same standard SSTM-20KN UTM machine, CF based reinforced polymer specimen has been tested. Similarly, three consecutive tests for composite material specimens (each having size 152.4 mm long, 25.4 mm wide and 1 mm thick) have been performed to investigate their mechanical behaviour. The results for composite material are given in Table 2.

Table 2: Tensile test results for developed composite material

Cotton Fabric 0/90^0	Strip 1	Strip 2	Strip 3	Mean
Tensile Strength (GPa)	1482.63	1482.62	1482.63	1482.63
Modulus of Elasticity (GPa)	470.03	510.40	471.93	484.12
Tensile Elongation (%)	7.46	6.87	7.43	7.25

3.3. COMPARISON OF CF AND COMPOSITE MATERIAL

The mechanical properties of the CF reinforcement material given in Table 1 and the composite material given in Table 2, are compared in Table 3. Table 3 shows the variation between the mean values of the mechanical properties for the mentioned materials. It is obvious that compared to CF, developed composite material found 1.2 times increased in tensile strength, 5.7 times increased in modulus of elasticity and 0.65 times decreased in tensile elongation.

Table 3: Comparison of mechanical properties between CF reinforcement material and developed composite material

Properties	CF reinforcement material	Developed Composite Material	Variation
Tensile Strength (GPa)	1261.86	1482.63	Increase 1.2 times
Modulus of Elasticity (GPa)	84.52	484.12	Increase 5.7 times
Tensile Elongation (%)	7.30	7.25	Decrease 0.65 times

3.4. COMPARISON OF DEVELOPED AND CONVENTIONAL COMPOSITE MATERIAL

Here, the observed mechanical properties for locally developed composite material are compared with closely related conventional composite materials. The conventional materials include E-Glass (U.D), Kevlar and E-Glass (M.D) reinforced polymer-based composites; see Figure 4. In these composites thermoset polymer is used as matrix material. The figure shows that compared to conventional composite materials, locally developed composite material gives 1.5-3.4 times improvement in tensile strength, 12.10-19.36 times increase in modulus of elasticity and 2.9- 4.26 times increase in tensile elongation; see (a), (b) and (c), respectively.

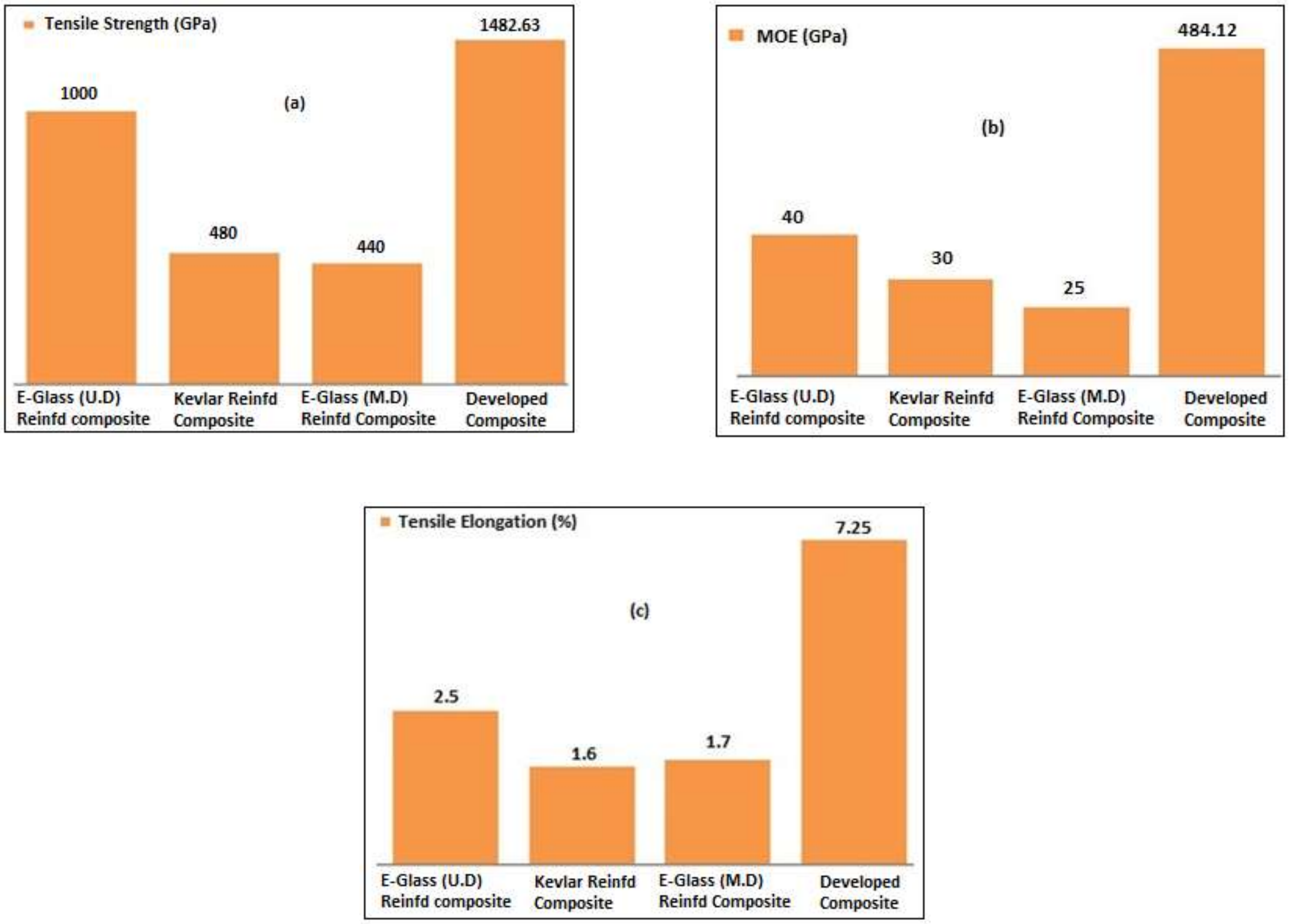

Figure 4: Comparison of mechanical properties between developed composite and conventional materials [13, 14]. (a) Tensile strength (GPa), (b) Modulus of elasticity (GPa), and (c) Tensile elongation (%).

4. CONCLUSION

A composite material using cotton fabric as reinforcement agent with matrix material (vinyl ester resin) has been developed through locally developed VARTM system.

The mechanical properties of the developed composite are analysed using standard SSTM-20KN UTM machine and compared with closely related conventional composites.

The results reflect that the developed composite material acquire significant enhancement in mechanical properties compared to conventional composite materials such as E-glass U.D, Kevlar Fabric and E-glass Fabric. Further, the developed composite material found ductile in nature.

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