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An Experimental Study of the Mechanical Properties of Glass Fiber Reinforced Polymer at Various Temperatures in the Environment

Prof. P. C. Sheth[1], Prof. H. M. Ravat[2], Dipen J. Bhadaja[3]

[1]Assistant Professor, Department of Mechanical Engineering, L. D. College of Engineering, Ahmedabad, India
[2]Assistant Professor, Department of Mechanical Engineering, Government Engineering College, Godhra, India
[3]PG Scholar, Department of Mechanical Engineering, L. D. College of Engineering, Ahmedabad, India

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ABSTRACT

Fiber Reinforced Polymer (FRP) composite materials are in high demand nowadays due to their excellent properties, which make them desirable at all times. High strength to weight ratio, low coefficient of thermal expansion, improved environmental compatibility, resistance to corrosives, and ease of fabrication over metallic parts are just a few benefits of glass fiber reinforced polymer composite material. Better qualities were still needed for some specialized advanced applications, like aerospace. Although it is more expensive, carbon fiber reinforced polymer, or CFRP, offers superior strength and elasticity modulus. Because of this, using GFRP and CFRP together provides a more cost-effective solution than using CFRP alone. The focus of the current study is on glass fiber reinforce polymers and glass/carbon fiber reinforce polymers under various environmental conditions, primarily at reduced temperatures. A consistent decline in ILSS was noted at low temperature conditioning, and a notable decrease was noted at ex-situ conditioning. This experiment demonstrates that G/C FRP yields superior results than GFRP.

Keywords : GFRP, CFRP, Fiber Reinforced Polymer

I. INTRODUCTION

One of the most widely used composite materials in the modern industry is fiber reinforced polymer composite. Composite materials are used in a variety of industries and sports, including the automotive, aerospace, and marine equipment sectors. characteristics that provide high strength to weight ratio, low density, high corrosion resistance, high endurance limit, and high stiffness, among others. Composite materials respond to diverse environmental conditions in a range of applications. Certain conditions lead to an increase in irregularities, which in turn causes a degradation in mechanical properties The unique characteristics of the fiber/matrix interface, the fibers, and the matrix

behavior all influence the various properties that the fiber-reinforced composite offers. Because each element has a unique coefficient of thermal expansion, when the temperature changes, the differences in the coefficients of thermal expansion cause thermal stresses, which in turn cause the formation of microcracks. Studying fiber-reinforced polymers at cryogenic temperatures is necessary because fiber-reinforced materials are currently widely used in aerospace as cryogenic fuel structures. Delaminates, localized surface degradation, and microcracks that form in the polymer matrix are examples of common degradations. Degradation failure is first detected at the microscopic level and then progresses to a detectable level. Current developments expand toward the hybridization of composite with two or more fiber mixes. This composite may contain matrix hybridization or two or more types of reinforcement. In order to take advantage of all the constituent reinforcements, hybrids are developed so that each of their individual properties can be used for one together. Given that glass fiber has a low specific strength and low specific modulus, a portion of the volume in the GFRP composite should be replaced with carbon fiber, which has a high specific strength and elasticity modulus. This will improve the GFRP composite's properties and produce a better outcome than using just glass fiber alone. Due to the low strain rate, high cost, and low coefficient of thermal expansion, it is necessary to balance cost and performance. various carbon fiber, epoxy, and glass fiber characteristics are displayed in the table 1

Table 1 Mechanical Properties of E-glass fiber, carbon fiber and Epoxy

Material	Tensile Strength (Mpa)	Young's Modulus (GPa)	Density (gm/cm^3)	Coefficient of Thermal expansion ($mm/^0C$)
E-glass fiber	2000	80	2.58	5.4
Carbon fiber	2900	525	1.85	2
Epoxy	85	3.5	1.2	1.5-10

II. METHODS AND MATERIAL

The current experiment compares the mechanical properties of hybrid fiber-reinforced polymers and glass fiber-reinforced polymers at high and low temperatures, as well as their respective performances.

MATERIALS

The development of two composite materials—GFRP (glass fiber reinforce polymer) and hybrid composite—as G/C fiber reinforce polymer is the focus of the current experiment. Diglycidyl ether of bisphenol A (DGEBA) based epoxy is used as the matrix, and triethylene tetra amine (TETA) is used as the hardener. According to standard procedure, a proportionate ratio of 10:1 is used for epoxy to hardener. Purchases of epoxy resin (Lapox L-12) and hardener (K-6) are made from Atul Ltd. in Gujarat. 40% of the glass fiber fabric used for reinforcement is a composite laminate made of 14 woven glass fiber layers created using the hand lay-up technique. Similarly, hand lay-up techniques were used to fabricate 20% of the woven glass fiber fabric with five layers and 21% of the woven carbon fiber fabric with four layers and an alternate number of layers. The fabrics were then heated for 20 minutes using a

compression press set to 60°C and 1 MPa of pressure. Laminates are dried for three hours at 50°C after they have cured. With the aid of a diamond cutter, samples are cut to the proper size and standards, and they are then baked for six hours at 140°C.

III. EXPERIMENTAL METHODS

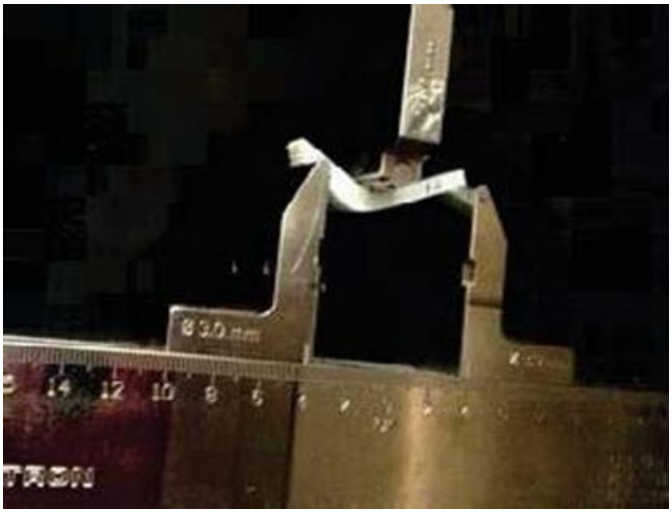
A. Short Beam Shear (SBS) test.

For the test, 3 point bending fixture in 5967 UTM as shawn in figure is used. For the calculation of ILSS capacity

A standard size specimen, ASTM D2344-84, was utilized. Both room temperature and low temperature conditions were used for the test. The specimen was permitted to freely reach room temperature up until it reached that point. Ex-situ conditions require the sample to be returned to room temperature for testing because the test is conducted at that temperature. To see the difference in properties, some specimens are condition for 24 hours and 8 hours. The sample must first reach room temperature in order to be tested, and once it does, the UTM machine is used right away. The UTM was tested at a speed of 1 mm per minute.

(a) Gfrp Standard Specimens

(b) G/C Hybrid Specimens



(c) Instron 5967 UTM with 3

Fig 1

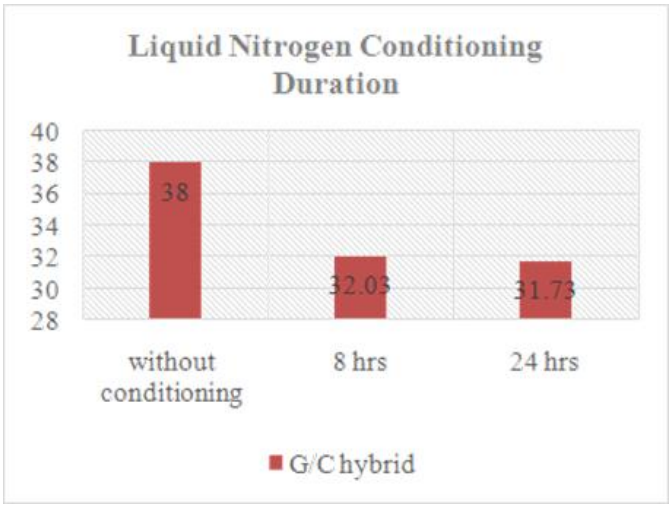


Fig. 2: G/C Hybrid FRP

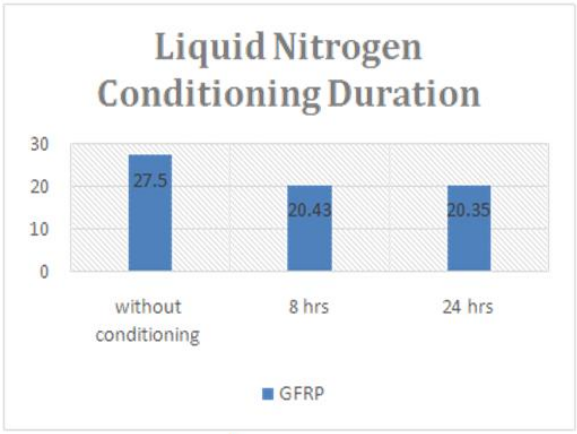


Fig. 3: GFRP Hybrid

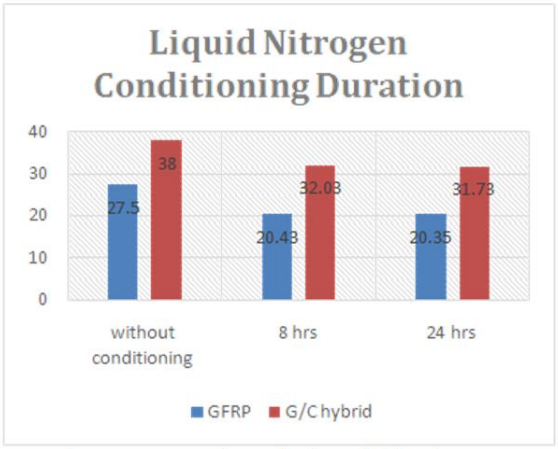


Fig. 4: Comparison OF G/C and GFRP

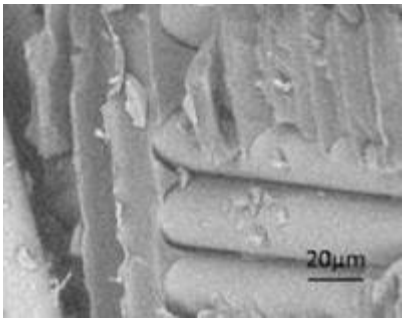
IV. RESULTS AND DISCUSSION

A. Liquid Nitrogen conditioning

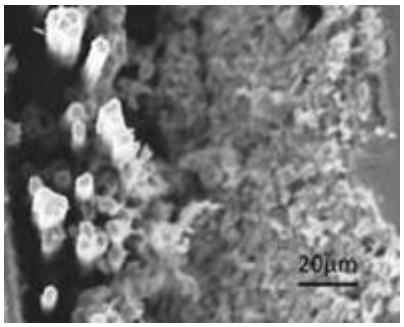
Samples were subjected to an 8-hour and 24-hour nitrogen bath at -196°C in order to compare the properties at different temperatures using liquid nitrogen temperature. The G/C Hybrid FRP ILSS of the conditioned sample was compared for room temperature, 8 hours, and 24 hours, as shown in the figure. Figure 2 illustrates how the ILSS of the G/C hybrid continuously drops, with values of 15.7% and 16.5% lower than when the system is operating at room temperature. Similar to this, figure 3 compares the GFRP at various temperatures and shows that the ILSS decreases by 25.7% and 26%, respectively, compared to room temperature. Figures 2 and 3 show that there is a slight variation between 8 and 24 hours. This suggests that the samples are nearly saturated at 8 hours and do not need to be economically continued through 24 hours until a certain value is reached. The microcrack density is what causes the saturation, and thermal stress could be the cause. As seen in the figure, there is a sudden drop in ILSS when the sample experiences a sudden dip in nitrogen as a result of sudden thermal stresses.

B. Fractography analysis

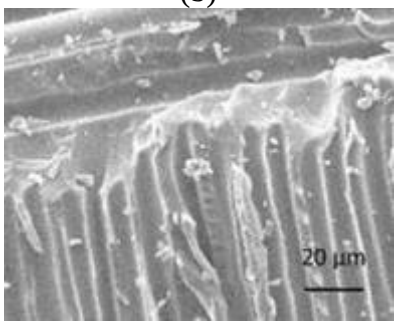
Once the three-point bend test procedure is complete, a scanning electron microscope (SEM) is used to analyze the surface failure mechanism and microcrack mechanism. The failure of the GFRP tested at room temperature is depicted in figure 5(a). Failures first arise from the interface's debonding, which subsequently causes the fiber and matrix to separate. There were extensive fiber imprints on the polymer matrix and matrix ligand attachment to the fibers. Figure 5(b) depicts the fracture surface of the G/C hybrid composite, showing the bundle of carbon at the matrix region. Cohesive force is the cause of matrix failure; higher interfacial strength can be attributed to epoxy resin and carbon fibers. The fracture surface of the G/C hybrid composite was tested for 24 hours at nitrogen temperature, as seen in figure 5(c). On their surface, polymer adherent on bare fibers is apparent. It demonstrates that loss of integrity or matrix-fiber separation in the composite is the cause of failure. The state of the GFRP sample's surface in liquid nitrogen is depicted in Figure 5(d). Delaminated surfaces were seen at lower temperatures.



(a)



(b)



(c)

Fig. 5: Scanning Electron Micrographs Of Fracture Surfaces Of (a) GFRP Tested At Room Temperature, (b) G/C Hybrid Composite Tested At Room Temperature And (c) Liquid Nitrogen Conditioned GFRP For 24 Hrs

V. CONCLUSION

The impact of mechanical properties on glass fiber (GFRP) and G/C hybrid was investigated at room temperature and at lower temperatures. The experiment that was conducted leads to the following conclusion.

- Compared to the atmospheric temperature, there is a reduction in ILSS in the case of GFRP for 8 hours and 24 hours by 25.7% and 26%, respectively.
- Compared to the ambient temperature, the G/C hybrid reduces ILSS by 15.7% and 16.5% over the course of eight and twenty-four hours, respectively.
- Conclusion: For the GFRP and G/C hybrid sample, there is a decrease in ILSS for 8 hours and 24 hours, and it reaches saturation after 8 hours (with no discernible difference between 8 and 24 hours).

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