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Evaluation of Mechanical Properties of Glass Fiber and Glass - Carbon Fiber Reinforced Polymer Hybrid Composites

Mr. Vishwanatha N R [1], Dr. Mallikarjuna C[2]

[1]Assistant Professor, Department of Mechanical Engineering, Navkis Colege of Engineering, Hassan, Karnataka 573217, India

[2]Associate Professor, Department of Mechanical Engineering, VTU Centre for Post Graduate Studies, Mysuru, Karnataka 570029, India

Abstract

Traditional materials are being replaced by composite materials because of their superior qualities, such as high tensile strength, low thermal expansion, and high strength to weight. On the anvil are new materials that are being developed, and they're getting better and better every day. It was because of their superior qualities for automobiles, aerospace, and marine applications that fibre composites like GFRP and CFRP became more desirable. The mechanical properties of GFRP, CFRP, and hybrid composites, such as tensile strength and impact strength, are examined in this research. Using a manual lay-up approach, the composites were created during the curing phase of composites, different moulding loads were used. As opposed to synthetic hybrid composites, we observed that high strength and high impact strength can be achieved with glass fibre reinforced composites in our experimental work. For the best mechanical qualities, combine the results and look for alternate composites.

Keywords: GFRP and hybrid composites, Hybrid composites, E- glass-carbonfibre composites.

1. Introduction:

[1][2] Main issues in FRP composites research and development today include material characterization and making sure that design assumptions are compatible with real-world manufacturing results, which is a major issue. Component materials and procedures are constantly changing, making the issue even more challenging. The characterisation of FRP materials is still behind due to the need for additional technology, and in this study, we introduce a new technique for performing tensile and impact tests in a universal testing machine to ensure an accurate result. Despite our best efforts, we are unable to predict the impact of manufacturing faults and damage on the mechanical properties of the glass fibre reinforced material. The cost of carbon fibres is prohibitive, so we are using a blend of glass fibre and carbon fibre. R&D is needed to improve fire performance, including lightweight fire protection devices, the creation of reliability-based design codes that take into account the multiple failure causes possible with composites, appropriate characterisation of nonlinear structural behaviour, including buckling, and recycling. Corrosion-resistant and high-strength fabrics are only a few of the many applications for glass fibres. Tanks and vessels made out of FRP commonly employ them. [3]. Carbon atoms make up the bulk of carbon fibre. There are sheets of carbon atoms arranged in a regular hexagonal arrangement in carbon fiber's atomic structure, which is similar to graphite's, but the sheets interlock differently. [4]. Building components that can withstand heavy loads are being made from composite materials like Carbon Fibre Reinforced Polymer (CFRP) and Glass Fibre Reinforced Polymer (GFRP). indentation test despite extensive literature research on the behaviour of LVIs and a quasi-static GFRP [5], CFRP [6,7], and structures made of hybrid materials [7], There hasn't been a systematic study to look at how each of the above factors affects the behaviour of composites, or to look at how each of the factors affects the behaviour of composites. Such a study would also help us understand how hybridization works.

2. Experimentation

2.1. Material

Fibers of two different kinds were used to make a reinforced composite material for comparison. There were two types of fibres that were bought: one was E-Glass fibre (400 gsm) and another was Carbon fibre (400 gsm). Both were used to make polyurethane/Vinyl ester interpenetrating polymer networks.

2.1.1. Glass Fiber:

[8Glass fibres are made of a mixture of B2O3, SiO2, Al2O3, Mg O, or Ca O powder. To make glass fibre, first the mixtures are heated through melting. Then, different dies are used to make filaments with a diameter between 9 and 17 micrometres, which is about the width of a human hair. It is then spun onto bobbins, making it easier to transport and handle the fibre. A lot of people use glass fibres to strengthen plastic, so it has a good place in the process of making something. It is a lot more cheap and easy to get than other fibre materials like carbon fibre and aramid fibre. Because glass fibre can't withstand as much heat as carbon fibre, it doesn't work well for things that need to be hot. When filaments are spun into threads with a bigger diameter, this process is called roving. Glass fibre threads are used for spray applications and in woven reinforcing glass fabrics.

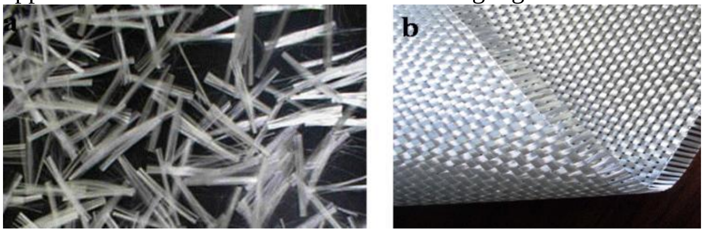

Fig. 2.1 a) Chopped E-glass fiber b) E-glass fabric

Table 2.1: Properties of E-glass [10]

Sl. No	Property	E-Glass
1	Density (gm/cm^3)	2.56
2	Tensile strength (MPa)	3445
3	Modulus of elasticity (GPa)	76
4	Tensile elongation (%)	2.75
5	Co-efficient of thermal expansion	5.0 X 10^{-6}/°C

2.1.2 Carbon Fiber

Polyacryl nitrite fibres or Pitch resin or Rayon are made into carbon fibres when they're heated up to a higher temperature, and this makes the fibres stronger. Graphitizing or stretching the fibres can help them become stronger or more elastic. With carbon fibres, they come in diameters that are about the same as those of glass fibres, from 9 to 17 micrometres. These fibres were made into bigger threads so that they could be transported and used in other processes. [9] If you want, you can weave or braid carbon fibre material to make fibres that can be used to strengthen things, just like with glass fibre material which will be used to make the things stronger.

Fig. 2.2 a) Chopped carbon fiber b) Carbon fabric

Table 2.2: Properties of bidirectional carbon fiber

Sl. No	Property	Carbon fiber (metric unit)
1	Density (kg/m^3)	1.49 X 10^3
2	Flexural strength (MPa) (perpendicular to fibers)	170
3	Compressive strength (MPa) (parallel to fibers)	134
4	Tensile strength (MPa) (parallel to fibers)	133
5	Modulus of elasticity (GPa) (parallel to fibers)	100
6	Flexural modulus of elasticity (GPa) (perpendicular to fibers)	63
7	Thermal conductivity (W/(m*K)) (parallel to fibers)	32
8	Thermal conductivity (W/(m*K)) (perpendicular to fibers)	7
9	Electric resistivity (Ohm*m) (25°C, parallel to fibers)	34*10^{-6}
10	Thermal expansion (°C^{-1}) (20-1000°C, parallel to fibers)	0.5*10^{-6}

2.1.3 Epoxy Resin

EPOXY: This is the cured final result of epoxy resins, and it is also an informal term for the epoxide functional group, which is what makes epoxy resin. People who make epoxy resins also call them "poly Epoxy." Epoxy resins are a type of polymer that can be made by reacting with other polymers and pre-polymers that have epoxide groups in them. Epoxy can be used for a wide range of things, from coating metal to making high-tension electrical insulators, fiber-reinforced plastic, and structural adhesives. In the early 1950s, epoxy resins were used in composites for the very first time for use. Work done with epoxy resin (LY556) This is used to connect the fibres that have already been used. The hardener (HY951) gives the material the strength and adhesion it needs. A 10:1 ratio of resin and hardener is used to get the best mix for the matrix.

Fig. 2.3 a) Epoxy resins LY 556, b) Hardener HY951

Table 2.3: Property of epoxy resin

Sl. No	Property	Epoxy
1	Viscosity at 25 °C μ (cP)	12000- 13000
2	Density ρ (g.cm^{-3})	1.16
3	Heat Distortion Temperature HDT (°C)	50
4	Modulus of elasticity E (GPa)	5.0
5	Flexural strength (MPa)	60
6	Tensile strength (MPa)	73
7	Maximum elongation (%)	4

2.2. Manufacturing process

2.2.1 Hand Lay-Up Method

People who want to do this study used a matrix made of vinyl ester with chemicals to help them grow. When you build something, you need to add things like glass fibres and carbon fibres to it. The composite laminate specimens are made with the hand layup method, and the specimens are tested as per the ASTM standards. Weaved fibres are used, and resin is spread across each fibre layer by rollers or brushes. Nip-roller impregnators, which use rotating rollers as well as a resin bath, are becoming more common. Laminates are cured in a normal atmosphere. They were made with 60% fibre and 40% matrix. When it comes to the thickness of the fibres, they're all lined up in 12, with thickness of 3 mm

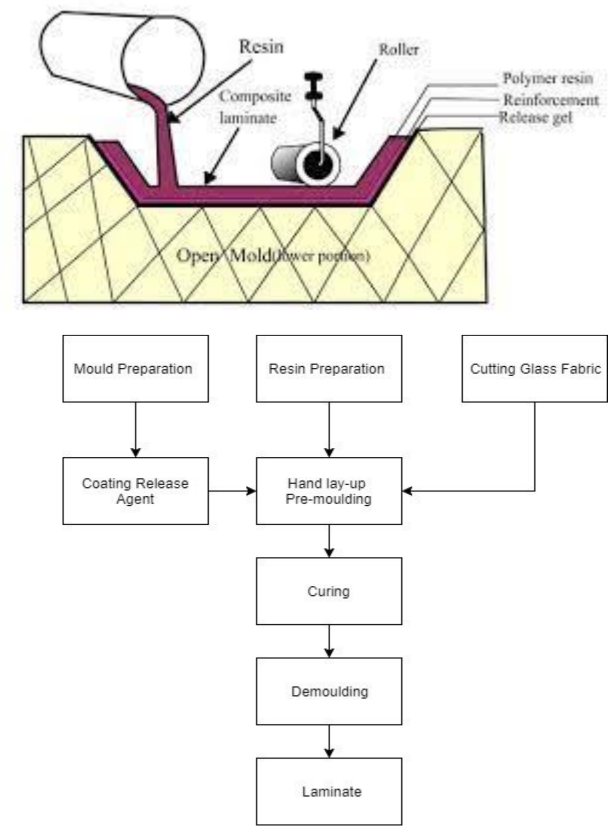

Fig. 2.4 Hand lay-up method

2.2.2 Specimen Preparation

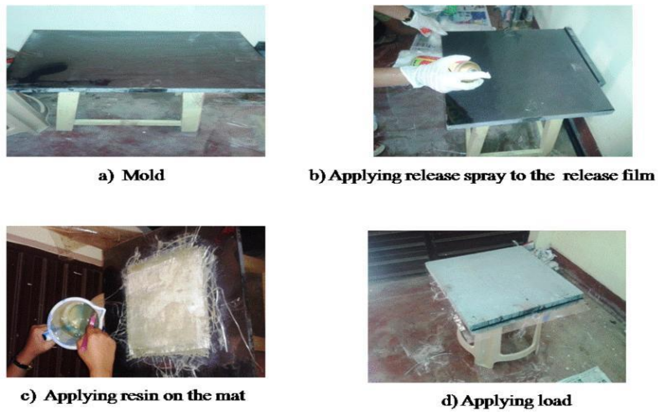

Fig. 2.5 Fabrication Process

2.2.3 Fibre volume and weight ratio relationship

In contrast to the fibre weight ratio, the fibre volume ratio is extremely difficult to calculate. Sample destruction is usually required in order to conduct an ASTM test. There are several methods for determining fibre volume ratio, such as comparing fibre to epoxy resin mass.

The fibre volume ratio is critical to the structural performance of a composite material. Using the fibre volume ratio, an engineering designer determines the lamina characteristics and hence, the structural qualities of laminated materials. Fiber volume ratios in wet lay-up procedures, however, necessitate a fibre weight-to-resin (Reinforcement) weight ratio. The ratio of fibre and resin densities determines the expressiveness. Fibers with low densities are more important than resins with high densities in this connection. Calculation of Lamina Specimens by Specimen Requirements for the lamination

Here's how it's done:

Table 2.4: Laminates designation as per stacking sequence

Sl. No	Fabric	No. of layer	Thickness
1	GFRP	12	3.12mm
2	GFRP + CFRP	06 + 04 = 10	3.16mm
Specimen calculation for the preparation of Lamina			
Required Laminates	Number of carbon fibrelayers (gsm: 0.40)	Number of glass fibre layers (gsm: 0.26)	Total Thickness
GFRP	-	12	3.12mm
GFRP + CFRP	04	06	3.16mm

2.3. Test setup

Tensile Test **Impact Test**

Fig. 2.6Test set up for Tensile and Impact

2.3.1 Tensile Test

In order to determine how much force is required to break a polymer composite specimen, ASTM D3039 tensile testing is employed. This testing is used to determine how much stretch or length is required to break the specimen. It is possible to determine the tensile modulus from a stress-strain diagram generated by tensile tests.

2.3.2 Impact Test

When a material is fractured, the amount of energy it absorbs is determined by an impact test. Toughness and temperature-dependent transitions can be studied by measuring the energy absorption of a material, which serves as an indicator of its toughness.

3. RESULTS AND DISCUSSION

3.1 Ultimate Load and Tensile Strength

During stretching or elongation, it is the amount of stress that a material can bear without breaking. One square inch of cross-sectional area can bear a load of one square inch of cross-sectional area in simple tension, which is the material's maximal resistance to fracture

Table 3.1: Experimental Load and Tensile Test Values

Load v/s displacement of Pure GL + Pure hybrid of GL and CL			Tensile strength of Pure GF + Pure hybrid of GF and CF	
Load	**GL**	**GL+CL**	**GL**	**GL+CL**
0	0	0		
1.4	0.6	0.6		
2.8	1.2	1.2		
3.35	1.8	1.8		
5.6	2.4	2.4		
7	3	3		
8.4	3.6	3.6	172.16	166.51
9.5	4.2	4.2		
11.2	4.8	4.8		
12.91	5.4	5.27		
14	6			
15.4	6.6			
16.55	6.8			

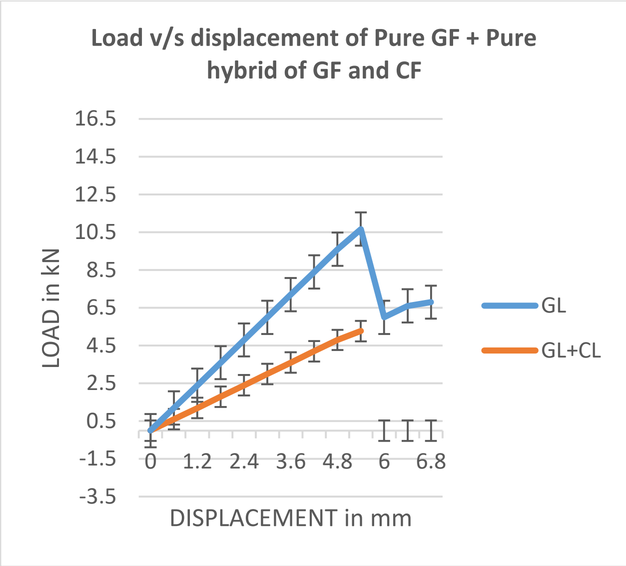

Fig. 3.1Graph of Load Vs Displacement

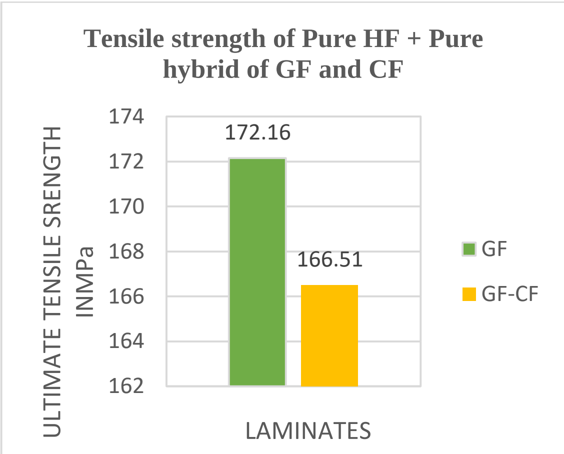

Fig. 3.2Graph of Tensile

The ultimate tensile and elongation properties of the laminates are compared between pure GF and pure hybrid laminates of GF and CF in this study. In terms of the ultimate tensile strength, GF was 172.16 MPa, while GF/CF was 166.51. Table 3.1 and fig. 3.2 reveal that the ultimate tensile strength of pure GF and the hybrid of GF and CF is the lowest. For 16.55 kN, the ultimate elasticity of the pure GF was 6.8 millimetres, while that of the hybrid of GL + CL was 5.27 millimetres. Hybrid laminate will fail if the load is increased by more than 12.91 kN.

3.2 Impact Strength

Table 3.2: Experimental Impact Test Values

Impact strength of Pure HL + Pure hybrid of GL and CL	
GF	**GF+CF**
24	26

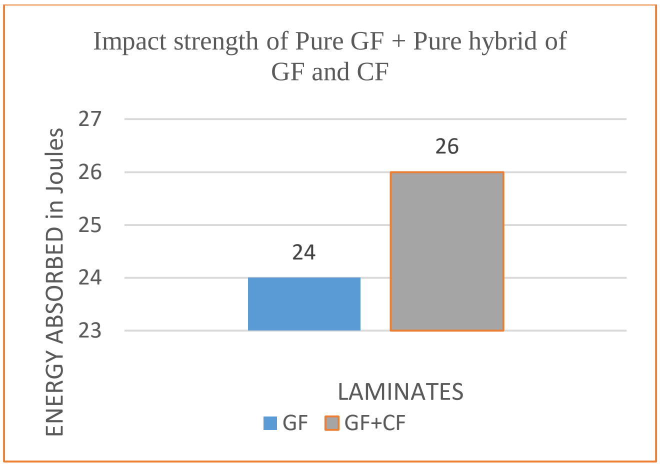

Fig. 3.3Graph of Impact Test

This is a preliminary impact test. Testing a material's impact resistance, which engineers use to make predictions about how the material will behave in real life. Flaws and cracks are common causes of failure in many materials when they are subjected to an impact. To put it another way: The ultimate impact strength of the pure fibreglass (GF), the hybrid fibreglass (GF-CF), and the pure fibreglass (CF) laminates were all 24 and 26, respectively, as shown in the tables and the figures.

4. CONCLUSION

The tensile and impact test results for the flat FRP sample were correct thanks to the technique utilised to hold it. Hybrid composites made of glass fibre and carbon fibre performed admirably when compared to materials reinforced with glass fibre in plastics. There is a need for very good mechanical qualities, hence this hybrid fibre reinforced composites has been used as a replacement for glass fibre reinforced plastic material.

The following conclusion can be derived from the testing and the results that were collected.

- ➢ According to our findings, the Hybrid Composite has lower tensile as well as mechanical properties than glass fibre composites with a thickness of three millimetres.
- ➢ Compared to glass laminates, hybrid laminates have a somewhat higher impact strength.
- ➢ Compared to hybrid laminates, the load-carrying ability of glass laminates is much higher.

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