Effect of Orientation of Glass Fiber on Mechanical Properties of GRP Composites

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Summary: Glass Fiber Reinforced polymer matrix composites are one of the most important engineering materials required for a variety of advanced and sophisticated applications in modern industry. The two components of a GRP composites are the matrix (the continuous phase) and the reinforcing glass. The matrix itself does not provide the strength, but it serves to bond the reinforcing glass fibers and to transfer the load to the reinforcing phase. Glass reinforcements provide strength for the GRP composites that is why we can say that mechanical properties of GRP composites depends mainly on the orientation, amount and type of fiber reinforcement present in it. The main applications of GRP composites are in chemical industry as storage tanks, in aerospace industry, and mainly in construction industry as cladding over other construction materials and other non-load-bearing applications.

In the present work different types of glass fabric like chopped strands and roving, were selected to study the effect of their different orientations on mechanical properties of GRP composites. Thickness of sheets and resin content were kept constant for all the samples. Hand lay up method was used for the production of GRP composite.

The mechanical properties like tensile strength, impact strength and hardness along with density of the samples were investigated using tensile testing machine, densitometer, charpy impact testing machine and rockwell hardness tester respectively.

Introduction

The composites are one of the most widely used materials because of their adaptability to different situations and the relative ease of combination with other materials to serve specific purpose and exhibit desirable properties [1].

Glass fiber reinforced polymer matrix composites are the most popular reinforced plastic material used in construction industry. Depending upon the formation and use, they may be fabricated into products that are light in weight, transparent or opaque, colorless or colored, flat or shaped sheets, with no limits of size of object can be made [2].

The reinforcing fiber or fabric provides strength and stiffness to the composite, whereas the matrix gives rigidity and environmental resistance. Reinforcing fibers are found in different forms from long continuous fiber to woven fabric to chopped fibers and mat. Each configuration results in different properties. The properties are strongly depend on the way by which fibers are laid in the composites [3].

Glass fiber reinforced polymeric composites materials have great quality such as, ratio of strength and ratio of stiffness unlike metal materials and are used in many areas because strength can be improved by orienting in certain direction. Therefore, it is possible to mold the parts because the flexibility of molding is wide. The cost of production can also be decreased, because of its high productivity. So, the use of molding of glass fiber reinforced polymeric composite materials is expanding to the structural material of air planes, cars, sports, and something related to energy instead of molding of the press [4]. Because of the greater number of factor that define GRP composites, the range of mechanical and other physical properties is very wide. For example tensile strength at room temperature may vary from 69 MPa (10^4 Psi) to 896 MPa ($13*10^4$ Psi) or higher and specific gravity may range from 1.2 to 1.9 [1].

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Results and Discussions

1. Density Test

The relationship between density and fiber orientation of the samples is shown in Table-1 and Fig. 1.

Table-1: Table between different orientations and density of GRP composites

Orientations	Density g/cm^3
Orientation A	1.1472
Orientation B	1.1702
Orientation C	1.2099

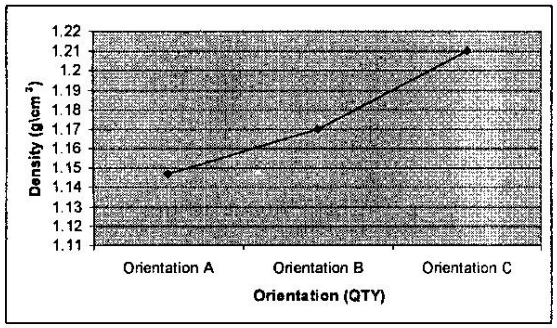


Fig. 1: Graph between different orientations and the density of the GRP composites.

From the above mentioned results it is clear that fiber orientation has no effect on the density of the composites and from previous studies [5, 6] it is clear that density mainly depends upon the fiber and resin contents (volume % or weight %) and also on the type of fiber and resin used. In this study the resin contents were kept constant.

Mechanical Testing

1. Hardness Test:

The relationship between hardness and fiber orientation of the samples is shown in Table-2 and Fig. 2.

From the above mentioned results it was studied that there is no significant effect on the hardness of the materials having different orientation.

2. Tensile Strength Testing

The relationship between tensile strength and fiber orientation of the samples is shown in Table-3 and Fig. 3.

Table-2: Table between different orientations and hardness of GRP composites.

Orientations	Hardness(HRR)
Orientation A	118.54
Orientation B	118.02
Orientation C	116.22

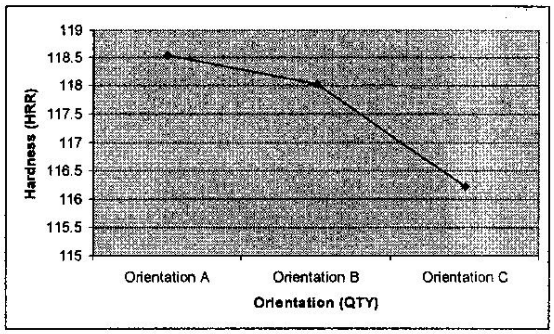


Fig. 2: Graph between different orientations and the hardness of the GRP composites.

Table-3: Table-between different orientations and hardness of GRP composites.

Orientations	Tensile Strength (Psi)	Tensile Strength (MPa)
Orientation A	15007.5641	103.4719
Orientation B	5101.17531	35.17082
Orientation C	10977.9295	75.68898

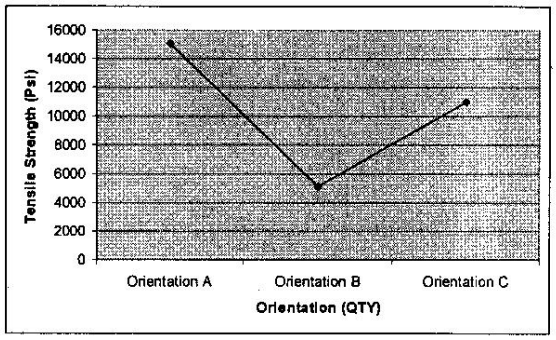


Fig. 3: Graph between different orientations and the tensile strength of the GRP composites.

The effect of change in orientation has a considerable effect on tensile strength of GRP composites. The result of orientation A shows the

optimum values due to the presence of vertical or parallel roving. Tensile strength in the transverse direction is always lower than that in the longitudinal direction [7]. Therefore orientation A (roving at 90°) has the maximum tensile strength and can be used for sports items.

3. Impact Strength Testing

The relationship between impact strength and fiber orientation of the samples is shown in Table-4 and Fig. 4.

The difference in the orientation had significant effect on the impact strength of the composite. From results given above it is concluded that the impact strength of short fiber thermoplastic composite is reduced with fiber orientation both parallel and perpendicular [7].

Table-4: Table-between different orientations and hardness of GRP composites

Orientations	Impact Strength (Joules)
Orientation A	37.926
Orientation B	41.454
Orientation C	41.69

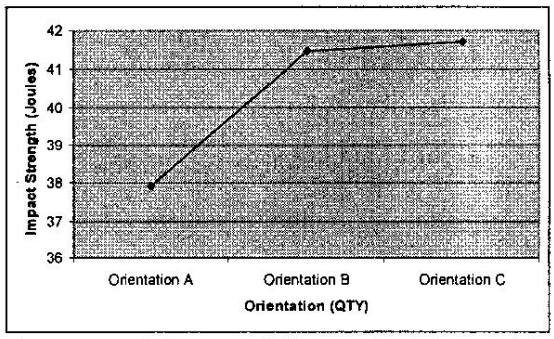
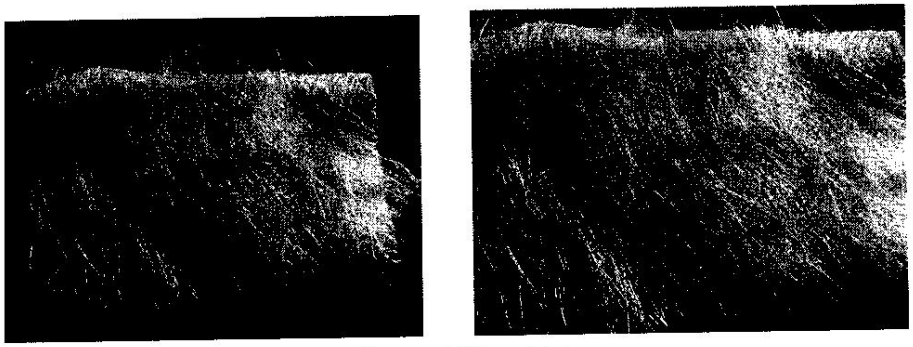


Fig. 4: Graph between different orientations and the impact strength of the GRP composites.

Experimental

Procedure

Marking of specific dimensions (150 mm × 300 mm) was done on the mould. Roving (300 mm), chopped fiber sheets (150 mm × 300 mm) and Woven Mat (150 mm × 300 mm) of same dimension was cut down followed by the application of the wax and PVA solution on the mould and was left for drying for 15 minutes. PVA works as releasing agent.



Chopped Fiber Mat

Roving / Strands

Material Required

- Gel coat

Sheet No	Type	Preparation
Orientation A	Chopped fiber sheet + roving at 90° (300 mm long strands) + Chopped fiber sheets	After gel coat Layer of resin Chopped fiber sheet + wetting Layer of resin Vertical Roving strands + wetting Layer of resin Chopped fiber sheet + wetting Layer of resin
Orientation B	Chopped fiber sheet + roving at 0° (300 mm long strands) + Chopped fiber sheets	After gel coat Layer of resin Chopped fiber sheet + wetting Layer of resin Horizontal Roving strands + wetting Layer of resin Chopped fiber sheet + wetting Layer of resin
Orientation C	Chopped fiber sheet + roving (300 mm long strands) at 45° angle + Chopped fiber sheets	After gel coat Layer of resin Chopped fiber sheet + wetting Layer of resin Roving strands at 45° angle + wetting Layer of resin Chopped fiber sheet + wetting Layer of resin

- Lay-up resin
- Catalyst
- Hardener
- Pigment
- Release Agents
- Metal Rollers
- Glass Fiber
- Ether
- Mixing containers
- Brushes and / or Roller

Gel coat was prepared in a separate container. Hardener (Cobalt Octate 2cc / kg gel coat) was added in commercially available gel coat followed by the addition of catalyst (Methyl Ethyl Ketone Peroxide 2cc / kg gel coat). Color pigments were added before catalyst and hardener to give color to the composite.

Gel coat was applied over dried PVA with the help of brush with a recommended thickness of 0.4-0.6 mm in a single continuous film without drainage on vertical or inclined surfaces. 600 g of resin covers approximately 1 square meter.

When gel coat was completely dried then lay up resin was prepared by adding color pigment, hardener (Cobalt Octate) and catalyst (MEKP). One kilogram of resin is needed per square meter of 450 gsm glass fiber. A polyester resin was applied over dried gel coat. Glass fiber reinforcement was placed over resin before drying of resin. After placement of glass fiber good rolling is essential, it should consolidate the reinforcement without disturbing or breaking the glass fiber strands into filaments. The basic purpose of using metal rollers was to roll out air pockets in resin and glass fiber layer. Then again layer of resin was applied on the glass fabric. The process is repeated for more than one sheet and after this composite is left for drying preferably in sunlight. The time taken for drying depends upon temperature conditions. After drying it was removed from the mould.

Following three different types of orientations were prepared to study the effect of orientation on the mechanical properties of GRP composites.

Density Measurement

The apparent density was determined by using densitometer following standard ASTM 3878. Minimum of 1 g of each sample was taken for calculating the density.

Tensile Tests

Mechanical properties of the samples were investigated by tensile tests using tensile testing machine following ASTM standard D 3039. The dimensions of the samples were 300 mm × 25 mm.

Hardness Testing

Rockwell hardness tester used to measure the hardness of the samples using following standards ASTM D 785. Dimension of the sample was 2 in × 2 in.

Impact Strength Testing

Impact strength testing was done by charpy impact testing Machine following the standards ASTM D-5379.

Conclusion

From the above discussion it is concluded that orientation of glass fiber has no effect on the hardness of the GRP composites. The difference in

values did not show any significant effect on the behavior of this type of composites. But difference in the orientation has a small effect on the density and the impact strength of the composite materials because of the difference in the number of strands per unit area but it widely affects the tensile strength of the composites. The maximum value of tensile strength is of orientation A (Chopped fabric + vertical roving). Therefore this kind of orientation can be used where high tensile strength is required.

References

1 A. Blaga, Glass fiber reinforced polyester (GRP) composites. Canadian building digest (1979).

2 S. C Sharma, Composite Materials. Narosa publishing house. New Delhi. pp. 98 (2000).

3 S. K. Mazumdar, Ph.D. Composite Manufacturing materials, products and process engineering. CRC press LLC. Florida. pp. 4 (2002).

4 J. W. Kim, J. J. Lee and D. G. Lee, Key engineering materials. vol 297-300. Trans Tech Publications Switzerland. Pp. 2897 (2005).

5 P. K. Mallick, Fiber reinforced composites materials manufacturing and design. 2nd edition. Marcel Dekker, Inc New York. pp. 81 (1993).

6 D. Gay, S. V. Hoa and S. W. Tsai, Composite materials design and applications. CRC press. Florida, pp. 35 (1997).

7 S. K. De and J. R. White, Short fiber polymer composites. Wood head publishing limited, England. pp. 101 (1996).