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EFFECT OF VARIOUS FORMS OF GLASS FIBER REINFORCEMENTS ON TENSILE PROPERTIES OF POLYESTER MATRIX COMPOSITE

By

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ABSTRACT

Unsaturated polyesters are important matrix resins used for glass fiber reinforced composites/plastics. The strength of fiber glass reinforced polyester composite is mainly related to the glass content of the material and the arrangement of glass fibers. In general, the higher the weight percent glass in the composites, the stronger is the reinforced composite.

Polyester matrix composites (PMC) have good specific strength, high thermal conductivity and low coefficient of thermal expansion at lower temperatures. They are being widely used for making boat hulls, building panels, structural panels for automobiles, plastic pipes, storage containers, etc.

In spite of having enough strength, they are not very stiff and do not display the rigidity that is necessary for certain applications such as for structural members for airplanes and bridges. Due to this reason, most of them are limited to service temperatures below 200 degree Celsius.
A detailed study of production and evaluation of properties of glass fiber reinforced polyester composites has been carried out by using various cross-sections of fibers in 1-ply, 2-ply and 3-ply sheets. The hand lay-up method has been chosen as the processing route for this purpose. PMC developed were evaluated in terms of their mechanical and metallurgical applications and characterized.

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INTRODUCTION

Composites materials are among the oldest and newest of structural materials. The older concept of composites is simply the mixing of two or more materials to rectify some shortcomings of a particular useful component The concept of combining two dissimilar materials has acquired a broader significance: the combination has its own distinctive properties in terms of strength or resistance to heat. The principle attraction of modern composites materials is that they are lighter, stiffer and stronger than any material produced ever before. Plastics do not prove themselves to be sufficiently strong, stiff and dimensionally stable for their use in high performance load bearing applications. On the other hand, glass Fibers possesses very high strength, sufficient stiffness and durability. By combining these two materials in specific weight ratio to produce glass reinforced plastics (GRP) with excellent mechanical and temperature resistance properties can be achieved. Proper composition and orientation of continuous fibers makes it possible to design a GRP of desired properties and functional characteristics. Such GRP can be several times stronger than steel, almost as stiff as aluminum, with a specific gravity of only one quarter that of steel. **[1]** Usually composite have two components that play major role in governing their properties:

- Continuous phase/matrix/resin
- Dispersed phase/reinforcement /filler/type of fiber.

Both the matrix and reinforcing phase play an important role in the strength of composite. The reinforcing phase is usually of low density, strong, stiff and thermally stable. [2] The reinforcements in polymer matrix composites are primarily fibers. The use of particles in polymer matrices is less common.

The overview of GFRP carried out focuses on the cost considered value in use of properties of principal interest in four fiber categories:

i) Natural Fibers
ii) Oxide Glass Fibers
iii) Aramid Fibers
iv) Carbon and Graphite Fibers [3].

Natural plant fibers offer adequate performance in interior composite application [4]. At lower cost than that of comparable composites from incumbent reinforcing fiber. The ultimate use temperature for glass fiber ranges from 500^oC to 1050^oC for different glass fibers.

The temperature at which sustained use of aramid fibers is possible at about 160^oC.[5] Over 90% of glass fibers general purpose fillers and known by the designation E-glass and are subject to ASTM specification [6]. The remaining glass fibers are premium special purpose products. Many like E-glass have letter designations implying special properties [7]. In depth discussion of composition, melt properties, fiber properties are mentioned in the next article [8], methods of manufacturers and significant product types.

Glass fibers and fabrics are discussed in depth and are employed in ever increasing varieties for a vide range of applications [9]. A data book is available [10] that covers all commercially available E-glass fibers, whether employed for reinforcement, filtration, insulation or other applications. Special purpose glass fibers are reviewed in article by W.W. Wolf and S.L. Mikese [11]. A companion data-book [12] is available that covers all commercially available high strength fibers.

FIBER LENGTH & DIAMETER

Fibers can be short, long or even continuous. Their dimensions are often characterized by aspect ratio *l/d*, where ***l*** *i*s the fiber length and ***d*** is the diameter. The strength of the composite is improved when the aspect ratio is large. Fibers often fracture because of surface imperfections. Making the diameter as small as possible gives the fibers less surface area and, consequently, fewer flaws can propagate during processing or under a load6. The ends f a fiber carry less of the load than the remainder of the fiber; consequently. The fewer the ends, the higher the load-carrying ability of the fibers

AMOUNT OF FIBER (VOLUME FRACTION)

The elastic modulus of the composites is given as rule of mixture

$$E_C = E_m V_f + E_f V_m$$

Where 'E', 'V', and subscripts 'c','m' and 'f' stands for young's modulus, volume fraction, composite, matrix and fibers respectely. Composite with greater volume fraction of fibers increases the strength and stiffness of the composite, as we would expect from the rule of mixtures. However, the maximum volume fraction is about 80%, beyond which fibers can no linger be completely surrounded by the matrix

ORIENTATION OF FIBERS

The reinforcing fibers may be introduced into the matrix in a number of orientations. Short. Randomly oriented fibers having a small aspect ratio--typical of fiber glass—are easily introduced into the matrix and give relatively **isotropic** behavior in the composite. Long or even continuous, unidirectional arrangements of fibers produce **anisotropic** properties. [3]

EXPERIMENTAL WORK

Glass fiber and cotton fiber reinforced composites were developed and characterized for their tensile properties. Hand lay up method was used for the development of the composite.

SAMPLE PREPARATION

➢Raw materials used for the sample preparation were:

- Different types of glass and cotton fibers.
- Polyester resin
- Initiator (methyl ethyl keton peroxide or MEKP)
- Wax
- Acetone(cleaner)
- Cobalt naphtha late (accelerator)

EQUIPMENT/TOOLS

Equipment/tools used for the composite development was:

1- Washer 2- rollers 3- Brushes 4- Steel die 5- Formica board 6- Scissors and cutter 7- Bowl
8-Gloves 9- Masks 10- Liner

FABRICATION TECHNIQUE

Hand lay up method was used to fabricate the composite. Releasing agents wax and PVA were applied on a smooth formica surface(mold) for easy removal of the composite. A sheet of fiber cloth or mat was laid down on it. The resin, premixed with some amount of accelerator, some drops of initiator and the coloring agent applied on the surface of a sheet of fiber cloth or mat. Different number of layers was added depending upon the thickness required by placing layers one by one. Fibers were assured for complete impregnation in the resin using washer rollers. Samples were then cured at room temperature for two days.

SAMPLE TESTING

Tensile test was carried out using universal tensile testing machine TIRA test 2810 E6 (German made) having capacity 10 KN?. The tensile specimen is shown in the figure 1 [4]?

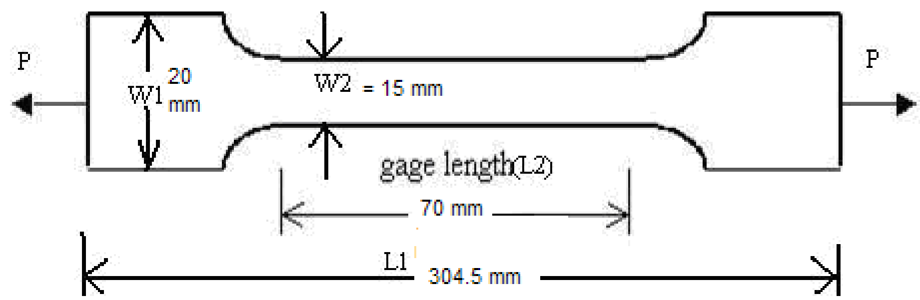

Figure 1:- *Tensile Specimen*.

Total length of the specimen = L_1 = 304.5 mm, Gauge length = L_2 = 70 mm, Width = W_1 = 20 mm, Width = W_2 = 15 mm.

TYPES OF REINFORCEMENTS USED

Glass fibers were used as reinforcements.
Four different forms of woven fabrics were used having specifications:
(i)175 g/sq.m, (ii) 9 200 g/sq.m, (iii) 400 g/sq.m, (iv)and 600 g/sq.m

TEST SAMPLES

Three sets (set-1, set-2, and set-3) of the tensile samples were made for each form of the fiber by using one layer, two layers and three layers in polyester resin in order to test the effect of volume fraction on the tensile properties of the composites.
The gauge-length and width of all the samples was same but due to different number of layers the thickness and the cross sectional area was different for each specimen.

Results and Discussion

The experimental table clearly indicates that as volume fraction of reinforcing material increases the strength gradually increases. Substantial increase of strength is observed in one ply reinforcement and three ply reinforcement. In case of two ply reinforcement the increase in strength is very small. If we see them even row wise, increase in tensile strength in two ply is small as compared to the results indicated in row one and three of the table as volume fraction gradually increases.

These results show that maximum tensile strength is a function of density of the reinforcement as well as number of layers The composite 175 g/sq.m (one-ply) has 69.19 M-Pa tensile strength while the same composite with two-ply has approximately 1.5 times tensile strength, similarly the tensile strengths of three-ply is 1.2 times the tensile strength of 2-ply. The gradual increase in tensile strength of the composite 200 g/sq.m and 400g/sq.m have followed the same

path as described for 175g/sq.m. However in the composite 600 g/sq.m, it slightly deviate that in first step increase is 1.2 times and then in three-ply, tensile strength was increased i.3 times as compared to two-ply strength.

The above results show that plies tensile strength is not increase in the same fashion as the weight of the reinforcement increases. This is probably due to the fact the compaction was not good as the plies are added up.

EFFECT OF VOLUME FRACTION

A grater volume fraction of fibers increases the strength and stiffness of the composite, as we would expect from the rule of mixtures.

$$\sigma_c = \sigma_f V_f + \sigma_m V_m$$

The graphs shown in figure 3 also show the same fact.

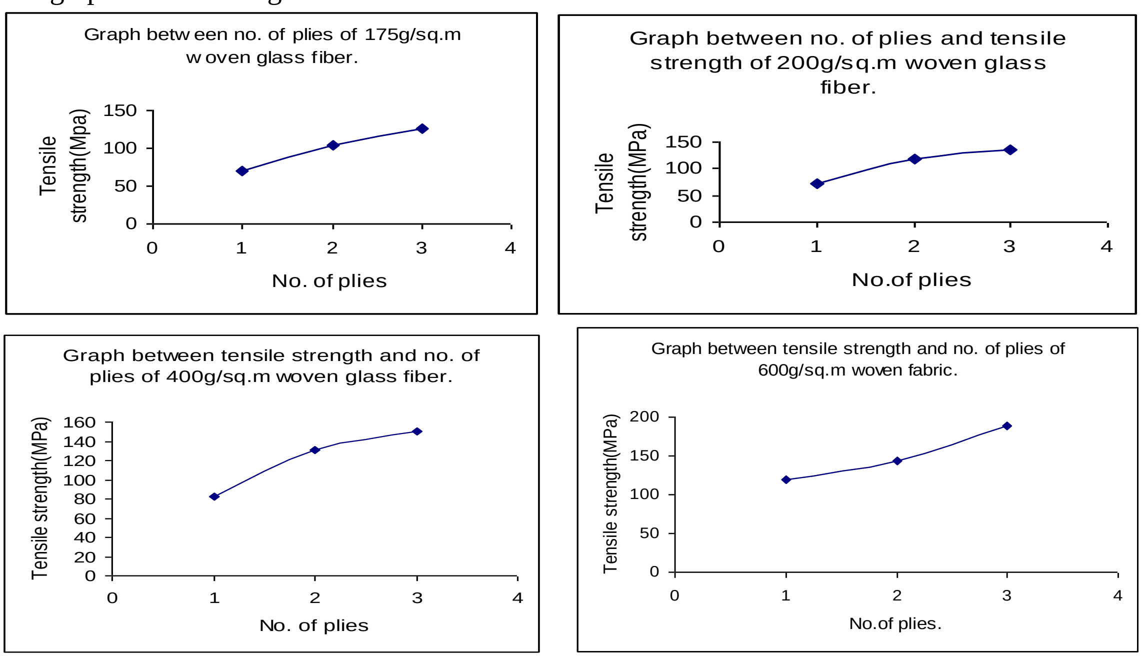

Figure:2 *Tensile strength as a function of different no of plies (volume fraction) for different modes of reinforcements used*

Figure: 2. Table of the Experimental data

No of Plies	***Type of Reinforcements***			
	175 g/sq.m	***200 g/sq.m***	***400 g/sq.m***	***600 g/sq.m***
	Strength (MPa)			
1-PLY Reinforcement	69.19	72.88	82.93	119.59
2-PLY Reinforcement	104.04	117.7	130.6	143.86
3-PLY Reinforcement	125.7	134.29	150.64	189.00

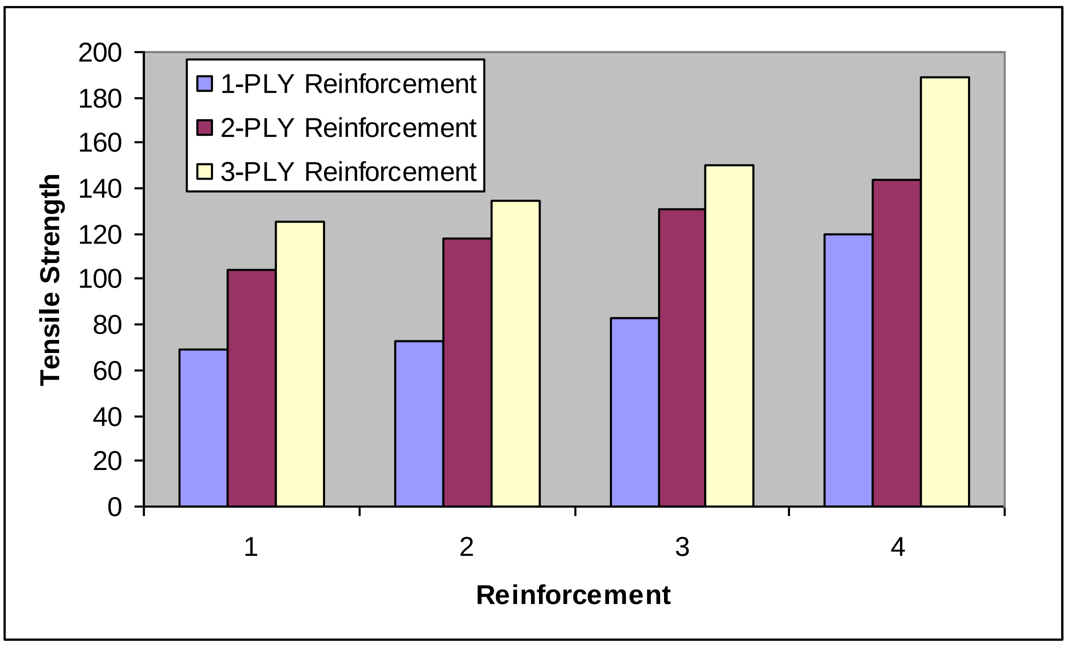

Figure.3 C*omparison of tensile strengths of different forms of glass fiber reinforcements (1: 175 g/m^2, 2: 200 g/m^2, 3: 400 g/m^2, 4: 600 g/m^2*)

CONCLSIONS

The reinforcement increases via its volume fraction the tensile strength of the composite increases e.g. the tensile strength of 600 g/sq.m with 1 ply was 119.6 MPa, with 2 plies it was 143.9 MPa and with still higher %age 3plies it raised to 189.4 MPa, showing that higher the volume fraction of reinforcement higher will be tensile strength of the composite.

Three ply phenomenon is different observation indicating that as layer number two is sandwich between first and third. Intermediate reinforcing layer will make strong bonding with layer lying on the mold and the outer most layer.

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