

Study of Variation of Mechanical Properties with Variation of Reinforcement and Matrix of Composite Material

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Abstract:

The developed polymer matrix composites are considered to be promising materials for low weight applications. Fibrous reinforced polymer matrix composite have high tensile strength, cross breaking strength and shear strength when compared with particle reinforced composite. Fibrous and particle reinforced composites were prepared with general polyester and epoxy as matrices. Under hand layup process the SiC particles were uniformly distributed in matrix and E-glass fibrous composites with G.P. and Epoxy were prepared. The tensile strength, cross breaking strength and shear strength values were evaluated. These values are higher for fibrous reinforced composite materials than particle reinforced composite material because of the tensile property of E-glass fibre. This E-glass fibre is best suitable reinforcement for composite materials with epoxy matrix. Because of the abrasive resistance of the SiC particles, the abrasive resistance of the composite material was increased.

Keywords:

General polyester (G.P), Silicon carbide (SiC)

1. INTRODUCTION :

A composite material can be defined as a combination of two or more materials that results in better properties than those of the individual components used alone. In contrast to metallic alloys, each material retains its separate chemical, physical, and mechanical properties. The two constituents are reinforcement and matrix. The main advantages of composite materials are their high strength and stiffness, combined with low density, when compared with bulk materials, allowing for a weight reduction in the finished part.

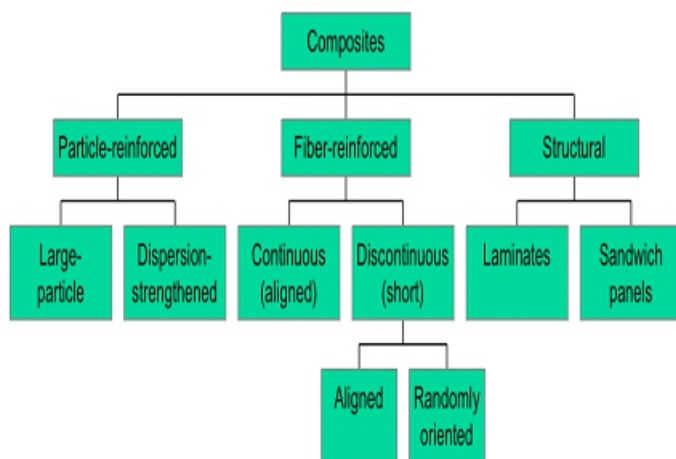
The reinforcing phase provides the strength and stiffness. In most cases; the reinforcement is harder, stronger, and stiffer than the matrix. The reinforcement is usually a fibre or a particulate. Particulate composites have dimensions that are approximately equal in all directions. They may be spherical, platelets, or any other regular or irregular geometry. Particulate composites tend to be much weaker and less stiff than continuous fibre composites, but they are usually much less expensive. Particulate reinforced composites usually contain less reinforcement (up to 40 to 50 volume per cent) due to processing difficulties and brittleness.

A fibre has a length that is much greater than its diameter. The length-to-diameter (l/d) ratio is known as the aspect ratio and can vary greatly. Continuous fibres have long aspect ratios, while discontinuous fibres have short aspect ratios. Continuous-fibre composites normally have a preferred orientation, while discontinuous fibres generally have a random orientation. Examples of continuous reinforcements include unidirectional, woven cloth, and helical winding, while examples of discontinuous reinforcements are chopped fibres and random mat. Continuous-fibre composites are often made into laminates by stacking single sheets of continuous as high as 60 to 70 percent.

Fibres produce high-strength composites because of their small diameter; they contain far fewer defects (normally surface defects) compared to the material produced in bulk. As a general rule, the smaller the diameter of the fibre, the higher its strength, but often the cost increases as the diameter becomes smaller. In addition, smaller-diameter high-strength fibres have greater flexibility and are more amenable to fabrication processes such as weaving or forming over radii. Typical fibres include glass, aramid, and carbon, which may be continuous or discontinuous.

The continuous phase is the matrix, which is a polymer, metal, or ceramic. Polymers have low strength and stiffness, metals have intermediate strength and stiffness but high ductility, and ceramics have high strength and stiffness but are brittle. The matrix (continuous phase) performs several critical functions, including maintaining the fibres in the proper orientation and spacing and protecting them from abrasion and the environment. In polymer and metal matrix composites that form a strong bond between the fibre and the matrix, the matrix transmits loads from the matrix to the fibres through shear loading at the interface. In ceramic matrix composites, the objective is often to increase the toughness rather than the strength and stiffness; therefore, a low interfacial strength bond is desirable. The type and quantity of the reinforcement determine the final properties. The highest strength and modulus are obtained with continuous-fibre composites. There is a practical limit of about 70 volume percent reinforcement that can be added to form a composite. At higher percentages, there is too little matrix to support the fibres effectively.

1.1 TYPES OF COMPOSITE MATERIALS :



1.2 PARTICLE REINFORCEMENT:

A particle has no long dimension. Particle composites consist of particles of one material dispersed in a matrix of a second material. Particles may have any shape or size, but are generally spherical, ellipsoidal, polyhedral, or irregular in shape. They may be added to a liquid matrix that later solidifies; grown in place by a reaction such as age hardening; or they may be pressed together and then inter-diffused via a powder process.

The particles may be treated to be made compatible with the matrix, or they may be incorporated without such treatment. Particles are most often used to extend the strength or other properties of inexpensive materials by the addition of other materials.

1.3 FIBER REINFORCEMENT:

A fiber has one long dimension fiber-reinforced materials are typified by fiber glass in which there are three components: glass filaments (for mechanical strength), a polymer matrix (to encapsulate the filaments); and a bonding agent (to bind the glass to the polymer). Other fibers include metals, ceramics, and polymers. The fibers can be used as continuous lengths, in staple-fiber form, or as whiskers (short, fine, perfect, or nearly perfect single crystals). Fiber-reinforcement depends as much on fabrication procedure as on materials.

1.4 POLYMER MATRIX COMPOSITES:

The matrix properties determine the resistances of the PMC to most of the derivative processes that eventually cause failure of the structure. These processes include impact damage, delaminating, water absorption, chemical attack, and high-temperature creep. Thus, the matrix is typically the weak link in the PMC structure. The matrix phase of commercial PMCs can be classified as either thermo set or thermoplastic. The general characteristics of each matrix type. However, recently developed matrix resins have begun to change this picture, as noted below.

1.4.1 THERMOSETS:

Thermosetting resins include polyesters, vinyl esters, epoxies and polyamides. Thermosetting polyesters are commonly used in fiber-reinforced plastics, and epoxies make up most of the current market for advanced composites resins. Initially, the viscosity of these resins is low; however, thermoset resins undergo chemical reactions that crosslink the polymer chains and thus connect the entire matrix together in a three-dimensional network. This process is called curing. Thermosets, because of their three-dimensional cross linked structure, tend to have high dimensional stability, high-temperature resistance, and good resistance to solvents. Recently, considerable progress has been made in improving the toughness and maximum operating temperatures of thermosets.

1.4.2 THERMOPLASTICS:

Thermoplastic resins, sometimes called engineering plastics, include some polyesters, poly amideimide, polyether-ether ketone (PEEK), and liquid crystal polymers. They consist of long, discrete molecules that melt to a viscous liquid at the processing temperature, typically 500° to 700°F (260° to 371° C), and, after forming, are cooled to an amorphous, semi crystalline, or crystalline solid. The degree of crystalline has a strong effect on the final matrix properties. Unlike the curing process of thermosetting resins, the processing of thermoplastics is reversible, and, by simply Reheating to the process temperature, the resin can be formed into another shape if desired. Thermoplastics, although generally inferior to thermoses in high-temperature strength and chemical stability, are more resistant to cracking and impact damage.

However, it should be noted that recently developed high-performance thermoplastic, such as PEEK, which have a semi crystalline microstructure, exhibit excellent high temperature strength and solvent resistance. Thermoplastics offer great promise for the future from a manufacturing point of view, because it is easier and faster to heat and cool a material than it is to cure it.

This makes thermoplastic matrices attractive to high-volume industries such as the automotive industry. Currently, thermo plastics are used primarily with discontinuous fiber reinforcements such as chopped glass or carbon graphite. However, there is great potential for high-performance thermoplastics reinforced with continuous fibers. For example, thermoplastics could be used in place of epoxies in the composite structure of the next generation of fighter aircraft.

2. MANUFACTURING METHODS :

Composite manufacturing: The primary manufacturing methods used to produce composites include:

- Manual Lay-Up
- Automated Lay-Up
- Spray-Up
- Filament Winding
- Pultrusion
- Resin Transfer Molding

Manual lay-up involves cutting the reinforcement material to size using a variety of hand and power-operated devices. These cut pieces are then impregnated with wet matrix material, and laid over a mold surface that has been coated with a release agent and then typically a resin gel-coat. The impregnated reinforcement material is then hand-rolled to ensure uniform distribution and to remove trapped air. More reinforcement material is added until the required part thickness has been built-up. Manual lay-up can also be performed using prepregged reinforcement material, called 'prepreg'. The use of prepreg material eliminates separate handling of the reinforcement and resin, and can improve part quality by providing more consistent control of reinforcement and resin contents. Prepreg must be kept refrigerated prior to use, however, to prevent premature curing. The productivity of the manual lay-up can be automated using CNC machines. These machines are used for both prepreg tape-laying and prepreg fiber-placement primarily in the aerospace industry. There is virtually no limit to the size of the work that can be tape-rolled, but the shape has to be relatively flat to butt each successive row without gaps, overlaps or wrinkles.

2.1 PREPARATION OF MOULD:

In the process of preparation of mould, we will choose a rod of 6mm and that is to be cut into four parts. In those four each two are of same size. First two parts are of 250mm and the remaining two are of 100mm. by using these, we will prepare a rectangular mould as per ISO standards.



Fig.1. Preparation of Mould

2.2 PREPARATION OF SILICON CARBIDE:

Silicon carbide can be prepared by many methods, the method of choice often being dictated particle size .the electric arc reaction of silica and coke provides relatively large particles, whereas various pyrolysis procedures can provide crystals several millimeters or larger in size, as well as finely divided powders which may be either amorphous or crystalline.

The high-temperature reactions of various materials previously described include, among other, the following:

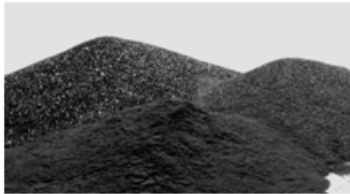


Fig.2. 1mm size of Sic

2.3 PREPARATION OF POLYESTER RESIN:

Polyester Resin is a liquid which will cure to a solid when the hardener is added. It has been specially formulated to cure at room temperature. The hardener, MEKP (Methyl Ethyl Ketone Peroxide) is added to cure, or harden the resin. MEKP hardeners for polyester resin often referred to as catalyst come in small plastic tubes or bottles with graduated measurements marked on them. Hardeners are measured in drops or fractions of teaspoons for most lay-up or repair jobs. Do not over-catalyze or under-catalyzed-- you may ruin the resin and have to start again. Always consult the manufacturer's instructions for mixing the correct proportions of hardener to resin. Factors that will affect the hardening time and working time are temperature, thickness of the application, quantities of resin mixed per batch and humidity.



Fig.3. Catalyst used in polyester

2.4 PREPARATION OF EPOXY RESIN:

Epoxy Resin is a liquid which will cure to a solid when the hardener is added. It has been specially formulated to cure at room temperature. The hardener is added to cure, or harden the resin. Cobalt hardeners for epoxy resin often referred to as catalyst come in small plastic tubes or bottles with graduated measurements marked on them. Hardeners are measured in drops or fractions of teaspoons for most lay-up or repair jobs.

Always consult the manufacturer's instructions for mixing the correct proportions of hardener to resin. Factors that will affect the hardening time and working time are temperature, thickness of the application, quantities of resin mixed per batch and humidity. Epoxy resins have a limited shelf life of one year.



Fig.4. Hardener used in Epoxy

3. METHODOLOGY OF THE PROJECT :

3.1 PROCEDURE FOR SiC-EPOXY SPECIMEN (C1)

Take two smooth tails and wash is cleanly. Apply wax-po and PV to the mould which helps the epoxy to remove easily from the mould .By adding the hardener to epoxy resin, we adding silicon carbide to resin as same quantity. Mixing it with a stirrer for uniform distribution of silicon carbide particles .This poured into the mould and again mix it using hand lay-up process. Leave it for queuing for 10 days.



Fig.5. Mixing of particles and resin

3.2 PROCEDURE FOR SiC-GENERAL POLYESTER SPECIMEN(C2):

Take two smooth tails and wash is cleanly. Apply wax-po and PV to the mould which helps the epoxy to remove easily from the mould .By adding the catalyst to polyester resin, we adding silicon carbide to resin as same quantity. Mixing it with a stirrer for uniform distribution of silicon carbide particles .This poured into the mould and again mix it using hand lay-up process. Leave it for queuing for 10 days.



Fig.6. Final components

3.3. PROCEDURE FOR E-GLASS FIBER-EPOXY RESIN(C₃):

In a mixing jar or pot, we have taken 400gms of epoxy resin and 40gms of A103 and C109. The mixture should be mixed thoroughly with a long stick and a mask should be wired because epoxy resin is very harmful to health if it is inhaled. It should be mixed completely so that the resin is uniform in every part of the mixture. Before mixing it, the glass fibers should cut and should be ready. The type of glass fiber used is E-Glass. We take two type of glass fiber cloth, i.e., Roving, CSM (Chopped Strand Material) . As per ISO Standard and our requirement of 6mm thickness, we have taken 8 pieces of Roving type, 8 pieces of CSM type. Roving type is found to have 400 gms in weight, CSM is found to have 440 gms in weight. The two types of Glass fibers should be cut with a dimension of 250 200mm (or) 25 20cm. These glass fibers types should be placed in a specific order as per ISO standards. The order is as follows:

CSM → Roving → CSM → Roving → CSM → Roving → CSM → Roving → CSM → Roving → CSM → Roving → CSM → Roving → CSM → Roving

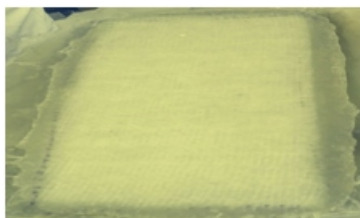


Fig.7. GLASS FIBERS WITH EPOXY RESIN

3.4. PROCEDURE FOR E-GLASS FIBER-GENERAL POLYESTER(C₄)

The above is the procedure for the Test piece of polyester Resin and Glass Fibers. Second Test piece is polyester resin with Glass Fibers.

In a mixing jar or pot, we have taken 400gms of polyester resin and 40gms of A103 and C109 . The mixture should be mixed thoroughly with a long stick and a mask should be worn because there would an polyester resin is very harmful for health if it is inhaled. It should be mixed completely so that the resin is uniform in every part of the mixture. Before mixing it, the glass fibers should cut and should be ready. The type of glass fiber used is E-Glass. We take two type of glass fiber cloth, i.e., Roving, CSM (Chopped Strand Material) . As per ISO Standard and our requirement of 6mm thickness, we have taken 8 pieces of CSM type, 8 pieces of Roving type. CSM type is found to have 440 gms in weight, Roving type is found to have 400 gms in weight. The two types of Glass fibers should be cut with a dimension of 250 200mm (or) 25 20cm. These fibers types should be placed in a specific order as per ISO standards. The order is as follows:

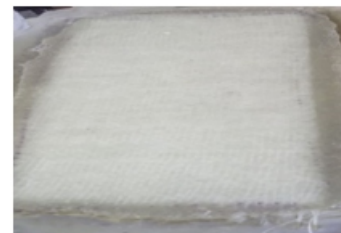


Fig.8. GLASS FIBERS WITH GP RESIN

So we have kept the test piece for 9 days for curing and after that seeing the IS standard book, we have marked the dimensions for TENSILE Strength Testing, FLEXURAL Property Testing and Inter laminar Shear Strength Testing.

4. RESULTS AND DISCUSSIONS :

After queuing the material is removed from the mould and then test have to be done on the specimen Following test are done on the work piece

A. Tensile test

$$\text{Tensile strength (T.S.)} = \frac{W}{B \times D}$$

B. Shear test

$$\text{Shear strength (S.S.)} = \frac{W}{2 \times B \times D \times K}$$

C. Cross breaking test

$$\text{Cross breaking strength (C.B.S.)} = \frac{1.5 \times W \times L}{B \times D^2}$$

D-Thickness, B-Width, L- Distance between the supports, W-Maximum Load(D-Thickness, B-Width, L- Distance between the supports, W-Maximum Load)

4.1 GEOMETRY OF SPECIMENS:

COMPOSITE	Tensile test	Cross breaking test	Shear test
C ₁	D=0.712 cm B=2.061 cm	L=10cm, B= 1.547 cm, D=0.654 cm	B= 0.669 cm D=0.642 cm
C ₂	D=0.71 cm B=2.054 cm	L=10cm B= 1.654 cm D=0.719 cm	B= 0.682 cm D=0.597 cm
C ₃	D=0.648 cm B=2.047 cm	L=10cm B= 1.591 cm D=0.661 cm	B= 0.652 cm D=0.595 cm
C ₄	D=0.648 cm B=2.047 cm	L=10cm B= 1.633 cm D=0.659 cm	B= 0.694 cm D=0.597

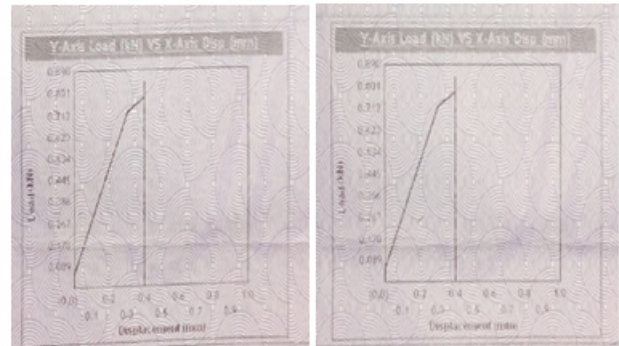
4.2 MAXIMUM LOADS ON SPECIMENS:

COMPOSITE	Tensile load W(Kg-F)	Load at fracture W(Kg-F)	Shear load W(Kg-F)
C ₁	89.70	24.46	348.62
C ₂	85.62	36.69	267.07
C ₃	2770.62	120.28	709.48
C ₄	2574.92	103.97	725.79

4.3 RESULTS

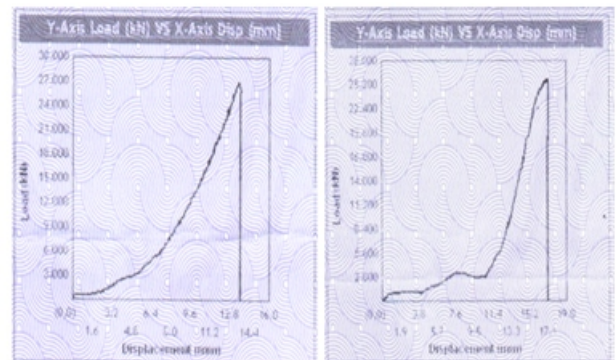
COMPOSITE	Tensile strength kg F/cm ²	Cross breaking strength kg F/cm ²	Shear strength kg F/cm ²
C ₁	61.14	555.068	388.2
C ₂	58.72	643.684	180.24
C ₃	2089.47	2596.07	915.45
C ₄	1941.87	2199.75	836.16

4.1 LOAD V/S DISPLACEMENT CURVES:



A) C₁

B) C₂

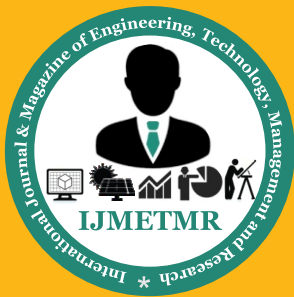


C) C₃

D) C₄

5. CONCLUSION :

From the above tests and results that fibrous reinforcement induces maximum tensile, cross breaking and shear strengths for composite materials than particulate reinforcement. SiC is best suitable reinforcement for general polyester which gives maximum tensile and shear strength and the value of cross breaking is higher for SiC in epoxy matrix. E-glass is suitable reinforcement for epoxy matrix composites and gives best results in tensile, cross breaking and shear strength tests. Because of the good tensile property of the fiber introduced, this will increase the tensile strength of the composite as per the basic rule of the composite. So we can make use of E-glass fiber reinforced composites with Epoxy as the matrix for high tensile strength needed applications. The SiC reinforced composite is suitable for the applications where we need good abrasive resistance.



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