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## Effect of Various Fillers on Mechanical Properties of Glass Fiber Reinforced Polymer Composites: A Review

Authors

**Prasad Galande<sup>1</sup>, S. E. Zarekar<sup>2</sup>**<sup>1</sup>Department of Mechanical Engineering Vidya Pratishthan's College of Engineering, BaramatiEmail: [prasad\\_galande@yahoo.com](mailto:prasad_galande@yahoo.com)<sup>2</sup>Assistant Professor Dept of Mechanical Engineering, Vidya Pratishthan's College of Engineering, Baramati

### Abstract

Filler materials are the inert materials which are used in glass fiber reinforced polymer (GFRP) composites for modifying the chemical and physical properties of the matrix polymers to reduce material costs, to improve processability, to improve product performance or to simply act as extenders or matrix diluents. Some of the commonly used fillers are carbon black, calcium carbonate, clay, alumina tri-hydrate, magnesium hydroxide, bone powder, coconut powder, hematite powder, TiO<sub>2</sub>, SiO<sub>2</sub>, ZnS, graphite, etc. Effect of these fillers on mechanical properties like tensile strength, flexural strength, inter laminar shear strength (ILSS), tensile modulus, impact strength, hardness were tested by various methods experimentally. Some of the authors also discussed the effect of filler size on the above mechanical properties.

**Keywords-** Fillers, glass fiber reinforced polymer composites (GFRP), Mechanical properties

### Introduction

Filler materials are generally the inert materials which are used in composite materials to reduce material costs, to improve mechanical properties to some extent, in some cases to improve processability and to improve product performance.

Two or more materials with different material properties are combined together they will form a composite material. Fibers when embedded with weaker matrix materials comprise of strong load carrying capacity. The fibers in the composite materials will improve the mechanical properties such as tensile strength, flexural strength, impact strength, stiffness and matrix will transfer stresses between the reinforcing fibers.

Fiber reinforced polymer composites are also called as fibrous composites because they consists of fibers as the reinforcing materials. The applications of composite materials are in automotive, marine, aerospace, etc. because of

having properties such as high specific strength and stiffness.

The types of composite materials are metal matrix composites, ceramic matrix composites and polymer matrix composites. When the matrix material is taken as ceramic it is called as ceramic matrix composite. The properties of ceramic matrix composites are better toughness, high strength, hardness, high temperature properties and better wear resistance. When the polymer resin is used as a matrix material then it is called as polymer matrix composite. These materials are having properties such as low density, good thermal and electrical insulator, ease of fabrication and low cost. The properties of polymer matrix composites mainly depend upon types of reinforcement that is particles and fibers, the type of polymer used and interface which is used between them. Polymers are classified into thermoplastics and thermosets. Thermoplastic materials are reversible and reshaped by

application of heat and pressure. Thermoplastic materials will show poor creep resistance at higher temperature when compared to thermosets.

Thermosets are materials which will undergo a curing process through part fabrication and once cured cannot be remelted and reformed. The mostly used resins in thermoset composites are epoxy, polyester, phenolics, vinyl ester and polyamides. Fiber reinforced polymer composites are also called as fibrous composites because they consists of fibers as the reinforcing materials. The applications of composite materials are in automotive, marine, aerospace, etc. because of having properties such as high specific strength and stiffness.

Fibers are very important class of reinforcing materials because they are having desired conditions and transfer strength to matrix constituent by influencing and enhancing their desired properties. Fiber can be classified as synthetic (manmade fibers) or natural fibers. Some examples of synthetic fibers are E- glass fibers which are having electrical applications, C-glass which can be used in corrosive environment and S-glass which can be used in structural application and at high temperatures. Glass fibers are available in the form of continuous, chopped and woven fibers, etc.

Because of the requirement of lightweight materials such as surface of ships lead to the development of fly ash based thermosetting resins. Addition of fly ash will reduce the density and increase the modulus of the composites. In recent years a growing number of engineering applications of light weight and energy efficient plastics can be found in high quality parts vital to the functioning of entire equipment and structures. Improved mechanical properties, mainly the balance of the stiffness and toughness are the desired features of new materials. Fillers are introduced into thermoplastics for many varied reasons, more generally to influence the physical properties of the polymer but occasionally to simply act as extenders or matrix diluents.

The published papers on structure property relationships and the successful products changed the perception of filled composites among their end users. The commonly used fillers are calcium carbonate, talc, mica, clay, alumina, tri-hydrate, magnesium hydroxide, carbon black. Filled thermoplastics are used in household items, durable goods, appliances, passenger cars, mass transport vehicles, aircraft, sporting and leisure goods, the electrical and construction industry, electronics, packaging, medical devices, etc. It has been estimated that about 30% of polymers produced worldwide is used to produce composites and filled plastics. Some of the sources has estimated that 50% of all produced polymers is in one way or another filled with inorganic fillers to achieve the desired properties. Over the years, there were attempts going on for using inert, low cost inorganic powder to replace part of the organic resin without comprising its mechanical properties and processability so as to reduce the final price of the materials. For modifying the chemical and physical properties of the matrix polymers and improving processing by shortening the production cycle inorganic fillers of specific properties are increasingly used to affect the environmental stability of the compounds.

Even though the number of thermoplastics and inorganic fillers suitable for compounding is limited for various reasons, one seems to be restricted only by ones own imagination in finding new meaningful matrix/filler combinations, especially with the advent of new technologies capable of engineering the interphase region in the imminent vicinity of the filler surface, the interphase, which has become the center of research and development activities worldwide.

The matrix is the load bearing component and all deformation processes takes place in matrix in the particulate filled thermoplastics. Due to the absence of interfacial friction for transferring stress, particulate fillers are in most cases not capable of carrying any substantial portion of the load.

By addition of filler it causes various changes in the molecular and super molecular structure of composite. Changes depend upon filler chemical composition, surface activity, particle size and shape, filler content, compounding technique and processing as well as on the initial matrix structure. Addition of solid fillers will cause reduction of molecular weight crystal and spherulite size and molecular mobility.

### Literature survey

S. Pichi Reddy et al.(2014) investigated the effect of fly ash content on tensile and flexural strength of glass fiber epoxy composites by varying the fly ash content from 0 to 10 grams in steps of 2 grams. The mould has been prepared and hand layup technique is used for the fabrication of composites. The highest tensile strength is observed containing 6 grams of fly ash in the composite, while highest flexural strength is for 4 grams of fly ash. The range of tensile strength is from 14.7727 Mpa to 27.1790 Mpa. The maximum tensile modulus of elasticity is observed with 8 grams fly ash. The range of flexural strength is from 81.648 Mpa to 110.497 Mpa.

Sudeep Deshpande et al. (2014) worked on the effect of bone and coconut powder as a filler material on hybrid fiber reinforced polymer (HFRP). HFRP is made by using E-glass fiber, jute fiber and epoxy as a resin. The tests were taken for 0%, 10%,15% volume fraction of coconut and bone powder. The fabrication of the composites is made by hand layup technique and mechanical properties such as ultimate tensile strength, flexural strength, inter laminar shear strength, tensile modulus, impact strength and hardness of the composites were tested and compared with unfilled HFRP composites. The maximum values of flexural strength, inter laminar shear strength, tensile modulus and hardness are obtained for 15% volume coconut shell powder. The maximum impact strength was achieved for 15% volume of bone powder. The

maximum ultimate tensile strength was observed for 10% volume of coconut shell powder.

K Naresh Kumar et al. (2013) studied the effect of addition of coal ash in the glass fiber reinforced polymer composites. The particle size of coal ash is 52 to 75 $\mu$ m. The hand layup technique is used for making specimen containing 0%, 4%, 8%, 12%, 16% and 20% weight percentage of coal ash. The tensile, flexural, compression and impact properties are studied according to ASTM standards. Experimentally it was found that 20% ash reinforced polymer composite is having better tensile strength, 16% ash reinforced composite is having better flexural strength and 12% ash reinforced composite is having better compression strength as compared to others. But better impact strength is observed for composites having no ash and there is no significant effect as such on impact properties by addition of fly ash.

Pritish Shubham et al. (2013) investigated the effect of varying ash concentration and modifying fly ash particle surface by a  $\gamma$ -aminopropyle triethoxy silane coupling agent. The DMA test result showed improvement in damping capability and thermal stability with lower concentration of fly ash but by modification of surface with silane resulted in decrease in damping capability. Due to the silanization there is improvement in strength compared to fly ash at same concentration. Also, there is improvement in the toughness due to silanization. During the SEM analysis it was observed that silanization will improve bonding with polymer resin which will result in lower damping capability, improved strength and toughness.

R Satheesh Raja et al. (2013) studied chemical composition of fly ash and its particle size in the enhancement of physical and mechanical properties of polymer matrix composites. Four different sizes of fly ash 50  $\mu$ , 480nm, 350nm and 300nm with 10 wt % are impregnated with epoxy resin in the polymer matrix composites. The ball milling technique is used for reduction of size of fly ash. Scanning electron microscope and energy dispersive spectroscopy were used for

characterization of fly ash. The effect of particle size is studied on hardness and impact strength. From the experimentation it was found that better impact energy and hardness values were obtained for 300nm size fly ash filler impregnated polymer composite. So as we go on reducing the size of filler we will get the better values of hardness and impact energy.

K Devendra et al. (2013) made an investigation on varying concentrations of fly ash, aluminium oxide, magnesium hydroxide and hematite powder on mechanical properties of E-glass fiber reinforced epoxy composites. The effect of these fillers on ultimate tensile strength, hardness and impact strength were studied. The test results showed that 10% magnesium hydroxide filled composite showed maximum ultimate tensile strength of 375.36 Mpa. Increase in addition of fillers tends to decrease the ultimate tensile strength. From the experimental results it was found that sample with 10% fly ash showed better impact properties compared to other fillers. As the percentage of hematite powder was increased the impact strength increases. Maximum hardness number is obtained for magnesium hydroxide filled composites of 88.69 BHN. Increase in addition of aluminium oxide and hematite increased the hardness but increase in addition of fly ash reduced the hardness of composite.

Michaela R. Petersen et al. (2015) determined that alumina trihydrate can be effectively used to increase the fire resistant of fiber reinforced polymer materials. Compression, tension and flexural properties are determined with 0%, 25% and 50% aluminium trihydrate filler material. It was found that composite with 0% aluminium trihydrate is strongest except in case of flexural strength. As the aluminium trihydrate percentage is increased the strength of the composite decreased and made it brittle.

Patil Deogonda et al. (2013) present the development and mechanical characterization of polymer composites by using fillers such as  $\text{TiO}_2$  and ZnS in glass fiber reinforced epoxy resin (GFRP). Tensile test, three point bending test

and impact tests were performed to find out the effect of fillers on the mechanical properties of GFRP composites. From the experimentation it was found that higher the filler material volume percentage greater the strength for both the fillers. For manufacturing of GFRP composites hand layup technique is used. ZnS filled composites showed better results as compared to  $\text{TiO}_2$ .  $\text{TiO}_2$  and ZnS fillers makes material harder and brittle so that the impact toughness value of unfilled glass composite is more than filled composite.

Ramesh K Nayak et al. (2014) worked on the modification of epoxy matrix by using  $\text{Al}_2\text{O}_3$ ,  $\text{SiO}_2$  and  $\text{TiO}_2$  micro particles in GFRP composite for the improvement of mechanical properties. For the fabrication of GFRP hand layup technique is used. The mechanical properties such as flexural strength, flexural modulus, ILSS, hardness and impact energy were tested experimentally. Accumulation of  $\text{Al}_2\text{O}_3$  micro particles is observed in SEM.  $\text{SiO}_2$  increases the mechanical properties such as ILSS, flexural strength and flexural modulus when compared with other fillers. By decreasing particle size mechanical properties get improved. Alumina tri-hydrate will increase the hardness and impact energy as compared to other fillers.

A. K. Parida et al. (2013) reported on the woven fabric material with two resins araldite LY556 and vinyl ester. While manufacturing 1% graphite and 1% ash clay are used as a filler material. Tensile test, low velocity impact test, end notch flexure test and scanning electron microscopy tests were performed. It was found that tensile strength is more in case of araldite but the flexural and impact strengths were more in case of vinyl ester as a matrix.

M. Sudheer et al. (2014) studied the effect of ceramic whisker (7.5 wt.%) and solid lubricant filler (2.5 wt.%) on mechanical and dry sliding wear behavior of GFRP composites. The impact, flexural and tensile properties were tested according to ASTM standards. The vacuum bagging technique was used for the fabrication of the composites. Pin on disk arrangement with

steel disc as counter face is used for dry sliding wear tests. Stiffness, friction coefficient and antiwear abilities of GFRP composites were improved with single incorporation of ceramic whisker while the strength properties were slightly reduced after whisker addition. But after the addition of solid lubricant as secondary filler it improved both mechanical and tribological properties of composites. By using SEM photographs the deformation and failure mechanisms were investigated under tensile loading and dry sliding.

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