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RESEARCH ARTICLE

EFFECT OF SILICA AND GRAPHITE FILLERS ON MECHANICAL BEHAVIOR OF EPOXY COMPOSITE LAMINATES

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ABSTRACT

Polymer matrix composites are emerging trend of promising materials in all engineering materials. The use of polymeric composite materials has increased considerably over the last decade. In the present study, graphite and silica filled epoxy composites with different particulate fractions were investigated for mechanical properties such as tensile strength, flexural strength, impact strength and hardness as per the relevant ASTM standards. The filler content was varied from 5, 10, 15, 20, and 25% by weight of total matrix of epoxy in the composite laminate. The results showed that the mechanical properties of the composites mainly depend on dispersion condition of the filler particles and aggregate structure. It also revealed that silica filled composites exhibited better than unfilled epoxy composites. The properties of composites improved in tensile strength, flexural strength, impact strength and hardness with increase of silica filler material content. But, these properties except hardness were shown decreasing trend by increasing the content of graphite filler material. The hardness of the composite laminate is increases with increasing in the content of graphite filler material. The 15% silica filled epoxy composite laminate has shown superior to other materials.

INTRODUCTION

Polymer Matrix Composites (PMC) are finding increasing applications in automotives, aerospace, machine elements, chemical industry and many other areas. Epoxy resin is one of the most widely used thermoset polymer matrix in the composite industry, due to its excellent adhesion to many reinforcements. It has excellent resistance to humidity, high hardness, good mechanical and thermal properties [1]. Composite material consists of one or more phases with different mechanical, physical and chemical properties. The mutual interaction between the matrix and reinforcement influences the resulting characteristics and behavior of the composite laminates. The individual phases are usually referred as the filler and the matrix. Filler can improve the mechanical properties like tensile strength, flexural strength, resistance to abrasive wear, hardness and impact strength etc.,. [2-4]. One of the major issues addressed in the polymer industry is to further modify the performance of epoxy resin by adding different fillers. Discontinuous reinforcements which include short fibers, whiskers and particulates have recently gained significant attention, since along with the improvement in the properties. The individual phases influence the resulting characteristics of the material by their own characteristics and by the mutual interaction of the matrix and the filler. The end properties of the composite depend not only on the matrix but also on the reinforcement and type of the interface between them. The reinforcement, depending on material composition, its volume, size, shape, and surface modification, can affect many properties including strength, hardness, wear resistance, heat dissipation, and dimensional stability. Many researchers have explored the possibility of modifying the behaviour of thermoset epoxy by reinforcing it with different types of fillers. Hard ceramics such as alumina (Al_2O_3), silicon carbide (SiC), and boron carbide (B_4C) are found to enhance mechanical properties of epoxy [5–7]. The soft or lubricant fillers such as graphite, molybdenum sulphide (MoS_2), and polytetrafluoroethylene (PTFE) are sometimes employed as filler for epoxy to make them suitable for low friction and low wear environments [8, 9]. To enhance the interfacial interaction between the filler and the matrix, fillers are subjected to different pretreatments. Such attempts are found to improve the mechanical and tribological properties of composites. The experimental results by Shi *et al*. [7] indicated that incorporation of nano-Al_2O_3 particles leads to increased flexural modulus and flexural strength of epoxy. Ji *et al*. [10] found that very small filler content of 0.2 vol% of nanosized

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SiC particles pretreated by graft polymerization of polyacrylamide effectively reduced the friction coefficient and wear rate of epoxy even under high contact pressures. Rodrigues and Broughton [11] have observed improvement in flexural and tensile strengths ranging between 24% and 56% in case of silane treated B_4C filled epoxy composites. Among the different pretreatments for reinforcements, silane coupling agents have been widely employed to enhance the adhesion between polymer and inorganic fillers [14]. Silane functionalization of different fillers is also found to improve the performance of filled epoxy composites [12, 13]. Kim *et al*. [15] observed the effect of filler morphology on the dry sliding performance of novolac resin based composites. They concluded that potassium titanate whisker (PTW) filled matrix resin exhibited smooth frictional behavior and better wear resistance than particulate (barite) filled resin composites. In another study on morphological effects Feng *et al*. [16] studied that small size PTW (diameter 0.77 μm and length 10.47 μm) at intermediate volume fraction of 5 wt% had improved tensile strength, elongation to break, notched impact strength, and thermal deformation temperature by 35.6, 46, 3, and 11% over PTFE, respectively. When the filler size was increased in their study, mechanical properties such as tensile strength, elongation, and hardness were found to deteriorate. Kumar *et al*. [17] studied the mechanical properties of polymer filled with wood flour and also states the optimum conditions to improve the mechanical chemical and thermal properties. Chen *et al*. [18] systematically evaluated the tensile strength of a series of PTW filled castor oil-based polyurethane/epoxy resin interpenetrating polymer networks and found an optimum increase in the tensile strength of the composites at 3% of PTW. Even though several reports are available on filled polymer composites, a systematic study dealing with the use of silica and graphite filler for epoxy resin has not been performed. Therefore the main objective of this study is the addition of different amounts of fillers to epoxy resin and specifically analyzing mechanical behavior of developed composites.

Experimental Work

Materials

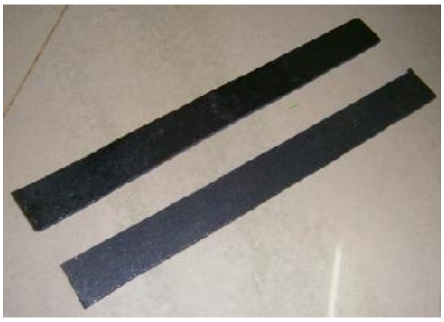
For this experimental work the commercially available epoxy resin (LY 556) procured from Ciba Geigy India Ltd was used as the polymer matrix. Aliphatic amine (HY-951) was used as the hardener for epoxy resin. The graphite and silica powder with a average particle size of 50micron is used to fabricate the composite laminates.

Fabrication of Composite Laminates

A weighted amount of epoxy resin and graphite powder were mixed in varying proportions(5, 10, 15, 20 and 25%) and then the hardener aliphatic amine (HY-951) was added in the ratio of 10:1to initiate the reaction. The mixture was then poured into the mould to fabricate the laminates. Different sheets of epoxy resin reinforced with varying amounts of graphite and graphite filler i.e. 5%, 10%, 15%, 20% and 25% (by weight of resin) were prepared separately for mechanical testing.

Testing of Laminates

The laminate is taken out from the mold and its edges are trimmed to size. Laminate is cut into specimens of appropriate dimensions for evaluating various mechanical properties as per ASTM standards. The testing standards for the relevant mechanical properties are given in Table 1. The photographs of test specimens used for testing mechanical properties are shown Fig. 1.



A graphite filler

B silica filler

Figure 1 Tensile test specimen of graphite and silica filled composite laminate

Table 1 Mechanical properties testing standards

Properties	Testing standards
Tensile strength	ASTM D 3039
Flexural strength	ASTM D 790
Impact strength	ASTM D 256
Hardness	ASTM D 2583

RESULTS AND DISCUSSIONS

The mechanical properties of composite made of high modulus filler and relatively low modulus polymeric matrix are sensitive to loading rate and temperature. The structure and properties of the filler matrix interface play a major role in the mechanical. The tensile strength, flexural strength, impact strength and hardness for the silica and graphite filled composite laminates are shown in Fig.2-5.

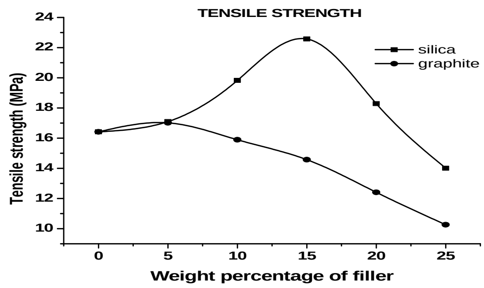


Figure 2 Effect of filler content on tensile strength

Figure.2 shows the effect of filler materials on tensile strength. The tensile strength of the laminate is increases with increasing in content of silica filler up to 15%. This may be due to the good mutual interaction between the silica filler and epoxy matrix. If the content of silica filler is more than 15%, there is a decreasing trend of tensile strength. This may be due to the high concentration of silica content which cause the high hardness of laminate, also the less interaction between filler material and epoxy matrix. The tensile strength of the graphite filled composite laminate is decreases with increasing in content of graphite filler material. This is due to high harness of filler material.

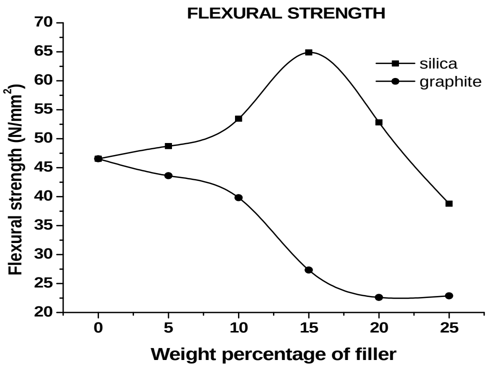


Figure 3 Effect of filler content on flexural strength

Figure.3 shows the effect of filler materials on flexural strength. The flexural strength of the laminate is increases with increasing in content of silica filler up to 15%. This may be due to the good mutual interaction between the silica filler and epoxy matrix. If the content of silica filler is more than 15%, there is a decreasing trend of flexural strength. This may be due to the high concentration of silica content which cause the high hardness of laminate, also the less interaction between filler material and epoxy matrix. The flexural strength of the graphite filled composite laminate is decreases with increasing in content of graphite filler material. This is due to high harness of filler material.

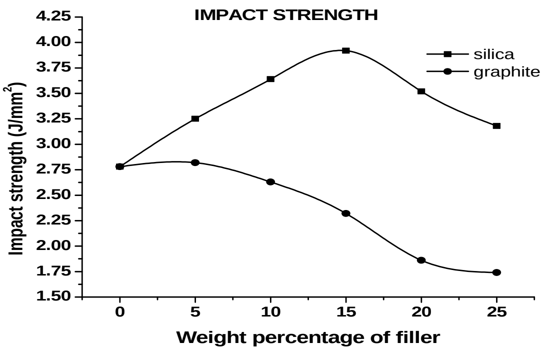


Figure 4 Effect of filler content on impact strength

Figure.4 shows the effect of filler materials on impact strength. The impact strength of the laminate is increases with increasing in content of silica filler up to 15%. This may be due to the good mutual interaction between the silica filler and epoxy matrix. If the content of silica filler is more than 15%, there is a decreasing trend of impact strength. This may be due to the high concentration of silica content which cause the high hardness of laminate, also the less interaction between filler material and epoxy matrix. The impact strength of the graphite filled composite laminate is decreases with increasing in content of graphite filler material. This is due to high harness of filler material.

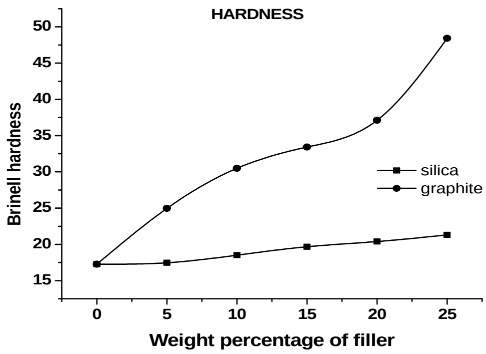


Figure 5 Effect of filler content on hardness

Figure.5 shows the effect of filler materials on hardness. The hardness of the laminate is increases with increasing in content of silica and graphite filler. This may be due to the good mutual interaction between the silica filler and epoxy matrix. The hardness of graphite filled composite laminate is greater than silica filled composite laminates. This is due to high harness of graphite filler than silica filler material.

CONCLUSIONS

The results showed that the mechanical properties of the composites mainly depend on dispersion condition of the filler particles and aggregate structure. It also revealed that silica filled composites exhibited better than unfilled epoxy composites. The properties of composites improved in tensile strength, flexural strength, impact strength and hardness with increase of silica filler material content. But, these properties except hardness were shown decreasing trend by increasing the content of graphite filler material. The hardness of the composite laminate is increases with increasing in the content of graphite filler material. The 15% silica filled epoxy composite laminate has shown superior to other materials.

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