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Review-Effect of Fillers on Mechanical Properties of Polymer Matrix Composites

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Abstract

Composites have ability to meet diverse properties required for various engineering applications with significant strength to weight ratio. Polymer based composites are being aptly used materials in engineering applications due to high specific strength and stiffness. The addition of fillers willenhance the mechanical properties of polymer matrix composites. With reference to this, mechanical properties such as ultimate tensile strength, impact strength and hardness of polymer matrix composites with different fillers are reviewed. Polymer matrix composites with different polymers/fibers aremixed with varying ratios of fillers like, aluminum oxide (Al_2O_3), silicon carbide (SiC), calcium carbonate ($CaCO_3$), Magnesium hydroxide(Mg(OH)2)and zinc oxide (ZnO) were used to study the mechanical properties.From the analysis it was found that fillers are exhibited enhanced mechanical properties of polymer matrix composites. And also, the major factors like, dispersion of fillers and distribution, adhesion and interface between filler and polymer matrix will also affecting the mechanical properties of polymer composites.

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*Keywords:*Composites, fillers, mechanical properties.

1. Introduction

Composites are combination of two or more constituents with different properties and which are chemically insoluble each other. Polymer based composites have replaced many of the conventional materials in various applications such as automotive, structural, sporting goods, household appliances [1], because of the advantages

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such as ease of processing/production, high specific strength and stiffness. Different types of polymers such as, epoxy, polyamide, polyvinyl, polystyrene etc., are used with continuous/short fiber such as carbon fiber, glass fiber etc.[2]. Polymer matrix composites being manufactured by hand layup, compression molding/injection molding in effective cost manner [3-6]. Addition of filler materials improves stiffness, toughness, hardness, heat distortion temperature significantly [7]. In fact, most of the polymer matrix composites are filled with different inorganic fillers (such as silicon carbide, aluminum oxide, silica, Magnesium hydroxide, zinc oxide etc.) to achieve the desired Mechanical properties [8-11]. Mechanical properties of fiber reinforced composites are depends on type, quantity, orientation and distribution of fiber and also mechanism of load transfer at the inter-phase plays a major role [12]. The main reason for using the fillers is to improve the properties of composites and to reduce the cost of the component. Most of the references are available in which they suggest investigation on number of material to be used as filler in polymer and in some case only they have used both fiber and filler combined [13-14]. Mechanical properties of PMCs strongly depend on the particle size, particle–matrix interface adhesion and loading. For example, polypropylene (PP) composites filled with smaller CaCO3 particles provide higher strength at a given particle loading [15]. In reference to this, mechanical properties such as ultimate tensile strength, impact strength and hardness of polymer matrix composites with different fillers are reviewed. Polymer matrix composites are prepared with different polymers/fibers and mixed with varying ratios of fillers like, aluminum oxide (Al_2O_3), silicon carbide (SiC), magnesium hydroxide (Mg(OH)2), calcium carbonate ($CaCO_3$), and zinc oxide (ZnO) and the mechanical properties of the fabricated composites were studied.

2. Mechanical Characterization

Mechanical properties of epoxy bases fiber-reinforced polymer composites are depending on the properties of the constituent materials (type, quantity, fiber distribution and orientation, void content). Along with those properties, the nature of the interfacial bonds and the mechanisms of load transfer at the inter phase also play an important role.

Mechanical characterization of epoxy based PMC consist of Plain weave woven glass fabrics which made of E-glass fibers with density of 360 g/m2 and diameter of about 12 μm have been employed. Along with two different fillers such as SiC and graphite were mixed (each 5 and 10 wt%) and mechanical properties such as tensile, bending and impact test have been conducted. These fillers were silanated and have an average particle size of about 25 μm. The Glass-Epoxy composite with 10% silicon carbide filler exhibits a tensile strength of 404.2 MPa and a modulus of 13.1 GPa as compared to 305MPa and 12.6 GPa of unfilled Glass-Epoxy composite. The addition of SiC/graphite increases the tensile strength of Glass-Epoxy as compared to unfilled composite due to interface between the epoxy and filler is stronger and stress is transferred from the epoxy matrix to the filler. And the interaction between the particle size distribution and the load carrying of SiC/graphite is extremely important. The Glass-Epoxy composite with 10% graphite shows the enhances the flexural strength, its due to 10% graphite particle content have lower bearing strength.The addition of fillers creates remarkable difference in impact strength of the Glass-Epoxy composites has decreases. The filler compatibility with epoxy seems to be not good and it decreases the impact strength of composite[16].

Silicon Carbide and Calcium Sulphate are used as filler materials for Glass-Epoxy composite and it shows the presence of Calcium Sulphate enhances the tensile strength and hardness of the composites and exhibits low impact strength and low thermal expansion as compare to unfilled composites [17].

Glass-Epoxy composite filled with 10% Volume Mg(OH)2 exhibited best ultimate strength as compared to other filled composites but lower than the un filled composite due to good particle dispersion and strong polymer/filler interface adhesion for effective stress transfer [18]. Composites filled by Al2O3 exhibited better ultimate tensile strength as compared to composites filled with fly ash and hematite, and this is due to Al2O3 having the ceramic particles these particles distributed uniformly throughout the composites and produces good bonding strength between polymer, filler and fiber. But as increase in addition of Mg(OH)2, Al2O3 and fly ash content up to 15% volume to the composites the tensile strengths is found to be less, and this is due to more filler material in the composites damages matrix continuity, less volume of fiber and more void formation in the composites. Ultimate tensile strength increases with increase in addition of hematite to composites this may be due to improve in inter facial bonding strength between filler, matrix and fiber. The composites were filled with 10% volume of fly ash having high impact strength. Composites filled with 10% volume Al2O3 and Mg(OH)2 exhibited good impact strength but increase in addition of Al2O3 and Mg(OH)2 leads to decrease in impact strength. Impact strength increases with adding more hematite powder to composites this due to improvement of bonding strength between filler and matrix and rigidity of filler particles absorbs the more energy. The experimental results indicated that composite filled by Mg (OH)2 exhibited maximum hardness also increase in addition of Al2O3 and hematite to composites increases the hardness of the composites. The hardness decreases with addition of fly ash to composites this is due to weak bonding strength and more possibility of void formation[18].

3. Conclusion

In the present paper analysis of mechanical properties has been carried out for polymer matrix composites with different polymers/fibers are filled with varying ratios of fillers like, aluminum oxide (Al2O3), silicon carbide (SiC), calcium carbonate (CaCO3), Magnesium hydroxide(Mg(OH)2)and zinc oxide (ZnO). From the analysis it was found that addition of fillers are exhibited enhanced mechanical properties of polymer matrix composites. And also, the major factors like, dispersion of fillers and distribution, adhesion and interface between filler and polymer matrix will also affect the mechanical properties of polymer composites.

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