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Effect of Solid Glass Microsphere Content and Size of Particles on Physical Properties of Polyester-Based Composites

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ABSTRACT

In the present work polyester-based composites are prepared using hand lay-up method. Solid glass microsphere (SGM) of three different sizes is taken as filler material. The content of SGM is varied from 5 wt. % to 25 wt. % and total five sets are prepared for each size of filler. The size of filler selected is 50 microns, 100 microns and 150 microns. In total fifteen sets are prepared and the fabricated samples are tested for their physical properties that includes density and void content of the material. From the experimental testing it is found that SGM being higher dense material results in increase in the density of polyester resin. Further they reported that, with increase in filler content, void content of the material also increases. Finally, they concluded that composites prepared with smaller size particles have higher density and fewer voids as compared to composites prepared with bigger size particles.

Keywords: Polyester, solid glass microsphere, density, voids content.

1. INTRODUCTION

Polymer matrix composites (PMCs) are the best-established form of advanced composite materials. Of the two classes of polymers used as matrices, thermosets and thermoplastics, thermosets dominate the market for structural applications. The mechanical properties of PMCs can vary widely depending on the choice of filler and matrix, the coating applied to the fillers, and the manufacturing route. The main reason for the popularity of PMCs is their ease of processing.

Micro-sized spheres of glass are being manufactured for a wide variety of uses in research, medicine, consumer goods and various industries. But its potential as a reinforcing element in polymers has not been adequately explored. Glass micro-spheres have several advantages and can be preferred over irregular ones in many engineering applications due to their low surface area to volume ratio, high density, good flowing ability and close sizing etc.

In 60s and 70s, numbers of researchers have investigated the relationship between the morphology, structure and properties of glass bead filled polymer composites [1-3]. Among them, Hasselman and Fulrath [1] were first to proposed a fracture theory. They derived a quantitative relationship and studied the effect of dispersed phase on the strength of the two-phase body. Broutmann and Sahu [2] studied the effect of interfacial bonding on the toughness of glass microsphere filled epoxy and polyester. Sahu and Broutmann [3] again took the same polymers and evaluated the mechanical properties of composite filled with solid glass microsphere of 30 micron size. They found the effect of surface treatment of glass particles on the strength of the interfacial bonding.

SGM are being used commercially with various resin, both thermoplastics and thermosets, mainly to improve its mechanical properties. Ramsteiner and Theysohn [4] studied the effect of shape and content of the glass beads on the tensile property of polymer composites and derived a model for the same. Liang and Li [5] found the effect of content and surface treatment of glass microsphere on the impact properties of the glass beads-polypropylene composites and found that with increase in filler impact energy increases and reported that there is no effect of surface treatment on such properties. Liang and Li [6] studied the effect of SGM content and size on mechanical properties such as Young's modulus, tensile strength, yield strength, impact strength and toughness of PP resin. They reported that with increasing filler loading in the range of 0-20 vol %, tensile modulus and yield strength increase linearly whereas, stiffness and yield strength decrease nonlinearly.Later, for same filler-matrix combination, dynamic mechanical properties were evaluated by Liang et al. [7] using dynamic mechanical analyzer and found that relative storage modulus and loss modulus including glass transition temperature increases non-linearly with filler content at 25°C. Exactly similar trend for various dynamic mechanical properties was observed for PP/SGM composite [8].

In a more recent work, Mishra and Satapathy [9] studied the heat conduction behavior of SGM reinforced epoxy matrix. They found that addition of SGM results in reduction of thermal conductivity of epoxy resin thereby improving its thermal insulation capability.Gupta and Satapathy [10] did the mechanical characterization together with study of tribological behavior of SGM filled epoxy resin. They found that with filler loading, hardness and impact strength of composite increase, whereas its tensile and flexural strength decrease marginally.

In a very recent work, Agrawal and Satapathy [11] used solid glass microsphere as filler in combination with ceramic fillers in polymer and studied its properties so that it can be used for microelectronic applications. In their early study, they used polypropylene as matrix material and reinforced glass microsphere in combination with aluminium oxide in different weight proportion and studied its various physical, mechanical, thermal and dielectric behavior. In their other work, Agrawal and Satapathy [12] used combination of aluminium nitride and solid glass microsphere and developed a hybrid composite taking epoxy as base matrix. From the analysis, they found that inclusion of hybrid combination of filler helps in enhancing the glass transition temperature. Similar hybrid combination of fillers results in decrement in the value of coefficient of thermal expansion. Further, they found that inclusion of AlN increases the thermal conductivity of epoxy matrix but inclusion of SGM decreases the thermal conductivity of the epoxy matrix. They also evaluated the mechanical, thermal and dielectric properties of epoxy composites filled with aluminum oxide and SGM and found similar improvement in thermal properties and controlled dielectric constant which are the requirement of micro-electronics material [13]. In a very recent work, Agrawal et al. [14] studied the physical, mechanical and sliding wear behaviour of epoxy composites filled with solid glass microsphere. From the analysis, it was found that most of the work reported with SGM as filler is with epoxy polymer and no work has been reported with polyester matrix.

Against this background, an attempt has been made in this research work to develop solid glass microsphere (SGM) based polyester composites using simple hand lay-up technique and to study their physical properties under controlled laboratory conditions. The physical properties include density and void content of the composite material further, the effect of change in size of the SGM on various physical properties of the composites were also taken into the consideration in present work.

2. MATERIALS AND METHODS

Material considered

Unsaturated isophthalic polyester supplied by Ciba-Geigy India Ltd. is taken as the matrix materials in the present investigation. Polyester resin composites are cost effective because they require minimal setup costs and the physical properties can be tailored to specific applications. Solid glass microsphere used as filler material in present work is procured from Scientific Ltd, Bhopal. The average size of SGM used in present work is 50 μm, 100 μm and 150 micron. In present investigation, the soda-lime glass is used in the form of microspheres and known as solid glass microsphere. These are also known as glass beads which provide multiple benefits including enhanced processing excellent chemical and heat resistance and thermally stable. Solid glass spheres have high crush strength which makes them suitable for high stress applications where microspheres are exposed to a lot of stress during processing or application.

Composite Fabrication

In the present investigation, SGM-polyester composite is fabricated using simple hand lay-up technique. The fabrication of composite using hand lay-up method involves following steps:

1. The room temperature curing polyester and corresponding hardener methyl ethyl ketone peroxide (MEKP) are mixed in which hardener is added 2 % by weight as recommended.
2. SGM will then add to the polyester-hardener combination and mixed thoroughly by hand stirring.
3. Before pouring the polyester/filler mixture in the mould, a silicon spray is done over the mould so that it will be easy to remove the composite after curing. The uniformly mixed dough is then slowly poured into the mould so as to get the specimens.
4. The cast is than cured for 24 hours before it was removed from the mould. In this process exothermic reaction between the matrix and hardener occur which hardened the composite body in this specified duration.

Composites were fabricated with different weight fraction of filler ranging from 5 wt. % filler to 25 wt. % filler. Three categories of composites are fabricated with different particle size.

Physical Characterization

The experimental density (ρce) of composites under study is determined by using Archimedes principle using distilled water as a medium (ASTM D 792-91). The theoretical density (ρct) of composite materials in terms of weight fractions of different constituents can easily be obtained using rule of mixture model. The volume fraction of voids in the composites is calculated using measure and calculated density.

3. RESULTS AND DISCUSSION

With the help of Archimedes method, density of neat polyester is predicted as 1.12 g/cm^3 which match with the value of density provided by the supplier. Hence, for evaluating the density of particulate filled composites, the same method is adopted. The densities of the filled composites were also evaluated theoretically. From the measured and the theoretical values, the amount of air got trapped while fabricating the composites can be evaluated. It can be symbolized as the void content generated within the composites body. All the three values, i.e. theoretical values, measured values and the corresponding void content for all three categories of composites i.e. polyester composites prepared with 50-microns SGM, 100-microns SGM and 150-microns SGM were presented in table 1, table 2 and table 3 respectively. Lot of important finding was produced from the generated data. Firstly, it was observed that density of the composite increased when the SGM is added inside the matrix body irrespective of the size of fillers. This increasing trend in the value of density is obvious as the intrinsic density of filler in more as compared to the intrinsic density of the polyester.

Table 1: Theoretical density, measured density and void content of polyester composites with 50-microns sgm

Set No.	Composition	Theoretical density (g/cm^3)	Measured density (g/cm^3)	Void content (%)
Set A1	Polyester + 5 wt. % SGM (50 microns)	1.148	1.141	0.66
Set A2	Polyester + 10 wt. % SGM(50 microns)	1.179	1.166	1.07
Set A3	Polyester + 15 wt. % SGM(50 microns)	1.210	1.193	1.43
Set A4	Polyester + 20 wt. % SGM(50 microns)	1.243	1.221	1.83
Set A5	Polyester + 25 wt. % SGM(50 microns)	1.279	1.248	2.43

Table 2: Theoretical density, measured density and void content of polyester composites with 100-microns sgm

Set No.	Composition	Theoretical density (g/cm^3)	Measured density (g/cm^3)	Void content (%)
Set B1	Polyester + 5 wt. % SGM(100 microns)	1.148	1.138	0.92
Set B2	Polyester + 10 wt. % SGM(100 microns)	1.179	1.162	1.41
Set B3	Polyester + 15 wt. % SGM(100 microns)	1.210	1.189	1.76
Set B4	Polyester + 20 wt. % SGM(100 microns)	1.243	1.216	2.23
Set B5	Polyester + 25 wt. % SGM(100 microns)	1.279	1.242	2.90

Table 3.theoretical density, measured density and void content of polyester composites with 150-microns sgm

Set No.	Composition	Theoretical density (g/cm^3)	Measured density (g/cm^3)	Void content (%)
Set C1	Polyester + 5 wt. % SGM(150 microns)	1.148	1.136	1.09
Set C2	Polyester + 10 wt. % SGM(150 microns)	1.179	1.159	1.67
Set C3	Polyester + 15 wt. % SGM(150 microns)	1.210	1.186	2.01
Set C4	Polyester + 20 wt. % SGM(150 microns)	1.243	1.212	2.56
Set C5	Polyester + 25 wt. % SGM(150 microns)	1.279	1.238	3.22

Further, it is seen from the table that with increase in the size of SGM, there will not be any change in the theoretical density as the density of SGM does not change with size of filler. But the measured density varied with filler size for a given content. Composites prepared with bigger size particles possess less density as compared to the composites prepared with smaller size particles. The increase in density for three set of composites are not a high value and be considered within the acceptable limit.

Further, it can also be noted from the tables that the calculated values are higher as compared to the values obtained from experimentation for every category of composites. Also, it is observed that void content slightly increases with filler content, but still they remain within the desired limit. The maximum void content for category I composite is 2.43 %. Similarly, maximum void content for category II and category III composites are 2.90 % and 3.22 %. With increase in the size of filler, density reduces and is mainly because of the presence of void content. Presence of voids is the significance of weak material. Hence, it can be said that, composite prepared with larger size particles are week as compared to the composites prepared with smaller size particles. Although maximum possible measures were taken to minimize the percentage of void fraction, but composites were fabricated by hand lay-up method, hence generation of voids in the composite cannot be avoided.

4. CONCLUSIONS

This experimental investigation on SGM filled polyester composites has led to the following specific conclusions:

1. Solid glass microsphere (SGM) possesses ample reinforcing potential to be used as a filler material in polymer matrices. Successful fabrication of polyester matrix composites reinforced with solid glass microsphere is possible by simple hand-lay-up technique.

2. With increase in content of SGM, density of the composites increases irrespective of the size of filler. Further, for smaller size filler increase of density is high as compared with large size filler.

3. These SGM filled composites possess very low amount of porosity. The maximum void content is reported to 3.22 % by volume, which is very less when the composite is fabricated by hand lay-up method. Again, it is observed that void content are increases with filler content and filler size.

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