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# Mechanical Properties of Solid Glass Microsphere Filled Polyester-Based Composites

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**ABSTRACT:** Present work comprises of fabrication and mechanical characterization of Solid glass microsphere (SGM) filled polyester composites. For fabrication of three different category of composites, three different sizes of SGM is taken as filler material. The size of filler selected are 50 microns, 100 microns and 150 microns. The content of SGM is varied from 5 wt. % to 25 wt. % and total five sets are prepared for each size of filler. The prepared samples are undergone for mechanical testing to study the effect of filler content and its size of various mechanical properties of the material. The various mechanical properties under study are tensile strength, flexural strength, impact energy and hardness. From the experimental analysis, they found that inclusion of SGM improves most of the mechanical properties. Further, smaller size particles enhance the mechanical properties in much better way as compared to the composites prepared with larger size particles.

**KEYWORDS:** Polyester, solid glass microsphere, tensile strength, flexural strength, impact energy, hardness.

## I. INTRODUCTION

Glass microspheres are of two types i. e. solid glass microsphere (SGM) and hollow glass microsphere (HGM). SGMs are a kind of small solid spherical particles with a smooth surface, whereas HGMs consist of an outer smooth stiff glass and an inner space filled with inert gas. Both types of glass microspheres are considered as potential fillers for polymer resin which are being used in various industries. Moreover, glass beads are preferred as fillers especially where properties like isotropy or low melt viscosity are of prime importance which does not create a source of stress concentration in the matrix unlike other long fibers or irregular shape fillers which have sharp edges leading to stress generation in the matrix and in turn early failure of the composites. In addition, because of the good flow properties of the glass microsphere filled composites, the power consumption in processing can be reduced to improve wearing of the equipment, which is beneficial to raise the production efficiency [1]. 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.

SGM are being used commercially with various resin, both thermoplastics and thermosets, mainly to improve its mechanical properties. Ramsteiner and Theysohn [2] 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 [3] 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 [4] 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. [5] 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 [6].

In a more recent work, Mishra and Satapathy [7] 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 [8] 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 [9] 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 [10] 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 aluminium oxide and SGM and found similar improvement in thermal properties and controlled dielectric constant which are the requirement of micro-electronics material [11]. In a very recent work, Agrawal et al. [12] 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 mechanical properties under controlled laboratory conditions. The mechanical properties include tensile strength, flexural strength, impact energy, hardness of the composite material. Further, the effect of change in size of the SGM on various mechanical properties of the composites were also taken into the consideration in present work.

## II. MATERIALS AND METHODS

### A. Material considered

75 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.  $\mu\text{m}$ , 100  $\mu\text{m}$  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 are 50

### B. 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 added 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 then 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. In total fifteen sets of composites are fabricated for evaluating the various mechanical properties of composites in order to investigate the effect of filler content and particles size.

### C. Mechanical Characterization

The tensile strength of the composite specimen is measured using universal testing machine (UTM) Tinius Olsen. ASTM D3039 tensile testing is used to measure the force required to break a polymer composite specimen and the extent to which the specimen stretches or elongates to that breaking point. The flexural test measures the force required to bend a beam under three-point loading conditions. The three-point bend test was carried out in Universal Testing Machine (UTM) in accordance with ASTM D790 to measure the flexural strength of the composites. Leitz micro-hardness tester is used to determine the micro-hardness of the fabricated composite. The tests are in accordance with ASTM E384. In order to determine the impact energy of the test specimen in present analysis, Izod impact test is



performed following ASTM D256 standard which is used for plastic materials. The size of the specimen for the impact test was  $64 \times 12 \times 3$  mm<sup>3</sup>.

### III. RESULTS AND DISCUSSION

#### A. Tensile strength

The tensile strength of all the fabricated samples are measured by universal testing machine and are shown in figure 1. From the figure it is observed that the tensile strength of composite decreases slightly with increase in filler content irrespective of the size of filler. The minimum tensile strength among the various fabricated samples was of sample with 25 wt. % of SGM for all size of SGM. Further it is observed that, composites prepared with smaller size particles delivers better tensile strength as compared to composites prepared with larger size particles. This is due to the less void content in smaller particle size composites than large particle size composite. This signifies that composite fabricated with small size particles behaves better under tensile loading condition.

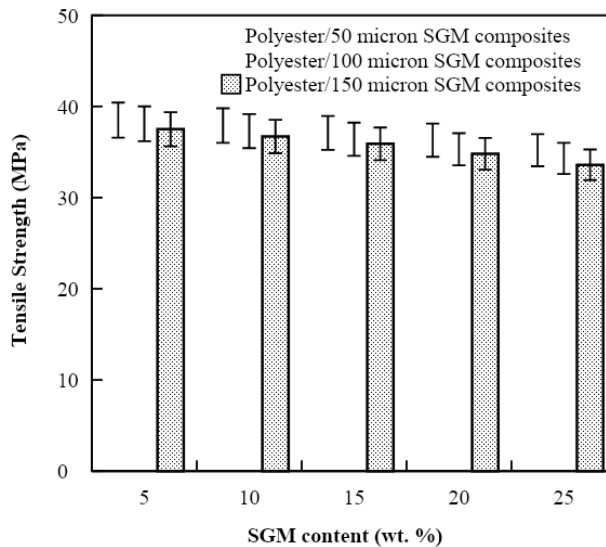


Fig. 1 Tensile strength of polyester/SGM composites as a function of filler content and particle size

The reduction in tensile strength with increase in filler reinforcement may be due to the weak chemical bond between filler and the matrix body which is unable to transfer the tensile load.

#### B. Flexural Strength

The flexural strength of different sets of composites are presented in figure 2. It is observed from the figure that there is a gradual increase in the value of flexural strength with increase in filler content irrespective of the size of the SGM used. The maximum flexural strength among the various fabricated samples was of sample with 25 wt. % of SGM for all size of SGM. Further it is observed that, composites prepared with smaller size particles delivers better flexural strength as compared to composites prepared with larger size particles. Similar behaviour is observed in case of tensile strength measurement as well. The reason behind the result is same. This is due to the less void content in smaller particle size composites than large particle size composite. This signifies that composite fabricated with small size particles behaves better under bending loading condition.

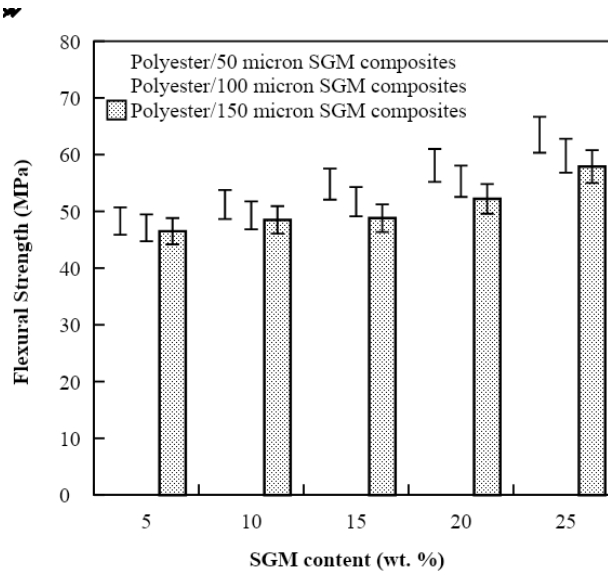


Fig. 2 Flexural strength of polyester/SGM composites as a function of filler content and particle size

C. Impact energy

The effect of filler content on the impact energy of the fabricated composites is shown in figure 3. It is seen from this figure that impact strength is gradually increasing with addition of SGM in polyester. Maximum impact energy is obtained for composites containing 25 wt. % of SGM irrespective of the size of filler. Further it is observed that, composites prepared with smaller size particles delivers better impact energy as compared to composites prepared with larger size particles. Similar behavior is observed in case of tensile strength and flexural strength measurement as well. The reason behind the result is same. This is due to the less void content in smaller particle size composites than large particle size composite. This signifies that composite fabricated with small size particles absorb more amount of energy under impact loading condition. When glass bead-filled polyester composites receive an impact force, the beads will induce crazes in the matrix around the surface because of stress concentration, and will increase surface area to absorb the impact fracture energy. At the same time, the beads play a role in hindering the propagation of the crack. Thus, the toughness of the composites can be significantly improved by the addition of glass beads to the polyester matrix.

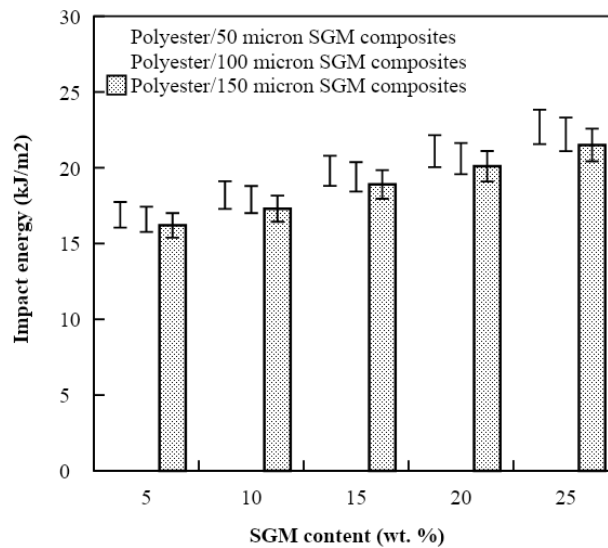


Fig. 3 Impact energy of polyester/SGM composites as a function of filler content and particle size

#### D. Hardness

In the present work, the micro-hardness of the fabricated composites is measured using Leitz micro-hardness tester. The presently used equipment works on the principle of Vicker's hardness testing method. The results obtained during the experimentation of are shown in figure 4.

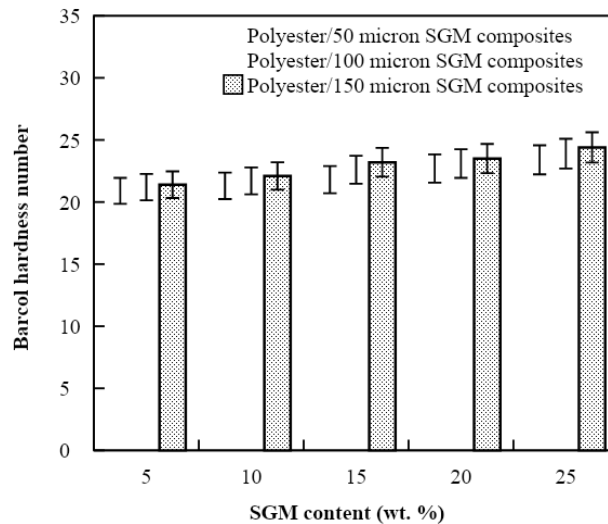


Fig. 4 Barcol hardness number of polyester/SGM composites as a function of filler content and particle size

In the present work, the micro-hardness of the fabricated composites is measured using Leitz micro-hardness tester. The presently used equipment works on the principle of Vicker's hardness testing method. The results obtained during the experimentation of are shown in figure 4. It can be seen from the figure that larger size particles are more impact on improving the hardness of material as compared to smaller size particles when the content of filler remains constant. The increase in hardness of composites with increase in content of SGM is because by the addition of SGM, the material gains its resistance to the indentation.

#### IV. CONCLUSION

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

- Successful fabrication of polyester matrix composites reinforced with SGM is possible by simple hand-lay-up technique.
- With increase in filler content an improved value of micro-hardness is reported. The hardness is very much dependent on the size of the filler. Larger size particles improve the hardness of composites in a larger rate as compared to smaller size particles
- It is reported that with increase in filler content, there is a marginal decrement in the value of tensile strength, which is mainly because of the generation of voids. Composites with smaller size particles possess higher tensile strength as compared to the composites prepared with larger size particles.
- With increase in filler content, flexural strength and impact energy increases as well and maximum improvement is reported for composites prepared with smaller size SGM. Void content are less for composites with smaller size particles.
- It is concluded that, smaller size particles are beneficial for improving tensile strength, flexural strength and impact energy, whereas, for improving the hardness, larger size particles are more impactful in polyester resin. From the overall investigation, it can be said that, composites prepared with smaller size SGM delivers better properties as compared to composites with larger size particles



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