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Mechanical Study of ZrO_2 & MoS_2 filled Epoxy Composites

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Abstract: ***Polymer matrix composites have been used in a variety of application. Because of their several advantages such as relatively low cost of production, light weight, easy to fabricate and superior strength to weight ratio. The performance of the composites can further be improved by adding particulate fillers to them. Ceramics are gaining importance due to their non-carcinogenic and bio-degradable nature. The $ZrO_2$is a ceramic material of prime importance. It has good thermal insulation, high electron conductivity due to present of free oxygen ion. In our work we have used ZrO_2& MoS_2 as the filler and by varying Wt. %. As ZrO_2 is a Ceramic and MoS_2 is a solid lubricant. The specimen was prepared by sit casting techniques. The testing of samples was done as per the ASTM standards. The mechanical properties such as tensile strength, flexural strength, Impact strength, hardness and density test were studied and found that the inclusion of fillers have increased the mechanical properties of composites as compared to bare polymer specimen.***

Keywords: Composites, ceramics, solid lubricant, ASTM, Stir casting techniques, mechanical properties

1. Introduction

In recent time drastic change in the production of fiber, filler reinforced composites applications due to their high strength and less weight. Composites are widely used in many industrial applications such as structural, aerospace, automobile and chemical. Due to addition of fillers in polymeric composites not only improve the mechanical and tribological property but also reduces cost and consumption of resin material. Polymeric composites are promising in mechanical and tribological application due to possibility of tailoring their properties with addition of fillers. [1]Zirconium dioxides possess excellent properties like high strength, high toughness, excellent wear resistance, high hardness and excellent chemical resistance. Hence zirconium dioxide Nano particle appears as attractive option to be used for reinforcement of polymer in order to produce composites with enhanced performance. [2]Epoxy is an excellent engineering thermoset plastic and its composites were evaluated for mechanical and abrasive wear performance.

The composites filled with fiber and solid lubricants both play an important role in influencing the performance of neat polymer in a beneficial manner. The Mos_2 proved to be beneficial in abrasive wear mode, and acted to deteriorate the mechanical performance. [3].The composites prepared by addition of zirconium and chopped carbon fiber have lead to improvement in the mechanical properties and the same time it improves the bonding strength. High thermal conductivity and high bending strength was obtained when Zr. content was 13.9 % [4]. There is significant improvement in the mechanical properties of zirconium oxide Nano composites from epoxidized soy bean oil. Almost 24% increase in the tensile properties with reinforcement of 7 % wt.ZrO_2 particle in the composites. [5]Specific fillers are added to modify the quality of composites, since it plays important role in determining the physical and mechanical properties of composites. Many industrial application of glass fiber reinforced epoxy composites, behavior plays important role. Experimental results shows composites with 10 % vol. Mg $(OH)_2$ maximum ultimate tensile strength, and composites filled Sic shows excellent impact strength, flexural strength and hardness.[6]

The mechanical properties of composites filled with metal powder were studied and results show that successful fabrication of the fillers was possible. Incorporation of these fillers improved the mechanical properties. The tensile strength was increased of composites with filler content when compared with unfilled composites. More ever the hardness was increased by 54% as compared with unfilled composites. [7]Graphite reinforced epoxy composites with different particulates fractions of graphite were investigated for mechanical properties; the graphite was varied from 2% to 8% by weight. Results show the mechanical properties depend upon dispersion condition of the filler particles, particle size and aggregate structure. Mechanical properties were also increased with addition of graphite in composites. [8]The behavior of silicon dioxide on mechanical and dry sliding wear behavior of glass-epoxy composites were investigated. The influence of sliding distance, sliding velocity and applied load on dry sliding wear behavior has been considered using Taguchi orthogonal array. Addition of SiO_2 increases the mechanical properties of Glass-epoxy composites. Tribological results showed increasing wear volume with increase in sliding distance, load and sliding velocity for Sio_2 filled glass epoxy composites. The SEM images of worn surfaces of composites samples of composites at different test parameters shows smooth surface, micro ploughing, and fine grooves under low load and velocity.[9]. The mechanical properties of wood dust reinforced epoxy composites focusing on natural fiber since they have small density, high strength, low cost, light weight, recyclability and biodegradability. The wood dust was taken 0-15 wt. % with difference of 2.5. Tensile test and flexural test were conducted as per the ASTM standards. Results show that inclusion of wood dust improves the mechanical properties of polymeric resin. The best mechanical properties were observed at 10% wt. filler and speed of 1mm/min and 2mm/min.[10]

2. Material and Methods

Epoxy resins a type of polymers thermo set, receive a lot of attention in polymer science because of its low viscosity, high service temperature as well as chemical resistance and stability. As compared to thermoplastics, thermo sets are used more often in demanding application, particularly as a matrix in polymer composites system. Araldite AW 106 & Hardener HV 953U Huntsman International (India) Pvt. Ltd. was purchased from local market. Zirconium oxide (97%) and Molybdenum disulfide (99%) was supplied from Otto chemie Pvt. Ltd., Mumbai. ZrO_2known as is a ceramic known for its resistance to crack propagation and high thermal expansion.$MoS_2$is the inorganic compound with the formula MoS_2It is a silvery black solid that occurs as the mineral molybdenite, the principal ore for molybdenum. Specimens were prepared in a mould of size given below. The mould conforms to the specifications necessary for laboratory testing. The dimension of die is 200mm length x 25mm width x 8mm thickness for mechanical testing samples shown in figure 2.

Figure 1: Epoxy Resin & Hardener

Figure 2: Metallic Die for specimen preparation

Stir casting techniques was used for specimen preparation. Stir casting technique is the simplest method. The infrastructural requirement for this method is also minimal. The processing steps are quite simple. The fabrication of the polymer matrix composites was done at room temperature. The required mixture of resin and hardener were made by mixing them in (1:1) part in a beaker by stirring the mixture in a beaker by a rod taking care that no air bubble should be entrapped inside the solution. The required ingredients of resin, hardener, Zirconium dioxide and molybdenumdisulphide were mixed thoroughly in the beaker. Then the mixture was poured in the metallic mould cavity coated with a silicon based release agent. The compositions of filler used are shown in table 1.The curing time was about 40 minutes at 100^0C. The samples prepared for mechanical test are shown in figure3. The mechanical testing was done according to ASTM standards at Central Institute of Plastic Engineering and Technology (CIPET), Aurangabad and ELCA labs, Pune.

Table 1: Nomenclature of Material Fabrication for Mechanical Testing

Material Designation	Epoxy (Wt. %)	ZrO_2 (Wt. %)	MoS_2 (Wt. %)
C0	100	00	00
C1	87.5	00	12.5
C2	87.5	2.5	10
C3	87.5	5	7.5
C4	87.5	7.5	05
C5	87.5	10	2.5
C6	87.5	12.5	00

Figure 3: Mechanical Testing Sample

3. Experimental Study

Tensile strength indicates the ability of a composite material to withstand forces that pull it apart as well as the capability of the material to stretch prior to failure. The most commonly used specimen geometries are dog-bone and the straight side type with end tabs. During the test a uni-axial load is applied through both the ends of the specimen. The tensile strength was conducted according to the ASTM D638 standard on computerized universal testing machine make was Shimadzu – Japan, model was Autograph, and range of machine was 1-100KN. The dimensions were as follows length (L), width (d) and thickness (t) of the test specimen used in the experimentation was 165mm, 12.7mm and 7.5mm respectively.

Flexural strength is the ability of the composite material to withstand bending forces applied perpendicular to its longitudinal axis. Flexural test were performed using 3-point bending method according to ASTM D790 standard procedure. Make was Shimadzu – Japan, model was Autograph, and range of machine was 1-100KN. The dimensions were as follows length (L), width (d) and thickness (t)of the test specimen used in the experimentation as 127mm, 12.7mm and 7.5m respectively. The flexural strength of composites was found out using the following equation

$$\tau = \frac{3fl}{2btt} \quad (1)$$

Where τ is the flexural strength, f is the load, l is the gauge length, b is the width and t is the thickness of the specimen under test.

Impact strength of a material is defined as the property of a material by virtue of which the material opposes it fracture under stress applied at high speed. The tests are done as per ASTM D 256 using an impact tester Impact strength of a polymer composite material is entirely related to its toughness as a whole. The instrument used for impact test in present study is Izod Impact Tester. The pendulum impact-testing Machine ascertains the notch impact strength of the material by shattering the V-notched Specimen with a pendulum hammer, measuring the spent energy, and relating it to the cross Section of the specimen

Hardness may be defined as a material's resistance to permanent indentation. Durometer, like many other hardness tests, measures the depth of an indentation in the material created by a given force on a standardized presser foot. This depth is dependent on the hardness of the material. The basic test requires applying the force in a consistent manner, without shock, and measuring the hardness (depth of the indentation). Hardness test was conducted as per ASTM D2240 at 24^0C.

Density is a characteristic property of a substance. The density of a substance is the relationship between the mass of the substance and how much space it takes up (volume). The mass of atoms, their size, and how they are arranged determine the density of a substance. Density test was performed as per ASTM D792 standards. The equipment used was Density measurement apparatus (Precision weigh Balance) make was Mettler Toledo- Switzerland, range was 0-220gms.

4. Results and Discussion

4.1. Tensile Tests

From the graphs it is clear that if the percentage of ZrO_2 increases the tensile strength also increases up to 12.5 % wt. Initially composite having maximum amount of only MoS_2 i.e.C1 the tensile strength is also high. But when MoS_2& ZrO_2 are combined the tensile strength increases gradually shown from C2 to C6. This implies that addition of ZrO_2 increases the tensile strength in composites C2 to C6.

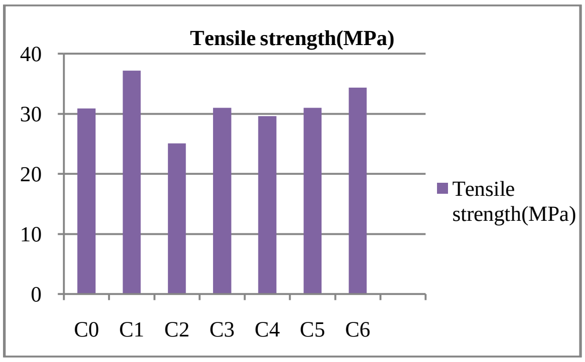


Figure 4: Tensile strength Vs. Filler contents

4.2. Flexural Strength

From the graphs it is clear that composite which have both ZrO_2& MoS_2 have flexural properties in the increasing trend i.e. if the % of ZrO_2 increases from 0 to 12.5 wt. % and MoS_2 decreases from 12.5 wt. % to 0, the flexural strength increases gradually from C2 to C5. The decreases in C4 might due to the presence of voids in the composites due to stir castings techniques.

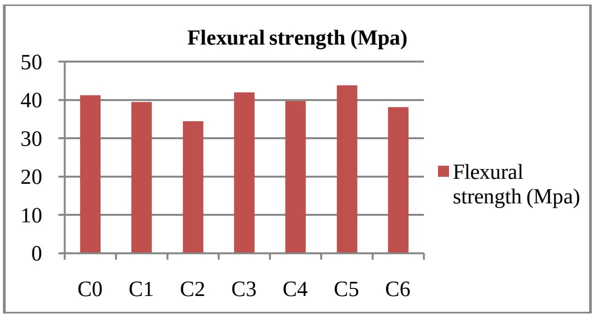
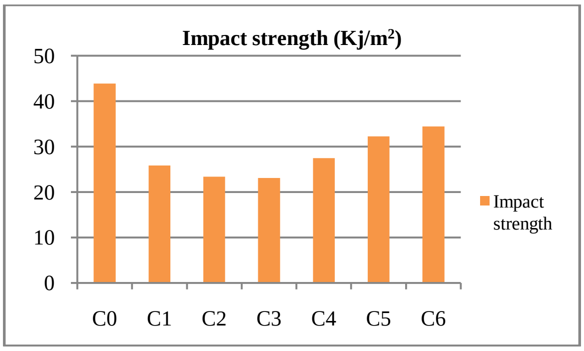


Figure 5: Flexural strength Vs. Filler contents

4.3 Impact Strength



From the graphs it is clear that composites containing no filler i.e. C0 shows good impact strength. But when the MoS_2 is high in composites C1 the impact strength is low but gradually when ZrO_2 is added the impact strength increases gradually upto ZrO_2 is at 12.5 wt.% . This implies that addition of ZrO_2 improves the impact strength.

4.3. Density Test

Figure 5 shows the density of neat polymer is 1.085 gm/cm^3 It is clear that if the composites is having maximum amount of only MoS_2(12.5 wt. %) i.e. C1 the density is 1.080 gm/cm^{3}and ZrO_2 (12.5 wt. %) i.e. C6 the density is 1.095 gm/ cm^3 shows that ZrO_2% increases the density of composites. But in combination of both fillers density increases gradually, implies that as % of zirconium dioxide increases density increases. Density of the synthesized polymer composite appeared to be more with filler wt. % by virtue of higher density of filler compared to neat polymer.

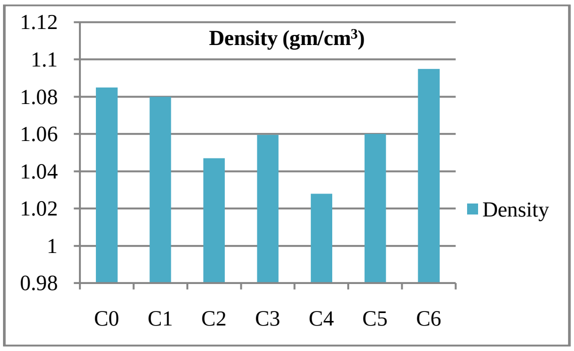


Figure 6: Density vs. Filler contents

4.4. Hardness Test

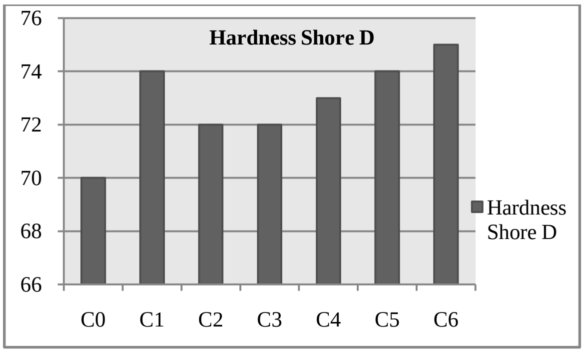


Figure 7: Hardness vs. Filler contents

Figures show that neat polymer (C0) shows least amount of hardness i.e. 70 and as the fillers % is increased the hardness increase simultaneously, from composites C2 toC6. In case of C1 there is only MoS_2 with 12.5 wt. % so it is possible that alone Mos2contribute to more hardness. But C6 has maximum amount of ZrO_2 alone and has shows maximum amount of hardness, implies that ZrO_2 contributes towards hardness.

5. Conclusion

- This work shows successful fabrication of ZrO_2& MoS_2in epoxy Matrix.
- Based on above results the mechanical properties i.e. tensile strength, flexural strength, hardness and density increases with in $ZrO_2$and decreased in Mos_2 simultaneously. Best mechanical properties were observed in C5 composites.
- Composite having fillers only MoS_2 and ZrO_2separately i.e. C1 and C6 respectively shows good Mechanical properties.

References

[1] J.S. Sidhu, G. S. Lathkar, S.B. Sharma "Mechanical properties of micro tungsten disulphide particles filled epoxy composites and its resistance against sliding wear" Malaysian polymer journal, vol. 9 No. 1, p 24-32, 2014

[2] A. Akinci, S. Sen, U. Sen " Friction and wear behavior of zirconium dioxide reinforced PMMA composites" composites : part B 56(2014) 42-47

[3] M. Sudheer, N. Karthik Madhyastha, M. Kewin Amanna, B. Jonthan and K. Mayur Jayaprakash "Mechanical and abrasive wear behavior of metal sulphide lubricant filled epoxy Composites" vol. 2013, article ID 242450, 8 pages

[4] Xiaoqing Gao, Lang Liu, Quangui, Jingli Shi, Gengtai Zhai " The effect on the microstructure and properties of chopped carbon fiber/ carbon composites" composites science and technology 67(2007) 525-529

[5] M. A. Sithique, M. Alagar, F.L. Ali khan, K.P. Nazeer " processing and characterization of zirconium oxide Nano composites from Epoxidized soy bean oil" Malaysian Polymer Journal vol. 6 No.1 p1-13, 2011

[6] K. Devendra, T. Rangaswamy "Determination of mechanical properties of Al_2O_3, Mg $(OH)_2$ and Sic filled E-glass/ Epoxy Composites" IJERA ISSN: 22248-9622 vol. 2, issue 5 September- October 2012, pp. 2028-2033

[7] Yibowei Moses, Ichetaonye Simon, Idehenre Maxwell "Mechanical Properties of Carbon Fiber and metal particles filled epoxy composites" IJETAE ISSN 2250-2459, ISO 9001:2008 vol. 3, issue 11, Nov. 2013.

[8] Subita Bhagat, Pradeep Kumar Verma "Effect of graphite on mechanical behavior of epoxy composites" ISSN 2250-2459, ISO 9001:2008 certified journal, volume 3, Issue2, February 2013.

[9] Naveed Anjum, S.L. Ajit Prasad and B. Suresha "Role of Silicon Dioxide Filler on Mechanical and Dry Sliding Wear Behavior of Glass Epoxy Composites" Hindawi publishing corporation volume 2013, article ID 324952, 10 pages.

[10] Rahul Kumar, Kaushikkumar, Sumit Bhowmik "Optimization of mechanical properties of epoxy based wood dust reinforced green composites Taguchi method" Procedia Material Science 5(2014) 688-696.

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