Studies on mechanicval behaviour of PMMA based composites

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***Abstract*—With the increasing dependence on metals, it has become the need of the situation to revert innovations on materials that are not on the verge of annihilations. Metals have been proven earnest for their exceptional properties of being lustrous, high density, high tensile strength, and high melting point and also possessing good conductive properties. But they have their own downfalls, from an engineering point of view. Despite the revolution in metallurgies, it is indisputably corrosive, limiting its applications in diverse fields. Peeking to the other spectrum, we have the polymers, revolutionizing material industries and their reliance to metals. Polymers have princely properties that outstood in materials paradigm. Garnishing our interest is the ability of the polymers to form composites, as metals do (metal-metal matrix). To revoke this detrimental property such as Low Density, eminent have come out with ideas of suffusing abrasive materials resulting in improved mechanical strengths. Microscopic investigation has ascertained the enhancements in the strength to weight ratio. The focus of our present venture is to give comprehensive review of high performance plastic materials and their applications. By reinforcing Silicon Carbide with PMMA, mechanical properties of the materials get enhanced and sustain intermittent loads.**

***Keywords—lustrous, corrosive, reliance, suffusing** (key words)*

I. Introduction

Polymer matrix composites (PMCs) have established themselves as engineering structural materials, not just as laboratory curiosities or cheap stuff for making chairs and tables. This came about not only because of the introduction of high-performance fibres such as carbon, boron, and aramid, but also because of some new and improved matrix materials. Nevertheless, glass fibre reinforced polymers represent the largest class of PMCs. Carbon fibre reinforced PMCs are perhaps the most important structural composites. Many techniques, originally developed for making glass fibre reinforced polymer matrix composites can also be used with other fibres. Glass fibre reinforced polymer composites represent the largest class of PMCs. Polymeric matrix materials can be conveniently classified as thermosets and thermoplastics. Recall that thermosets harden on curing.

Curing or cross linking occurs in thermosets by appropriate chemical agents and/or application of heat and pressure. Conventionally, thermal energy (heating to 200°C or above) is provided for this purpose. This process, however, brings in the problems of thermal gradients, residual stresses, and long curing times. Residual stresses can cause serious problems in non- symmetrical or very thick PMC laminates, where they may be relieved by warping of the laminate, fibre waviness, matrix micro cracking, and ply delamination. Electron beam curing offers an alternative that avoids these problems.

II. Structural Properties of PMC

A. *Mechanical behaviour*

Most thermoset matrix composites show elastic behavior right up to fracture, i.e., there is no yield point or plasticity. The strain-to-failure values are rather low, typically, less than 0.5%. Consequently, the work done during fracture is also small. Aramid fibre has superior impact characteristics; therefore, aramid fibre-based polymer composites will show better ballistic resistance against impact resistance in general. Similar observations can be made regarding strength characteristics of the polymer matrix composites. High damping or the ability to reduce vibrations can be very important in many applications.

Key strength of SiC over other ceramics:

- Low density
- High strength
- Low thermal expansion
- High thermal conductivity
- High hardness
- High elastic modulus
- Excellent thermal shock resistance
- Superior chemical inertness

III. LITREATURE REVIEW

This chapter covers the literature review of results obtained from Experimental Investigation of mechanical behaviour of Poly Methyl methacrylate (PMMA) based polymer composites with Silicon Carbide (SiC). Apart from the polymer composite, reinforcement used, manufacturing methods, this survey includes the developments in the mechanical behaviour of polymer based composites at different compositions of SiC reinforcements.

Polymer-based composites, especially PMMA-based composites, have gained substantial attentions as a new branch of materials due to their superb mechanical properties, high durability, impact resistance and light weight since firstly heralded in the 1960s. A series of potential applications in magneto-electric, biomedical, chemical engineering, automobile and optical field can be realized through appropriate tailoring. It is well recognized that the type of polymer matrix and its properties have a great influence on the performance of composites. However, the composites must withstand high mechanical loads in various conditions, so it is necessary to enhance mechanical properties using reinforced materials for special applications, such as in military and aerospace industry.

Diwakar Padalia et.al (2013), discussed about the fabrication and characterization of Cerium doped Barium Titanate / PMMA nano composites as a kind of suitable materials for integral thin film capacitors and electric stress control devices. $BaTiO_3$ system by cerium doping was tailored to achieve low loss and fine grains. On the other hand, the insulating PMMA shell around the $BaTiO_3$ nano particles could retard the movement of charge carriers in the nano composites and thus has the potential to surpass conventional composites to produce low dielectric loss. Different polymer nano composites were made by solvent evaporation method while cerium doped $BaTiO_3$ nano fillers were obtained via solid state reaction. In all polymer nano composites the filling level was 30% w/w and all of them were treated by micro waves (2.4 GHz). The results show that the thermal and dielectric behavior of the resulting nano composites can be improved by varying the Ce-doping in $BaTiO_3$ nano filler.

Leslie Banks-Sills et.al (2016), studied about the Experimental determination of mechanical properties of PMMA reinforced with functionalized Carbon nanotubes (CNTs). Carbon nanotubes (CNTs) are one of the strongest materials known to man. This material is a carbon allotrope like graphite, diamond and fullerene. Early references to carbon structures date back to the 1970s; but it was not until the discovery of CNTs in and the investigations that followed in the early 1990s that carbon nanotubes were produced and their potential was understood. Unfortunately, although CNTs possess excellent mechanical, thermal and electrical properties, they usually cannot be used by themselves. Nevertheless, CNTs have the potential to be used in composites of different matrices.. The goal of this investigation is to determine the mechanical properties of a PMMA matrix reinforced with functionalized CNTs and to compare the results obtained with the same material containing CNTs which were not functionalized. The CNTs were functionalized by two methods. Hence, the determined mechanical properties are also compared for the two functionalization methods. The evaluation of the mechanical properties was determined by means of tensile tests conducted on dog-bone specimens. The composite material was manufactured using a twin screw extruder. The specimens were produced by means of an Injection Moulding (IM) procedure.

IV. RESUIL AND DISCUSSION

A detailed literature survey was undertaken on polymer composites with emphasis on reinforcements, process, characterization and correlation between the microstructure and the properties like hardness, tensile strength properties as well as statistical modeling studies. Based on the literature survey, the following areas have been identified for further research.

PMMA-SiC alloy is not yet to be tried as polymer composite material. This one is easy to fabricate by means of Injection moulding or Hand Layup process due to it is better casting qualities. In particle reinforced composites, the properties of the PMMA composites was observed to depend on reinforcement type, reinforcement particle size, nature of interface, volume fraction of reinforcement. Silicon Carbide (SiC) can be used as reinforcement due to LowDensity, High Strength, Low thermal expansion, High thermal conductivity, low reactivity and also SiC is cost effective when compared to the similar property ceramic like Boron Carbide.

MATERIAL SELECTION

1. To fabricate the following by injection molding process: a. PMMA – SiC polymer composite.
i. 95% wt of PMMA - 5% wt of Silicon Carbide (SiC).
ii. 97.5% wt of PMMA – 2.5% wt of Silicon Carbide (SiC).
2. To fabricate the ASTM Standard plates with Poly Methyl Methacrylate (PMMA) as matrix and SiC as reinforcement, in different proportions.
3. To cut various sizes of ASTM Standard specimen from the fabricated plate by using Water Jet Machining (WJM) process.
4. To evaluate the mechanical behaviour of the ASTM standard specimen by performing various mechanical testing over the existing specimen of various proportions.
5. To study and evaluate the microstructure, density, hardness, and tensile strength of the above specimen and defining the change in properties occurred in comparison with a Pure PMMA.

MANUFACTURING METHODS

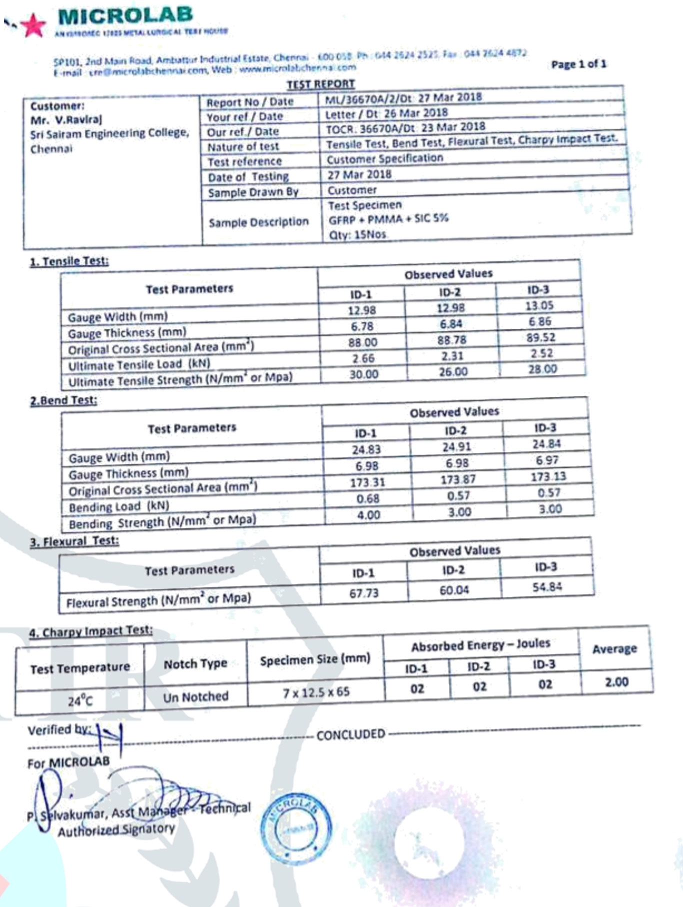
Because natural moissanite is extremely scarce, most Silicon Carbide is synthetic. Silicon Carbide is used as an abrasive, as well as a semiconductor and diamond simulant of gem quality. The simplest process to manufacture Silicon Carbide is to combine silica sand and carbon in an Acheson graphite electric resistance furnace at a high temperature, between 1,600 °C(2,910 °F) and 2,500 °C (4,530 °F). Fine SiO_2 particles in plant material (e.g. rice husks) can be converted to SiC by heating in the excess carbon from the organic material. The silicafume, which is a byproduct of producing Silicon metal and ferroSilicon alloys, also can be converted to SiC by heating with graphite at 1,500 °C (2,730 °F).

Fig 1. Synthetic SiC crystals (~3 mm in diameter)

Fig 2. Synthetic SiC lely crystals

The material formed in the Acheson furnace varies in purity, according to its distance from the graphite resistor heat source. Colorless, pale yellow and green crystals have the highest purity and are found closest to the resistor. The color changes to blue and black at greater distance from the resistor, and these darker crystals are less pure. Nitrogen and aluminium are common impurities, and they affect the electrical conductivity of SiC.

Pure Silicon Carbide can be made by the Lely process, in which SiC powder is sublimated into high-temperature species of Silicon, carbon, Silicon di Carbide (SiC_2), and di Silicon Carbide (Si_2C) in an argon gas ambient at2500 °C and redeposited into flake-like single crystals, sized up to 2×2 cm, at a slightly colder substrate. This process yields high-quality single crystals, mostly of 6H-SiC phase (because of high growth temperature). A modified Lely process involving induction heating in graphite crucibles yields even larger single crystals of 4 inches (10 cm) in diameter, having a section 81 times larger compared to the conventional Lely process. Cubic SiC is usually grown by the more expensive process of chemical vapor deposition (CVD). Homo epitaxial and hetero epitaxial SiC layers can be grown employing both gas and liquid phase approaches. Pure Silicon Carbide can also be prepared by the thermal de composition of a polymer, poly(methyl silyne), under an inert atmosphere at low temperatures. Relative to the CVD process, the pyrolysis method is advantageous because the polymer can be formed into various shapes prior to thermalization into the ceramic.



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TEST REPORT

Customer: Mr. V.Raviraj Sri Sairam Engineering College, Chennai	Report No / Date	ML/36670A/2/Dt: 27 Mar 2018
	Your ref / Date	Letter / Dt: 26 Mar 2018
	Our ref / Date	TOCR. 36670A/Dt: 23 Mar 2018
	Nature of test	Tensile Test, Bend Test, Flexural Test, Charpy Impact Test.
	Test reference	Customer Specification
	Date of Testing	27 Mar 2018
	Sample Drawn By	Customer
	Sample Description	Test Specimen GFRP + PMMA + SIC 5% Qty: 15Nos

1. Tensile Test:

Test Parameters	Observed Values		
	ID-1	ID-2	ID-3
Gauge Width (mm)	12.98	12.98	13.05
Gauge Thickness (mm)	6.78	6.84	6.86
Original Cross Sectional Area (mm^2)	88.00	88.78	89.52
Ultimate Tensile Load (kN)	2.66	2.31	2.52
Ultimate Tensile Strength (N/mm^2 or Mpa)	30.00	26.00	28.00

2.Bend Test:

Test Parameters	Observed Values		
	ID-1	ID-2	ID-3
Gauge Width (mm)	24.83	24.91	24.84
Gauge Thickness (mm)	6.98	6.98	6.97
Original Cross Sectional Area (mm^2)	173.31	173.87	173.13
Bending Load (kN)	0.68	0.57	0.57
Bending Strength (N/mm^2 or Mpa)	4.00	3.00	3.00

3. Flexural Test:

Test Parameters	Observed Values		
	ID-1	ID-2	ID-3
Flexural Strength (N/mm^2 or Mpa)	67.73	60.04	54.84

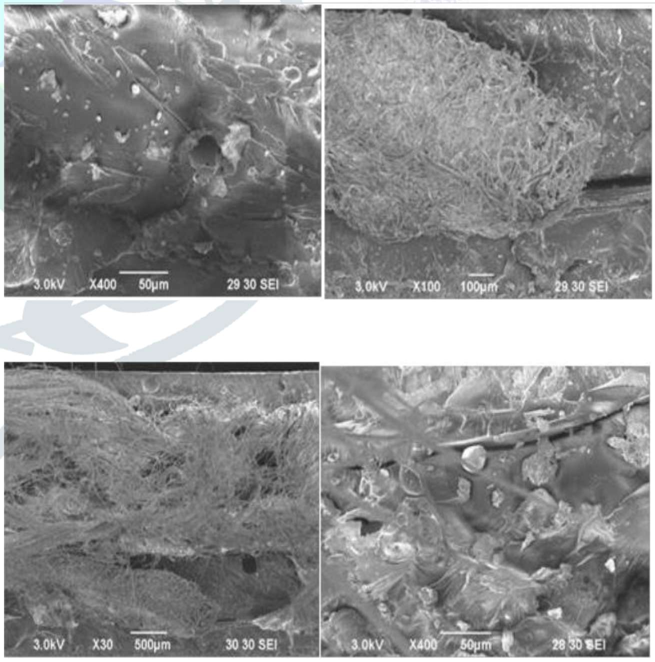
4. Charpy Impact Test:

Test Temperature	Notch Type	Specimen Size (mm)	Absorbed Energy – Joules			Average
			ID-1	ID-2	ID-3	
24°C	Un Notched	7 x 12.5 x 65	02	02	02	2.00

Verified by: ---------- CONCLUDED ----------

For MICROLAB

P. Selvakumar, Asst Manager - Technical
Authorized Signatory



V. CONCLUSION

SiC:B4C/PMMA composites were successfully prepared by injection moulding process and its mechanical properties were demonstrated in this work. A marginal reduction in tensile strength and significant improvement in hardness was noticed with an increase in the SiC content in the bend. To evaluate the mechanical properties at intermediate SiC composition within the range of 2.5 wt% and 5 wt% , [4]quadratic polynomial fit curves were generated and it was observed that the tensile strength of 46.57 MPa and 46.93 MPa respectively. Polymer parts are lighter and therefore provide immense advantages over metal by offering lower life time freight costs for equipment that is regularly transported or handled over the products lifetime. Our research on reinforcing PMMA with SiC has shown valuable outcomes, thereby enlisting this composite as a viable alternative.

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