



Review on Recent Advancements in the Field of Reinforced Epoxy Nano Composites

Sandesh K S¹, Mahesh V M², Muralidhara B K³

¹Research Scholar, ²Assistant Professor, ³Professor

Department of Mechanical Engineering

^{1,2}JSS Science and Technology University, Mysore, Karnataka, India

³Nitte Meenakshi Institute of Technology, Bangalore, Karnataka, India

ABSTRACT

Composite materials especially the polymer matrix materials are well acknowledged for their applications in aerospace, automotive and structural applications. They are considerably light weight and offers high strength weight ratio. Epoxy is one of the widely used matrix material in PMCs (Polymer matrix composite) due to its exceptional bonding capabilities, it finds applications in the field of coating, adhesives and composite materials. Graphene is a novel material in the field of composite materials it offers high strength, very high electrical conduction and heat transfer. The composites of Epoxy and Graphene hybrids exhibit very high mechanical and thermal properties.

Keywords: *composites, polymer matrix, Epoxy, Graphene, hybrid, mechanical, thermal*

I. INTRODUCTION

A composite is a material made from two or more different constituent materials having different physical or chemical properties which do not merge in the finishing structure, i.e., the individual constituents retain their properties. In recent years, polymeric based composites materials are being used in many application such as automotive, sporting goods, marine, electrical, industrial, construction, household appliances, etc Polymeric composites have high strength and stiffness, light weight, and high corrosion resistance.

In engineering and material science, composites are defined as physical mixtures of chemically different materials that are insoluble in each other and are thus present as distinct phases: usually a continuous phase (matrix), and a discontinuous phase.

II. CLASSIFICATION OF COMPOSITES

A. Classification Based on Reinforcements

1. Particle-reinforced composites
2. Fiber-reinforced composites

Composites in which the dispersed reinforcing phase is present in the form of particles is called particle-reinforced composites. Composites in which the dispersed reinforcing phase in the form of fiber are called fiber reinforced composites (FRC).

B. Classification Based on Matrix

1. Polymer Matrix Composites (PMC)
2. Metal Matrix Composites (MMC)
3. Ceramic Matrix Composites (CMC)

In polymer matrix composites, the matrix phase is polymer and the reinforcing phase may be fibers or ceramic particles. These materials are used in various composite applications, and also in large quantities because of their low cost and ease of fabrication.

In metal matrix composites, the matrix is a ductile metal or alloy and the reinforcing medium is continuous like fibers of carbon, silicon carbide, boron and alumina. Discontinuous reinforcement includes silicon carbide whiskers, chopped fibers of carbon and alumina, particulates of silicon carbide and alumina.

In ceramic matrix composites, particulates, fibers or whiskers of one ceramic material are embedded into the matrix of another ceramic material. These ceramic composites have improved fracture toughness and high stress application compared to the ceramic material alone. Ceramic composite materials are

meant for high temperature applications like heat shield of re-entry spacecrafts.

III. GRAPHENE

Graphene is a semi-metal with small overlap between the valence and the conduction bands. It is an allotrope (form) of carbon consisting of a single layer of carbon atoms arranged in a hexagonal lattice. It is the basic structural element of many other allotropes of carbon, such as graphite, diamond, charcoal, carbon nanotubes and fullerenes.

Graphene has many interesting properties. It is the strongest material ever tested, efficiently conducts heat and electricity, and is nearly transparent. Graphene shows a large and nonlinear diamagnetism, greater than that of graphite. Graphene has a theoretical specific surface area (SSA) of 2630 m²/g. This is much larger than that reported for carbon black (smaller than 900 m²/g) or for carbon nanotubes (from ≈ 100 to 1000 m²/g) and is similar to activated carbon. Applications of graphene include lightweight, thin, flexible materials, lightweight electric/photonics circuits, solar cells, and various medical, chemical and industrial processes enhanced or enabled by the use of new graphene materials.

IV. EPOXY RESIN

Epoxy resins are low molecular weight pre-polymers or higher molecular weight polymers which normally contain at least two epoxide groups. The epoxide group is also sometimes referred to as a glycidyl or oxirane group. As with other classes of thermo set polymer materials, blending different grades of epoxy resin, as well as use of additives, plasticizers or fillers is common to achieve the desired processing or final properties, or to reduce cost. Use of blending, additives and fillers is often referred to as formulating.

The applications for epoxy-based materials are extensive and include coatings, adhesives and composite materials such as those using carbon fiber and fiberglass reinforcements. The chemistry of epoxies and the range of commercially available variations allow cured polymers to be produced with a very broad range of properties. In general, epoxies are known for their excellent adhesion, chemical and heat resistance, good mechanical properties and electrical insulating properties. Many properties of epoxies can be modified by adding the modifiers. In the composite production, epoxy is used as a structural matrix

material which is then reinforced by fiber. Typical fiber reinforcements include glass, carbon, Kevlar, and boron.

V. LITERATURE REVIEW

A literature review has been carried out about the recent applications in the field of Epoxy, Graphene composites with emphasis on new processing techniques and novel applications of the composite material

Mahesh *et al.* [1] studied hybrid graphene multiwall carbon nanotube reinforced epoxy composites fabricated with different weight fraction of the reinforcements. The composites are subjected to hardness test as well as tensile test. The mechanical properties of these composites are investigated and increase in hardness and young's modulus with increased weight fraction of the reinforcements is observed.

Mahesh *et al.*, [2] developed carbon nanotube reinforced epoxy hybrid materials for enhanced wear resistance. The reinforcement of carbon nanotube showed positive effect on the wear resistance of the composite. The wear rate decreased with increased weight fractions of the reinforcements.

Czél, Jalalvand and Wisnom, [3] proposed a novel approach for eliminating stress concentration in tensile and compressive testing of unidirectional Epoxy-carbon composites, an hybrid specimen is proposed to reduce the stress concentration at the grips of the testing apparatus and to protect the underlying composite from failure. The developed specimen produced consistent gauge sections.

Leopold *et al.*, [4] studied the size effect of unmodified and Graphene nanoparticle modified matrix, fibres is experimentally investigated. Neat matrix fibres show a clear size effect of increasing tensile strength with decreasing volume due to a statistical defect distribution. The nanoparticle modified matrix shows no significant size effect.. The maximum stress in specimen of small volume depends on Graphene layer orientation, so that ideally, the covalent bonds of the nanoparticles should be orientated in loading direction.

Ervina, Mariatti and Hamdan, [5] studied the effect of filler loading on the tensile properties of Multi-walled Carbon Nanotube and Graphene nanopowder filled

Epoxy Composites, In this work, multi-walled carbon nanotube (MWCNT) and Graphene nanopowders (GNP) filled Epoxy composites were fabricated via ultrasonication and casting method. The experimental results prove that the strength and modulus of filler (MWCNT and GNP) filled epoxy composites are lower as compared to clean epoxy. However, the addition of GNP at 0.8 vol% had slightly increased the composite tensile modulus which was approximately. Thus, in general it indicates that the addition of filler (MWCNT and GNP) had reduced the mechanical properties of Epoxy composites.

Shi *et al.*, [6] calculated the Influence of microstructural features on thermal expansion coefficient in Graphene/Epoxy composites. Theoretical calculations were conducted to determine the coefficient of thermal expansion (CTE). The influences of microstructural features were investigated. Calculated results demonstrated strong anisotropy of CTE when all Graphene sheets in the composite were aligned in the in-plane direction due to the large difference between the elastic moduli of the graphene and epoxy.

Lu *et al.*, [7] made a comparison of the elastic properties of graphene and fullerene reinforced polymer composites with varying filler size and morphology. By systematically varying filler concentration, morphology, and size, they clearly identified clear trends in composite stiffness with reinforcement. Spherical fullerenes provided a nearly size-independent level of reinforcement. In contrast, two-dimensional graphene flakes induce a strongly size-dependent response.

Leopold *et al.*, [8] calculated the Influence of carbon nanoparticle modification on the mechanical and electrical properties of epoxy in small volumes. Three types of particles, representing spherical, tubular and layered morphologies are used. A clear size effect of increasing true failure strength with decreasing volume is found for neat and carbon black modified epoxy. The results show the possibility to detect internal damage in small volumes by measuring electrical resistance and therefore indicate to the high potential for using carbon nano tube modified polymers in fibre reinforced plastics as a multifunctional, self-monitoring material with improved mechanical properties.

Hallad *et al.*, [9] investigated the behaviour of a polymer matrix beam reinforced with graphene and carbon fibres at nano and micro level reinforcements, respectively, to study the strength aspects for structural applications. Reinforcement of polymer beams with graphene alone by weight of the polymer matrix showed enhanced results when compared to carbon fibres alone, while the use of combined nano and micro reinforcements showed performance lying in between nano and micro fillers in the polymer. Scanning electron microscopy and energy dispersion X-ray spectroscopy was conducted to examine the interfacial surface adhesion between the fillers and the polymer matrix.

Jarosinski *et al.*, [10] examined the possibility of increasing the thermal conductivity of the filled epoxy resin systems, applicable for electrical insulation, by the use of composites filled with graphene nanoplatelets. It is remarkable that the addition of only 4 wt.% of graphene could lead to 132 % increase in thermal conductivity. The obtained results show potential for application of the graphene nanocomposites for electrical insulation with enhanced thermal conductivity.

Jiang *et al.*, [11] developed Composites of epoxy/graphene modified diamond filler for enhanced thermal conductivity and high electrical insulation. Performance of the epoxy was improved by incorporating diamond microparticles that were covered with few-layer graphene sheets on surfaces it not only improved dispersion of diamond in the polymer matrix but it also decreased the interfacial thermal resistance between the diamond and Epoxy while preserving an excellent electrical insulation.

Gresil *et al.*, [12] studied the thermal diffusivity mapping of graphene Based polymer nanocomposites. Majidian *et al.*, [13] evaluated the role of the particle size, polydispersity in the electrical conductivity of carbon nanotube- Epoxy composites.

Zabihi *et al.*, [14] proposed a new method of large scale manufacturing of engineered graphene like nanomaterials for development of high-performance polymer nanocomposites. They introduced a quick and cost-effective approach to scalable production of functionalized graphite nanoplatelets using “kitchen blender” approach and Diels-Alder chemistry.

Watson *et al.*, [15] studied the Tensile and Flexural Properties of Hybrid graphene oxide / epoxy carbon fibre reinforced composites. Nano sized graphene oxide sheets were homogenously dispersed via sonication methods in Epoxy followed by vacuum resin infusion for the fabrication of the epoxy, graphene oxide (GO) and micro-sized carbon fibre reinforced nanocomposites (EP/CF/GO). graphene oxide concentrations ranging from 0.1 – 0.5 wt. % were studied to investigate the effect on tensile and flexural strength. It was observed that the tensile strength of the EP/CF decreased with the addition of GO but increased with GO weight concentration for the inclusion of 0.1 to 0.5 wt.% GO respectively.

Ramos-Galicia *et al.*, [16] studied the enhancement of mechanical properties of epoxy/graphene nanocomposites. Two types of Epoxy composite were developed which are epoxy /graphene nanocomposite and epoxy/modified graphene nanocomposite. The fabrication of graphene was going through thermal expansion and sonication process. Chemical modification was only done for modified graphene where Methylene diphenyl diisocyanate (MDI) is used. The mechanical properties of both nanocomposite, such as Young's modulus and maximum stress were investigated, for maximum stress, neat Epoxy showed the best result compared to both nanocomposite due to the changes of material properties when adding the filler into the matrix.

Zhang *et al.*, [17] developed a novel method for preparing polymer/graphene oxide nanocomposites by using two-step strategy composed of in situ polymerization and melt process. Pickering emulsion-templated polystyrene (PS)/graphene oxide (GO) composite microspheres were prepared using surface-functionalized silica as the stabilizer. These preformed polymer/GO composite microspheres were then melt-blended into polymer matrix to prepare nanocomposite materials in a short minute using HAAKE torque rheometer.

VI. CONCLUSION

From the above literature survey it is clear that the polymer composites' applications are increasing rapidly, and graphene as a novel material is being used extensively in newer applications. Graphene as a filler material significantly improves the properties of the composite material developed. Although multiple extensive researches are being carried out in the field

of polymer graphene composites the applications are ever increasing.

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