Research Paper
International Journal of Aerospace System Engineering
Vol.7, No.1, pp.16-20 (2020)

ISSN 2383-4986
EISSN 2508-7169
http://dx.doi.org/10.20910/IJASE.2020.7.1.16

Effect of graphite particulate on mechanical properties of glass fibre reinforced composite

Antara Bhattacharjee†, Kanchan Roy, B.K. Nanda
Department of Mechanical Engineering, National Institute of Technology Rourkela
India
†E-mail:antarabhattacharjee91@gmail.com

Abstract

The recent trend is increasing towards the usage of polymer matrix composites since they have a wide variety of applications. They have applications in the field of aircraft and space industry, sporting goods, medical devices, marine and automotive applications and also in commercial usage. The most commonly used fibre-reinforced polymer matrix composite is Glass fibre reinforced epoxy (GFRE) composite which is used in aviation, sports and automotive industries. However, the strength of GFRE composites is not adequate for structural applications. Therefore, the current research focuses on increasing the strength of GFRE composites by reinforcing with micro Graphite (Gr) particulates. The Gr used is an ultra-fine powder with particle size 250 μm. Gr is known to have good wear resistance, thermal conductivity and can operate at high temperatures. Gr particulates are mixed with the epoxy matrix in various weight ratios. Hand-lay technique is used for fabricating the composites. Mechanical properties such as tensile strength, elongation, compressive strength and flexural strength are obtained experimentally to study the effect of change in Gr content (0-5 wt. %). The tests were done as per ASTM standards.

Key Words : GFRE, Gr particulates, Tensile strength, Flexural strength, Compressive strength

1. Introduction

In the past few years, the demands of polymer matrix composites (PMC) have rapidly increased due to certain advantages such as easy manufacturing, lesser production cost, high strength and stiffness, superior fatigue and damping properties. Moreover, PMCs can be fabricated in any desired shape with lesser energy consumption. Various types of polymer are used for manufacturing composites such as epoxy, polyester, urethane etc. PMCs can be reinforced by either short or long fibres or even particulates. Of all these polymers, epoxy is widely used as matrix material and is usually reinforced with glass fibres. Glass fibres are widely used due to their easy availability and less cost. However, the strength and stiffness of the PMCs are enhanced if both fibre and particulates are used for reinforcements. Therefore, the current research focuses on improving the mechanical properties of glass fibre reinforced epoxy (GFRE) composites by adding Graphite (Gr) particulates.

Agarwal et al. [1] have shown that addition of SiC particulates enhances the thermo-mechanical properties of GFRE composites. Suresha et al. [2] have demonstrated that filling glass epoxy composite with graphite particulates improves the mechanical properties such as hardness, tensile strength, tensile modulus, percentage elongation as well as wear resistance. Sun et al. [3] demonstrated that adding graphite to epoxy enhances the elastic strength and moduli of the composites. The hardness of epoxy

Received: Oct. 13, 2018 Revised: Jul. 15, 2019 Accepted: Dec. 28, 2020
† Corresponding Author
Tel: +91-8018281480, E-mail: antarabhattacharjee91@gmail.com

was found to increase with a decrease in the size of SiC nanoparticles by Birru et al. [4]. Baptista et al. [5] observed that increasing graphite content of carbon fibre reinforced epoxy matrix composites increases the elastic modulus, shear modulus and flexural shear modulus of the composite. Shalwan et al. [6] have shown that the addition of graphite enhances the wear characteristics of the polymer composites.

Therefore, the current research focuses on the study of the effect of the addition of Gr particles as filler material on the mechanical properties of GFRE composites.

2. MATERIALS AND METHODS

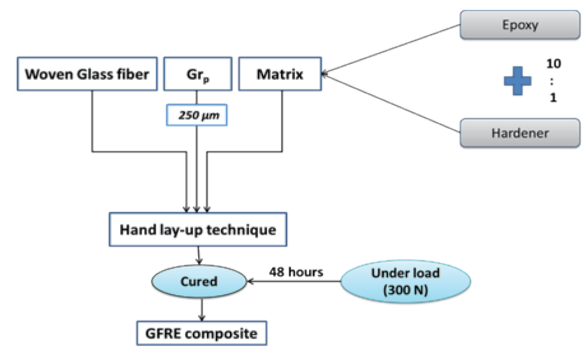
2.1. Fabrication of composites

The composite materials are fabricated by hand layup technique. Woven E-glass fibre mat is taken as reinforcement with epoxy resin and hardener under trade-name Bisphenol-A-Diglycidyl ether and tri-ethylene tetra-amine respectively. Graphite particles are used as filler material. The average size of graphite particles is 60 mesh or 250 μm. The combinations of weight percentage of the various components used for manufacturing composites are given in Table 1.

Table 1 Composite designations and constituents

Composite	Glass fibre content wt. %	Matrix content wt.%	Gr particulate content wt.%
C1	50	50	0
C2	49	50	1
C3	47.5	50	2.5
C4	45	50	5

The epoxy and hardener are mixed in the weight ratio of 10:1 at room temperature. A mould of dimension 250 ×150× 20 mm is used for composite fabrication. The filler material is mixed with epoxy and hardener according to requirement. Mould relieving spray and sheet is used to cover the mould surface. A sonicator is used to ensure proper mixing of epoxy and hardener in which the liquids are thoroughly mixed using ultrasonic vibrations for three minutes. Moreover, the epoxy-hardener mixture is made as per the number of laminate layers for proper matrix coating on the glass fibres. Hand roller is used on each layer of woven laminate to remove any trapped gas or tangled fibres. The composite is cured at room temperature for 48 hours under a constant weight 300 N. The number of laminates is determined from the volume fraction of the constituents using the rule of mixture. A detailed



description of the fabrication steps is explained with the help of a flowchart, as shown in Fig. 1.

Fig. 1 Flowchart depicting fabrication of GFRE filled Gr composite

2.2. Experimentation details

Composite samples are prepared for the tensile test as per ASTM standard ASTM3039-76. The effective length of the specimens is maintained 152 mm, with an average thickness of 5 mm. The tensile tests are performed in the Universal testing machine (INSTRON UK/SATEC 600 kN) at a cross-head speed of 2 mm/min. Microstructural analysis of the fractured surfaces of the broken tensile samples is done using scanning electron microscopy (SEM, Model: JEOL-JSM 6480LV). Samples for flexural tests are prepared as per ASTM standard ASTM D2344-84. Compressive test samples are prepared as per ASTM standard D7137/7137M. Three sets of experiments are conducted, and the average value is considered for better accuracy.

3. RESULTS AND DISCUSSIONS

3.1. Tensile properties

The engineering stress-strain curves for the four composite samples are obtained from the tensile tests. The stress vs strain plot for the four composites is presented in Fig. 2. It can be observed from the figure that the tensile strength decreases with increase in Gr content, whereas a reverse trend occurs for the tensile strain of the composites.

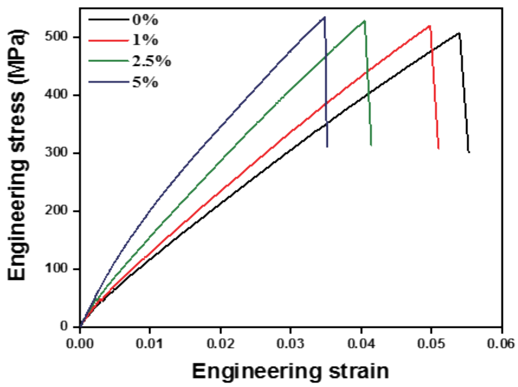


Fig. 2 Engineering stress-strain plot of the GFRE composites

This variation of tensile strength and strain with Gr particles content is shown in Figs. 3 and 4 respectively. It is observed in Fig. 3 that tensile strength increases with increase in Gr filler content.

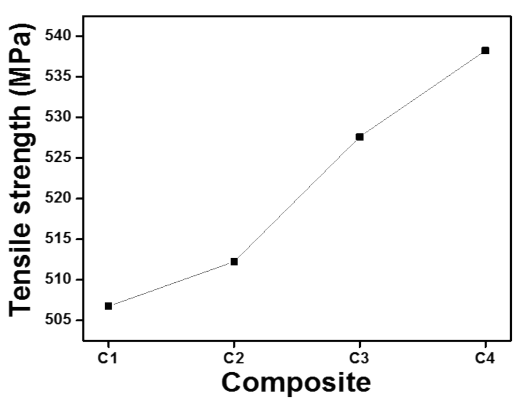


Fig. 3 Effect of Gr particle content on the tensile strength of GFRE composites

It is observed that the tensile strain decreases with increase in Gr particles content, as shown in Fig. 4. This is due to the uniform distribution of Gr particles on the matrix, which improves the tensile strength of the composites. Moreover, the high strength and aspect ratio of Gr particulates, as well as good interfacial adhesion between epoxy and Gr particles, also attributes to the increased strength. However, the increased concentration of Gr particles makes the composite more brittle.

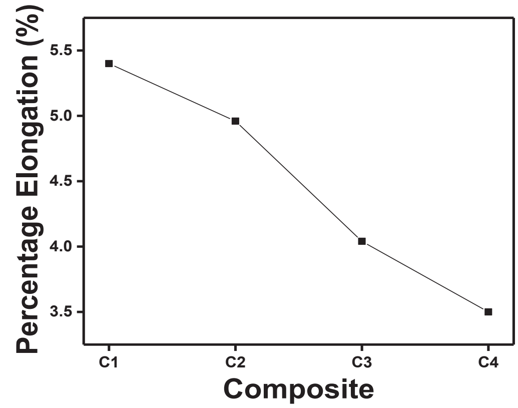


Fig. 4 Effect of Gr particle content on the ductility of GFRE composites

Typical SEM image of the fracture surface of the composite samples is shown in Figs 5-8. From Figs. 5 and 6, it is found that the fibre-matrix delamination and fibre pull out are the major reasons for fracture. However, Figs. 7 and 8 reveal different morphology for fracture in Gr filled GFRE composites. Fibre imprints on the matrix layer, matrix crumbling, and fibre-matrix de-bonding can be observed in these two images. Moreover, simultaneous breakage of fibre-matrix has occurred, which proves better interfacial adhesion [Figs. 7 and 8] which led to a higher tensile strength.

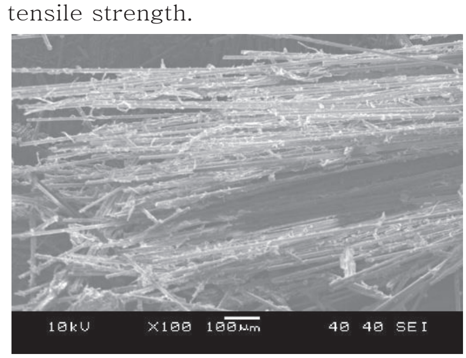


Fig. 5 Fracture surface morphology of C1 composite

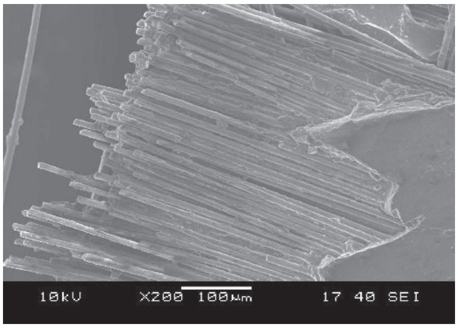


Fig. 6 Fracture surface morphology of C2 composite

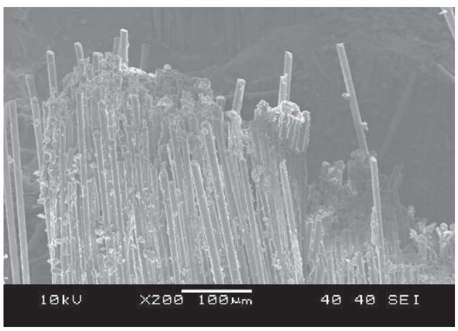


Fig. 7 Fracture surface morphology of C3 composite

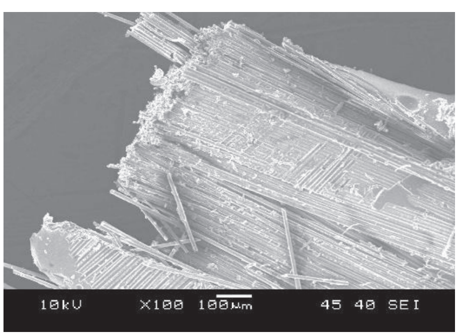


Fig. 8 Fracture surface morphology of C4 composite

3.2. Flexural strength

The flexural strength of the GFRE composites reinforced with Gr fillers with different % filler loading is plotted in Fig. 9. From Fig. 9, it is observed that the flexural strength of the GFRE composite increases with increase in Gr particles content. The increase in flexural strength occurs due to the increased bonding between the Gr/glass fibre and matrix, which helps in transferring loads across the specimen. Moreover, the uniform dispersion of Gr particles in the matrix restricts the propagation of the failure in the loading direction. This also attributes to the increased flexural strength of the GFRE composites.

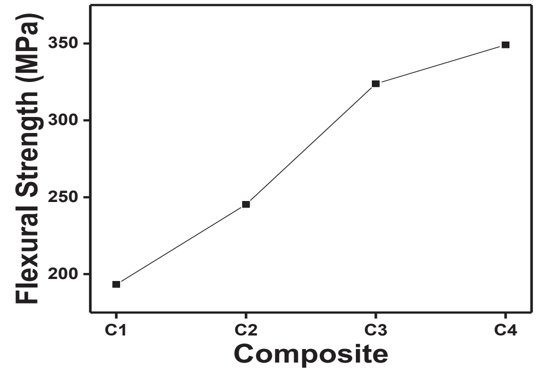


Fig. 9 Effect of Gr particle content on flexural strength of GFRE composites

3.3. Compressive strength

The variation in compressive strength of the GFRE composites with Gr particles content is shown in Fig. 10. It can be observed that on the addition of Gr particles there is a steep rise in compressive strength of GFRE composite. However, when the Gr content increased from 1 to 2.5 wt. % there is a marginal increase in compressive strength, which further decreases with increase in Gr content beyond 2.5 wt. %. The increased wt.% of Gr leads to a reduced matrix content which results in an ineffective transfer of load from one part to another. This minimizes the bonding and thus, the compressive strength of the composite.

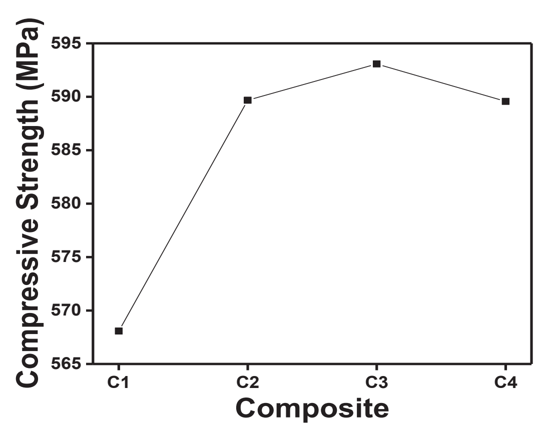


Fig. 10 Effect of Gr particle on compressive strength of GFRE composites

4. Conclusions

The experimental study of the effect of graphite particles reinforcement on the mechanical properties of GFRE composites has led to the following conclusions. It is found that the tensile strength of GFRE composites increases with increase in Gr filler content, whereas there is a decrease in the tensile strain of the composites. The increased tensile strength of the GFRE is due to the high strength and aspect ratio of Gr particles as well as uniform distribution of the filler particles resulting in good interfacial adhesion between the filler and the matrix. It is also observed that the flexural strength of the GFRE composite increases with increase in Gr particles content. The increased bonding between the Gr/glass fibre and epoxy matrix helps to transfer the load across the specimen, thus increasing flexural strength. Further, it is witnessed that on the addition of Gr particles there is a steep rise in compressive strength of GFRE composite. However, there is a marginal change in the value of compressive strength of GFRE composite with the increase in Gr filler content.

References

[1] G. Agarwal, A. Patnaik, and R.K. Sharma, "Thermo-mechanical properties of silicon carbide-filled chopped glass fiber-reinforced epoxy composites", Intl. J. Adv. Struct. Engg., vol. 5, no. 1, pp. 21-28, 2013.

[2] B. Suresha, G. Chandramohan, N.M. Renukappa, and Siddaramaiah, "Mechanical and tribological properties of glass-epoxy composites with and without graphite particulate filler", *J. App. Poly. Sci.*, vol. 103, pp. 2472-2480, 2006.

[3] Sun, Chin-The, and K. J. Yoon, "Mechanical properties of graphite/epoxy composites at various temperature", *High temperature materials information analysis center* west Lafayette in, 1988.

[4] A. K. Birru, G. K. Reddy, G. Ajay and N. K. Kumar, "Effect of reinforced Silicon Carbide Nanoparticles in Epoxy Composites", *Mater. Today: Proc.*, vol. 2, pp. 4348 – 4352, 2015.

[5] R. Baptista, A. Mendao, F. Rodrigues, C. G. Figueiredo-Pina, M. Guedes and R. Marat-Mendes, "Effect of high graphite filler contents on the mechanical and tribological failure behavior of epoxy matrix composites", *Theor. Appl. Fract. Mec.*, vol. 85, pp. 113–124, 2016.

[6] A. Shalwan and B. F. Yousif, "Influence of date palm fibre and graphite filler on mechanical and wear characteristics of epoxy composites", *Mater. Design*, vol. 59, pp. 264–273, 2014.