Jayaseelan et al. 2015. *Int. J. Vehicle Structures & Systems*, 7(4), 165-168
ISSN: 0975-3060 (Print), 0975-3540 (Online)
doi: 10.4273/ijvss.7.4.10

International Journal of Vehicle Structures & Systems
Available online at www.maftree.org/eja

Effect of Graphene Filler Content on Mechanical Strength and Hardness for Goat Hair Fibre Reinforced Epoxy Composites

J. Jayaseelan[a,c], P. Palanisamy[a], K.R. Vijayakumar[a] and A. Dhanam Maria Vinita[c]

[a]*Mech. Engg. Dept., Advanced Research Institute,*
Dr. MGR Educational and Research Institute University, Maduravoyal, Chennai, India
[b]*Corresponding Author, Email: see_lan@yahoo.com*

[c]*National Centre for Nano Science and Nano Tech., University of Madras, Guindy Campus, Chennai, India*

ABSTRACT:

Graphene when mixed in small quantity to host matrix like epoxy improves the mechanical, thermal and electrical properties. Fabrication of natural composite is made with goat hair as fibre with 37.5% fibre content by weight and graphene filled epoxy as matrix to enhance the properties. In the process of composite fabrication, five layers of goat hair fibre is sandwiched using resin by compression moulding method. Four composite specimens respectively epoxy with no Graphene content and 0.25% to 0.75% Graphene filled epoxy matrix are tested for tensile strength, flexural strength, impact strength and hardness. The mechanical properties of the four composite specimens are analysed. The experimental test results have demonstrated that graphene filled epoxy matrix reinforced with goat hair fibre specimens had better mechanical properties than composite with no graphene content.

KEYWORDS:

Goat hair fibre; Graphene; Epoxy matrix; Nanomaterials; Mechanical strength; Hardness

CITATION:

J. Jayaseelan, P. Palanisamy, K.R. Vijayakumar and A. D.M. Vinita. 2015. Effect of Graphene Filler Content on Mechanical Strength and Hardness for Goat Hair Fibre Reinforced Epoxy Composites, *Int. J. Vehicle Structures & Systems*, 7(4), 165-168. doi:10.4273/ijvss.7.4.10

1. Introduction

Composite material consists of two or more chemically distinct constituents on a micro scale with a defined interface separating them. One or more discrete phase is embedded in a continuous phase to form a composite. The discontinuous phase made of fibre is usually harder and stronger than the continuous phase and is called the reinforcement, whereas the continuous phase made of resin is termed as matrix. There is increase in demand for environmental friendly materials such as natural fibre composites to replace the traditional fibre (i.e. carbon, glass and aramid fibre) composites [1, 2, 5, and 12]. The reasons are: biodegradability, less emissions to the atmosphere, abundant, renewable, availability and can be produced at low cost in many parts of the developing world. In recent years, composite materials have found increasing applications in construction, aerospace and automotive industries due to light weight, improved strength, corrosion resistance, controlled anisotropic properties. However, there is a growing demand to improve on composite materials with reduction in the cost of manufacture [3].

Goat hair is a natural fibre extracted from the goat hide. Goat hair has got potential mechanical properties like length varying between 30 to 120mm, bulk density between 1.10 to 1.25 gm/cc, diameter between 80 to 105 microns, tensile strength between 80 to 110 MPa, moisture absorption around 7%, and elongation at shear between 30 to 60%, bio-degradable, eco-friendly, smooth, wear resistant, soft, elastic, low-cost and available in plenty [4]. Even though goat hair is used for many applications not much attention and work has been tried out in composite applications. Disposal of goat hair in tannery process is a perennial problem. When graphene is added in minute quantity with epoxy matrix, it improves the mechanical performance, thermal conductivity, electrical conductivity and permeation barrier properties of a range of composites [6].

In comparison with carbon nanotubes, graphene exhibits potential advantage of low cost, high surface area, ease of processing and safety [7], excellent thermal conductivity [8] and strong mechanical strength [9]. Gouda [10] has studied the effect of adding 0.2% multi-walled carbon nano tubes (MWCNT) and graphene on the mechanical properties of glass carbon epoxy hybrid composite by varying fibre content. They concluded that modulus of elasticity was increased by 10 to 15% and also sustained greater loads, flexural strength was decreased by adding graphene fillers, impact strength and hardness were increased by 37% and 12.34% respectively in case of composite made with graphene and MWCNT respectively. Delamination and fibre breakage are minimal by adding graphene and MWCNT fillers. Fibre pullout is seen in tensile and flexural loadings, but with impact load there is less fibre pullout. These factors influenced the authors to study the hybrid goat hair fibre composite by varying the graphene nano filler content in the epoxy matrix.

2. Test specimens preparation

The present investigation has been carried out with compression moulded composite specimens with various proportions of graphene content. Graphene, a fluffy, very light weight powder is a nano powder generated from graphite by chemical exfoliation method. Its diameter in x and y dimensions are between 10 to 20 microns and thickness in z direction is between 3 to 6 microns. Its purity is between 96 to 99%. Average number of layers is between 3 to 6. Thermal conductivity is 3000 W/mK, very high surface area between 323 to 600m^2/g, bulk density is 0.241 gm/cc, high aspect ratio is about 1000, tensile strength is more than 5GPa and tensile modulus is more than 1000GPa. Graphene layers are entirely disassociated ensuring good dispersion and ease of handling while enhancing the performance [17]. Goat hide is purchased from a goat slaughter house. Within 10 hours of slaughter, the goat hide is soaked in boiling water for two minutes and goat hair is pulled out from hide manually. Goat hair fibre is washed thoroughly many times in warm water, then using mild detergent and dried. It is washed again with acetone and finally washed in warm water, then dried in sunlight. Dried goat hair is manually separated and inspected for presence of foreign particles. Dust free goat hair is measured using weighing scale and prepared as layers manually. Each layer of goat hair fibre measures 10 grams. Five layers of goat hair, as shown in Fig. 1(a), are used to fabricate the composite specimens.

Epoxy resin is the most widely used material due to its prevalent mechanical and thermal properties even at elevated temperatures and low shrinkage after curing and great synthetic safety. LY556 Epoxy and HY951 hardener are used as matrix material with a mixing ratio of 10:1 by weight [11]. The epoxy matrix of 62.5% by weight is used. The platen before moulding is shown in Fig. 1(b). Graphene of 0.25% to 0.75% by weight is added to epoxy and then mixed thoroughly by mechanical means to get uniform distribution. Graphene filled epoxy and hardener is mixed in the ratio 10:1 and composite is fabricated using compression moulding. Moulds measuring 360mm×360mm×10mm are used for composite fabrication by compression moulding. Mould set is placed in the compression moulding press under a pressure of 105 bar and left undisturbed for 36 hours and then the finished composite plate, as shown in Fig. 1(c), is released from the mould. Table 1 shows the composition of fibre and graphene filled epoxy matrix for the fabricated composite specimens.

Fig. 1: (a) Goat hair layer; (b) Goat hair layer reinforced epoxy; (c) Compression moulded composite specimen

Table 1: Composition of composite specimens

Specimen	Goat hair fibre (% weight)	Epoxy matrix (% weight)	Graphene filler (% weight)
Composite 1	37.5	62.50	0
Composite 2	37.5	62.25	0.25
Composite 3	37.5	62.50	0.50
Composite 4	37.5	62.75	0.75

3. Results and discussion

3.1. Tensile test

Tension testing is a fundamental materials science test in which a specimen is subjected to a controlled tension until failure [13]. Composite specimens are tested for tensile strength as per ASTM D638-03 test standard. Figs. 2(a) and (b) show the tensile test results of all four specimens. The tensile strength and elastic modulus are given in Table 2. It is observed that addition of graphene has a positive effect of enhancing the tensile strength and tensile modulus of composite. This result is in agreement with the work done by Gouda [10] and [18].

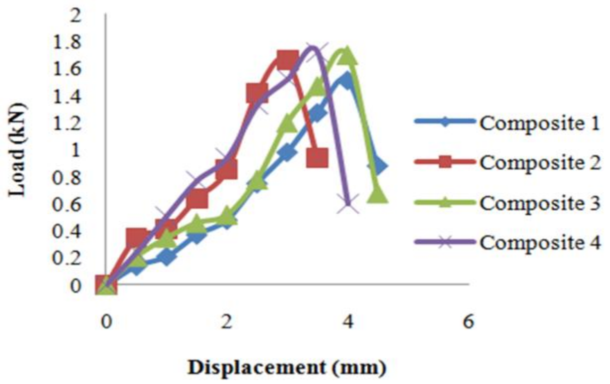

Fig. 2(a): Load vs. Displacement

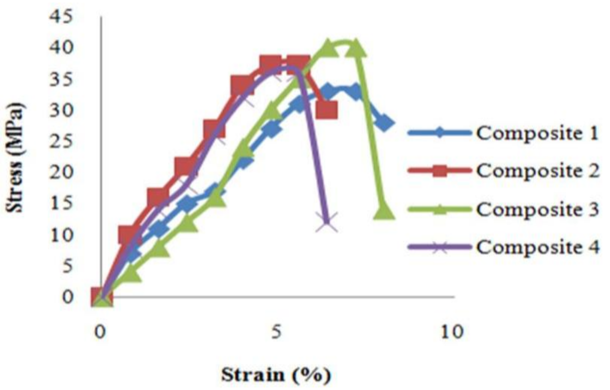

Fig. 2(b): Stress vs. Strain

Table 2: Ultimate strength and Young's modulus of composites

Specimen	Ultimate strength (MPa)	Young's modulus (MPa)
Composite 1	33	515
Composite 2	37.2	581
Composite 3	40	625
Composite 4	36	562

3.2. Flexural test

Flexural strength is defined as the material's ability to resist deformation under load. Flexural test is conducted as per ASTM D790 standard. The transverse bending test is the most frequently employed test, in which a specimen having either a circular or rectangular cross-section is bent until fracture using a three point contact technique [14-15]. From flexural test results as shown Fig. 3 and Table 3, it is observed that addition of graphene enhances the flexural strength and flexural modulus of composite. Composite 1 has got the least flexural strength (2.30MPa), whereas Composite 2, 3 and 4 show better tensile strength than Composite 1. Upto 0.75% graphene addition, a marginal increase in flexural strength is observed.

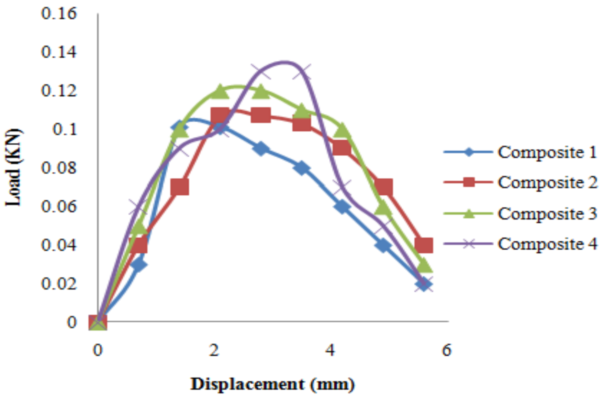

Fig. 3: Flexural load vs. Displacement

Table 3: Flexural strength of composite specimens

Specimen	Flexural strength (MPa)	Diff. with Composite 1
Composite 1	2.3	-
Composite 2	2.76	+20%
Composite 3	2.91	+26.5%
Composite 4	3.14	+36.5%

3.3. Impact test

The charpy impact test is carried out as per ASTM D256 standard. The charpy v-notch test is a standard high strain rate test which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of composite materials notch toughness and acts as a tool to study temperature-dependent ductile-brittle transition. From impact results, as shown in Table 4, it is observed that addition of graphene enhances the impact energy of composite. It is observed that, up to 0.5% graphene addition, the impact energy has increased. At 0.75% Graphene, the impact energy has dropped.

Table 4: Impact energy of composite specimens

Specimen	Impact Energy (J)	Diff. with Composite 1
Composite 1	0.7	-
Composite 2	0.85	+21.4%
Composite 3	1	+42.8%
Composite 4	0.75	+7.1%

3.4. Hardness test

Hardness test is carried out at room temperature as per ASTM D2240 using durometer hardness tester [16]. A 1/4" ball indenter of the tester is pressed into the material under hand pressure on the knob which is at the top of the instrument. The hardness of the specimen tested is indicated directly on the dial gauge of the instrument. From Table 5, it is observed that addition of graphene enhances the hardness of composite. The mechanical properties of graphene filled epoxy reinforced with goat hair fibre composites are found to increase with increase in graphene content upto 0.5%. The reason for this trend may be attributed to the possible hydrogen bonding between the hydroxyl and carbonyl groups of graphene with that of epoxy resin system. Beyond 0.5% graphene content, marginal drop in tensile, impact, interlaminar properties are noted. It may be due to possible agglomeration at high graphene content.

Table 5: Hardness of composite specimens

Specimen	Hardness (HRL)	Diff. with Composite 1
Composite 1	52.3	-
Composite 2	65.6	+25.4%
Composite 3	79.2	+51.4%
Composite 4	82.9	+58.5%

3.5. Scanning Electron Microscope (SEM)

SEM image has been captured for Composite 1. SEM images with ×150 and ×500 magnifications are shown in Figs. 4(a) and (b). It is observed that there are no voids left, epoxy distribution is uniform, compaction is good, fibres are randomly distributed evenly and also bonding of goat hair with epoxy is good.

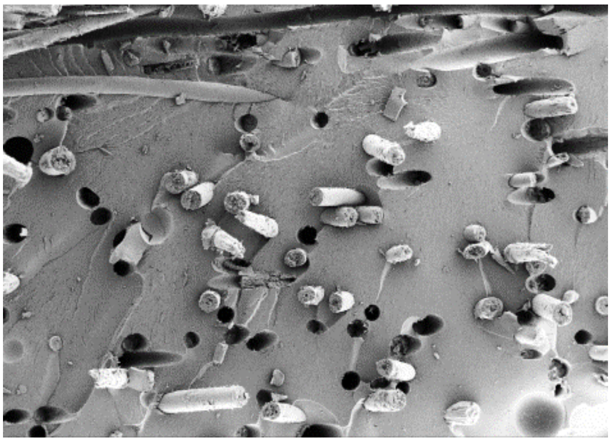

Fig. 4(a): SEM image of Composite 1 specimen, ×150 magnification

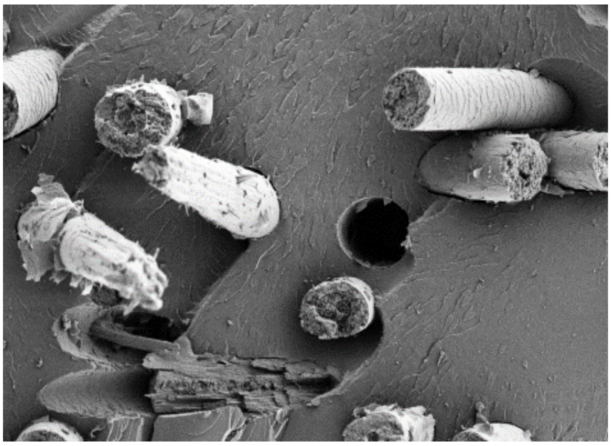

Fig. 4(b): SEM image of Composite 1 specimen, ×500 magnification

4. Conclusions

Addition of graphene nano particle with epoxy matrix, upto 0.50%, reinforced with goat hair fibre has improved the mechanical properties of composite like tensile strength, flexural strength, impact strength and hardness. However at 0.75% graphene addition, a reduction in tensile strength, impact strength and a marginal increase on hardness and flexural strength were observed. By adding graphene upto 0.5%, the tensile strength was increased by 18%, flexural strength was increased by 21%, impact strength was increased by 30%, and hardness was increased by 34%.

ACKNOWLEDGEMENTS:

The authors express sincere thanks to Er. A.C.S. Arun Kumar, Dr MGR. Educational Research Institute University, Chennai and its management and faculties for providing opportunity to do this research work. Authors also thank Dr. P. Aravindan, Dr. P. Palanisamy and all the colleagues at Advanced Research Institute for their guidance, suggestions, inputs, support and encouragement throughout this research.

REFERENCES:

[1] D. Chandramohan and K. Marimuthu. 2011. A review on natural fibers, *Int. J. Research and Review in. Applied. Science.*, l8(2), 194-206.

[2] S. Choudhry and B. Pandey. 2012. Mechanical behaviour of polypropylene and human hair fibres, *Int. J. Mechanical and Industrial Engineering*, 2(1), 118-121.

[3] M.M. Thwe and K. Liao. 2003. Durability of bamboo-glass fibre reinforced polymer matrix hybrid composites, *Comp. Sci. Tech.*, 63(3-4), 375-387. http://dx.doi.org/10.1016/S0266-3538(02)00225-7.

[4] S. Negahdari and M. Salehiranian. 2012. The survey on quantity and quality of hair produced by goats under fars province conditions, *J. Applied Animal Science*, 2(1), 27-32.

[5] M.S. Sreekala, J. George, M.G. Kumaran and S. Thomas. 2002. The mechanical performance of hybrid phenol-formaldehyde-based composites reinforced with glass and oil palm fibres, *Comp. Sci. Techno.*, 62, 339. http://dx.doi.org/10.1016/S0266-3538(01)00219-6

[6] F.H. Gojny, M.H.G. Wichmann, B. Fiedler, W. Bauhofer and K. Schulte. 2005. Influence of nano-modification on the mechanical and electrical properties of conventional fibre-reinforced composites, *Composites Part A: Applied Science and Manufacturing*, 36, 1525-1535. http://dx.doi.org/10.1016/j.compositesa.2005.02.007.

[7] M. Segal. 2008. Selling graphene by the ton, *Nat. Nanotech*, 4, 611-613.

[8] A.A. Balandin, S. Ghosh, W.Z. Bao, I. Calizo and D. Teweldebrhan. 2008. Superior thermal conductivity of single-layer Graphene, *Nano Letters*, 8, 902. http://dx.doi.org/10.1021/nl0731872

[9] C.X. Lee, D. Wei and J.W. Kysar. 2008. Measurement of the elastic properties and intrinsic strength of monolayer graphene, *Science*, 321, 385-388. http://dx.doi.org/10.1126/science.1157996.

[10] P.S.S. Gouda. 2013. Effects of multi walled carbon nanotubes and graphene on the mechanical properties of hybrid polymer composites, *Adv. Mat. Lett.*, 4(4), 261-270.

[11] Czichos and Horst. 2006. *Handbook of Material Measurement Method*, Springer, Berlin.

[12] J. Mussig. 2010. *Natural Fibre-Reinforced Polymers in Automotive Interior Applications*, John Wiley & Sons.

[13] A.M. Marc and C.K. Kumar. 1998. *Mechanical Behaviour of Materials*, Prentice Hall.

[14] D.H. Pahr, F.G. Rammerstorfer, P. Rozenkrans, K. Humer and H.W. Weber. 2002. A study of short-beam-shear and double lap shear specimens of glass fabric/epoxy composites, *Composites Part B*, 33, 125-132. http://dx.doi.org/10.1016/S1359-8368(01)00063-4.

[15] K.T. Kedward. 1972. On the short beam test method, *Fibre Science and Technology*, 5, 85-95. http://dx.doi.org/10.1016/0015-0568(72)90001-2.

[16] ASTM D2240: *Standard Test Method for Hardness*.

[17] W.C. Buong and N.A. Ibrahim. 2012. Graphene nanoplatelets as novel reinforcement filler in poly (lactic acid)/epoxidized palm oil green nano composites, Mechanical Properties, *Int. J. Molecular Science*, 13(9), 10920-10934. http://dx.doi.org/10.3390/ijms130910920.

[18] J. Jayaseelan, P. Palanisamy and K.R. Vijayakumar. 2013. Design fabrication and characterisation of nano-tubes reinforces epoxy carbon fibers, *Int. J. Applied Research*, 3(2), 228-231.

EDITORIAL NOTES:

Edited paper from National Conference on Technological Advances in Mechanical Engineering TAME 2015, 20 August 2015, Chennai, India.

GUEST EDITOR: Dr. K. Umanath, Dept. of Mech. Engg., VelTech HighTech Dr. Rangarajan Dr. Sakunthala Engg. College, Chennai, India.