Investigation of Tensile Behaviour of Graphene Composites

B. Vijaya Ramnath, N Abishek, J. Melvin Antony, D. Kumaran and C. Nikhil Kumar

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B.Vijaya Ramnath[1], N.Abishek[2], J.Melvin antony[1], D.Kumaran[1], C.Nikhil kumar[1].

[1]Department of Mechanical Engineering, Sri Sairam Engineering College,

West Tambaram, Chennai-44.

[2] Engineer (R&D),Brakes India Pvt Limited, Chennai.

***Corresponding author mail ID: vijayaramnathb@gmail.com**

Abstract

In this paper potential solution to the production of nature fibre composite laminates using graphene has been discussed. It explores the effect of graphene when it is reinforced with hemp fibre and its ability to withstand erratic environment. In this work, Hemp fibers of two different laminates with graphene are prepared. The manufacturing of composites was done by hand layup method by blending graphene with epoxy resin of grade LY556 along with hardener HY 951. This leads to laminate formation with 2% graphene nano platelets. The mechanical properties namely tensile behaviours are analysed due to the inclusion of graphene is found.

Keywords: Fiber composites, tensile properties, SEM analysis

1.0 Introduction

Various researchers carried out different work using hemp fiber as refinement with some other natural fibers namely jute, sisal banana etc. thet normally used epoxy resign as matrix. Few researchers used grephene mixed with epoxy resin. Some of the researches are discussed here.

Shuai Jiang et al (2016) developed the Multiscale graphene oxide/carbon fiber (GO/CF) reinforcements with polyurethane (PU) elastomer to prepare composites. GO was laminated by electrophoretic deposition which improves CF/PU interfacial shear strength. Later fibers were then mechanically mixed with GO to achieve a multiscale reinforcement. The strengthening of the matrix, especially the local buildup of fiber/matrix interphase, is beneficial for the interfacial mechanical anchoring. They found that, compared with untreated-CF/PU, individual process of EPD treatment and mechanical mixing of GO resulted in an improved strength. The enhanced reinforcing performance of GO-deposited CFs improved fiber–matrix intermolecular forces, chain entanglements or both, across the interfaces.

Xuqiang Ji et al (2016) analyzed fictionalization, arrangement and properties of graphene polymer composite fibers. Graphene can be prepared in two ways. One way is via the spinning processes which include melt spinning, electrostatic spinning and wet spinning. Another way is related to the neat fibers which are prepared firstly and then graphene is sprayed or dug on the fiber surface. Thus, graphene enhanced fibers can be used in special clothing, reinforcement of rubber and plastic, reinforcement of cement. VijayaRamnath et al (2014) evaluated the mechanical properties of abaca– jute–glass fiber reinforced epoxy composite and found that the abaca–jute hybrid composite has better properties than the abaca fiber in tensile and shear properties. The internal structure of the composite is observed under Scanning Electron Microscope (SEM) from which it is observed that fiber pull out and voids are observed due to improvement in fabrication procedure.

Dimitrios et al (2017) studied intrinsic mechanical properties of graphene-family of materials along with the preparation and characteristics of bulk graphene based nanocomposites. Based on the findings, the best quality graphene for use in nanocomposites can be considered to be material with the largest aspect ratio and with a thickness of few layers. The bonding between the filler and the matrix must also be very strong, so that efficient stress transfer can take place. Mehmet Bulut (2017) investigated the influence of graphene nano-pellets (GnPs) on mechanical properties namely tensile, flexural and impact resistance of basalt/epoxy composite laminates. They found the variation of mechanical properties by using different GnPs loading by weight ratios (0.1, 0.2 and 0.3 wt %) between epoxy and filler, controlling with full basalt/epoxy laminates (unfilled). Then, the failure characteristics of the prepared samples were presented and compared along with GnPs filler loadings. They concluded that incorporation of GnPs fillers at 0.1 wt % significantly enhanced the mechanical properties of basalt/epoxy composites due to high bonding strength at the interphase between GnPs epoxy-fiber interactions.

Zaid et al (2015) studied non-toxic and eco-friendly approach for the devaluation of graphene oxide nanosheets using natural b-carotene. The FTIR spectroscopy and thermogravimetric analysis expose the oxygen scavenging property of b-carotene and successfully removes oxygen functionalities on GO nanosheets. The high resolution transmission electron microscopy image provides clear evidence for the production of few layers of graphene nanosheets. Moreover, the mechanism of GO reduction by b-carotene has been proposed. They concluded that the electrochemical testing displays good charge storage properties of b-carotene reduced GO with stable cycling for up to 1000 cycles. The findings suggested that the devaluation of GO nanosheets by b-carotene is a applicable approach in producing graphene nanosheets for supercapacitor electrode.

Hsu et al (2015) studied effect of various solid constituents of graphene nanosheets on the mechanical properties of nanosheets and polypropylene composites formed by injection molding. The experimental results indicated that the GNS/PP composites had a maximal tensile strength of 29.54 MPa when the solid GNS content was 0.2 wt%. The flexural strength of the GNS/PP composites achieved a maximal value of 25.47 MPa when the solid GNS content was 0.4 wt%. The GNS/PP composites exhibited a maximal value of impact energy of 861.39 J/m when the solid GNS content was 0.2 wt%. they suggested that the high GNS content caused an increase in the rigidity and the Young modulus and reduced the tensile elongation and flexural and impact strength. Ovidko (2013) reviewed the research efforts taken by researchers in polymer-matrix nanocomposites containing graphen. The concluded that, due to the effects of graphene inclusions several mechanical characteristics of graphene-polymer nanocomposites increases while decrease in plasticity.

Rajesh et al (2018) investigated mechanical behaviour of natural fiber composite with respect to fiber orientation. They found that fiber orientation has its effect on mechanical behaviour of composites. Mechanical behaviour of basalt- banana fiber composites and hemp fiber composites were studied. It was concluded that hybrid composites has good mechanical behaviour the mono finer/single fiber composites. [13,16,19,10]. Mechanical behaviour of glass fiber based composites were studied and their various applications were analysed .[12,17]. Mechanical and other behaviour of natural and sandwich composites were reviewed and suggested that various works can be performed using natural fiber composites and also natural fiber composites can be used for automotive aerospace and marine applications. [14,15, 18].

2.0 Materials used

2.1 Hemp fiber

Hemp fibers are one of the strong members of bast natural fibers that are derived from the hemp plant under the species of Cannabis. Due to their good mechanical, thermal and biodegradability nowadays, these fibers are well received as reinforcements in composite materials. In general, short hemp fibres are used by the automotive industry as reinforcement in moulded composites with thermoplastic and thermoset matrices.

2.2 Graphene

Graphene sheets are composed of carbon atoms linked in hexagonal shapes with each carbon atom covalently bonded to three other carbon atoms. Each sheet of graphene is only one atom thick and each graphene sheet is considered a single molecule. A graphene sheet ,because of the strength of covalent bonds between carbon atoms, leads to high tensile strength.

2.3 Resin and hardener

Epoxy resin is used to give great binding properties between the fibre layers to form the matrix. The Epoxy resin used at room temperature is LY 556. Hardener (HY 951) is employed to improve the interfacial adhesion and impart strength to the composite. A resin and hardener mixture of 10:1 is used to obtain optimum matrix composition. Epoxy resins are best known for their excellent adhesion, chemical and heat resistance, mechanical properties, and outstanding electrical insulating properties. Epoxies are more expensive than polyesters, and cure times are longer, but their extended range of properties can make them the cost/performance choice for critical applications.

2.4 Cleaning of fibers

In general, retting process is employed to dissolve the cellular tissues and also for facilitating separation of fibre from the stem. It is used to make fibre from plant such ashemp stalks and coir fiber from coconut husks. Thereafter, water Retting in which water, penetrating to the central stalk portion, swells the inner cells, bursting the outermost layer, thus increasing absorption of both moisture and decay-producing bacteria. Following retting chemical treatment, drying and combing process are followed.

2.4.1 Chemical Treatment

Alkali treatment is one of the simple and effective surface modification techniques which are widely used in natural fiber composites by which tensile and flexural properties will be increased while the impact strength decreased. The fiber- matrix interface plays an important role on the transformation of load from matrix to the fiber.

2.4.2 Drying

Drying is a process in which of the removal of water or another solvent by evaporation from the fibres. A source of heat is used to dry food, grains, fibres and pharmaceuticals like vaccines, the solvent to be removed is almost invariably water.

2.4.3 Combing

Combing is the method for preparing carded fiber for spinning which is classified as linear and circular combing. The process of combing is followed by gilling, a process which used for straightening carded or combed top for making it suitable for spinning. After the combing, the fiber is measured for its length and it is reduced to a length of 14inch according to the plate preparation.

2.5 Hand layup Method

Hand lay-up process is used for the production of fibre laminate which is easy and cost effective. But this method is generally limited to the manufacture of parts with relatively simple shapes that require only one face to have a smooth appearance. Normally, resins are permeated by hand into fibers which are in the form of woven, knitted, stitched or bonded fabrics using rollers or brushes.

HEMP (NaOH)(0° Orientation)
RESIN + HARDENER + GRAPHENE
HEMP (NaOH)(0° Orientation)

Figure 1: Composite laminate fabricated

The resin and hardener is mixed in the ratio of 10:1.Graphene Nano platelets in the ratio of 2 grams for 100 grams of resin is mixed and prepared for one layer of fibre and it is stirred consistently. Once the Resin-Graphene mixture is prepared, ultrasound is employed to obtain proper dispersion of graphene substance with the help of a sonicator. Figure 1 shows Composite laminate fabricated for treated hemp fiber. Similar way for untreated fiber also composite laminate prepared. The combed Hemp fibres are placed in 0° orientations in the die module and Resin-Graphene mixture is coated for setting. With an increasing use of nip-roller resin forced into the fabrics by means of rotating rollers. Laminates are left to cure under standard atmospheric conditions. It is recommended for small and medium volumes requiring minimal investment in molds and equipment. In this work composite laminate of 300mm * 300mm is fabricated. Finally, the specimens are kept under load of 15 kg for proper binding and expanding bonding for 12 hours. Thus the fiber gets into proper shape. Two different specimen plates are prepared to examine their mechanical behaviour.

Table 1: Composition of Laminates

SPECIMEN	HEMP FABER	NaOH TREATMENT	GRAPHENE PLATELETS	EPOXY RESIN
1	500 (g)	5(%) solution	2(%)	1 (Kg)
2	500 (g)	-	29(%)	1 (Kg)

3.0 Testing of composites

3.1 Tensile Test

Tensile test of materials is one in which a sample is subjected to a controlled tension until failure. The results from the test are commonly used to select a material for any application, to predict how the material reacts under other types of forces. Properties namely ultimate tensile strength, maximum elongation and reduction in area are found by this tensile test. Using above measurements the properties namely Young's modulus, Poisson's ratio and yields strength are calculated. The fabricated laminate is cut using a saw cutter to getthe dimension of the specimen for tensile testing as per ASTM:D638 standards. The schematic diagram of tensile test specimenis shown is Fig.2

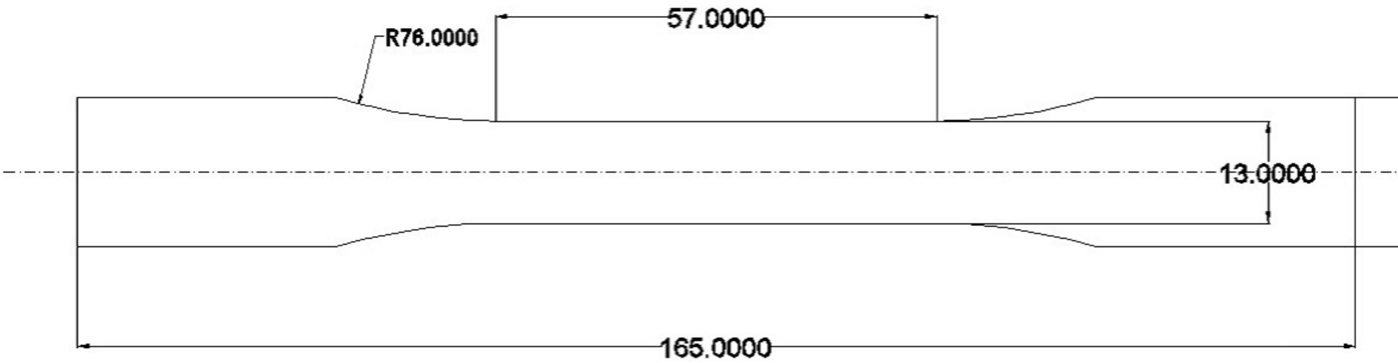

Figure 2: Schematic diagram of tensile test specimen

4.0 Results and Discussion

4.1 Result of Tensile Test

The tensile results for various specimens fabricated in this work are furnished in table 2.

Table 2: Tensile strength of composite

COMPOSITION OF COMPOSITE	TENSILE STRENGTH
HEMP FIBER(untreated) + GRAPHENE	30.86 (MPa)
HEMP FIBER (treated)+ GRAPHENE	40.03 (MPa)

The result shows that, the tensile strength is high for specimen 2 while compare with specimen 1. It is also observed that addition of few grams of graphene has much impact on its strength although hemp is a weak fibre. The graph shows result of specimen at various strengths.

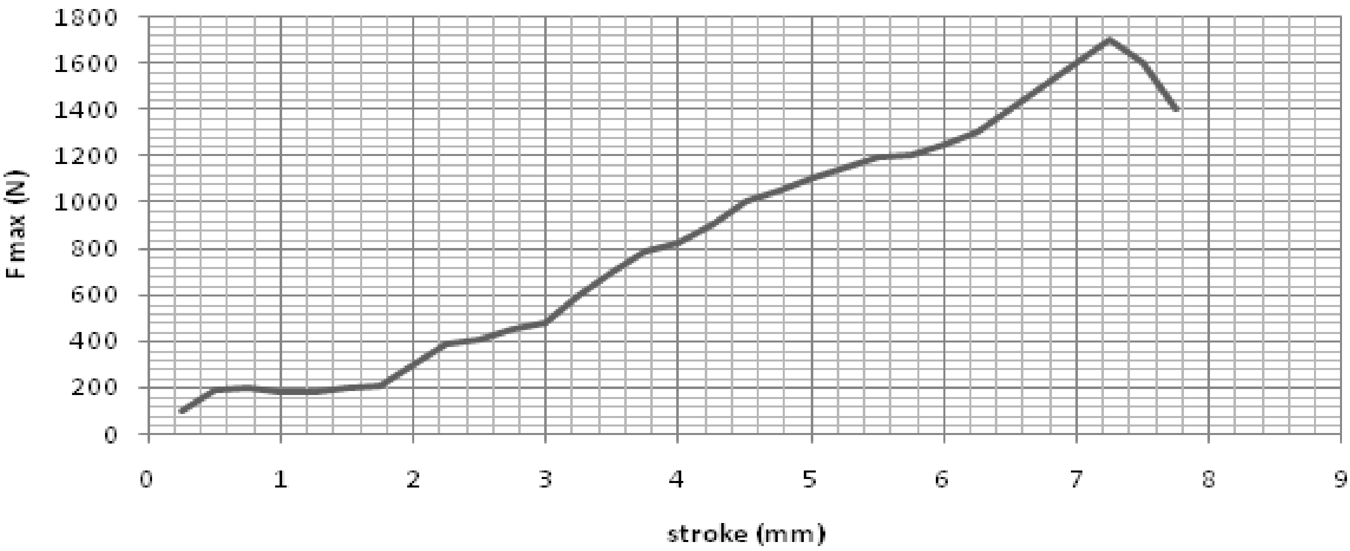

Figure 3: Result of Tensile Test (Hemp (untreated) and Graphene (3%))

From figure 3 it is observed that there is a linear change in cross section of the composite sample 1 while applying tensile load, by which, it is clear that the fibre are packed or compressed neatly without any air pocket. It is also seen from the graph that at a maximum tensile load of 1760 N, the specimen started to break.

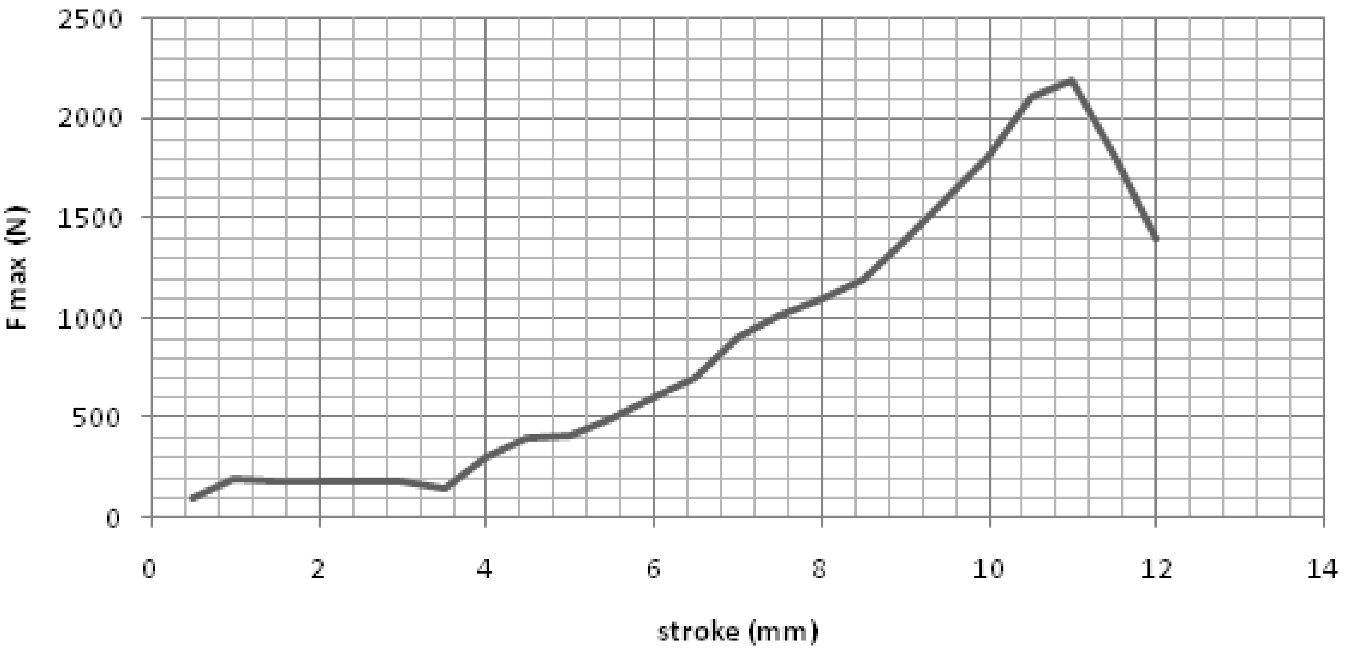

Figure 4: Result of Tensile test (Hemp (treated) and Graphene (5%))

Figure 4 also shows linear change in cross section of specimen during tensile loading, but the sample started to break at maximum tensile load of 2200 N. While compared to sample 1, the tensile behaviour of sample 2 is better which is due to the following reasons.

(i) The fibre treatment improves strength of fibres.
(ii) Addition of graphene also improves the tensile strength of sample 2.

Hence, it is concluded that fibre treatment has its own effect on improvement of mechanical behaviour of laminated composite.

5.0 SEM ANALYSIS

Morphological analysis has been performed using scanning electron microscope has been performed on the tested composites to analyse the internal structure of fabricated specimens.. It guides the tester to do the analysis on bond presence and molecular structure. Following are the SEM images taken on fractured surface of tensile and impact a specimen which has been shown here.

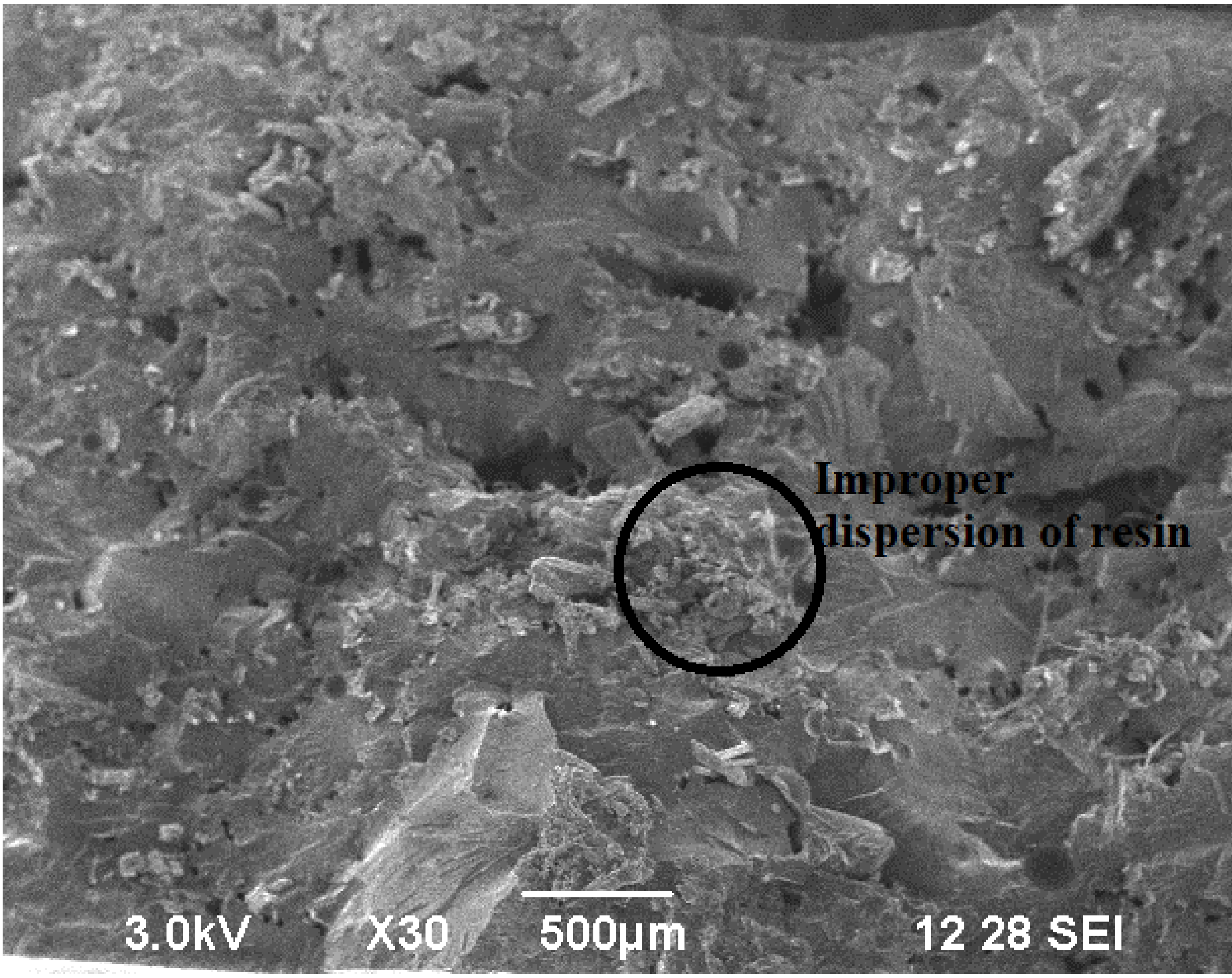

Figure 5: SEM image of tensile fractured

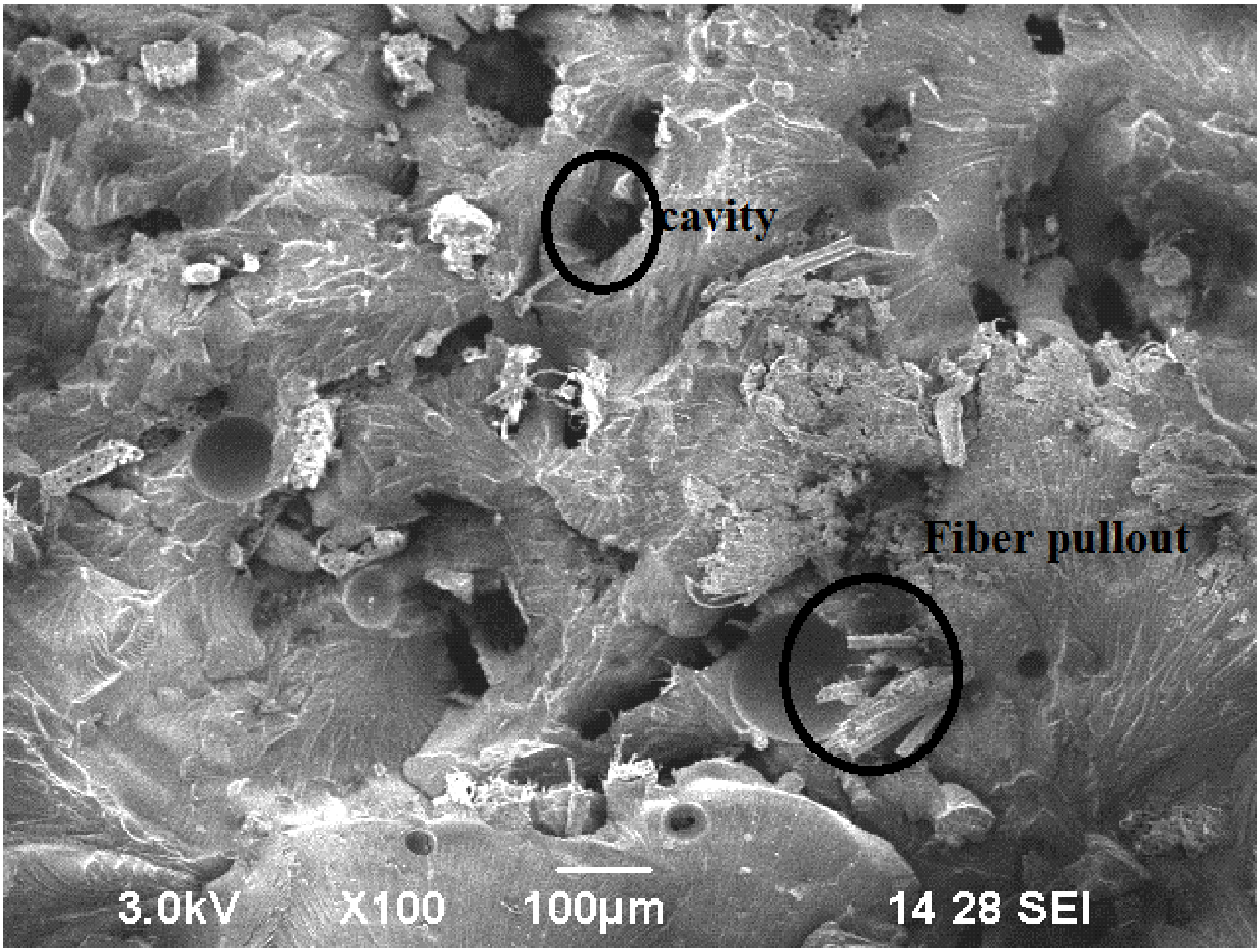

Figure 6: SEM image of tensile fractured

From Figure 4 and 5 it is observed that, complete dispersion of graphene in the matrix which in the result of sonication. Moreover, fiber breakage cavity and blow holes are observed which is the result of improper curing time, improper ratio of resin and hardener mixing of the composites fabricated.

6.0 CONCLUSION

In this work graphene based natural fibre composite has been fabricated by hand layup process and their tensile behaviour was evaluated. It found that the addition of graphene improves the tensile strength of composite laminate. Moreover, morphological analysis shows internal failures namely blow holes and cracks are formed due o improper curing time and improper resin, hardener mixing.

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