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DEVELOPMENT OF GFRP NANO COMPOSITE FOR BETTER DAMPING AND WEAR PROPERTIES BY REINFORCING DIFFERENT NANO FILLERS

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ABSTRACT

Nano particles mixed with epoxy resin enhance the dynamic and mechanical behavior of polymeric composites. In this work, the nano particles of carbon, and granite were introduced into an epoxy matrix system of Glass Fiber Reinforced Composites to find out the damping and wear properties of the composites. The volume fractions in the matrix were chosen as 1%, 2% and 3%. Granite powder which is waste material in the granite industries collected and made into nano using planetary ball mill used as filler into the composites. The damping and wear properties were greatly influenced by the reinforcement of nano particles into the glass fiber composites. The loss factor tan δ increases with filler addition and it is maximum for the composites with 2% volume fraction of carbon nano filler composites. The glass transition temperature of the composites with nano fillers is slightly less than that of glass fiber epoxy composites. Similarly the loss modulus is also maximum for the composites with 2% volume fraction of carbon nano filler. The tensile strength of the composites slightly decreases with addition of the filler. The wear of the composites were influenced by many parameters like impingement angle and impact pressure. The erosion rate decreases with the addition of filler. As the impact pressure increases the erosion rate of the composites also increases. The erosion rate of the composites were investigated at different angles 300, 600 and 900. The erosion rate first increases and then decreases and it is maximum at 600.

Keywords- *Carbon and Granite nano fillers, dynamic mechanical analysis, glass transition temperature, tensile strength, erosion rate*

I. INTRODUCTION

Glass Fiber reinforced plastic (GFRP) composites are widely used in ship hull, airframe and wind turbine structural applications due to their high specific strength and stiffness. The use of polymers and polymer-based composites is very common in situations where a combination of good mechanical and damping properties are required. In the case of particulate reinforced polymer composites, the properties depend on the shape and size of the filler, the amount that is compounded with the plastic, the bonding between the filler and the plastic. Low cost particulate fillers are added to plastics in commercial production primarily for reasons of economy and improvement in molding characteristics. Composite materials are constituted of two phases: the matrix, which is continuous and surrounds the other phase, often called as reinforcing phase. Epoxy resins are widely used as matrix in many fiber reinforced composites.

Granite powder obtained during the sizing of granite stones by processing granite slabs has no end use. The granite waste generated by the industry has accumulated over years. Only insignificant quantity has been utilized and the rest has been dumped unscrupulously resulting in pollution problems. In the present study, granite powder and carbon powder mixed with epoxy resin in different volume fractions is used as the reinforcement to the matrix system to prepare composites

Dynamic mechanical analysis (DMA) is used for the study and characterization of the mechanical properties of materials in general, and of composite materials in particular, owing to the dynamic loading situations frequently found where composites are used. The correct measurement of visco elastic properties of a material is subject to discussion and depends on equipment used.

Hui Qian et al [1] studied the mechanical properties of carbon nanotubes (CNTs) into conventional fibre reinforced polymer composites. Mechanical tests of hierarchical CNT/ epoxy composites with glass and carbon fibers, have confirmed that, the properties are significantly affected by the introduction of CNTs (1 to 3 wt%).
The fatigue properties of glass fiber reinforced epoxy laminates were improved by the addition of small amounts of nanoparticles [2-3]. The fatigue properties improvement of fiber reinforced composites depends on the filler size and filler structure.

R. Chandra et al [7] studied the Damping properties of fiber reinforced composites involving macro mechanical, micro mechanical and viscoelastic (relaxation and creep) approaches; models for interphase damping, damping and damage in composites.

C.F. Deng et al [8] studied the damping behaviors of carbon nanotube reinforced aluminum composite were investigated with frequency of 0.5, 1.0, 5.0, 10, 30 Hz, at a temperature of 25–400 °C. The experimental results show that the frequency significantly affects the damping capacity of the composite when the temperature is above 230 °C; meanwhile, the damping capacity of the composite with a frequency of 0.5 Hz reaches 0.975, and the storage modulus is 82.3 GPa when the temperature is 400 °C, which shows that CNTs are a promising reinforcement for metal matrix composites to obtain high damping capabilities at an elevated temperature without sacrificing the mechanical strength and stiffness of a metal matrix.

The mechanical properties of composites with filler as granite powder [10] were studied. They found that mechanical properties like tensile strength and compressive strength were increased with granite powder. It examined the possibility of using granite powder as replacement of sand.

II. MATERIALS AND METHODOLOGY

Material Selection
In the present work E-Glass fiber in the mat form is selected as reinforcement and Epoxy resin LY 556 used as matrix. Hardener (HY951) is added to epoxy resin in a ratio of 10:1 by weight for bonding. Two nano fillers, carbon powder and granite powder which is waste material in granite industries made into nano scale using ball mill added into the composites with different volume fractions.

SEM Analysis
The scanning electron microscope (SEM) was used to identify the images of nano powders and the range of size. The nanoparticles carbon and granite are provided as a dry powder. The granite and carbon powder contains particle agglomerates with sizes in the nanometer to micrometer range, which consist of nanoparticles sticking strongly together as shown in figure 2.1 and figure 2.2.

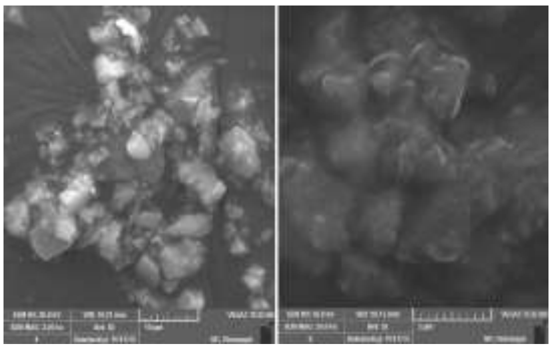

Figure 2.1. SEM images of granite nano particle

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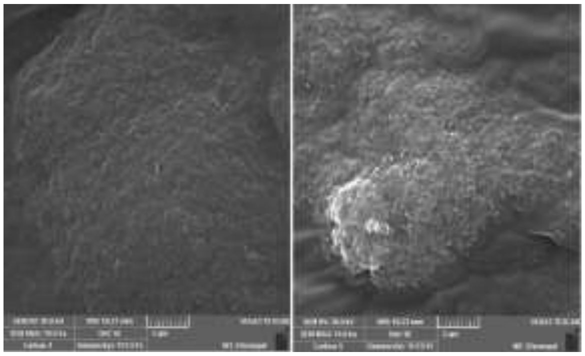

Figure2.2 SEM images of carbon nano particles

Density of Nano Powders

Density of Carbon and Granite nano powders were measured using the Pycnometer method. In this method the liquid used is kerosene. The density of kerosene is taken as standard value i.e. 0.8 gm/cc.

Density of Carbon Powder:
Mass of empty bottle = 26.564 gm
Mass of bottle + Mass of sample = 27.2787 gm
Mass of sample (m_2) = 27.2787-26.564 = 0.7147 gm
Mass of bottle filled with liquid (m1) = 68.1968 gm
Mass of sample and liquid together in pycnometer (m3) = 67.4068 gm
Then the density of sample (carbon powder) can be calculated as

$$\rho_s = 0.8\frac{0.7147}{68.1968+0.7147-67.4068} = 0.38 \text{ gm/cc}$$

Density of Granite Powder:
Mass of empty bottle = 26.564 gm
Mass of bottle + Mass of sample = 27.2899 gm
Mass of sample (m_2) = 27.2899-26.564 = 0.7259 gm
Mass of bottle filled with liquid (m1) = 68.1968 gm
Mass of sample and liquid together in pycnometer (m3) = 68.6976 gm

Then the density of sample (granite powder) can be calculated as

$$\rho_s = 0.8\frac{0.7259}{68.1968+0.7259-68.6976} = 2.58 \text{ gm/cc}$$

Composite Preparation

The method that is used in the present work for manufacturing the laminated composite plates is hand layup. The type of Glass Fiber mat selected to make specimens was, Mat–225GSM. The glass fiber is reinforced with Epoxy LY556 resin, which is used as the matrix material. The low temperature curing epoxy resin (Araldite LY556) and corresponding hardener (HY951) are mixed in a ratio of 10:1 by weight as recommended.

Two material compositions of Glass/Epoxy (G-E) composites were chosen namely G-C-E and G-G-E. Each material composition has been fabricated for three different volume fractions, the details of the percentage volume fractions of epoxy resign, glass fabric and fillers are shown in **Table 2.1**. The cast of each composite is cured under a load of about 50 kg for 24 hours at room temperature before it removed from the mould. Specimens of suitable dimension are cut using a diamond cutter for mechanical testing. Utmost care has been taken to maintain uniformity and homogeneity of the composite.

Table 2.1 Representation and Composition of Composites

Sl. No.	Filler Volume Fraction	Representation
1	Glass Fabric 40% + Epoxy 60%	GE
2	Glass Fabric 40% + Epoxy 59% + Carbon 1%	GCE-I
3	Glass Fabric 40% + Epoxy 58% + Carbon 2%	GCE-II
4	Glass Fabric 40% + Epoxy 57% + Carbon 3%	GCE-III
5	Glass Fabric 40% + Epoxy 59% + Granite 1%	GGE-I
6	Glass Fabric 40% + Epoxy 58% + Granite 2%	GGE-II
7	Glass Fabric 40% + Epoxy 57% + Granite 3%	GGE-III

Tensile Testing

After fabrication the test specimens were subjected to various tensile tests as per ASTM standards. The tensile test is generally performed on flat specimens prepared as per **ASTM D638** standard of specimen dimension is **165X19 mm** and the gauge length and cross head speeds are chosen according to the standard. The specimen is loaded between two manually adjustable grips of a **20 KN Computerized Universal Testing Machine (UTM)**. The tensile test is performed on Universal testing machine (UTM) at room temperature conditions (**303K**) and at a travel head speed of **2mm/min**

Erosion Testing

The erosion rate of the composites were investigated using Magnum Air Jet Erosion Test Rig. The specimen size for the erosion test were as per standards ASTM G-76. The size of the specimen is 2X2 cm^2. The erosion rate in the present investigation was found at room temperature. The erosion rate depends on many parameters like impingement angle, pressure, size, material etc. In the present investigation the parameters are impingement angle and pressure. The photographic image air jet erosion test rig.

Dynamic Mechanical Analysis (DMA)

DMA testing of the composite were done using RSA-G2 Dynamic Mechanical Analyzer. The RSA-G2 features a variety of sample clamps that provide multiple modes of deformation to accommodate a wide range of sample stiffness. In the present testing all the seven samples of composites were tested using three point bending method. The sample size for testing of DMA was 50x12x2.5 mm.

Figure 2.3 DMA samples

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III. RESULTS AND DISCUSSION

Tensile Property of Composites

The tensile strength of different composites with different nano fillers were investigated and discussed. The stress strain graphs of glass fiber composites compared with composites with different nano fillers were shown below. Figure 3.1 shows the stress strain curve glass fiber composites compared with composites with carbon nano filler. It was observed that as the percentage of carbon nano filler increases the tensile strength of the composites slightly decreases and the observation is shown in the Table 3.1.

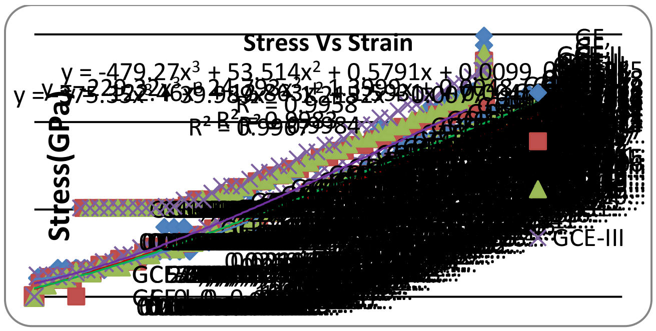

Figure 3.1 Stress strain graph for composites with carbon nano filler

The figure 3.2 shows the stress strain curve for composites with granite nano fillers. it was observed that as percentage of the granite filler increases, the tensile strength of the composites slightly decreases which is similar to carbon filler composites and observation was shown in the Table 3.1.

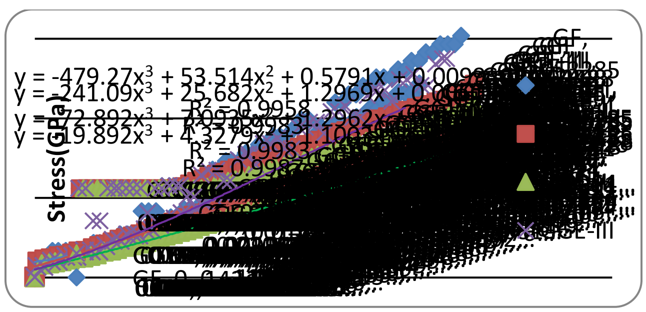

Figure 3.2 Stress strain graph for composites with granite nano filler

The properties of the composites with different nano fillers under this investigation are presented in Table 3.1

Table 3.1 Tensile strength of composites

Composites	Tensile strength(MPa)
GE	120.99
GCE-I	106.9
GCE-II	110.98
GCE-III	105.35
GGE-I	90.64
GGE-II	79.34
GGE-III	106.67

DMA Results

DMA results of different compositions gives loss factor tan δ, storage modulus E´, loss modulus E´´ with respect to temperature. The results were shown below and were compared glass fiber with nano filler composites. For these the frequency set as constant i.e. 6.28 rad/s. Figure 3.3 shows the loss factor tan δ of glass fiber composites with carbon nano fillers with respect to temperature. It shows that the filler addition increases loss factor tan δ. It also shows that for carbon nano fillers the composite with 1% volume fraction has highest loss factor at temperature 76.77ºC. The loss factor for the composites is high in the temperature range of 65-100 ºC. The glass fiber without filler has high loss factor at 91.8 ºC.

Figure 3.4 shows the loss factor tan δ of glass fiber composites with granite nano fillers with respect to temperature. It shows that the filler addition increases loss factor tan δ. Here it shows the granite filler with 2% volume fraction has highest loss factor at temperature 77 ºC

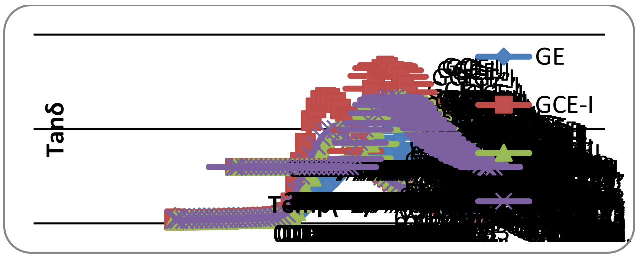

Figure 3.3 Effect of temperature on Tanδ value of composites of carbon nano filler

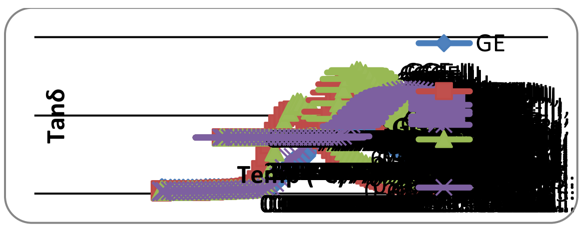

Figure 3.4 Effect of temperature on Tanδ value of composites of granite nano filler

Figure 3.5 shows the loss factor tan δ of all the glass fiber composites both nano fillers with respect to temperature. In all the seven composites prepared the composite with 1% volume fraction of carbon nano filler has highest loss factor. It also shows that as the filler volume is much it reduces loss factor.

Figure 3.6 shows the storage modulus E´ of glass fiber composites with carbon nano fillers with respect to temperature. The storage modulus is low for composites with 1% volume fraction of carbon filler. Here the storage modulus is high for composites with 2% volume fraction of carbon filler.

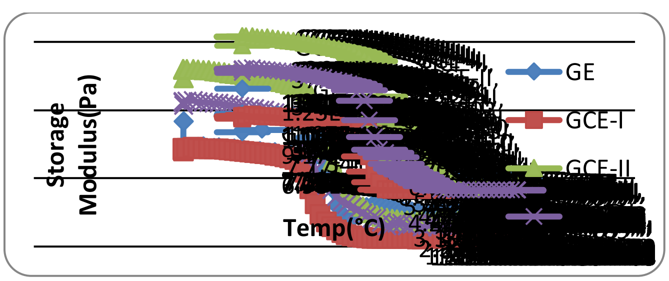

Figure 3.6 The variation of storage modulus with temperature of composites of carbon nano filler

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Figure 3.7 shows the storage modulus E´ of glass fiber composites with granite nano fillers with respect to temperature. The storage modulus is low for glass fiber composites without filler. Here the storage modulus is high for composites with 2% volume fraction of granite filler.

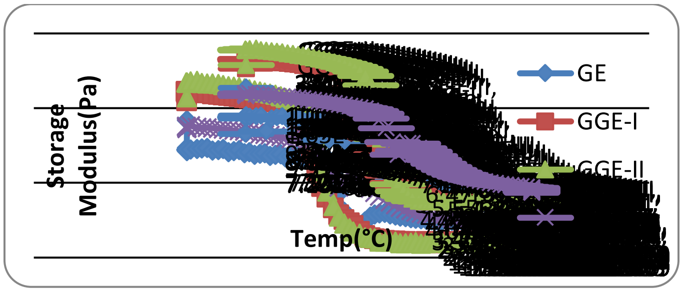

Figure 3.7 The variation of storage modulus with temperature of composites of granite nano filler

Figure 3.8 shows the storage modulus E´ of all seven glass fiber composites with granite and carbon nano fillers with respect to temperature. It shows that the composites with 1% volume fraction of carbon nano filler has less storage modulus. It also shows as the temperature increases the storage modulus decreases. The storage modulus drops at 69 ºC for almost all the composites.

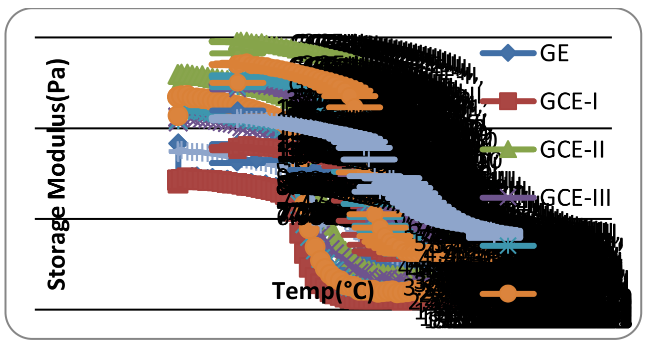

Figure 3.8 The variation of storage modulus with temperature of composites

Figure 3.9 shows the loss modulus E´´ of glass fiber composites with carbon nano fillers with respect to temperature. The loss modulus is high for composites with 2% volume fraction of carbon filler at 75.5 ºC. The loss factor for the composites is high in the temperature range of 65-85 ºC. The addition of filler increases the loss modulus.

Figure 3.10 shows the loss modulus E´´ of glass fiber composites with granite nano fillers with respect to temperature. The loss modulus is high for composites with 1% volume fraction of granite filler at 72.9 ºC. Here by the addition granite filler increases the loss modulus. Glass fiber without filler has high loss modulus at higher temperatures

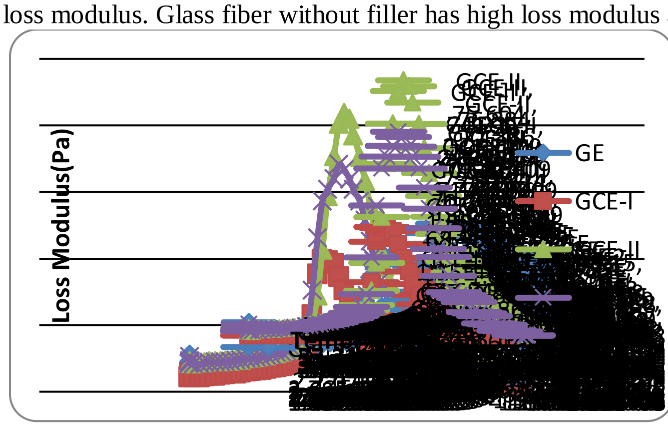

Figure 3.9 The variation of Loss modulus with temperature of composites of carbon nano filler

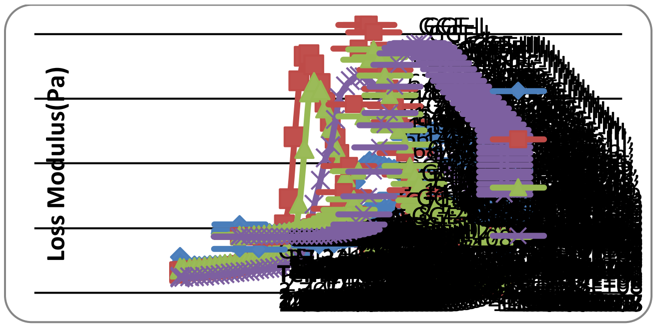

Figure 3.10 The variation of loss modulus with temperature of composites of granite nano filler

Figure 3.11 shows the loss modulus E´´ of all glass fiber composites with carbon and granite nano fillers with respect to temperature. In all the composites the composite with 2% volume fraction of carbon nano filler has high loss modulus. It shows by the addition of filler the loss modulus increases. At higher temperatures the loss modulus decreases for composites with fillers.

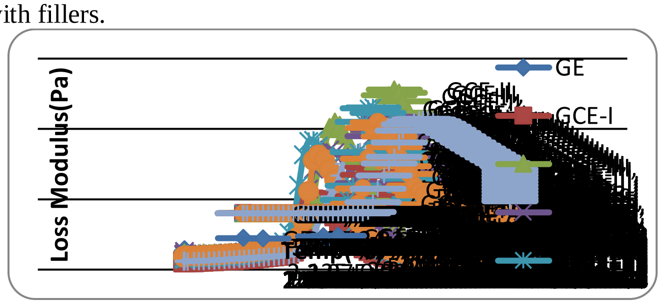

Figure 3.11 The variation of loss modulus with temperature of composites

Erosion Test

Erosion rate is the material removal rate of the composites. The erosion rate of different composites with different nano fillers were found with different parameters. The erosion rate of the composites were influenced by many parameters like impingement angle, impact velocity, hardness of the eroding particles, shape and size. In this erosion test sand was used as eroding particles. Figures 3.12 and 3.14 shows erosion rate of composites decreases with increase of filler percentage i.e. the composite becomes resistant to erosion wear rate with increase of filler percentage.

Effect of Impingement Angle

Impingement angle is defined as the angle between the eroded surface and the trajectory of the particle immediately before impact. Wear rate is usually measured in weight loss of the material during test time but it was converted into volume rate (mm^3/min). Figure 3.12 shows the erosion rate with respect to impingement angle at a pressure of 1 bar on different composites with carbon nano filler. It shows that the erosion rate first increases as the angle increases and then decreases. The erosion rate is maximum at 60^0 angle. It also shows erosion rate decreases with filler addition. Similarly figure 3.13 shows erosion rate with respect to impingement angle on different composites with granite nano filler.

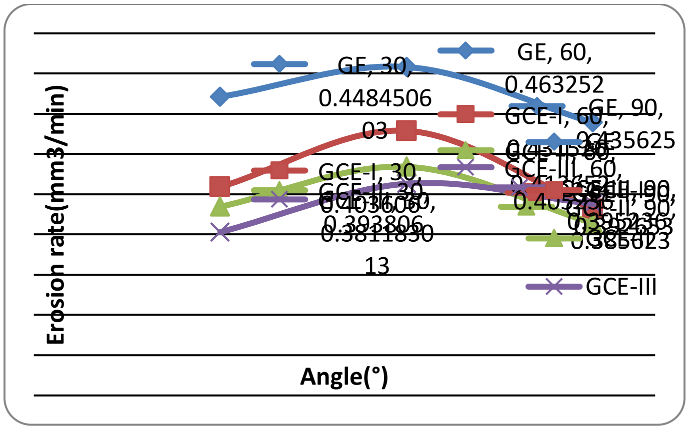

Figure 3.12 Effect of impact angle on erosion rate of carbon filler composites

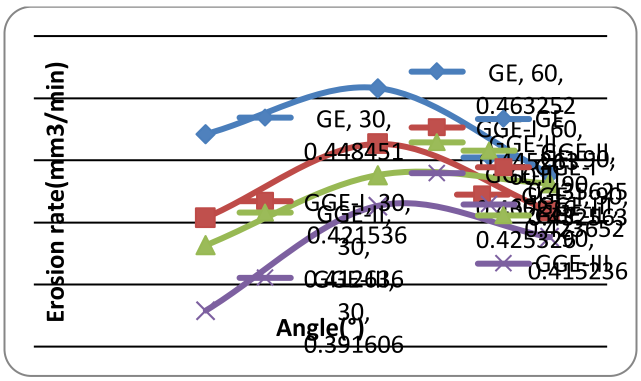

Figure 3.13 Effect of impact angle on erosion rate of granite filler composites

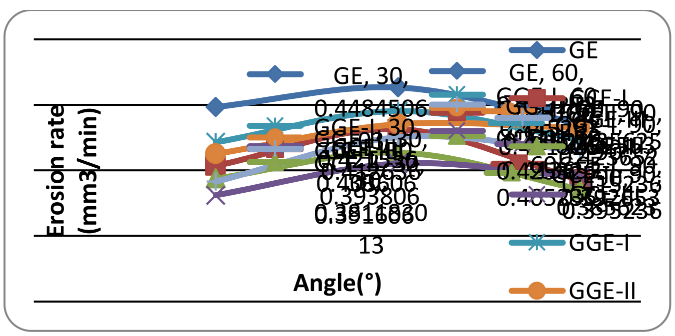

Figure 3.14 Effect of impact angle on erosion rate of composites

Figure 3.15 shows the erosion rate with respect to impingement angle at a pressure of 1 bar on all the composites. It shows that the composite with carbon nano filler of 3% volume fraction has less erosion rate. The erosion rate is less in carbon nano filler composites compared to granite nano filler composites.

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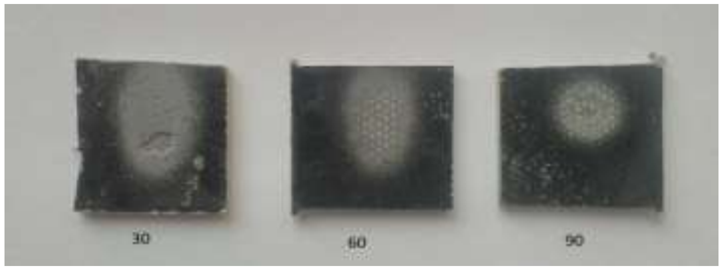

Figure 3.15 Effect of impact angle on composites

Effect of Impact Pressure

Impact pressure is the pressure at which the sand particles impact on the eroded surface. Figure 3.16 shows the erosion rate with respect to impact angle at an angle of 30^0 on the composites with carbon nano filler. It shows that the erosion rate increases as the pressure increases. It also shows erosion rate decreases with the addition of filler. Similarly figure 3.17 shows shows the erosion rate with respect to impact angle on the composites with granite nano filler.

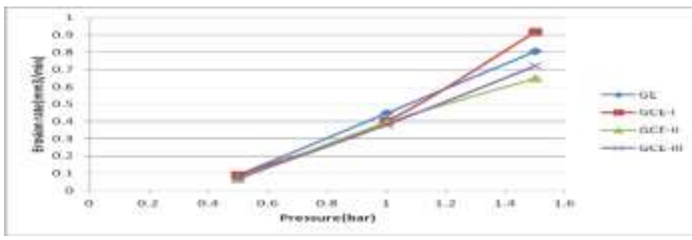

Figure 3.16 Effect of impact pressure on erosion rate of composites with carbon nano filler

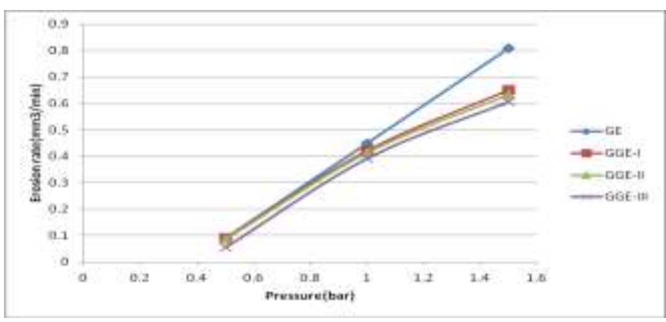

Figure 3.17 Effect of impact pressure on erosion rate of composites with granite nano filler

IV. CONCLUSION

- This experimental examination of glass fiber epoxy composites with different nano fillers indicates to the many conclusions.
- The utilization of granite powder will avoid the disposal problems and related environmental issues.
- The successful fabrication of a glass fiber reinforced epoxy composites with different nano fillers and with different volume fractions has been done by simple hand lay-up technique.
- It has been observed that as the filler percentage increases in the composites the tensile strength of the composites slightly decreases.
- It has been noticed that the dynamic mechanical properties of the composites are greatly influenced by reinforcement of nano filler into the composites. The filler addition improves the dynamic mechanical properties.
- It was observed that the loss factor tanδ is maximum for the composite with 1% carbon nano filler. The glass transition temperature with 1% carbon nano filler composite is 76.77°C

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- It shows that the composites with 1% carbon nano filler has less storage modulus E´. The storage modulus drops at 69 ºC for almost all the composites.
- The loss modulus E´´ of the composite with 2% volume fraction of carbon nano filler is maximum. At higher temperatures the loss modulus decreases for composites with fillers.
- The erosion rate of different composites with different nano fillers were found with different parameters like impingement angle, impact pressure. The erosion rate increases with increase in impact pressure. The erosion rate is maximum at the impingement angle 60^0.
- XRD analysis reveals that the material is strain as the peaks are shifted towards left and no precipitates has been formed.

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