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The Development of Epoxy Hybrid Composite for Engineering Application

[1*]Agunsoye O. Johnson, [2]Talabi I. Segun, [1]Hassan B. Sulaiman, [1]Bello A. Sefiu, [1]Bello B. Luqman

[1]Department of Metallurgical and Materials Engineering, University of Lagos, Akoka (jagunsoye@unilag.edu.ng)

[2]Department of Materials and Metallurgical Engineering, University of Ilorin, Ilorin (isaacton@yahoo.com)

[1]Department of Metallurgical and Materials Engineering, University of Lagos, Akoka (profsbolajihassan@gmail.com)

[1]Department of Metallurgical and Materials Engineering, University of Lagos, Akoka (adekunle_b@yahoo.com)

[1]Department of Metallurgical and Materials Engineering, University of Lagos, Akoka (bellotuns@yahoo.com)

*Corresponding Author

Abstract

The morphology, thermal stability and wear characteristics of the glass/graphite particulate hybrid epoxy resin composite have been studied. 80µm particulate sizes of glass and graphite were incorporated in the epoxy resin. The TGA 701 and wear on disc machine were used to characterise the epoxy resin graphite /discarded florescent tube particulates (ER/DFT/GP) composites' ability to withstand heating and resistance of the composite to surface abrasion under dry lubrication conditions. The result revealed that the addition of graphite/glass particulates improved significantly the thermal stability and wear resistance of the ER/DFT/GP composites. The two parameters of load and speed caused increase in the wear volume of the ER/DFT/GP composites. Furthermore, the wear resistance increased as the percentage volume of the glass particles increased. Hence, the incorporation of the DFT and GP in the epoxy *resin improved the thermal stability and wear resistance of the epoxy resin.*

Keywords
Epoxy resin, wear, thermal properties, thermal analysis.

1 Introduction

Epoxy resins are important thermosetting resins which usually display excellent mechanical strength, electrical; chemical resistance; good thermal characteristic and fine adhesion to many substrates after cure. They are used as matrix resins for reinforced composites, in aerospace industry, adhesives in car, as insulating materials for electrical and electronic industry. However, when compared to other light materials like aluminium they have low mechanical strength and thermal characteristic and fracture toughness [1]. Hence, there is need to reinforce epoxy resin for improved mechanical properties as well as good thermal characteristic. The mechanical performance of the fiber-reinforced composites usually depends on the properties of the matrix and fiber materials [2-4]. Several researchers have worked on the development of hybrid reinforced epoxy resin composite [5-9]. But, within the scope of the worked reviewed, no work has specifically address the choice of graphite and glass waste as filler in reinforcing epoxy resin. A reinforcer such as glass has good thermal resistance and strength, but they have low fracture toughness ([10-12]. Also, in the development of wide variety of composites for application in areas such as aerospace industry, automobile industries and sporting goods, carbon fiber has been used as the reinforcing material [13-14]. Carbon fibre reinforced polymer composites are been used in a wide range of engineering applications because of increase in the impact energy absorption per unit weight, reduce noise and vibrations and excellent resistance to fatigue [15]. Hence, the composites of these three engineering materials, i.e. polymer–matrix composites with small amount and size of glass and particulate carbon reinforcements, could improve strength, thermal properties and impact energy of the composites. This is the thrust of this research i.e. to use the good properties offer by both glass and carbon particles to reinforce epoxy resin to develop composites with improved properties. Such composites made from high-performance fibers (e.g., carbon and glass fibers) embedded in compliant polymeric resins can be used in a wide range of fields such as aerospace engineering and sports utilities. The developed composites are expected to have high specific strength and toughness, superior manufacturability, as well as excellent corrosion resistance and fatigue tolerance [16]

In this work, an attempt has been made to develop a hybrid polymeric composite from epoxy resin **(LY 556)** reinforced with glass and graphite particles. The thermal characteristics, wear behaviour, phase morphology and distribution in the matrix of the developed composites were also reported. The glass particulate used was from discarded fluorescent tubes which have the potential of causing serious environmental harm due to mercury. The mercury from just one fluorescent tube is enough to pollute 30,000 litres of underground water so that the water is no longer safe to drink [17]. Hence, this research was aimed at eliminating this challenge by making use of this potential harmful material (discarded fluorescent tube) as reinforcer in the production of composites for engineering applications.

2 Materials and Methodology

A total of 20 long discarded florescent tube (RFTG) of 50.6mm diameter by 1214.4mm were submerged in a 330 litres water plastic drum covered with 2kg ground sulphur powder. The drum was covered and left in a well-ventilated workshop for 24 hours, during which the sprinkled sulphur powder reacted with mercury inside the tube to form mercury sulphide. Then the tubes were removed and washed in water after which they were sun dried for 48 hours and then ground into powder in a mortar. The powdered florescent tube (PFT) was sieved into different mesh sizes ranging from 80 to 150µm in accordance with BS 1377: 1990 standard. Solid graphite electrode was also ground and sieved in a similar manner to powdered florescent tube (PFT). The discarded florescent tube, the crushed florescent tube and sieved glass recovered from the discarded florescent tube are presented in Plates 1-3. Plate 4 show the ground electrode powder used as graphite. A mixture containing 2% by weight graphite particles (GP) at 80µm size, 5% by weight of discarded florescent tube particulates (DFTp) at 80µm size and 93% by weight of epoxy resin (LY 556) were mixed and stirred manually for 2minutes with a wooden plough inside a 500cm^3 aluminium cup. The mixture was then poured into a medium carbon steel die mould (see Plate 5) at room temperature; through a cold casting process.

Plate 1. Discarded Florescent Tube (DTF).

Plate 2. The Crushed Florescent Tube.

Plate 3. The Powdered Florescent Tube (PFT).

Plate 4. The Graphite Particles (GP).

To ensure the curing of the casting, it was left in the mould for 24 hours after which the cast ingot (ER/5DFTp/2GP) was knocked out of the mould. The same procedures were repeated for casting the remaining ER/DFT/GP composites with %composition as 88/2/10; 83/15/2; 78/20/2 at 80µm size both for discarded florescent tube powder (DFTp) and graphite powder (GP). The cast ingot is presented in Plate 6. Each sample of the ER/DFT/GP composites was prepared into different coupons for Thermo gravimetric analysis (TGA) and wear tests. Thermal stability of the discarded florescent tube/graphite reinforced epoxy resin (ER/20DFTp/2GP, ER/15DFT/GP, ER/10DFT/2GPand ER/5DFT/2GP) and epoxy resin (ER) samples were investigated with the aid of TGA 701. Each sample was heated at a rate of 10°C from room temperature in a linear temperature ramp to a maximum temperature (900°C).The thermo gravimetric analysis (TGA) of the epoxy resin (ER) and the glass/graphite reinforced epoxy resin composite (ER/DFT/GP) composites were studied as a function of weight loss as temperature and time increased (See Figure 1-6). The TGA analysis for the developed composites has been performed in an oxidising environment with a linear temperature gradient. The samples were heated from room temperature (about 30°C) to the maximum temperature where the weight of the samples remained unchanged which implies the temperature at which all possible reactions have been completed (all the polymeric molecules have been burnt off leaving behind non-volatile oxides).

Plate 5. A medium carbon steel die mould with Improvised cavity.

Plate 6. The ER/DFT/GP Cast Ingot.

This method gives three important numerical pieces of information which are weight loss, heating time and oxidation temperature. Oxidation temperature includes onset oxidation temperature (T_{on}) and maximum oxidation temperature (T_o). The latter is the temperature at which the oxidation rate is at maximum i.e. where the weight loss is at maximum and the former corresponds to the temperature when the oxidation of the polymeric material just begins. It is very difficult to determine the T_{on} accurately due to resistance of material to thermal application. The resistance to thermal application at initial stage might be attributed to the presence of graphite and glass particles in the reinforced epoxy resin composites because of the refractory nature of the fillers. However the T_{on} characterise the fillers rather than the matrix.

Rectangular shape coupon of dimensions 50x10x10mm each of the recycled waste florescent tube glass/graphite reinforced epoxy resin (ER/20DFT/2GP, ER/5DFT/2GP) and epoxy resin (ER) samples were subjected to wear analysis to investigate their resistance to surface abrasion under dry lubrication condition in accordance with ASTM standard.
The wear test was carried out on a 200mm circular rotating disc with attached emery paper of 180 grit size. The surface of the test sample was placed against the rotating disc for a period of 60s under different loads and speeds. The experiment was repeated for four times and corresponding weights measured. Weight losses were calculated using equation 1

Weight loss (w_l) = initial weight –final weight 1

The average weight losses for each run of experiments at a given applied load and Speed were estimated using equation 2.

Volume loss= w_l/ρ..2

Sliding distance and sliding moment were calculated using equations 3 and 4 respectively

Sliding distance= sliding Speed x time………3

Sliding moment = Applied load x sliding distance..................4

The wear coefficient of each sample was calculated using equation 5

Wear coefficient = volume loss(V_l)/sliding moment (M).............5

Results and Discussion

3.3 Thermo gravimetric analysis

Figure 1 shows the thermogravimetric analysis on the epoxy resin sample. For the epoxy resin, degradation of the resin began in the temperature range of 100-150°C corresponding to time interval between 40 and
45min which is accompanied with breakage of C-C, CO, C-H and OH bonds of the resin while the initial and final decomposition temperatures (IDT and F On the other hand, the glass/graphite reinforced composites generally have an initial decomposition temperature ranges from 300-420°C and final decomposition temperature range from 460 to 600°C respectively (see Figures 2-6).

The increase in the values of the initial and final decomposition of the recycled florescent tube reinforced composites is attributed to the ability of the recycled florescent tube/graphite in the matrix of the developed composites to retain temperature for long time with little or no oxidation, thereby the thermal stability of the developed composites. The filler additions also act as barriers that prevent the transport of volatile products out of the composite during thermal decomposition [18, 19].
Furthermore, the various peaks along with the TGA curves indicate that the composites contain some incorporated impurities/fillers (glass and graphite particulates). The number of these peaks is a function of the amount, morphology and distribution of the fillers. Besides, those peaks represent a number of regions where the endothermic and exothermic reactions occur at different temperatures and mark the points where the composites' thermal behaviour changes [19].

DT) are 250 and 320°C respectively (see Figure 1).

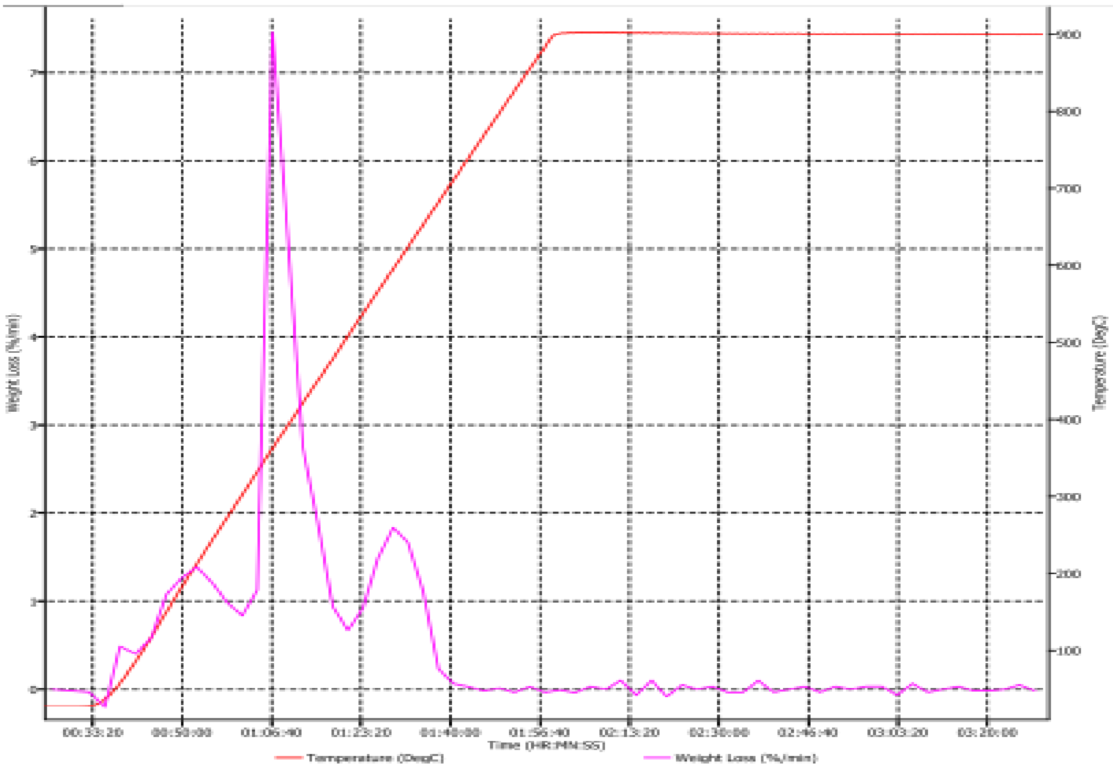

Figure 1. TGA of the Epoxy Resin.

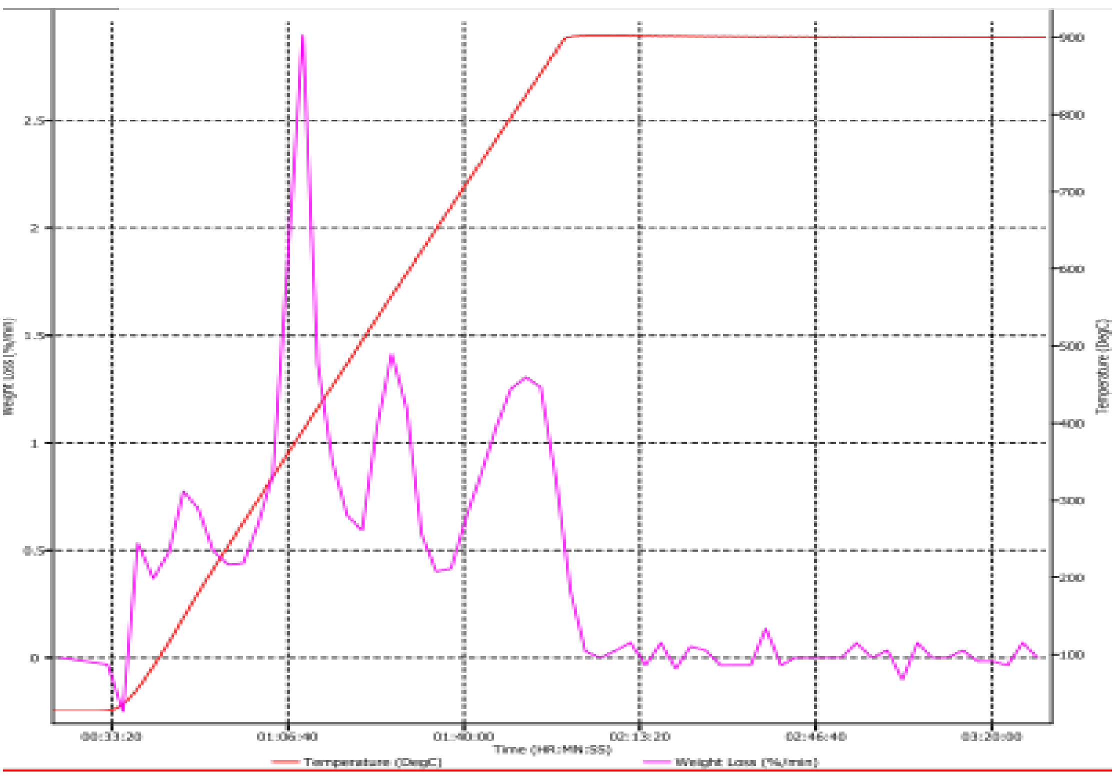

Figure 2. TGA of the ER/5DFT/2GP Composite.

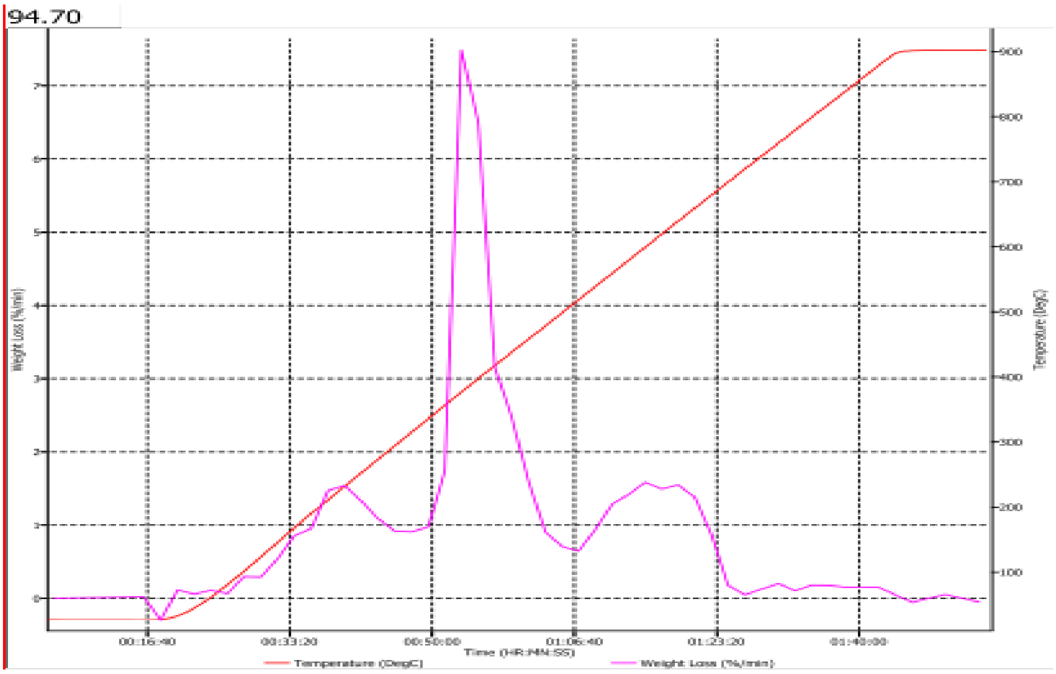

Figure 3. TGA of the ER/10DFT/2GP Composite.

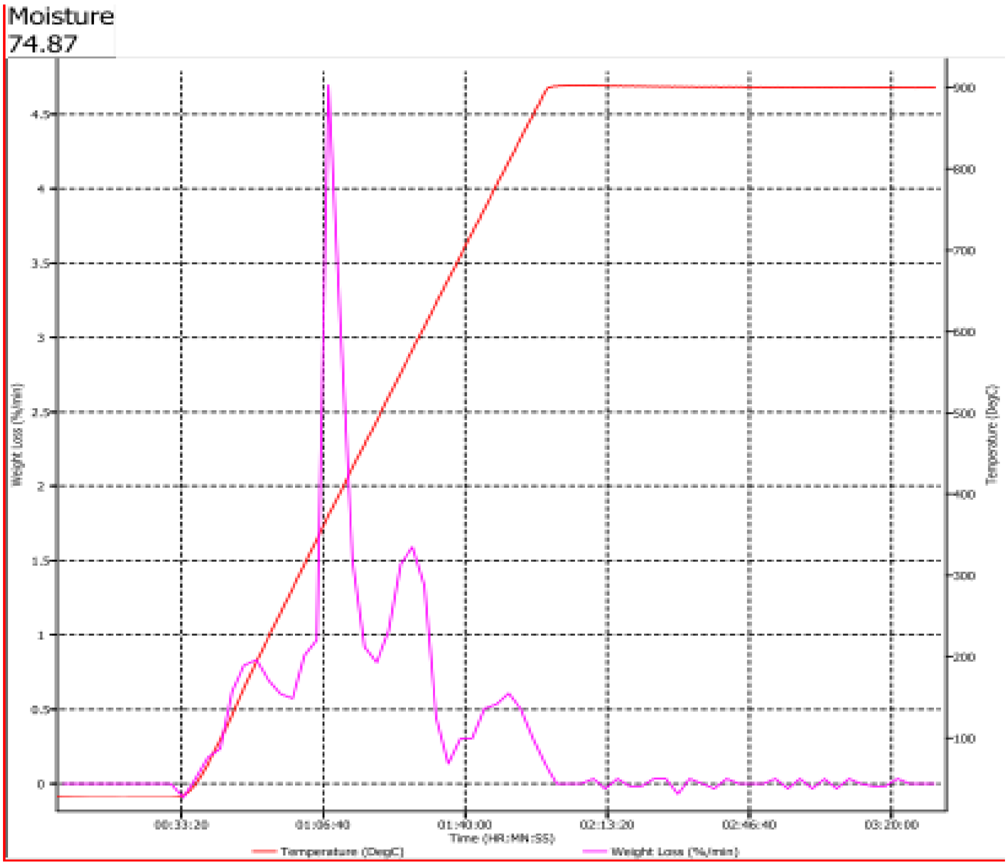

Figure 4. TGA of the ER /10DFT/2GP Composite.

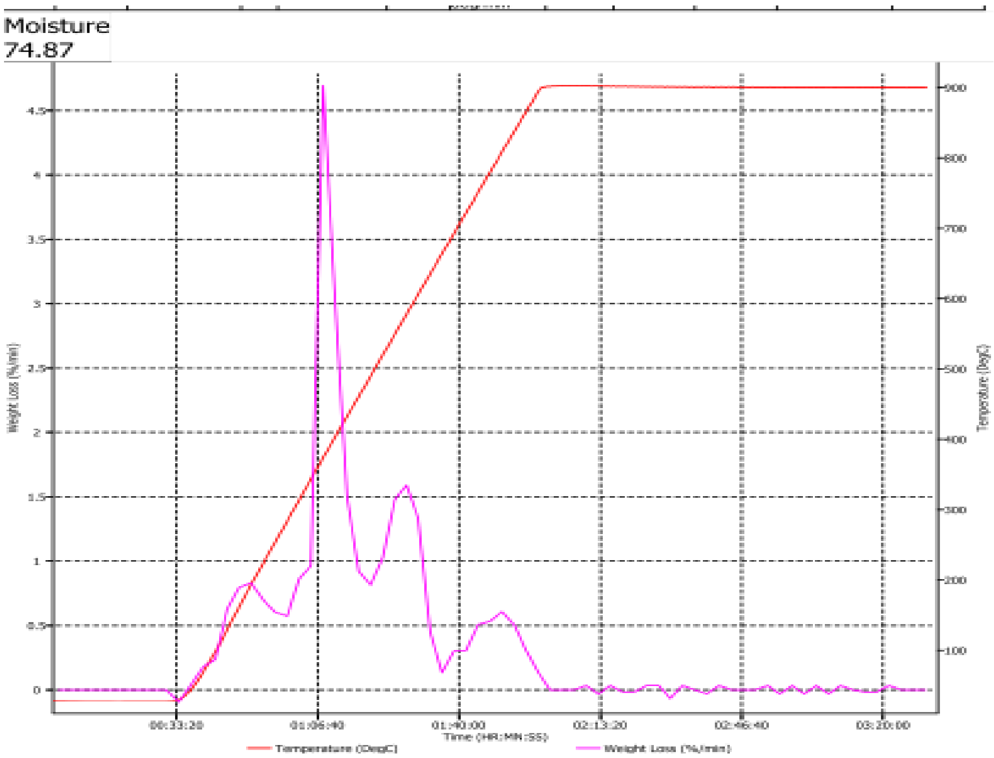

Figure 5. TGA of the ER/15DFT/GP Composite

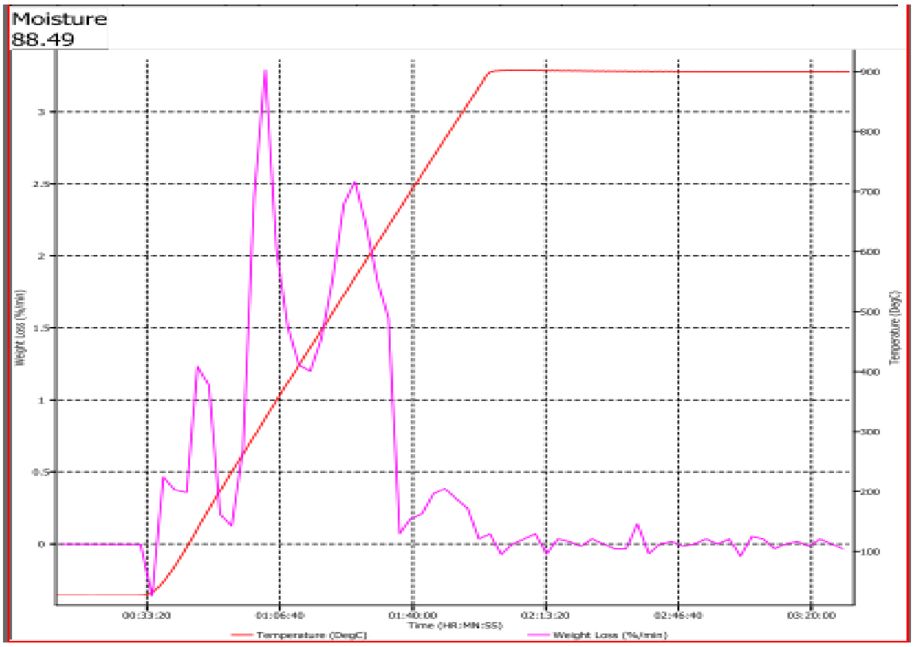

Figure 6. TGA of the ER/20DFT/GP Composite.

3.4 Wear Analysis

Figures 9-14 show the relationship between wear coefficient and time under different loads at the speed of 2.36 and 4.72ms^{-1} respectively for the control sample of the epoxy resin as well as 5wt %discarded florescent tube/graphite epoxy resin ER/5DFT/2GP composite and 20wt %discarded florescent tube/graphite hybrid epoxy resin ER/20DFT/2GP composites. Generally, it was discovered that the wear coefficient decreased as the time and speed increased at different applied loads from 6 to 16N. For the control sample, the wear resistance is improved (i.e. wear coefficient is lower) due to fillers additions. This finding is in perfect agreement with earlier work by [20].

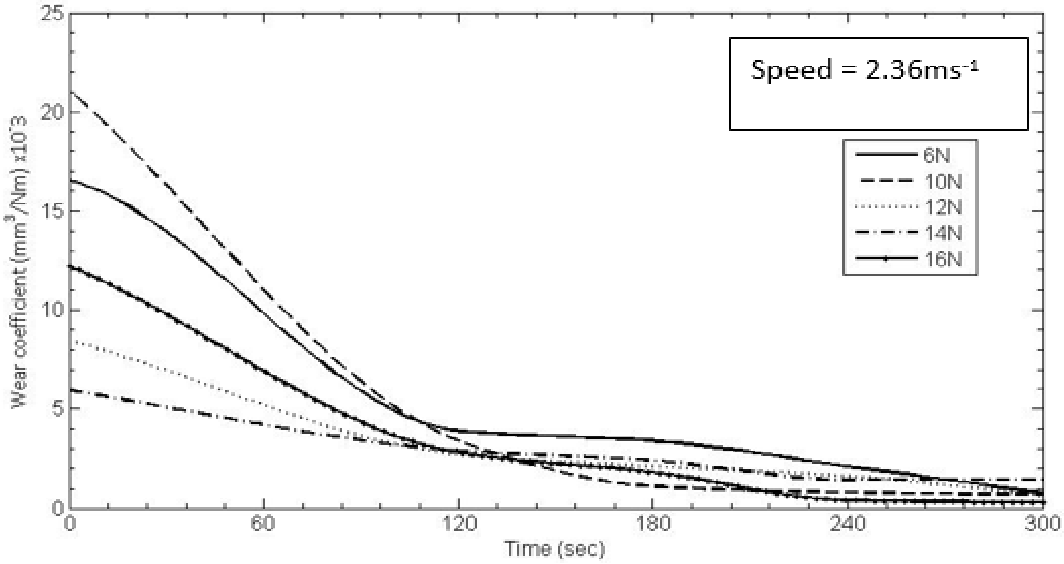

Figure 9. Wear Coefficient of Epoxy Resin (Control Sample) as a function of Time at $2.36ms^{-1}$

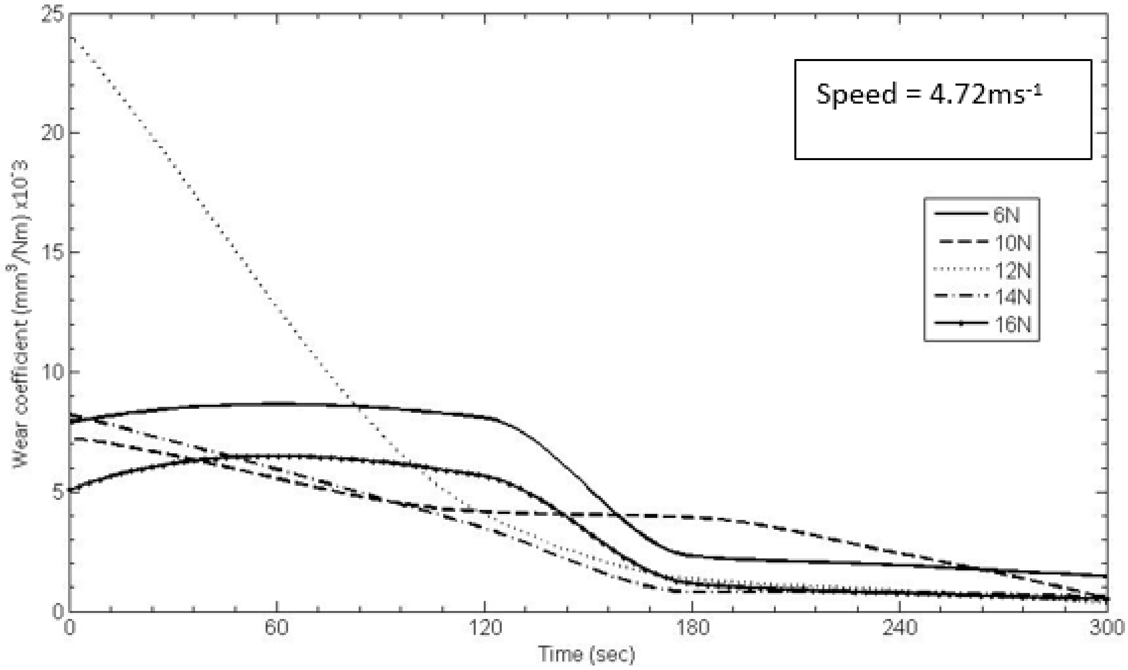

Figure 10. Wear Coefficient of Epoxy Resin (Control Sample) as a function of Time at $4.72ms^{-1}$

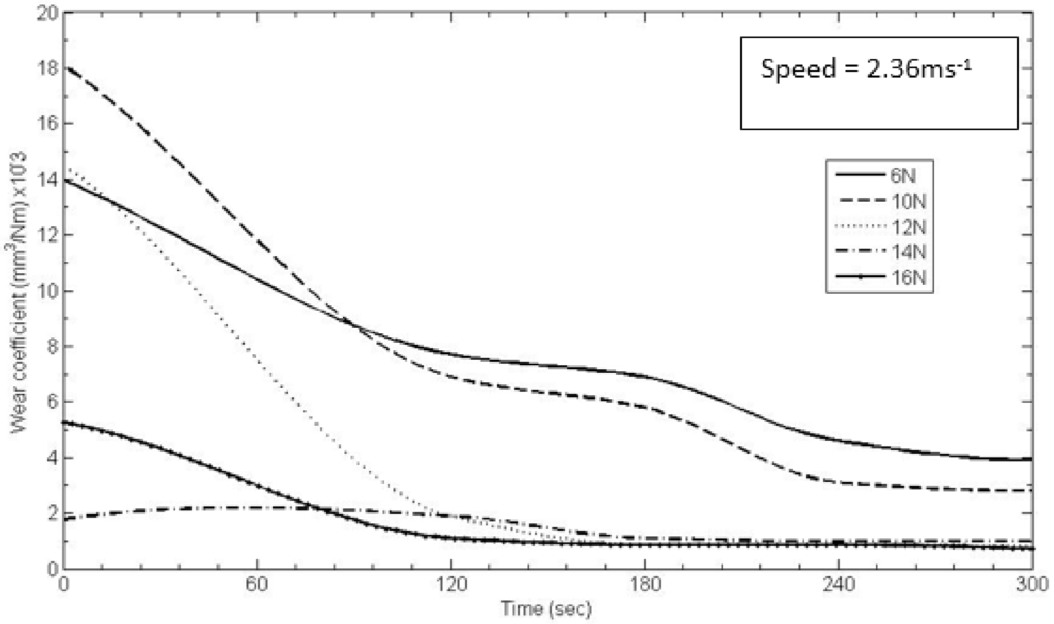

Figure 11. Wear Coefficient of the ER/5DFT/2GP Composite as a Function of Time at 2.36ms^{-1}

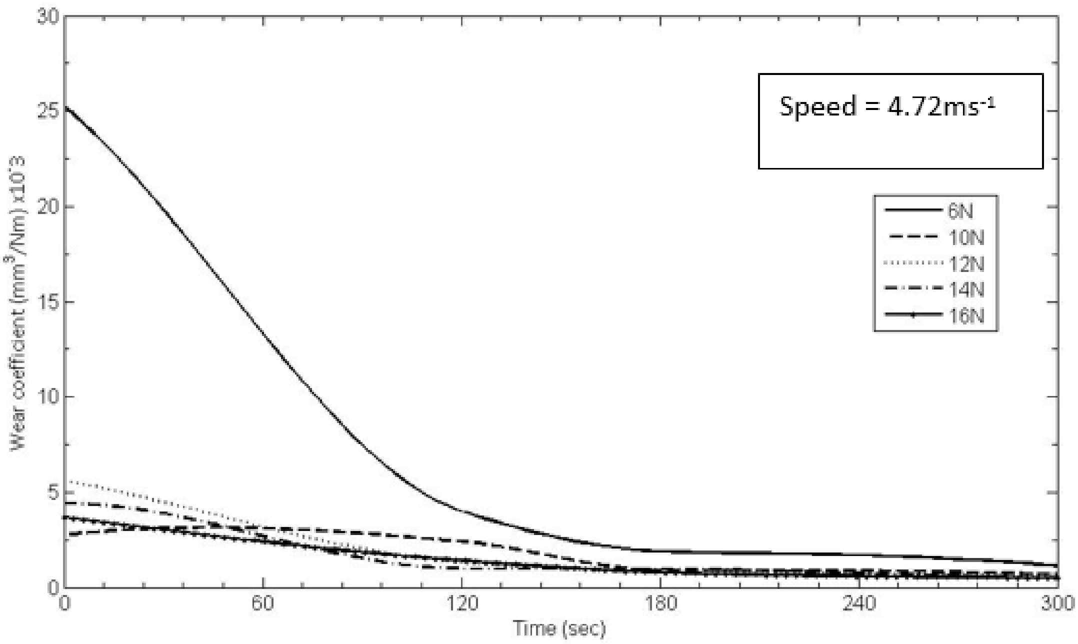

Figure 12. Wear Coefficient of the ER/5DFT/2GP Composite as a Function of Time at 4.72ms^{-1}

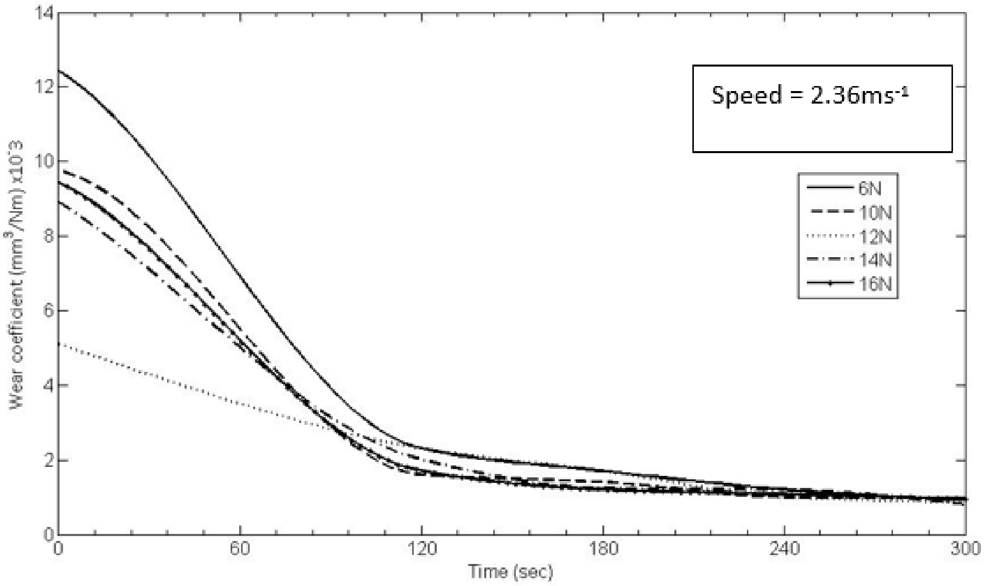

Figure 13. Wear Coefficient of the ER/20DFT/2GP Composite as a Function of Time at 2.36ms^{-1}

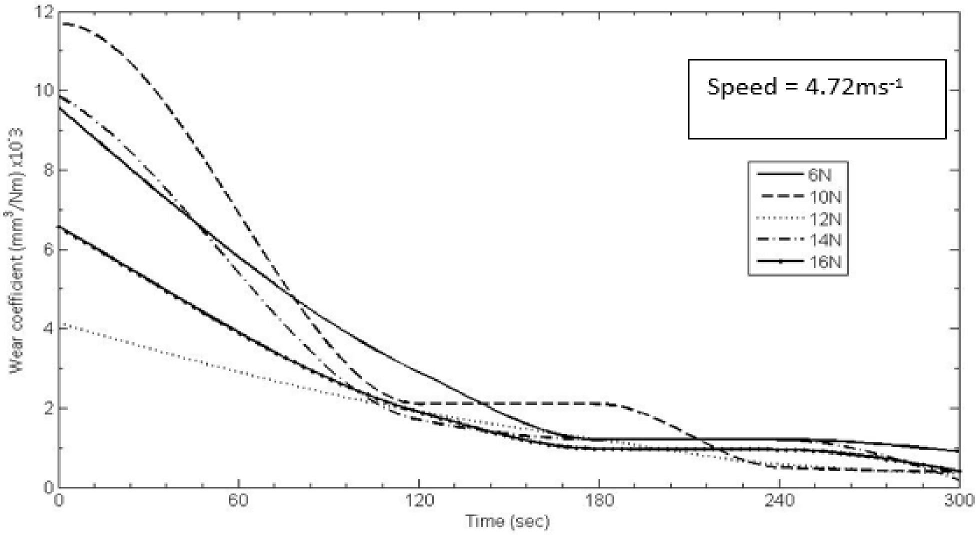

Figure 14. Wear Coefficient of the ER/20DFT/2GP Composite as a Function of Time at 4.72ms^{-1}

4 Conclusion

Additions of graphite and glass particulates to epoxy resin enhanced the thermal stability of the developed composites. The enhanced thermal stability of the developed composites was attributed to the ability of the recycled florescent tube/graphite in the matrix of the developed composites to retain temperature for long time with little or no oxidation, thereby the thermal stability of the developed composites. The filler additions were found to also act as barriers that prevent the transport of volatile products out of the composite during thermal decomposition. The developed hybrid composites developed higher resistance to wear as the speed increases. The applied load increase increased the volume loss. Hence, it impacts negatively on the wear resistance of the developed composites

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