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# TRIBOLOGICAL AND MECHANICAL BEHAVIOUR OF POLYETHERIMIDE REINFORCED WITH GLASS FIBER & GRAPHITE POWDER

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## ABSTRACT

Polyetherimide (ULTEM 1000) in granules form is one of the newest high-performance thermoplastics. Its graphite and short-glass-fiber filled composition was evaluated for mechanical and wear properties. Wear behavior of glass fiber reinforced PEI composites with different percentage of graphite powder is observed on pin on disc apparatus at different loads. It was observed that the adhesive wear is decreased remarkably due to increasing percentage of graphite powder. The wear mechanism was studied with scanning electron microscopy by analyzing the worn and unworn surfaces of the specimen. The mechanical properties were also improved slightly.

*Keywords: Composites, Accumulative diffusion bonding, shear strength, bonding strength*

## 1.Introduction

The composite materials have got widely applications in all cutting-edge ranges of advanced materials as aeronautics, automotives, boats, sports parts and medical devices [1]. A composite is a structural material which consists of two or more constituents , combined at a macroscopic level and are not soluble in each other. One constituent is called reinforcing phase and the other, in which reinforcing material is embedded is called the matrix. The reinforcing material may be in the form of particles, fibers, tubes or flakes. The matrix phase materials are generally continuous [2]. The wood is the best example of natural composite in which, the lignin matrix is reinforced with cellulose fibers. The other suitable example is bones in which the bone-salt plates made of calcium and phosphate ions reinforce soft collagen. The roles of matrix in composite materials are to give shape to the composite part, protect the reinforcements to the environment, transfer loads to reinforcements and toughness of material, together with reinforcements. The reinforcements is done to increase the mechanical properties such as strength, stiffness, tensile strength etc. of the composites, dominate other properties as conductivity, temperature stresses and thermal transport [3]. Third component of a composite is a filler material, which is mixed with the matrix material during fabrication phase. Fillers do not have significant effect on mechanical properties of the composite but they are used to improve some other characteristic of the composites [4]. Examples include: hollow glass microspheres are used to reduce weight, clay or mica particles are used to reduce cost, carbon black particles are used for protection against ultraviolet radiation, and alumina trihydrate is used for flame and smoke suppression.

## 2. Experiment

### 2.1 Fabrication of Composites

The PEI in granular form (ULTEM 1000) was supplied by GE Plastics, USA. The glass fiber is supplied by GE Plastics, USA. Dichloromethane ($CH_2Cl_2$) is used as a solvent to make the PEI solution. All composites were prepared by impregnation technique followed by Compression molding. The plies of size (300mm×300 mm) were cut from the fabric roll. To prevent the fiber misalignment a special tape (PTFE coated glass fabric tape) is used to seal the all sides of fiber seats, when dipped or taken out of the solution. The plies were dipped in the semi-liquid solution of PEI, Dichloromethane and graphite powder for 12 hours [5]. Container which contains solution and fabric ply had been covered and sealed properly to avoid any vapour leakage. After 12 hours, Prepegs had been took out of container and allowed to dry in an oven for 2 hours at 80-100°C. Total no. of 20 Prepegs prepared and stacked to attain the thickness of 3-4 mm. The mould of compression molding machine was heated up to temperature of 400 °C. Two intermittent breathing approximate 3sec each were provided during compression to remove the residual

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solvent. PTFE coated glass fabric was placed on the top and bottom of stacked Prepegs in the mould. Then the prepegs were compressed at same temperature under the pressure of 8MPa. Then the composite were cooled under same pressure for 3 to 4 hours.

### 2.2 Adhesive wear studies

In present work, the friction and sliding wear performance evaluation of PEI composites having different percentages of graphite powder (i.e 0%,5% and 10%) under dry sliding conditions were carries out on a pin-on-disc type friction and wear monitoring test rig as per ASTM G99 [3]. The Specimen size is 10mm×10mm×3-4mm of composite which is rotated against a high speed steel disc which have surface roughness of Ra~.3μm. The operating parameters were taken as follows [6].

Track Dia. : 80mm
Disk Speed : 400 rpm
Load : 100, 150 and 200N
Duration : 1 hours
Velocity : 1.67m/s
Distance Travelled: 6.033 km

The specific wear rate was calculated using the equation [7,8]:

$$k = {}^{\Delta m}/_{\rho L D}$$

Where *Δm* is the weight loss in kg,
*ρ* is the density in kg/m$^3$,
*L* is load in N and
D (sliding distance in m)= 2πRN/60 .

### 2.3 Abrasive wear studies

The abrasive wear behavior of PEI composites having different percentages of graphite powder (i.e 0%,5% and 10%) under dry sliding conditions were carries out on a pin-on-disc type friction and wear monitoring test rig as per ASTM G99. Specimen pin of size 10mm×10mm×3-4mm of composites rotated against silicon carbide (SiC) paper. The operating parameters were taken as follows:

Track Dia. : 80mm
Speed : 400 rpm
Load : 20, 30 and 40N
Duration : 10 min.
Velocity : 1.67m/s
Distance Travelled : 1.005 km

The specific wear rate was calculated using the equation [7,8]:

$$k = {}^{\Delta m}/_{\rho L D}$$

Where *Δm* is the weight loss in kg,
*ρ* the density in kg/m$^3$,
*L* is load in N and
D (sliding distance in m)= 2πRN/60

**Fig. 1 Tribometer Layout used for experiments**

## 3. Result and Discussion

**Table 1. Mechanical and Physical Properties of PEI composites.**

| **Specimen** | **GF+PEI** | **GF+PEI+5 %GP** | **GF+PEI+ 10%GP** |
|---|---|---|---|
| Fiber Contents Wt.% | 55 | 55 | 55 |
| Density (g/cc) | 1.989 | 1.795 | 1.890 |
| Tensile Strength (N/mm$^2$) | 172 | 122 | 148 |
| Elongation (%) | 1.70 | 2.20 | 2.40 |
| Flexural Strength (N/mm$^2$) | 18 | 20 | 21 |
| Hardness (Shore D) | 48 | 56 | 58 |

Table 1 shows that there is a significant increment in the mechanical and physical properties of PEI composites with the increased percentage of graphite powder except tensile strength which is decresed slightly as the percentage of graphite powder was increased.

### 3.1 Friction and Wear

The Fig. 2 presents the variation of coefficient of friction with applied load (100, 150 and 200N) at velocity of 1m/s under sliding conditions.

The experimental result shows that with increase in applied load, coefficient of friction increases slightly for all PEI composites. Under dry conditions, increasing applied load increases the temperature at interface. Due to increase in temperature thermal penetration occurs which results in weakness in bond at the interface. As a result coefficient of friction increases.

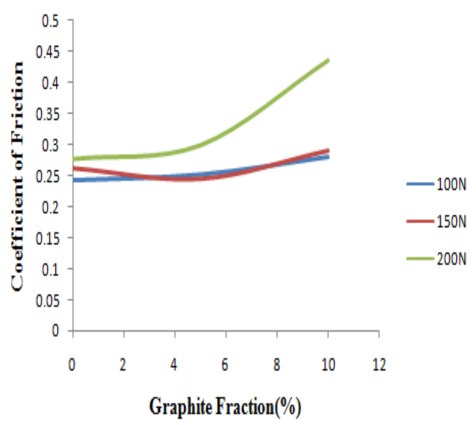



**Fig. 2 A graphical plot of Friction coefficient vs. Load for adhesive wear.**

Adhesive wear as a function of Graphite fraction of PEI composites is shown in Fig. 3:

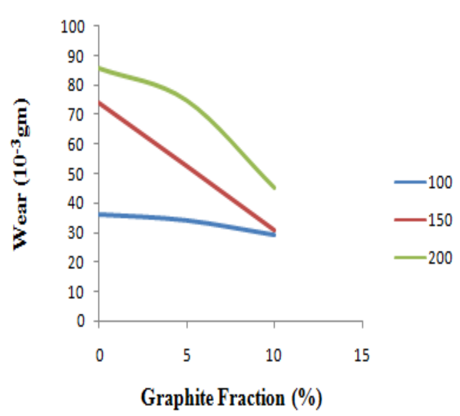



**Fig. 3 A graphical plot of Adhsive wear vs. Graphite fraction**

Variation of Specific wear with graphite fraction of PEI composites is shown in Fig. 4.

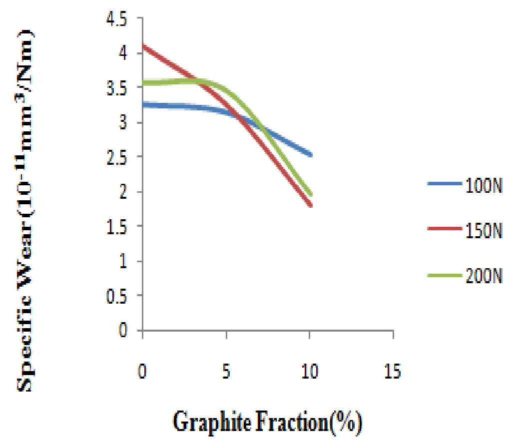



**Fig. 4 A graphical plot of Specific Wear vs. Graphite fraction**

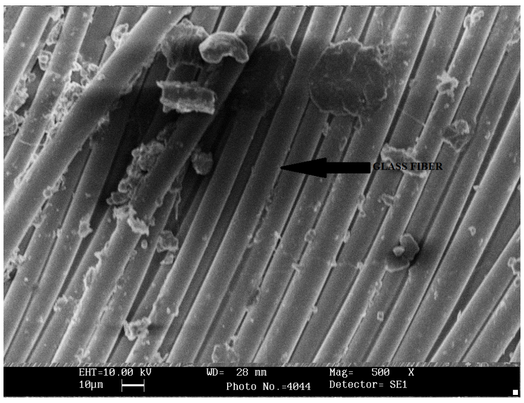
### 3.2 Scanning Electron Microscope (SEM)

A scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons. SEM is carried out to study the surfaces of unworn and worn surfaces of composites, to conclude mechanism and modes of wear in composites.

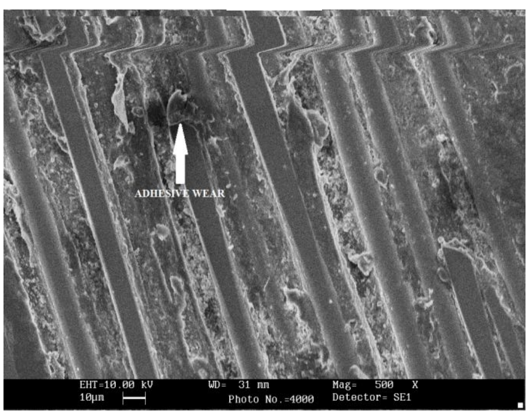
Fig. 5 (a) & 5 (b) shows unworn and worn surfaces of PEI composite without filler material. Fig. 5 (c) & 5 (d) shows the SEM images of Polyetherimide reinforced with Glass Fibers filled with 5% of graphite powder by wt. While Fig. 5 (e) & 5 (f) gives details of SEM of Polyetherimide reinforced with Glass fiber filled with 10% of graphite powder by wt. From Fig.s 5 (a) we can see that unworn composite shows a good packing or adhesion of matrix and reinforcement. The fiber weaves are closely packed. While from Fig. 5 (b) can see worn surface of PEI composites without filler material. Arrows show the areas of cracking of fibers. The wear of Glass fiber reinforced PEI composite is because of cracking of fiber weaves.

The Fig. 5 (c) shows the unworn surface of the glass fiber reinforced PEI composite filled with 5% graphite powder. The graphite particles are seen on the surface as shown in Fig. 5 (c). From the SEM image 5(d) which shows the worn surface of PEI composite filled with 5% graphite powder revealed that there is less cracking on the surface due to graphite powder which acts as a solid lubricant.




**(a)**

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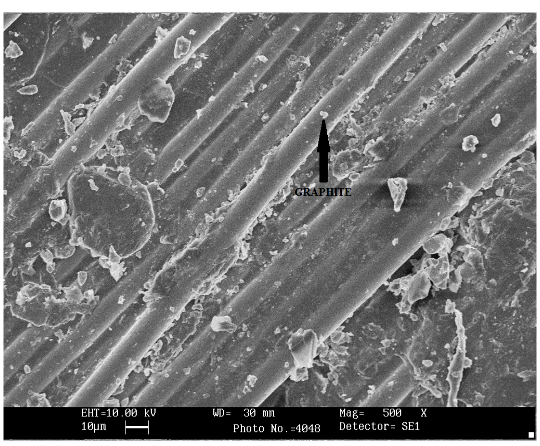
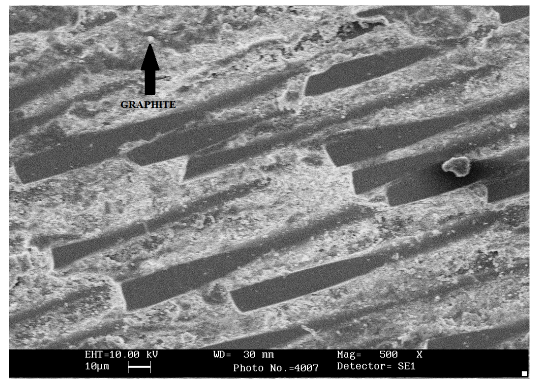
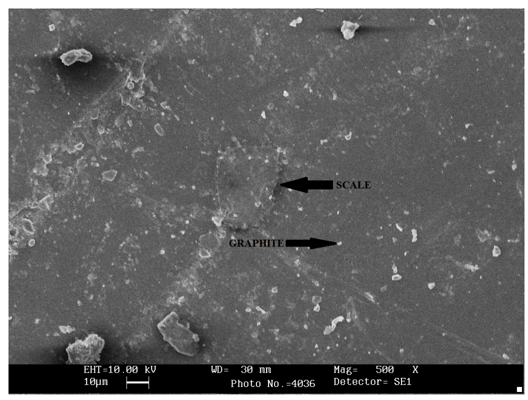


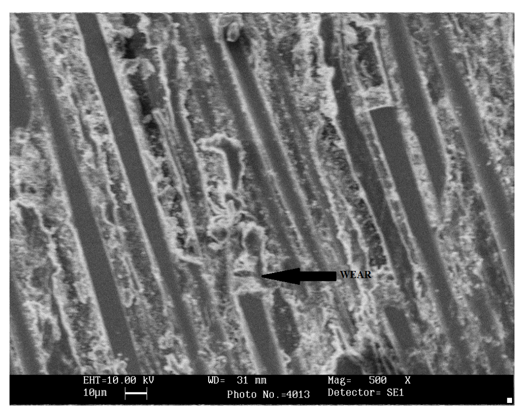

**(c)**




**(d)**




**(e)**




**(f)**

**Fig. 5 (a), (b), (c), (d), (e) and (f) shows the SEM images worn and Unworn surfaces of Polyetherimide reinforced with Glass fiber and different percentages of Graphite powder i.e. 0%,5%,10%.**

Fig. 5 (e) shows unworn surfaces of PEI composites filled with with 10% graphite powder. It can be seen that there is the surface has good smoothness due to increasing percentage of graphite powder Fig. 5 (f) shows the worn surface of the same. From the SEM images it is concluded the increasing the amount of graphite powder increases the smoothness of the surfaces which results in decrement in adhesive wear..

## 4. Conclusion

The present fabrication and characterization of polyetherimide reinforced with glass fiber and graphite powder leads to the following conclusion:

- Results revealed that the flexural strength is improved 18 – 21 $N/mm^2$ with the addition of 5% & 10% graphite powder by wt. .
- The hardness of the PEI + GF composite without glass fiber is less (48) than the hardness of graphite added composite which is 56 at addition of 5% graphite powder and 58 when added 10 % graphite powder by weight.
- Tensile strength shows the different trends with increased graphite powder fraction.
- The adhesive wear is reduced considerably from .036 gm to .029 gm with the addition (5% and 10%) of graphite powder.
- The abrasive wear of composite without graphite powder is less than the 5% &10% added graphite powder due to breakage of the friction film which protects the surface.

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