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Analysis of Polyetherimide Reinforced with Glass Fiber & Graphite Powder

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***Abstract*-The purpose of this research paper is fabrication of polyetherimid(PEI)reinforced with glass fiber and graphite powder and to study two types of wear (i.e adhesive and abrasive wear) of PEI composites with different percentages of graphite powder. Polyetherimide(PEI) composites with fiber contents 55 wt.% are fabricated using compression molding technique. (ULTEM 1000) in granules form is one of the newest high-performance thermoplastics. Wear behavior of glass fibre reinforced PEI composites with different percentage of graphite powder is observed on pin on disc apparatus at different loads. Composites were analyzed by SEM for wear mechanism, fiber failure and surface topology.**

Keywords- Polyetherimid (PEI),Dichloromethane (DCM),cold remote nitrogen plasma (CNROP)

I. INTRODUCTION

A composite is a structural material that consists of two or more combined constituents that are combined at a macroscopic level and are not soluble in each other. One constituent is called reinforcing phase and one in which it is embedded is called the matrix. The reinforcing phase materialmay be in the form of fibers, particles or flake. The matrix phase materials are generallycontinuous. The composite materials have got a widely applications in all cutting-edge ranges of advanced materials as aeronautics, automotives, boats, sports parts and medical devices**.**

Constituents of composites

1. Matrices
2. Reinforcing Fibers
3.Filler materials

Glass is the most commonly used fiber of all reinforcing fibers for polymeric (plastic) matrix composites (PMCs). The principal advantages of glass fiber are low cost, high tensile strength, high chemical resistance and excellent insulating properties. Glass fiber reinforced composite consists 30-60% glass fibers by volume..

II. LITERATURE SURVEY

This chapter discusses the literature on performance properties of polyetherimide reinforced with glass fiber and graphite composition.Thereview carried out in order to identify the research gaps in the broader area of *Research on Polyetherimide (PEI) reinforced with Glass fibers and Graphite powder at 5% and 10% by wt. is not doneyet*and*Wear behavior of PEI reinforced with Glass fibers and Graphite powder is other area of research,Comparative study of wear of PEI*so that the problem could be identified and accordingly, the objectives be formulated to accomplish using a systematically devised methodology/approach.

Among the available papers published on the mechanical and wear performance of composites, only those papers were selected which distinctly dealt with the performance properties closely relevant to the research work presented in the thesis. Several researchers have proposed their theories, experimental results regarding various properties of composite materials under different types of loading and boundary conditions.

J.bijwe, J.Indumathi[1] selected a high performance engineering polymer, polyetherimide and its two composite one containing only short glass fiber (20%) and the other containing 25% glass fiber and three solid lubricants for studying the four types of wear. the addition of solid lubricants has improved the adhesive wear resistance but the abrasive wear increased with addition of fillers against SiC papers

U.S.Tiwari et al. [2] states that Polyetherimide is one of the newest high-performance thermoplastics. Its graphite and short-glass-fibre (GF) filled composition was evaluated for friction and wear properties. Tribological studies of the material sliding against mild steel, under different loads, counter face roughnesses and sliding distances were performed on a pin and disc configuration. He observed that this composite displayed very good wear resistance due to glass-fibre reinforcement and low friction due to the solid lubricant graphite. The wear mechanism was studied with scanning electron microscopy by observing the worn pin and disc surfaces. Fatigue was observed to be the main factor in wear, along with adhesive and abrasive modes.

J.VINA et al. [3] investigated the wear behavior of a thermoplastic polymer, polyetherimide, and of a composite with this polymer as matrix and a reinforcement of glass fiber. The investigation shows that the reinforced material has higher wear strength then the non-reinforced material. The effect of temperature on wear performance is also studied which shows that when the temperature is increased the wear was increased, except to 2000C . At 2000C there was an important decrease because it would be close to glass transition temperature of the polymer (2170C) which causes micro-structural variation in the material.

A.P.HARSHA et al. [4] investigated the solid particle erosion behavior of randomly oriented short E-glass, carbon fiber and solid lubricants (PTFE, graphite, MoS2) filled polyetherimide (PEI) composites. The erosion rates of these composites have been evaluated at different impingement angles (15-900) and impact velocities (30-88 m/s). Polyetherimide and its glass, carbon fiber reinforced composites showed semi-ductile erosion behavior with peak erosion rate at 600 impingement angle. However glass fiber reinforced PEI composite filled with solid lubricant showed peak erosion rate at 600 impingement angle for impact velocities of 30 and 88 m/s. whereas for intermediate velocity (52 & 60 m/s) peak erosion rate observed at 300 impingement angle. It is observed that 20% glass fiber reinforcement helps in improving erosive wear resistance of neat PEI matrix.

Guijun Xian et al. [5] studied the sliding wear of graphite flake filled polyetherimide against polished steel counter parts at various temperatures. The addition of 5 -20 vol. % of graphite contributed to an obvious improvement of tribological performance of PEI at either room temperature or elevated temperature (up to 2200C). Higher filler content (≥ 15 vol. %) leaded to a very low coefficient of friction when temperature exceeded 1500C. the specific wear rate was also reduced. Microscopy studies suggested that friction films were formed on both the counterpart and the worn surface of composite. An interface layer is formed between the friction films at elevated temperature for high content graphite filled composites, which contributes to the unusual improvement of wear properties.

Klaus Friedrich et al. [6] in his research, he has a particular emphasizes on special filler reinforced thermoplastic and thermosets. The effect of particle size and filler contents on the wear performance was summarized. He observed that once the particle sizes are diminishing down to nano scale significant improvements of wear resistance of polymer were achieved at very low nano filler content (1-3 vol. %).

V.K. Srivastava et al. [7] investigated the effect of particulate additions on the friction and wear of short glass fiber reinforced epoxy resin composites. Particles of graphite were mixed with the epoxy resin prior to composing with short glass fiber. Tests were performed on bushing samples to obtain the friction and wear for the composites with varying applied load and sliding time. It was found that graphite has an important impact on the wear and friction properties of glass fiber reinforced epoxy resin composites. It is clear that after an incubation period, there is a nearly linear relationship between wear load and sliding time. Wear increases with load and time, but as the amount of graphite in the composite increases, its value decreases irrespective of the applied load and sliding time, due to increase of wear resistance in matrix materials. However, friction increases only with sliding time but decreases with the increase of graphite particles irrespective of time.

Li Chang et al. [8] was found that conventional fillers, i.e. SCF and graphite flakes, could effectively enhance both the wear resistance and the load-carrying capacity of the base polymers. With the addition of sub-micro particles, the frictional coefficient and wear rate of the composites were further reduced especially at elevated temperatures. On the basis of microscopic observation of worn surfaces, dominant wear mechanisms are discussed.

J. bijwe et al. [9] was selected three weaves (plain, twill and woven) of glass fiber asreinforcement for developing composites based on polyetherimide matrix also another composite containing additional filler was formulated to investigate the influence of fillers on wear performance. It was observed that plain weave proved to be best effective in enhancing the wear behavior of PEI three times. Twill weave and fillers, however, performed poorly resulting significant deterioration in wear performance while woven fabric showed some improvement in wear performance at higher loads. Mechanical properties of the composites did not support the trend in the wear behavior.

SudhirTiwari, et al [10] studied the influence of plasma treatment on Carbon Fabric for enhancing Abrasive Wear Properties of PEI Composites. Interfacial adhesion between matrix and fibre plays a crucial role in controlling performance properties of composites. Carbon fibres have major constraint of chemical inertness and hence limited adhesion with the matrix. Surface treatment of fibres is the solution of the problem. In this work, cold remote nitrogen plasma (CNROP) was used for surface treatment. Twill weave carbon fabric (55-58%) was used with and plasma treatment with varying content of oxygen (0-1%) in nitrogen plasma to develop composites with PEI composites.

III. AIM OF THE OBJECTIVES

Based upon the research gaps identified the following objectives were formulated:-

1. To study the Adhesive wear behavior of Polyetherimide reinforced with glass Fiber filled with differentpercentage of graphite powder at different loads.
2. To study the Abrasive wear behavior of Polyetherimide reinforced with glass Fiber filled with different percentage of graphite powder at different loads.
3. To study Mechanical properties of Polyetherimide reinforced with glass fibres and different percentage of graphite powder i.e. 5% & 10% by weight.
4. To compare the two types of wear (adhesive & abrasive wear) of polyetherimide reinforced with glass Fiber filled with graphite powder.

IV. METHODOLOGY

Experimental Setup

Polyetherimide (PEI) is used as matrix and Glass Fibre is used as reinforcements. Graphite powder is used as a filler material.Compression molding machine used for the compression and fabrication of PEI composites. Composites had been fabricated at workshop, M. M. University, Mullana. Adhesive and abrasive wear experiments had been done on Pin-on-Disc arrangement at Tribology Lab, Mechanical Engineering Department, M.M. University, Mullana (Ambala). .

Fig. 1:Pin On Disc

RAW MATERIALS

- Dichloromethane (DCM)
- Polyetherimide (ULTEM 1000)
- Glass fiber
- Graphite powder

Mild steel (AISI 1018) is selected for this experiment. The dimensions of the plates are 100×100mm each and 10 mm thick. Mild steel is the most common high volume steel in production. Mild Steel is used for almost all non-specialist steel products- cars, domestic goods, constructional steel work etc.

Preparation of Solution

The solution is prepared by adding polyetherimide (PEI) in dichloromethane (DCM) in the ratio of 1:15 by vol. i.e. 15 g of PEI had been immersed in 100 ml of DCM. The Polyetherimide was in granule's form. After adding the PEI granules in appropriate amount in DCM, it is allowed to be in the container for 24 hours. Polyetherimide granules are mixed with DCM and form a semi-liquid and thick solution. DCM works as a solvent in which when PEI granules are mixed, the granules chemically react with DCM and form solution. After 24 hours container is opened to check whether solution is prepared.

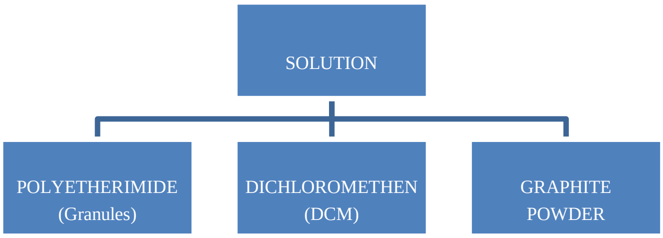

Figure 2 Component of Solution

Cutting of Fabric/Prepegs cutting

After the preparation of solution of PEI, DCM and graphite powder the glass fiber was cut in the form of prepeges in required dimensions with the help of special fibre scissor. In the present work fabric was cut wrap direction of the fabric weave. Prepegs or Fabric with dimensions 30mm×30mm were cut from fabric roll.

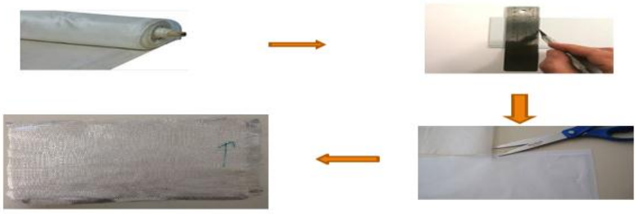

Figure 3 Cutting of Glass Fabric Prepegs

Sealing of Prepegs

After cutting the fibreprepegs in required dimensions from the roll,theprepegs were sealed from all the sides with the help of PTFE tape coated with Glass Fabric. The sealing is done to prevent the misalignment of weave of the prepegs.

Dipping of Prepegs

After sealing the glass fabric prepegswere dipped in the prepared solution (PEI+DCM+Graphite powder). The Prepegs were dipped in the solution so that solution get mixed with the fabric and get entrapped in the weave uniformly. The glass fabric prepegs were dipped in the solution for 24 hours.

Drying the Prepegs

After 24 hours the Prepegs were taken out of the sealed container. Now prepegs allowed to dry for 4-5 hours under some weight so that there is no bends or curls in the weave. 20 no. of Prepegs prepared to get a desired thickness of a single composite specimen.

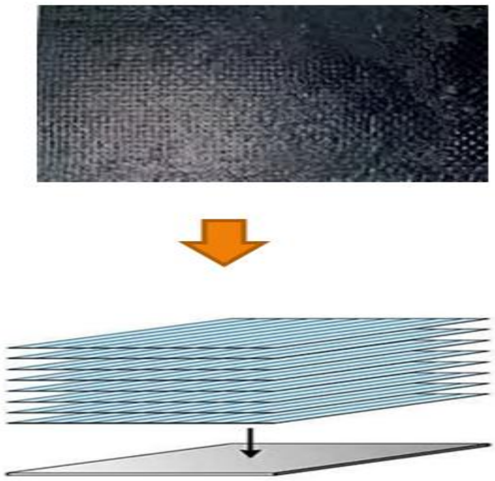

Figure 4 Stacking of Glass Fabric Prepegs

After stacking the dry glass fabric prepeges were brought to Compression moulding machine. The stacked prepegs were compressed in compression moulding machine at temperature 400ºC for two hours. Pressure of machine is 80MPa. Two or three no. of breathings of 20 seconds each are provided so that Extra Polymer solution flew away from the Prepegs. After compression, prepared composite is allowed to cool under same pressure for 4-5 hours. Thermocouple is used to ensure right temperature of mould during compression moulding.

Specimen Preparation

Fig 5Test Specimen

Now a sheet of composite is ready. From this sheet of composite the specimens had been cut according to test requirement with the help of hand cutter. For adhesive and abrasive wear study, the dimensions of the specimens were: 10mm×10mm. Figure shows the specimen used in Adhesive and Abrasive wear study of PEI composites. PEI composites reinforced with Glass Fiber with increasing percentage of Graphite powder (from left to right) Specimen used for Mechanical and Physical Testing is shown in figure. PEI reinforced with Glass Fiber with increasing percentage of Graphite powder (from left to right).

V. RESULT AND DISCUSSION

Tensile Test:

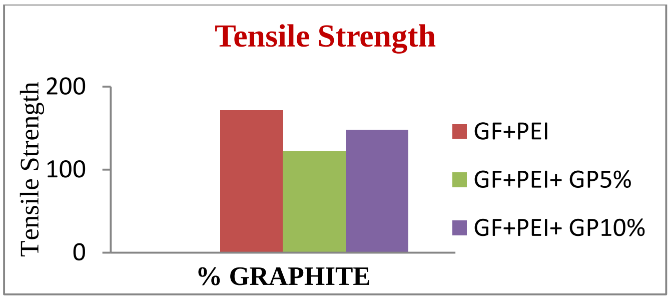

Fig. 6 Tensile strength Chart

There is considerable increment in tensile strength with reinforcement, but with addition of graphite powder there is a dereament in tensile strength. PEI reinforced with glass fibres (GF+PEI) only showed the maximum tensile strength as compare to PEI composite in which graphite powder is added.

HARDNESS TEST (SHORE D):

The fibre reinforcement results in improvement in hardness of PEI composites. Hardness follows the same trend as tensile strength of PEI composites. The composite of PEI reinforced with Glass fibre only is showed least hardness (48) among all the reinforcement of PEI. When we added 5% graphite powder by weight the hardness improved (56) considerably and increased (to 58) slightly when adding more graphite powder.

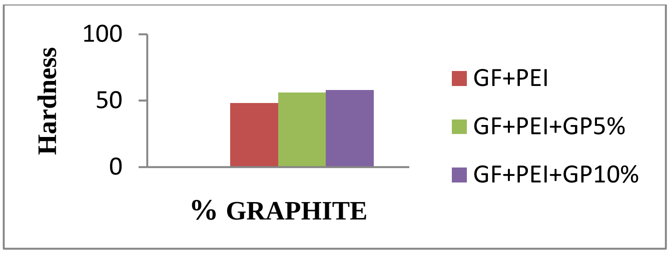

Fig. 7 Hardness Chart

Abrasive wear of Glass fibre reinforced PEI composites at various Load

Load (N)	Wear (g)			Sp. Wear $K_0 \times 10^{-10}$		
	PEI+GF	PEI+GF+5%GP	PEI+GF+10%GP	PEI+GF	PEI+GF+5%GP	PEI+GF+10%GP
20	.0283	.0344	.0349	7.08	5.7	4.075
30	.0301	.0688	.0671	8.3	13.4	15.1
40	.0723	.0724	.0762	19.2	12.3	8.82

Table 1 Wear properties of the Glass fibre reinforced Polyetherimide

The graphical representation of Abrasive wear rate of Glass fibre reinforced PEI composites is drawn on graph in fig.8

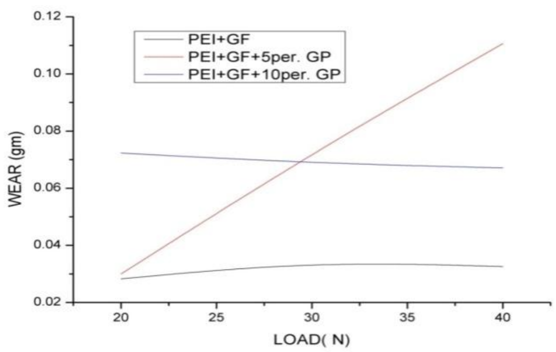

Fig.8 Abrasive wear rate of PEI composites at various loads

It is clearly shown by the chart that wear rates increase as we increase the load.

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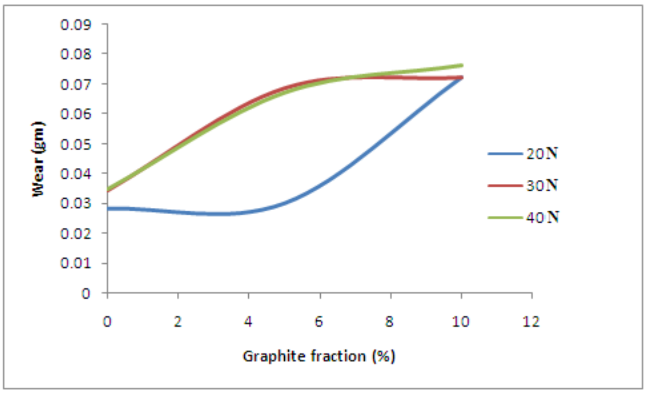

Fig.9 Variation of Abrasive wear rate Vs. Graphite Fraction

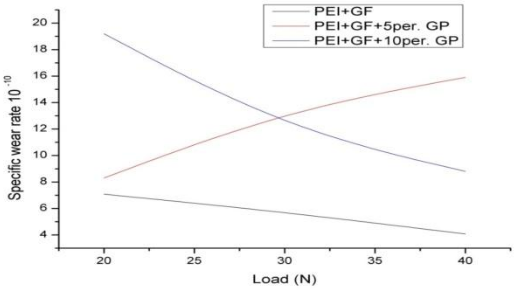

Fig. 10 Specific Abrasive wear of PEI composites Vs. Load

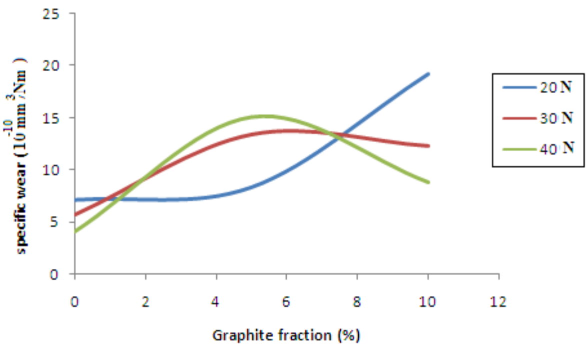

Fig. 11Specific Abrasive wear of PEI composites Vs. Graphite Fraction

Figure 10 and 11 shows the comparison of Specific Wear of PEI composites with different loades and with different percentages of Graphite powder. From figure it is revealed that specific wear of Polyetherimide reinforced with Glass fibre without using any filler material is least at all loads. It is evident that the specific wear decreased considerably for the composite without filler material as the load is increased. But when the 5% & 10% GP is mixed then the specific wear increases with load. The specific wear for the PEI composite using GP as a filler material does not follow the same trend as in case of Adhesive wear. The reason behind it, is that a friction film form on the surface when the composite is abraded against the SiC paper.

VI. CONCLUSION

This research work leads to following conclusions:

- Results revealed that the flexural strength is improved 18 – 21 N/mm2 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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