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Evaluation of mechanical properties of B_4C filled glass-epoxy composites

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Abstract: Polymers and their composites are emerging as viable alternative products to metal based and alloy based ones in many common and advanced engineering applications. In the last decade, most of the studies in polymers based only on micro composites and reinforcement of PMC with the micro fillers. The comparative performance of glass –epoxy composites with influence of Boron Carbide(B_4C) fillers were experimentally investigated under varying applied load, sliding distance and sliding velocity by using a pin-on-disc apparatus. Addition of B_4C fillers in glass-epoxy composite exhibits higher weight loss for increased applied load. The laminates were fabricated by the hand lay-up technique. The volume percentage of filler materials in the composite was varied and the excellent wear resistance and other mechanical properties were obtained from glass-epoxy containing with micro fillers.
Keywords: B_4C fillers, wear resistance, weight loss, Mechanical properties.

1. Introduction:

Polymer composites are progressively used because of their high stiffness, specific strength and wear resistance. The function of the matrix is to bond the reinforcements together and transmit the loads between them. Polymer materials are being increasingly used in wide variety of application in which wear resistance is important and it is used for ideal application where their general resistance to corrosion, galling and seizure, their tolerance to small misalignments and shock loading are necessary. The low density and high toughness are the desirable properties. In many applications, polymers are subjected to abrasive wear, due to the presence of contaminants and such abrasion may result in loss of function. Over the past decades, polymer matrix composites are made and most widely used for structural application in the aerospace automotive and chemical industries and in providing alternatives to traditional metallic materials[1]. The features that make composites so promising as industrial and engineering materials are their high specific strength, high specific stiffness and opportunities to tailor material properties through the control of fiber and matrix compositions. Composites are developed for superior mechanical strength and this objective that conflicts with the simultaneous achievement of superior wear resistance[2]. From the above results, these materials are found to be used in mechanical clutches, conveyors, transmission belts, bushes and bearings. In most of the applications, the components are subjected to tribological loading conditions, where the likelihood of wear failure becomes greater.

Epoxy resins are widely used in the industry, being one of the most applied materials as matrix in composite materials, due to their excellent adhesion to different reinforcements and their slight shrinkage during the curing process. Their low viscosity, high hardness, and good resistance to humidity and fatigue must also be highlighted. They are also used in the atomic energy field, e.g., floor painting in radiation facilities and for nuclear fuel casks, as they have good durability to gamma rays [3]. Moreover, epoxy resins show excellent durability to reactor neutrons with a degassing character and form stability.

Epoxy resins require a curing process to be cross linked and produce polymers with three-dimensional and insoluble networks. The final properties of the cured epoxy arise from the nature of the epoxy resin and curing agent, the curing cycle, degree of conversion, and degree of crosslinking among other factors [4].

Boron carbide (B_4C) ceramics and composites are important high-tech materials, mainly due to their high level of hardness and low density [5]. Specifically, B_4C is the third hardest material after diamond and cubic boron nitride [6]. One of the major uses of B_4C is as an abrasive. Different authors have studied B_4C wear, with and without additives [7,8]. The influence of particle properties on the erosive wear of sintered boron carbide has also been studied [9]. It was found that different erodents (silica, alumina, silicon carbide) cause different erosion mechanisms. B_4C also presents a high melting point and high neutron absorption cross-section [10, 11]. Despite being a neutron absorber material, it does not detect luminescence intensity at low temperatures (below 5 K) and it is opaque to visible light [12]. Its behavior is similar to other weak neutron absorber materials such as acrylic or tetra phenyl butadiene (TPB) evaporated on Gore-Tex1. Few researches deal with B_4C reinforced polymer matrix composites

(PMCs) B_4C has been used with polyethylene at a concentration of 2 wt %, improving the radiation shielding properties of the neat polyethylene [13]. B_4C -epoxy composites serve as components of the neutron shield for the fission residues located outside the cavity of a nuclear reactor, likewise preventing neutrons from escaping and creating a time-dependent background [14]. Also, epoxy resin mixed with neutron shielding materials (including B_4C) have been used for several components of neutron spectrometer construction [15], such as shielding blocks, bricks, beam narrower, and stoppers.

The addition of micro B_4C with epoxy gives the low viscosity for the long curing time; the particles were deposited and tended to agglomerate until gelation was produced. Epoxy –B_4C composites shows the lower glass transition temperature, excellent bending strength and increases the abrasive wear of the material [16].

2. Experimental Details

2.1 Materials and Fabrication

The matrix material used was a medium viscosity epoxy resin (LAPOX L-12) and at a room temperature for curing polyamine hardener (K-6). This matrix was chosen since it provides good adhesive properties owing to the cross-linking chain between the resin polymer and the hardener. Hence, the shrinkage after curing is usually lower. The reinforcement material employed was bidirectional perpendicular yarns of 7-mil E-glass fiber. B_4C powder was selected as the filler material on the basis of their demonstrated ability to withstand high temperatures and to form transfer film during lidding and low thermal expansion. The composites were prepared in the form of blocks of (300mm x 300mm x 3 mm) by the hand layup technique (figure 1). The fillers are mixed with known amount of epoxy resin and detail composition of the composite is given in Table 1.

Table 1 Details of Composite prepared.

Specimen code	Matrix Volume (%)	Reinforcement volume (%)	Filler Volume (%)
1	39.5	60	0.5
2	39	60	1
3	38	60	2
4	37	60	3

After the completion of hand laying technique, the laminate was cured at a temperature of 80°C under the 3000 ton of compressed pressure by using the compression molding machine by maintaining the constant temperature for 1 Hour (figure 2) and the laminate is again cured at room temperature for a period of about 24 hours for the betterment of the properties. The cured laminated are cut using diamond tipped cutter to yield wear test specimen of size 6mm x 6mm x 3 mm (figure 3).



Figure 1: Hand Lay-up Technique Figure 2: Compression Molding Machine Figure 3: Fixing of Specimen in Pin – on- Disc Wear Test

2.2. Test details

The tensile test has been taken for the failure was estimated for various stress under different load conditions and it is carried out with FIE make UTE/E – 40 model Universal Testing machine with data acquisition software to plot stress-strain curve accurately and reading can be given accurately for yield stress, tensile strength, peak load and elongation of the specimen.

A pin-on-disc wear test apparatus was used for the dry sliding wear experiments. The disc used was an alloy steel with 165 mm diameter and 8 mm thick, with the hardness of 62 HRC and with a surface roughness of 1.2 µm. The test was conducted on a track of 130 mm diameter for a specified test duration, applied load and sliding velocity. The surface of the specimen was perpendicular to the contact surface. Before taking the test, the specimen pin was rubbed over an emery (600-grade SiC) sheet to ensure proper contact during sliding. The surface of both the specimen and the disc were cleaned with a soft paper soaked acetone before the test. The initial and final weights of the specimen are also measured by using an electronic digital balance with the accuracy of 0.0001 g. After fixing both the disc and the specimen pin in their respective positions, the normal load to the pin was applied through a pivoted loading lever with a string and pan assembly. The required loads were applied by placing known weights on the pan. At the end of the test, the pin assemble was again weighed in the same balance and difference was taken as weight loss.

2.3. Test Parameters

The test parameters used in the present study are applied load, sliding velocity and sliding distance. A minimum of two trials were conducted to ensure repeatability of test data. The repeatability of wear test runs was established by determining the coefficient of variation which was well within the acceptable limit of 10%. The tests were conducted in three phases, in first phase sliding velocity is varied where as applied load and sliding distance is kept constant. During second phase applied load is varied, but sliding velocity and sliding distance are kept constant. Sliding velocity and applied load are kept constant; sliding distance is varied in the third phase.

3. Results

3.1. Tensile Load


Figure 4: Specimen for Tensile test **Figure 5: Specimen after Tensile test**

The tensile test was carried out on all varieties of specimen in accordance with ASTM: D3528 - 96(2008) standards. The failure of specimen is merely based on the bearing loads experienced by the specimen during loading. Testing has been carried out on a FIE make UTE/E-40 model UTM with Data Acquisition Software was employed to take the accurate reading. The specimen is cut by diamond tip cutting tool as shown in **figure 4** for the gauge length of 80 mm. The tests were performed with a minimum increment load step of 0.5 KN. Load displacement data was recorded for all the specimens.

The tensile strength was increased with the addition of the boron carbide filler with glass- epoxy composites where as the yield strength shows the variation with 1 % filler and the maximum elongation(figure 5) can be occurred at the 1% B_4C filler as shown(figure 6).

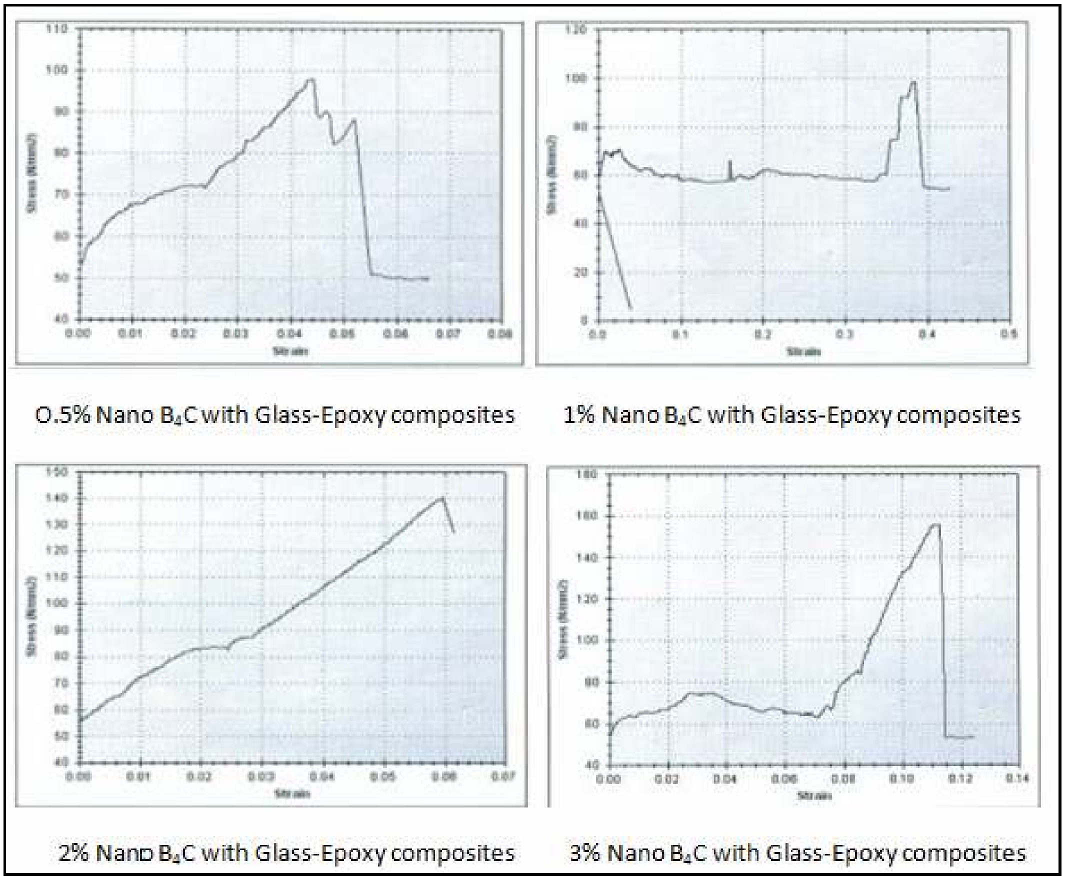

Figure 6: Stress - Strain curve – Data Acquisition Software

3.2. Applied load

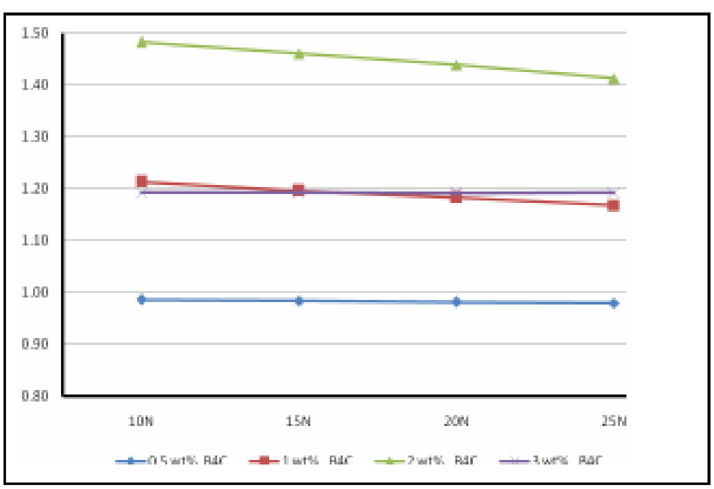

Fig 4: Variation of weight loss Vs Applied load

Fig 4 shows the variation of the weight loss against applied load on the filler content of B_4C. Applied load is varied but sliding velocity and sliding distance were kept constant. Weight loss is dropped from 0.986 to 0.981 g for 0.5% B_4C filled glass-epoxy composites. As the applied load increases from 10 N the weight loss slightly reduces 25 N and by further increasing in applied load the weight loss increases sharply. The 0.5% B_4C filled glass-epoxy specimen shows the poorest wear performance as compared to other reinforcements and but not much difference seen in 3% B_4C filled glass-epoxy composites.

At the lower load of 10 N, the weight loss of the 0.5% to 2 % has increased gradually from 0.986 g to 1.483 g and dropped suddenly with 3% specimen to 1.193 g. The 2% B_4C filled reinforcement had higher weight loss whereas 0.5% B_4C filled reinforcement had lesser weight loss of 0.986 g. The weight loss of the composite with B_4C as filler was found to be marginally effected with the change in applied load.

4. Conclusions

The following conclusion can be drawn from the experimental study on wear behavior and tensile test of glass-epoxy composites with B_4C fillers. Addition of boron carbide fillers increases the tensile strength where as the little deviation of yield strength. In term of elongation, 1% B_4C with glass-epoxy reinforcement obtains maximum elongation. In addition B_4C in glass-epoxy composite exhibits lower weight loss and drops further by increasing the content of filler material. This is due to a thin coherent and uniform film was transferred on the disc and the inter phase also contained lubricant particles thereby reducing the severity of the three body abrasion.

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