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WEAR PROPERTIES OF NANO SCALE FILLERS ON VINYL ESTER-GLASS FIBRE HYBRID COMPOSITES

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ABSTRACT

Polymer and their composites are finding ever increasing usage for numerous industrial applications such as bearing material, rollers, seals, gears, cams, wheels and clutches. Many researchers are focusing on the wear behavior and to improve the wear resistance of polymeric composites. A pin-on-disc setup (Magnum Engineers, Bangalore) was used for wear experiments. The Results of wear properties of vinyl ester-Glass fibre composites with varying percentage of TiO2, Al2O3 and MoS2 filled composites were presented in the present paper. The wear loss increases with increase in sliding velocity and load. Fillers filled composite materials having high wear resistant and low specific wear rate. The hardness of filled composite was substantial compared to hardness of unfilled composite.

Key words: Vinyl ester-glass fiber composites, nano fillers, Hybrid composites.

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1. INTRODUCTION

Most of the recent engineering applications subjected to wear have created a horizon for the search of newer materials. The engineers are started researching to have materials which can resist wear and has less weight to strength ratio. Glass fiber reinforced polymer composites have gained lot of importance due to their high specific strength and been used for seals, gears, cams, rollers and bearing materials. These materials generally wear according to four mechanisms such as micro ploughing, micro cutting, micro fatigue and micro cracking [1].Wear is removal of material gradually due to the rubbing surfaces [2].Most

of the material [60-70%] wear due to abrasion[3].Abrasive wear takes place due to three body abrasion, that is due to hard particles present between the surfaces under relative motion[4]. The Industrial applications look for materials with good mechanical and tribological properties [6]. Abrasive wear encountered in vanes and gears, in pumps handling industrial fluids, sewage and abrasive-contaminated water, roll neck bearings in steel mills subjected to heat, shock loading; chute liners abraded by coke, coal and mineral ores; bushes and seals in agricultural and mining equipment, which have received increasing attention. [7].The easy process ability and flexibility of orientation of mat in bi-direction makes FRP's much sought material [8]. Presently along with the fibers, fillers especially nano-particles are added to enhace properties are gaining importance. The matrix also plays a important role in deciding the melting and processing temperature.

2. EXPERIMENTAL PROCEDURE

The resin (vinyl ester) was poured into a bowl and slowly adds the particulate filler by using mechanical stirrer. Then Cobalt octate (0.35% by volume resin) is added to act as accelerator. Methyl Ethyl Ketone peroxide (MEKP) 1% by volume is added to act as the catalyst. Then the promoter (2%of resin volume) was added to this composition. Mixer was thoroughly mixed using stirrer. The use of accelerator was to promote curing of the vinyl ester resin. Sufficient time was allowed to die for the bubbles formed during stirring. The amount of accelerator, promoter and catalyst should be optimal in proportion to have control on the gel time of vinyl ester resin and may adversely affect the impregnation.

In the present investigation Glass fiber of 360 gsm and bi-directiona was used. Glass fiber mats were cut in to size (280*280) mm to get a required size of 250mm*250mm after the trimming operation of plates and thickness of minimum 3mm was maintained. The mould surface was thoroughly cleaned by thinner to make it free from dirt and any other foreign materials before applying the releasing agent over the surface..

The first layer of the resin coat laid on the release film. Then the first layer of the Glass mat is laid and resin mixture is spread uniformly over the mat by means of a brush. Similarly second layer of glass mat is laid and resin is spread uniformly over the mat by means of brush. After the second layer, to enhance wetting and impregnation, a teethed steel roller is used to roll over the fabric before applying resin. This process is repeated till all the fourteen fabric layers are placed. Then another release film is placed over the fabric layers.

In order to maintain accurate thickness of (3mm) of laminate spacers were used. Another surface plate is placed over the spacers and loaded with uniformly distributed weight on the upper surface. Symmetry should be maintained in stacking the fiber layers. In non symmetric laminate, a bending – stretching coupling causes an undesirable warping of the composite plate. The casting is cured at room temperature for 6-8 hours and finally removed from the mould to get a glassy fine finished composite plate.

A pin-on-disc setup (Magnum Engineers, Bangalore) was used for wear experiments. The surface of the specimen having a size of 3mm x3 mm glued to a pin of dimensions 3 mm diameter and 50 mm length comes in contact with a hardened disc of hardness 62 HRC. The disc was made of En32 steel having dimensions of 160mm in diameter, 8mm in thickness and surface roughness of 0.84 micrometers. The test was conducted on a track of 115mm diameter by selecting the test duration, load and velocity in accordance with ASTM G-99. Prior to testing, the test samples were polished against a 600 grade SiC paper to ensure proper contact with the counter surface.

Figure 1 Photograph of a pin-on-Disc wear tester

The surfaces of both the sample and the disc were cleansed with a soft cloth thoroughly dried before the test. The pin assembly was initially weighted to an accuracy of $1.0x10^{-4}$g in a digital electronic balance (SCHEMANDU, 200g). The dry slide wear tests were conducted for different samples as per the following table.. The differences between the initial and final weights were taken to estimate the wear loss. For each condition, tests were performed and the mean value of weight loss was recorded. A 20kg load cell was fixed tangential to the lever arm through which the friction force was measured.

Table 1

Material	Vinyl ester	Woven GF mat	TiO_2	MoS_2	A_2O_3
G-V	40	60	---	---	-----
1TiO_2 filled G-V	32.5	60	7.5		
2TiO_2 filled G-V	30	60	10		
3TiO_2 filled G-V	27.5	60	12.5		
1MoS_2 filled G-V	32.5	60		7.5	
1Al_2O_3 filled G-V	32.5	60			7.5
2Al_2O_3 filled G-V	30	60			10
3Al_2O_3 filled G-V	27.5	60			12.5

Note : G- glass fiber , V- vinyl ester.

3. RESULT AND DISCUSSIONS

3.1. Discussion on Hardness Test Results

The table 1 shows the results of Brinell hardness test of filled and unfilled composite materials and the comparison of hardness of filled composite with unfilled composite. The comparison of vinyl ester with varying percentage of TiO2, Al_2O_3 and MoS_2 filled composites were presented in the following graphs. The hardness of filled composite was substantial compared to hardness of unfilled composite. It was clear

from the following graphs with the addition of filler volume percentage there has been increase in hardness of the composites.

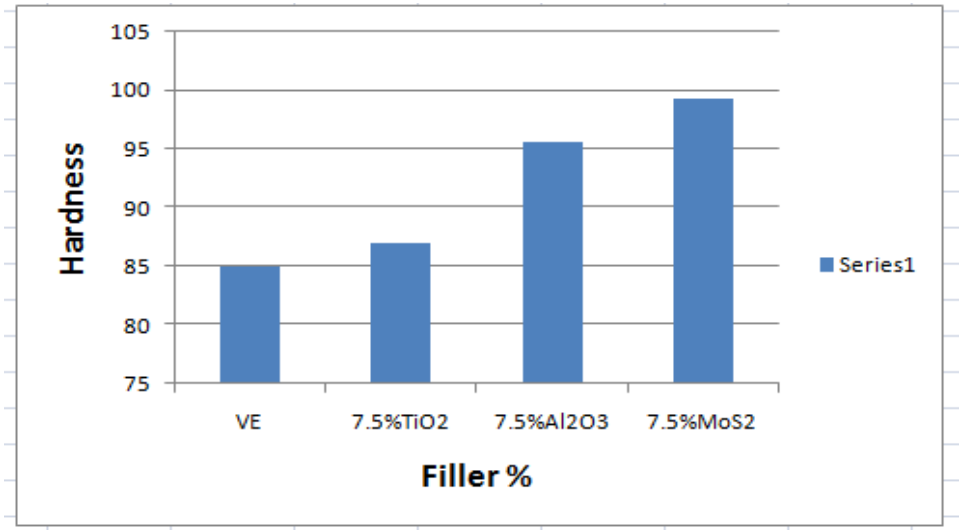


Figure 2.1 Comparission of Hardness of VE with 7.5% of TiO_2, Al_2O_3 and MOS_2

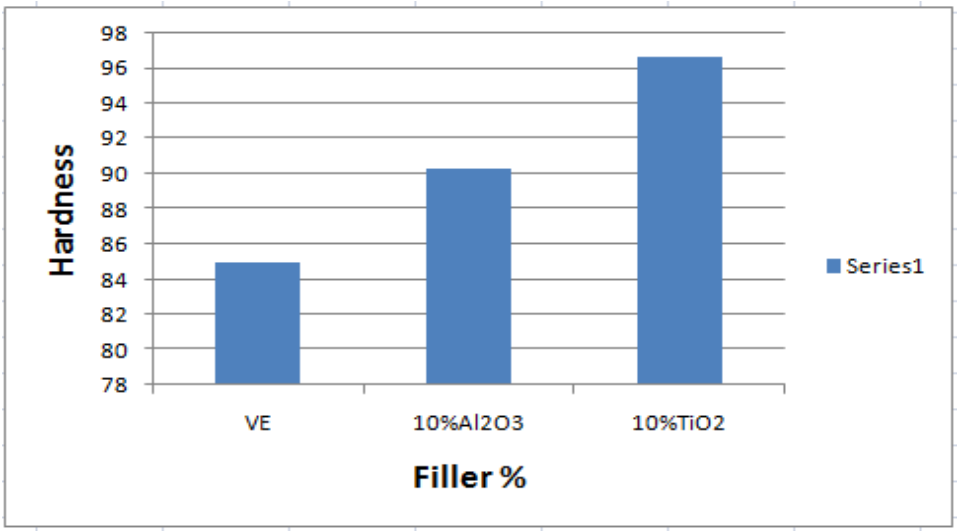


Figure 2.2 Comparission of Hardness OF VE with 10% OF TiO_2 and Al_2O_3

It is reported that improvement in mechanical properties of composites using matrix modification depends largely on the interface to volume ratio and filler size [9,10]. So in this direction nanofillers are playing important role for the modification in polymer matrix. Some of the work has been already reported on the modifications of composite interface by reinforcing mechanism. The modification combines effect was explained from a variety of interface theories such as chemical bonding [10), wetting, mechanical interlock [11] and local stiffness of polymer matrix[12]. In this area, enhancement in mechanical properties of composites has been reported by incorporating nano-scale fillers such as CNT [13-16], fullerenes [17,18] and nanoclay [19,20].

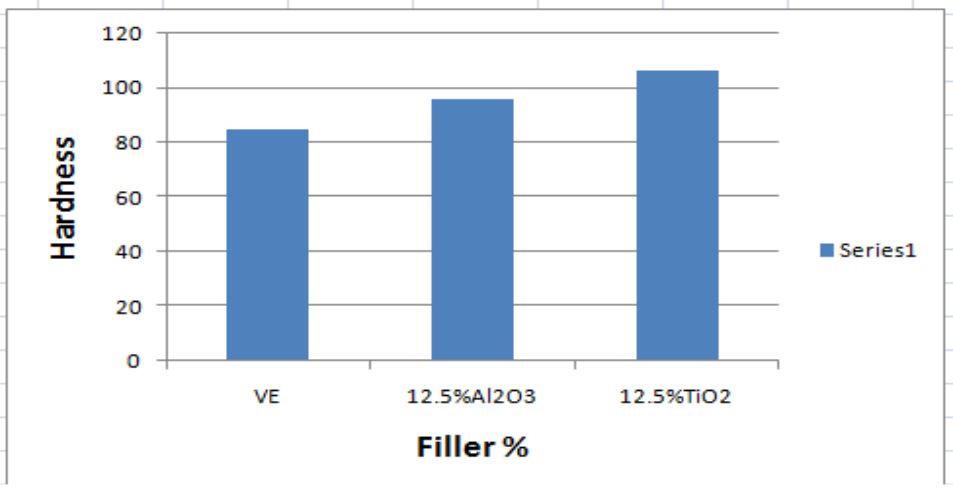


Figure 2.3 Comparisson of Hardness of VE with 12.5% TiO_2 and Al_2O_3

3.1.1. Friction and Dry Slide Wear behavior

The acceptability of material depends on wear loss and the frictional force for industrial applications. Polymer based composite materials are the ones employed in such applications owing to their ever increasing demand in terms of stability at higher loads, better lubrication and wear properties. The introduction of filler and fibers to the polymer matrix enhances tribological characteristics. This work deals with the experimental investigation of dry slide wear behaviour of Glass fabric and different ceramic reinforced particulates as fillers.

3.1.2. Effect of Load

Glass fabric reinforced composites enhaces the tribological characteristics, toughness, and dimensional stability. The dry slide wear behaviour of Glassfabric reinforced composites is carried out as a function of sliding velocity, for different loads and sliding distance. The effect on various parameter are compared through graph and discussed by scanning electron microscopy study. The variation in wear loss with different sliding velocity for G-V samples of different sliding distance is shown in the Fig. 3.1 to3.4. The variation of wear loss with respect to the sliding distances varies uniformly with respect to the load applied. The interesting feature observed is that wear loss value is higher at higher sliding velocities. Thus the wear loss increases with increase in sliding velocity and load.

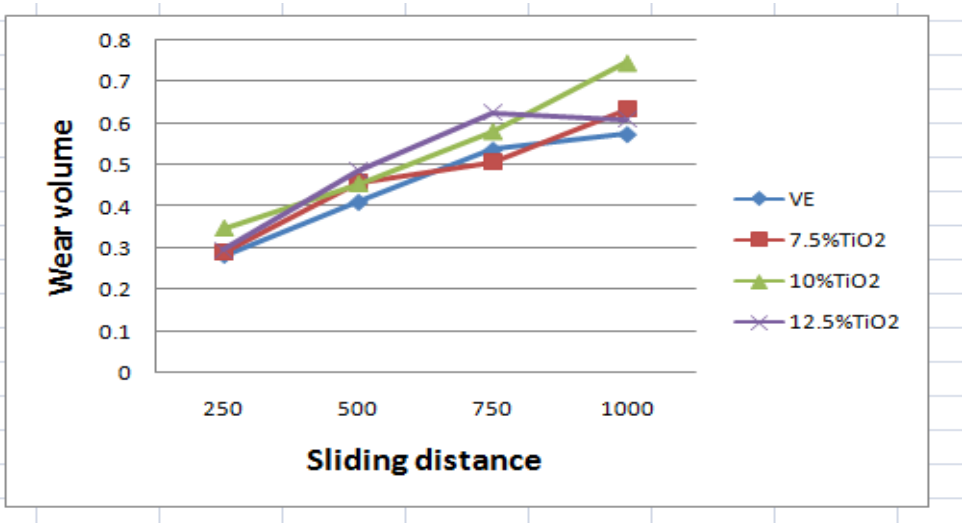


Figure 3.1 Comparision of VE with VE+TiO_2

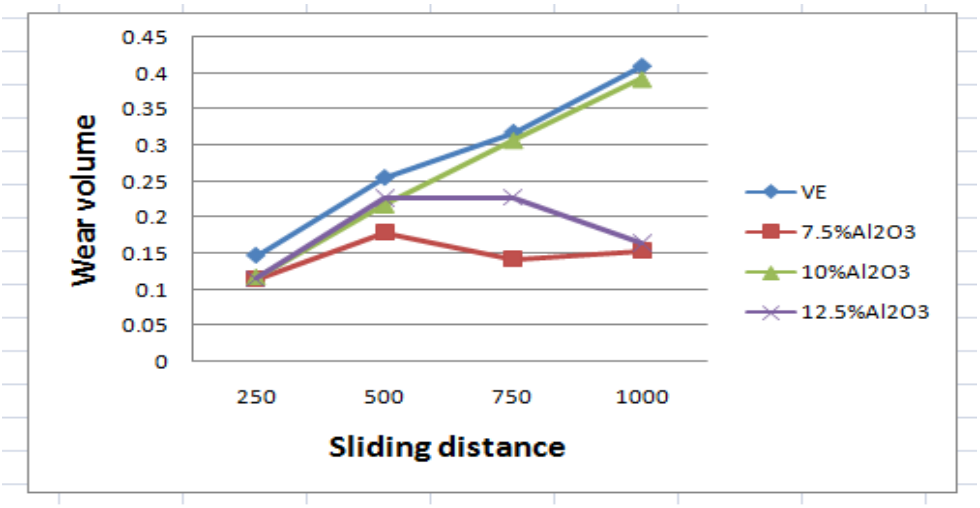


Figure 3.2 Comparision of VE with VE+Al2O3

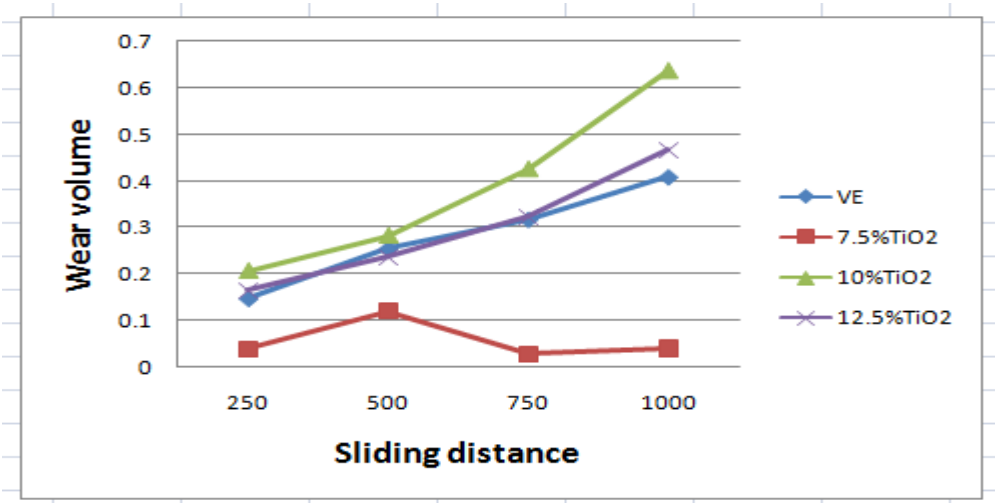


Figure 3.3 Comparision of VE with VE+TiO2

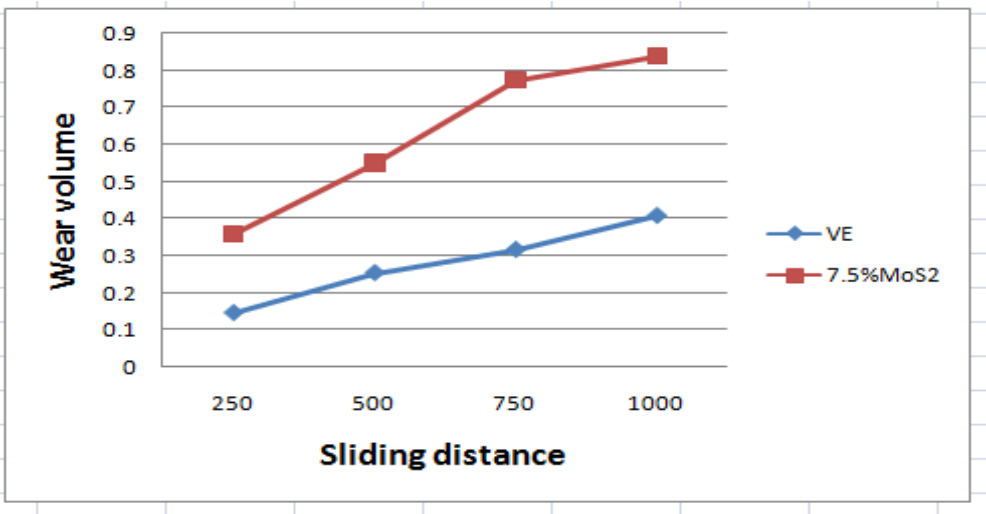


Figure 3.4 Comparision of VE with VE+MOS2

TEST FOR 36N LOAD

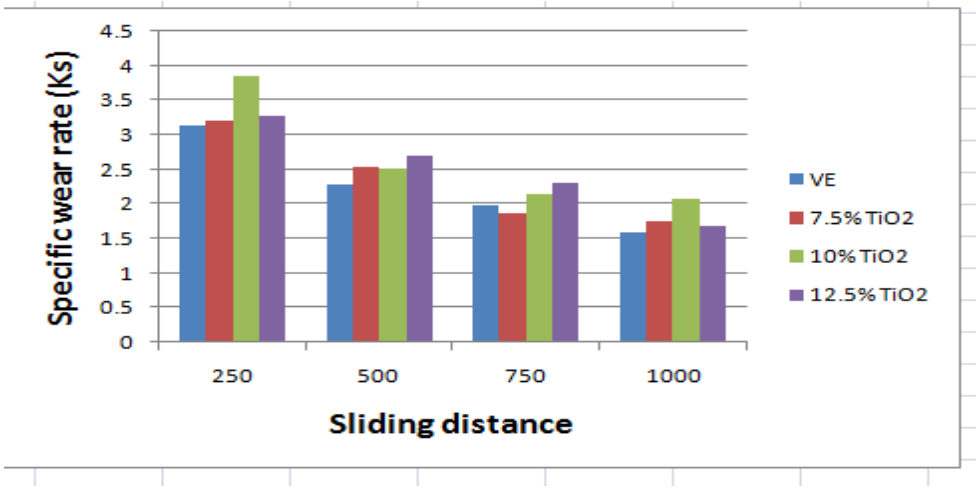


Figure 4.1 Comparision of VE with VE+TiO_2

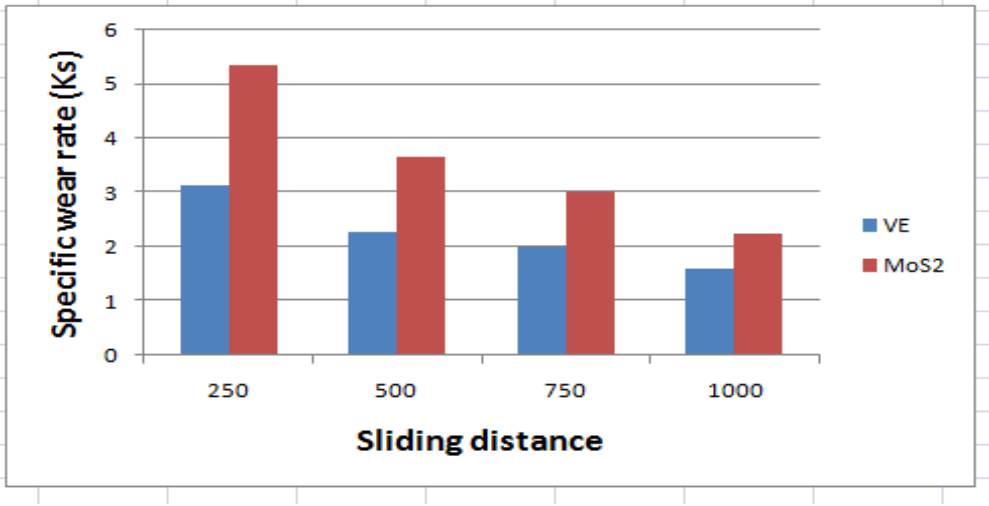


Figure 4.2 Comparision of VE with VE+MOS_2

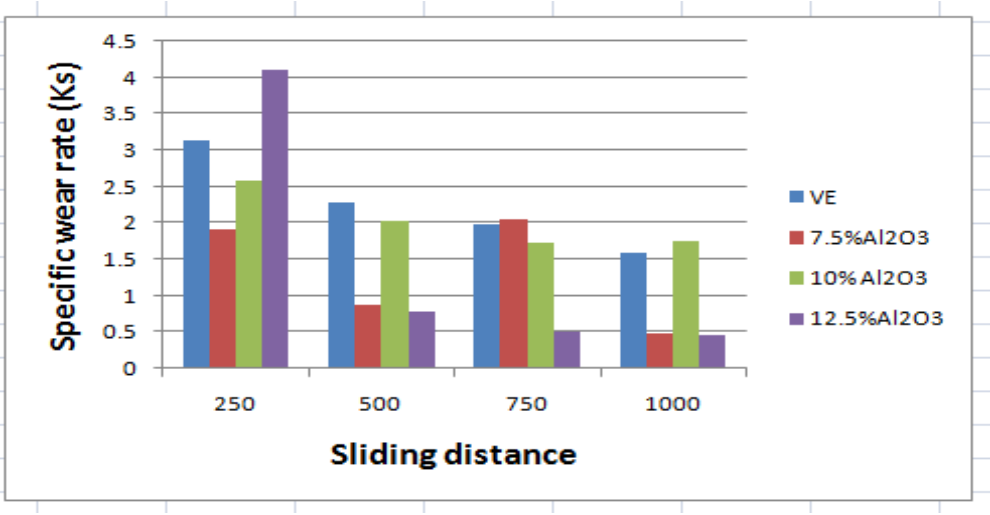


Figure 4.3 Comparision of VE with VE +Al_2O_3

TEST FOR 23N LOAD

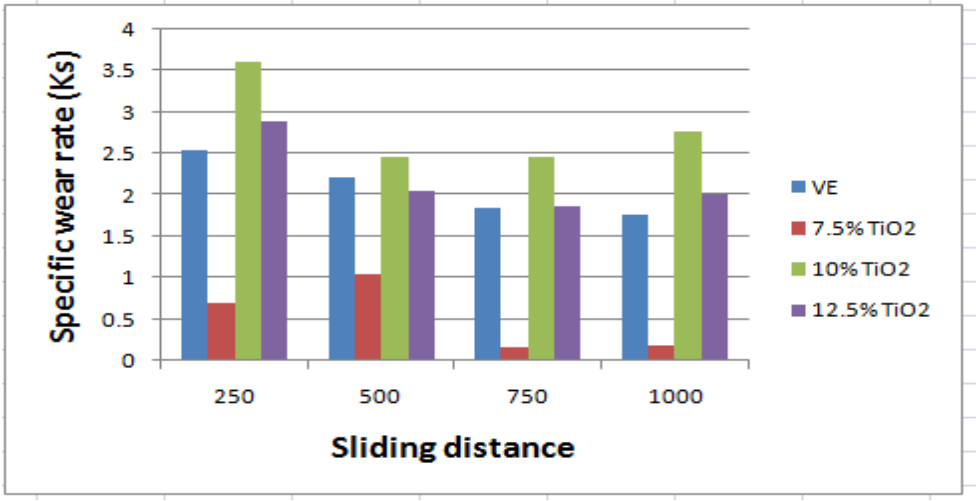


Figure 4.4 Comparision of VE with VE+TiO_2 23N

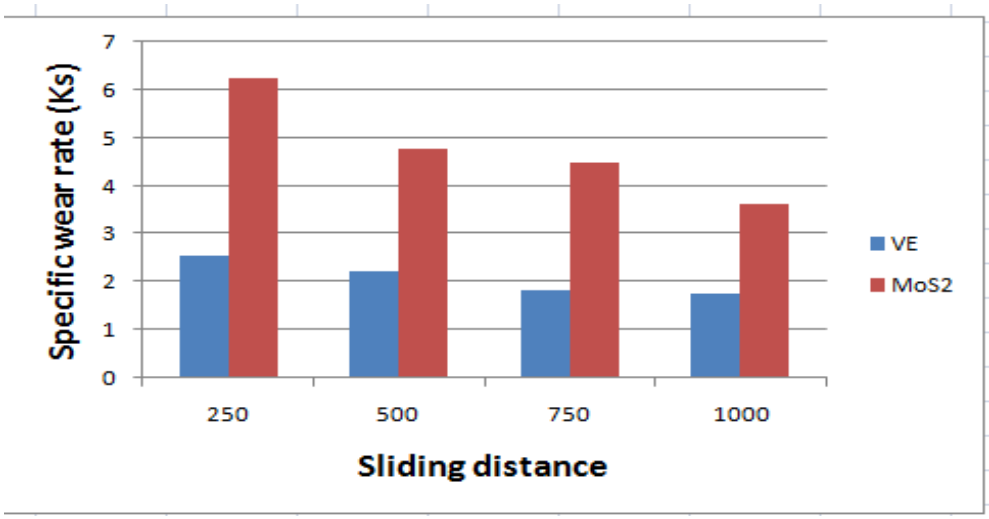


Figure 4.5 Comparision of VE with VE+MOS_2

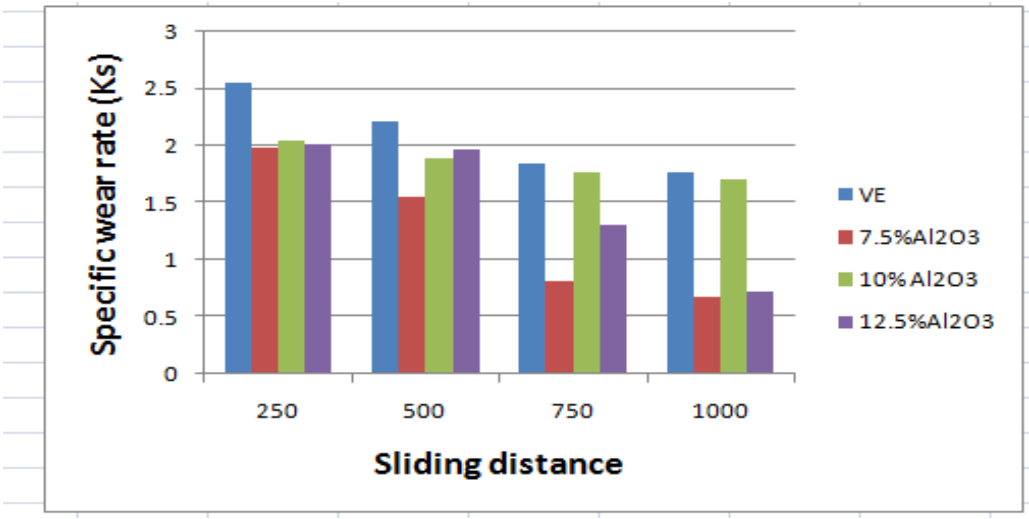


Figure 4.6 Comparision of VE with VE+$Al2O_3$

The variation in specific wear rate of composites worn at load 23N and 36N against abrading distances of 250m, 500m, 750 and 1000m respectively is shown. Fig.4.1 to fig.4.6.Investigations on this field reveal that the filler filled composite materials having high wear resistant and the specific wear rate decrease with increase abrading distances. In our investigations from the figure no 4.1to4.6, it was observed that the wear rate decreased drastically with increase in the percentage of fillers from zero to 7.5 percentages and reduces with further increase till 10 percentage. For the load of 36 N, increase of percentage MOS_2 which did not shown good result due to low wetting with vinyl ester resin. In case of 36 N load 7.5% and 12.5% of TiO_2 Yielded good results. In case of $Al2O_3$ filler 7.5% and 10% have high specific wear rate compared to vinyl-ester glass fibre composites.

Further it was observed that the specific wear rate decrease with increase in abrading distances on applied load of 23N. The $Al2O_3$ composites show higher specific wear rates compared to the other fillers and unfilled materials.

3.1.3. Scanning Electron Microscopy

The material microstructure plays a major role in determining the wear mechanism in fiber reinforced composites. Better surface finish and higher fibre density leads to better wear resistance. Severe wear was noticed at higher applied load and higher sliding velocities. The photomicrographs (Figure 5.1-5.4) are obtained through scanning electron microscopy for the selected parameter conditions the tests are taken out. By comparing the fiber surfaces of the samples at different parameter conditions wear rate and tribological characteristics can be predicted easily.

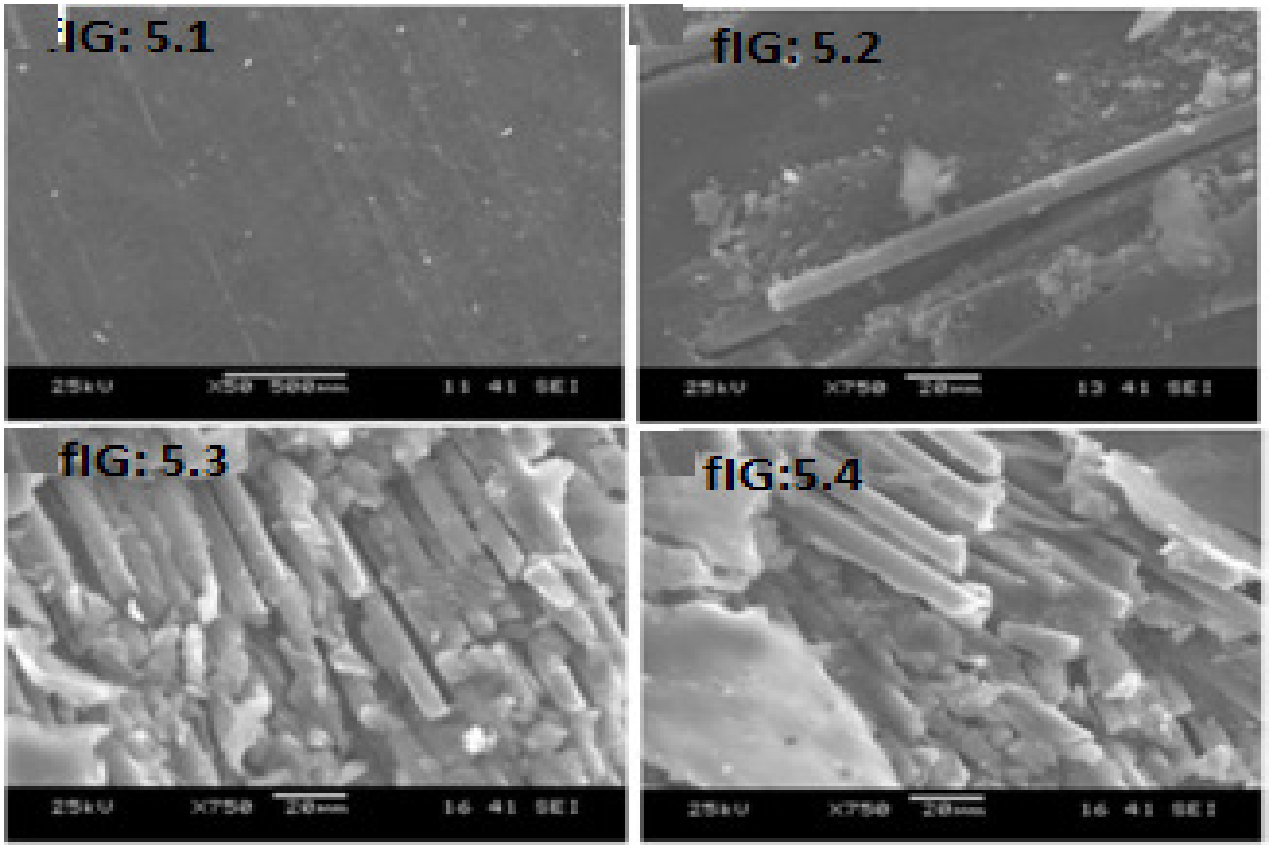
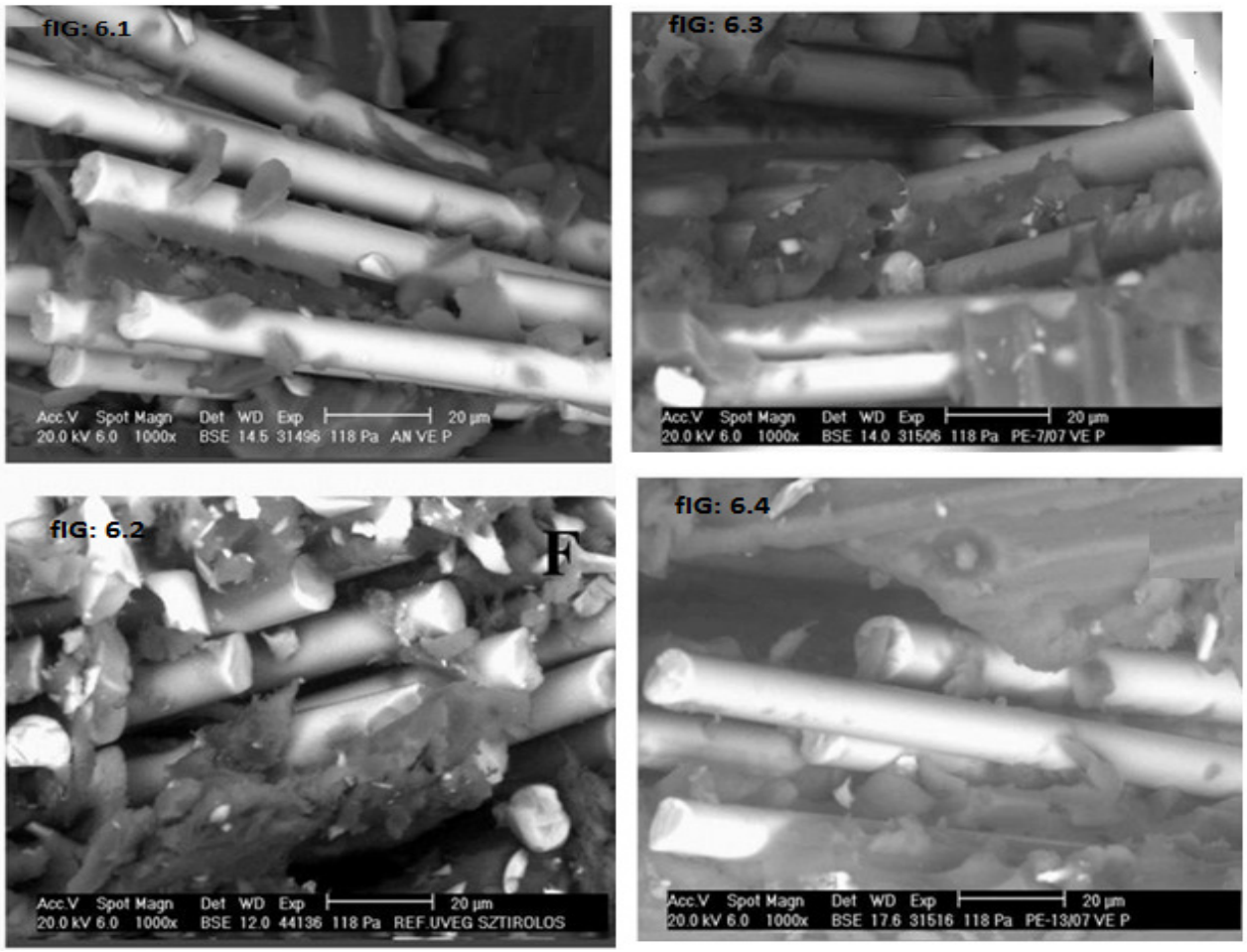


Figure (a) SEM showing matrix wear and fibre thinning, **(b)** shows fibre broken in the wear process, **(c)** shows interfacial deboning of fibre from matrix and **(d)** shows fibre peeling-off during wear process.

The last two stages occurred sequentially, i.e. the interfacial debonding was followed by fibre removal. Therefore, the serious breakage of the matrix in the interfa-cial region was found to occure. (Figure 6.3) could result in a large area of the fibre exposure and thus a massive fibre removal (Figure 6.4).



Further the researcher observes and agree with other researchers that the fibres were removed with larger patches and severe wear occurs,ess [20,21]. Moreover, the large fibre debris could further decrease the wear resistance of compos-ite owing to a three-body abrasive wear effect [22], whereas the smaller ones were believed to be helpful in the formation of the transfer film and led to a reduced frictional coefficient [23–26].

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