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RESEARCH ARTICLE

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DEVELOPMENT AND STUDY OF ABRASIVE WEARS AND MECHANICAL BEHAVIOUR OF PARTICULATE FILLED POLYMERIC COMPOSITES

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ABSTRACT

The aim of this experimental study is to study the three body abrasive wear, dry sliding abrasive wear and mechanical behaviour of neat Vinyl Ester and Al203, TiO2 and MoS2 filler of 4% and 8% filled particulate reinforced composites have been investigated along with the subsequent study of the Mechanical and Wear Properties of the material. Thus intend to contribute to the final aim of optimizing the quantity of the different filler materials.Neat vinyl ester filled glass fiber is taken as the reference material. Abrasive wear testing is done by dry sand abrasive wear testing machine in ASTM 65 standard using Silica sand. The load applied 23N and 36N in this experiment with sliding distances of 500m and 1000m respectively.Mechanical testing like tensile, flexural, Impact is done using universal testing machine. Hardness test is done by Vickers hardness machine. The weight loss of different wear testing samples, Abrasive wear volume and specific wear rate as a function of applied normal load and abrading distance is also calculated.The results shows that abrasive wear situations, for increased load and sliding distance wear losses are found to be higher. Wear volume is increased with the increase in the abrading distance. Experimental results show that the wear resistance is increased with increase in percentage of filler materials. 4% Weight of TiO_2 (filler) is shown higher wear resistance. In case of mechanical properties filler filled materials showing good results than unfilled materials.

Keywords: Titanium Dioxide (TiO2); Aluminium Oxide (Al2O3); Molybdenum Di Sulphide (MOS2).

INTRODUCTION

1.1 Composites

The development of composite materials and related design and manufacturing technologies is one of the most important advances in the history of materials. Composites are multifunctional materials having unprecedented mechanical and physical properties that can be tailored to meet the requirements of a particular application. Many composites also exhibit great resistance to high temp corrosion and oxidation and wear. These unique characteristics provide the mechanical engineer with design opportunities not possible with conventional monolithic materials. Composites technology also makes possible the use of an entire class of solid materials, ceramics, in application for which monolithic versions are unsuited because of their great strength scatter and poor resistance to mechanical and thermal shock. Further, many manufacturing processes for composites are well adapted to the fabrication of large, complex structures, which allows consolidation of parts, reducing manufacturing costs

1.2 Vinyl Ester

Vinyl Ester is a resin produced by the esterification of an epoxy resin with an unsaturated monocarboxylic acid. The reaction product is then dissolved in a reactive solvent, such as styrene, to a 35–45 percent content by weight.It can be used as an alternative to polyester and epoxy materials in matrix or composite materials, where its characteristics, strengths, and bulk cost intermediate between polyester and epoxy.

1.3 Glass fibers

Glass for reinforcement is available in several forms like fibres, rovings, chopped strands, yarn and mats. There are a number of grades available for reinforcement purposes Glass fibres are useful because of their high ratio of surface area to weight. However, the increased surface makes them much more susceptible to chemical attack. Humidity is an important factor in the tensile strength. Glass strengths are usually tested and reported of virgin fibres which have just been manufactured. Because glass has an amorphous structure, its properties are the same along the fibre and across the fibre.

1.4 Aluminium Oxide (Al2O3)

Alumina is the most cost effective and widely used material in the family of engineering ceramics. The raw materials from which this high performance technical grade ceramic is made are readily available and reasonably priced, resulting in good value for the cost in fabricated alumina shapes. With an excellent combination of properties and an attractive price, it is no surprise that fine grain technical grade alumina has a very wide range of applications.

1.5 Molybdenum Di Sulphide (MOS2)

Molybdenum disulphide is the inorganic compound with the formula MoS2. This black crystalline sulfide of molybdenum occurs as the mineral molybdenite. It is the principal ore from which molybdenum metal is extracted. The natural amorphous form is known as the rarer mineral jordisite. MoS2 is less reactive than other transition metal chalcogenides, being unaffected by dilute acids. In its appearance and feel, molybdenumdisulphide is similar to graphite, is widely used as a solid lubricant because of its low friction properties, sometimes to relatively high temperature.

1.6 Titanium Dioxide (TiO2)

Most of the industrial application of titanium is in the form of titanium dioxide (TiO2), used as a dense, fade-resistant pigment in paints, paper, plastics, toothpaste. Titanium dioxide has excellent covering power. An interesting note is that the pigment is used by astronomers because of its ability to reflect infrared radiation. It is also especially useful in hot climates to keep interiors cooler when used in exterior paint. When used in paper or cement, the compound also imparts greater strength to the material.

1.7 Studies Conducted

In last two decades many epoxy and ceramic filled polymer composites are investigated. Influence of graphite filled epoxy resin on sliding wear and abrasive wear behaviour carbon fabric reinforcement has shown that the filler improves the material characteristics and then 10% graphite shown highly good results. [1]. The bidirectional fabric reinforcement offers a unique solutions to the increasing demands on the advanced materials in terms of better performance and ease in processing.[2]The matrix materials also plays an important role as is the case for thermoset resin matrix composite.[3].The effect of particulate filers of polyamide nano-composites are investigated for mechanical properties and shown that mechanical properties are also improved due to the fillers.[4]Mechanical behaviour and fatigue damage of Titaniamatrix reinforced with continuous SiC fibers are also investigated at room temperature and 550$^{\circ}C$ and they have seen that SiC fibers improves the creep resistance at 550℃.[5] The mechanical and three body abrasive wear behaviour of 3 dimensional glass fabric reinforced vinyl ester composite comparing with 2-dimensional glass fabric and have seen that 3-dimensional fabric reinforcement with vinyl ester is more effective than 2-dimensional.[6] Body abrasive wear experiments wear performed under multi-pass condition using silicon carbide (SiC) of 150 and 320 grit abrasive papers. Excellent wear characteristics wear obtained with carbon epoxy containing graphite as filler. Especially, 10% weight of graphite in carbon epoxy gave a low wear rate. [7] Till date several researchers studied the tribological properties of polymer blends and pointed out that the friction and wear properties varied continuously with the compositions for the most polymer blends and the optimal properties were found at a certain composition, although some data reported were contradicting. [8]. The mechanical and three body abrasive wear behaviour of poly methyl methacrlate (PMMA) and thermoplastic polyurethane (TPU) blend has been studied. In this study three body abrasive wear tests were carried out using rubber wheel abrasion tester under different abrading distances at 200rpm and 22 N load. A significant reduction in tensile strength and tensile modulus have seen with an increase in TPU content in the blend .Three body abrasive wear result were indicate that the wear volume increase with increase in abrading distance for all the samples. Neat PMMA showed the better wear resistance as compared to the PMMA/TPU blends. [9]. The incorporation of silicon carbide (SiC) and graphite fillers on the three body abrasive wear behaviour of glass vinyl ester (G-V) composite has been investigated. Dry sand rubber wheel abrasion tests were carried out at 200 rpm test speed. The test were carried out at 22N and 32N loads by varying the abrading distance from 270 to 1080 m in steps of 270 m. The abrasive wear volume increases with increase in abrading distance /loads for all the samples. Graphite filler addition in G-V composite was observed to be not very beneficial to the abrasive wear performance [10].

2. Experimental procedure

2.1 sample preparations

The steps that we have done to fabricate the laminates are as follows:

Step 1: Calculations

Calculations of parameters and weighing the same are done using electronic weighing machine.

Step 2: Selection of Mould

For Hand Lay-up technique, two moulds are necessary. The pattern of mould can be either of woods or plaster of Paris, Mosaic slabs. In this fabrication mosaic slab are used as moulds.

Step 3: Preparation of Matrix Material

The resin (vinyl ester) is poured into a bowl and slowly the particular filler is added with continuous stirring 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. A promoter (2% of resin volume) is also added to thecomposition and mixed continuously. The use of accelerator is important because without accelerator resin does not cure properly. After adding the accelerator, catalyst and promoter to the vinyl ester resin, it is let to stay for some time so that bubbles formed during the stirring may die out. The amount of accelerator, promoter and catalyst should not be high because a high percentage reduces gel time of vinyl ester resin and may adversely affect the impregnation.

Step 4: Preparation of Reinforcement

Glass fiber, 360 gsm and bi-directional is used as reinforcement. Glass fiber mats are cut in to 14 pieces of size (280*280) mm to get a required size of 250mm*250mm after the trimming operation of plates and thickness minimum 3mm.

Step 5: Application of Releasing Film

The mould surface must be thoroughly cleaned by thinner to make it free from dirt and any other foreign materials before application the releasing agent over the surface. The surface is then cleaned by using a sponge.

Step 6: Preparation of Laminate

The first layer of the resin coat is 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. Likewise 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 a stopper is used. After placing the stoppers on the first surface plate another surface plate is placed inverted over the laminate. Then a uniform weight is placed 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.

3. RESULTS AND DISCUSSION

3.1 Mechanical test

3.1.1 Tensile test result

3.1.1.1 Young's modulus

The figure 3.1 shows the comparison of neat vinyl ester with 4% TiO_2, 4%AL_2 O_3 and 4%MoS_2 and figure 3.2 shows the comparison of neat vinyl ester with 8% TiO_2, 8%AL_2 O_3 and 8%MoS_2 From the figure3.1it can be observed that addition of filler 4% TiO_2 increases the young's modulus compared with the addition of other filler materials and neat vinyl ester without filler material. From the figure3.2 it can be observed that addition of filler 8% AL_2O_3 increases the young's modulus compared with the addition of other filler materials and neat vinyl ester without filler material.

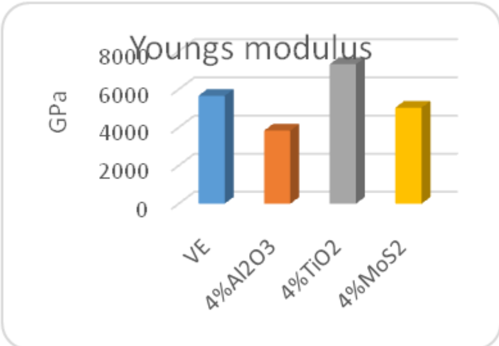

Fig 3.1:COMPARISON OF NEAT VINYL ESTER WITH 4% TIO_2, 4%AL_2 O_3 AND 4%MOS_2

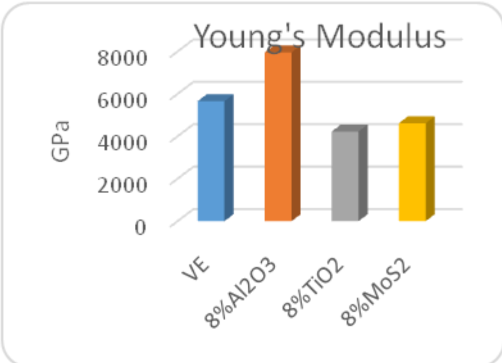

Fig 3.2: COMPARISON OF NEAT VINYL ESTER WITH 8% OF TIO_2, AL_2 O_3 AND MoS_2

3.1.2 Flexure test

The figure 3.3shows the comparison of neat vinyl ester with 4% TiO_2, 4%AL_2 O_3 and 4%MoS_2 and figure 3.4 shows the comparison of neat vinyl ester with 8% TiO_2, 8%AL_2 O_3 and 8%MoS_2From the figure 3.3 it can be observed that addition of filler 4% AL_2 O_3 increases the flexibility of the material compared with the addition of other filler materials and neat vinyl ester without filler material. From the figure 3.4 it can be observed that addition of filler 8% TiO_2increases the flexibility of the material compared with the addition of other filler materials and neat vinyl ester without filler material.

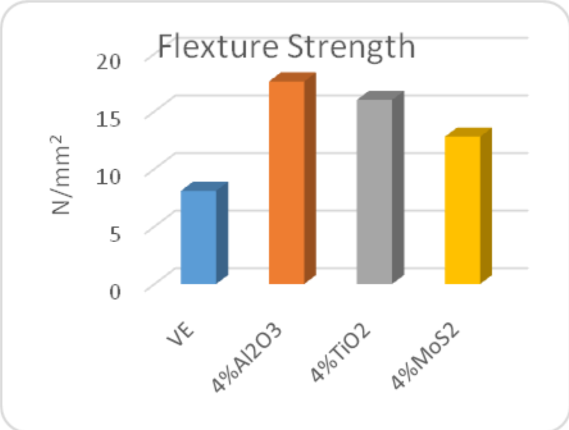

Fig 3.3 COMPARISON OF NEAT VINYL ESTER WITH 4% TIO_2, 4%AL_2 O_3 AND 4%MOS_2

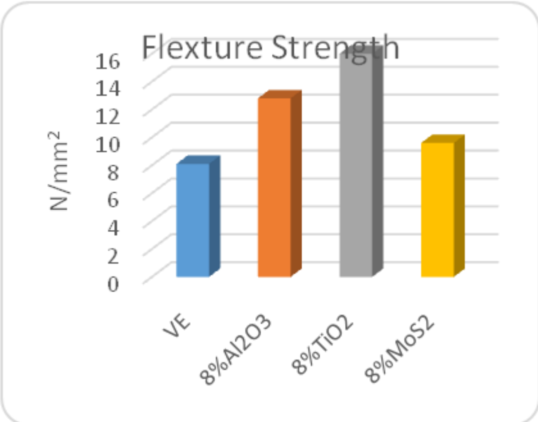

Fig 3.4 COMPARISON OF NEAT VINYL ESTER WITH 8% TIO_2, 8%AL_2 O_3 AND 8%MOS_2

3.1.3 Stiffness

The figure 3.5 shows the comparison of neat vinyl ester with 4% TiO_2, 4%AL_2 O_3 and 4%MoS_2 and figure 3.6 shows the comparison of neat vinyl ester with 8% TiO_2, 8%AL_2 O_3 and 8%MoS_2From the figure 3.5 it can be observed that addition of filler 4% Al_2O_3 increases the stiffness of the material compared with the addition of other filler materials and neat vinyl ester without filler material. From the figure 3.6 it can be observed that addition of filler 8% TiO_2increases the stiffness of the material compared with the addition of other filler materials and neat vinyl ester without filler material.

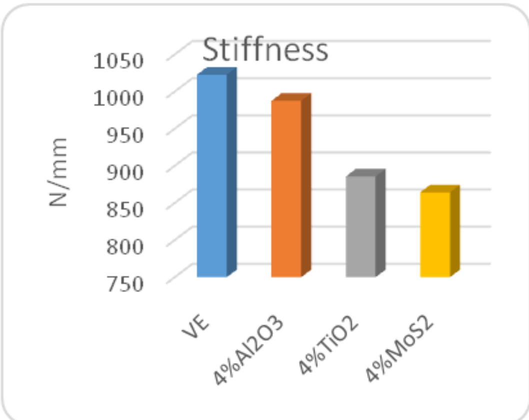

Fig 3.5 COMPARISON OF NEAT VINYL ESTER WITH 4% TIO_2, 4%AL_2 O_3 AND 4%MOS_2

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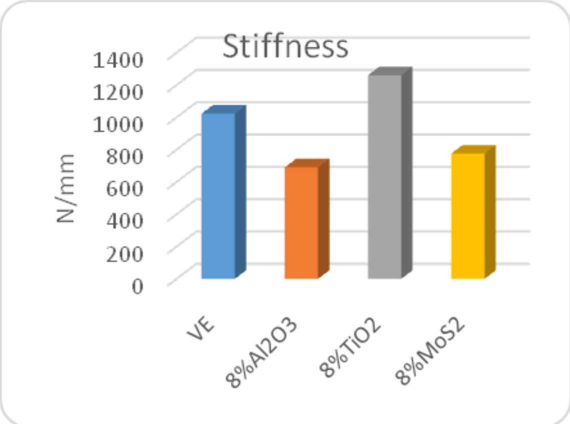

Fig 3.6 COMPARISON OF NEAT VINYL ESTER WITH 8% TIO_2, 8%AL_2O_3 AND 8%MOS_2

3.2 Hardness test results

3.2.1 Result table

MATERIAL	VICKERS HARDNESS NUMBER
VE	16.4
4%AL_2O_3	15.5
8%AL_2O_3	15.8
4% TiO_2	17.2
8% TiO_2	16.7
4%MoS_2	16.2
8%MoS_2	17.6

The above table shows the result of Vickers hardness test of filled and unfilled composite material.The figure 3.7 shows the comparison of neat vinyl ester with 4% TiO_2, 4%AL_2O_3 and 4%MoS_2 and figure 3.8shows the comparison of neat vinyl ester with 8% TiO_2, 8%AL_2O_3 and 8%MoS_2.From the Figure 3.7 it can be observed that addition of filler 4% TiO_2increases the hardness of the material compared with the addition of other filler materials and neat vinyl ester (i.e. without filler material). From the figure 3.8 it can be observed that addition of filler 8% MoS_2increases the hardness of the material compared with the addition of other filler materials and neat vinyl ester without filler material.

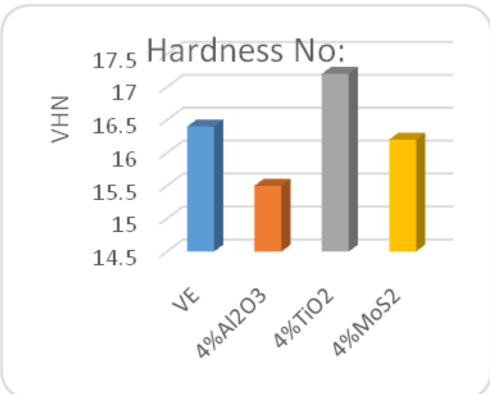

Fig 3.7 COMPARISON OF NEAT VINYL ESTER WITH 4% TIO_2, 4%AL_2O_3 AND 4%MOS_2

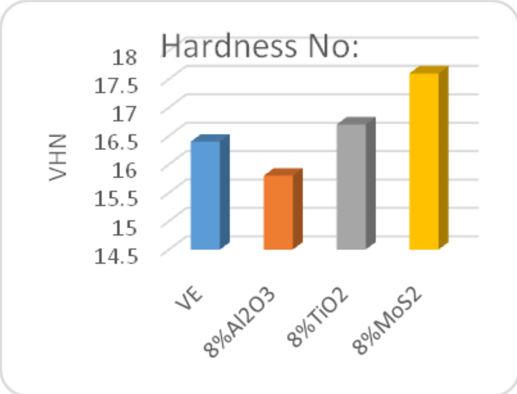

Fig 3.8 COMPARISON OF NEAT VINYL ESTER WITH 8% TIO_2, 8%AL_2O_3 AND 8%MOS_2

3.3 Charpy Impact Test

3.3.1 Result Table

Material	Impact energy absorption (joules)
VE	4
4%AL_2O_3	6
8%AL_2O_3	8
4% TiO_2	6
8% TiO_2	8
4%MoS_2	10
8%MoS_2	8

The above table shows the result of Charpy impact test of filled and unfilled composite material. From the table it clearly shows that 4% MoS_2 has the maximum impact energy compared with the addition of other filler materials and neat vinyl ester without filler material. 8% TiO2 and Al2O3 too shows good results.

3.4 Dry Sand Abrasive Wear Test

3.4.1 Formulas Used For Calculation:

Determination of Velocity

V= ((22/7)*D*200)/(60*1000)

V= ((22/7)*223*200)/(60*1000)

V=2.3361RPMWhere, D=wheel diameter of abrasive wear machine=223mm

Determination of time

T=sliding distance/velocity

T=500/2.3361

T=214.032+10=224.032 =3MIN 27SEC

T=1000/2.3361

T=428.06+10=438.06=7MIN 45SEC

Sand flow rate

Initial weight of bowl=0.103kg

Final weight of bowl at 2min=0.5967kg

Final weight of bowl at 3min 45sec=1.1188kg

Final weight of bowl at 5min 30sec=1.641kg

Final weight of bowl at 7min 15sec=2.163k

3.4.2 Result table for 23 N loads (Weight Loss in)

SPECIMEN	500m	1000m
V-E	0.3656	0.4295
4%Al_2O_3	0.3911	0.612
8% Al_2O_3	0.3994	0.5347
4%TiO_2	0.3537	0.3966
8%TiO_2	0.4328	0.6345
4%MoS_2	0.5596	0.5826
8%MoS_2	0.499	0.6185

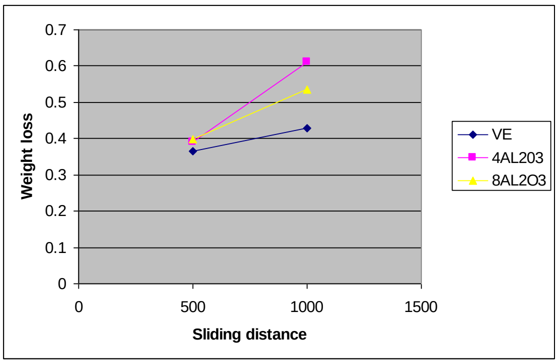

Fig 3.9:Comparison of V-E with V-E+Al2O3

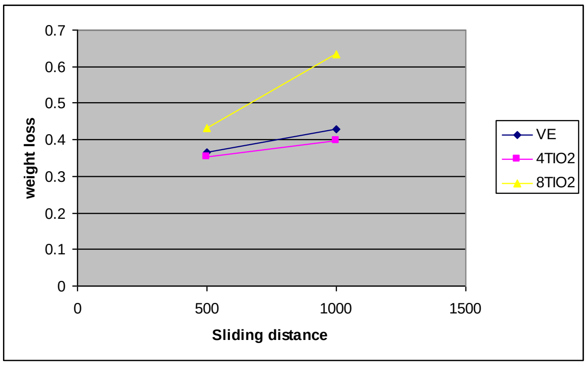

Fig 3.10:comparison of V-E with V-E+TiO2

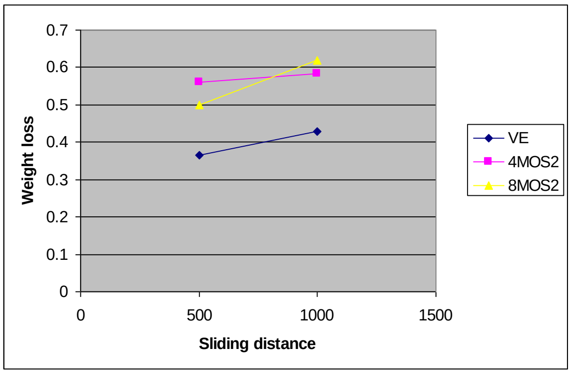

Fig 3.11: comparison of V-E with V-E+MOS_2

3.4.3 Result table for 36 N load (Weight Loss in)

SPECIMEN	500m	1000m
VE	0.416	0.545
4%Al_2O_3	0.5053	0.7404
8%Al_2O_3	0.6272	0.7922
4%TiO_2	0.3972	0.4994
8%TiO_2	0.6276	0.805
4%MoS_2	0.5734	0.6129
8%MoS_2	0.6748	0.6558

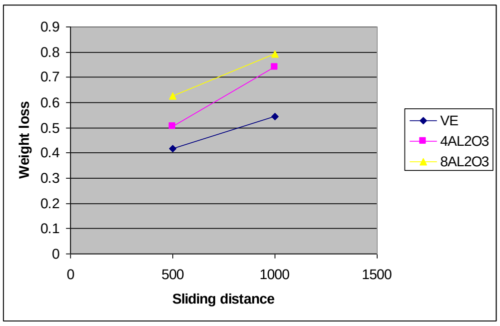

Fig 3.12: comparison of V-E with VE+AL2O3

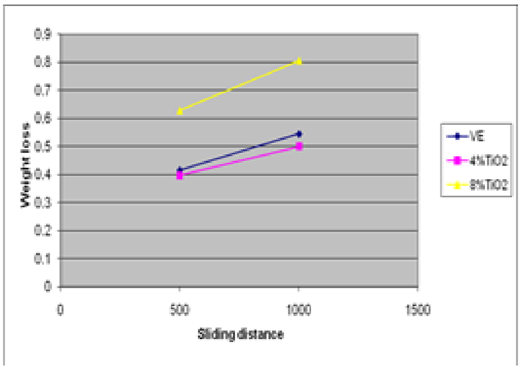

Fig 3.13 comparison of V-E with VE+TiO2

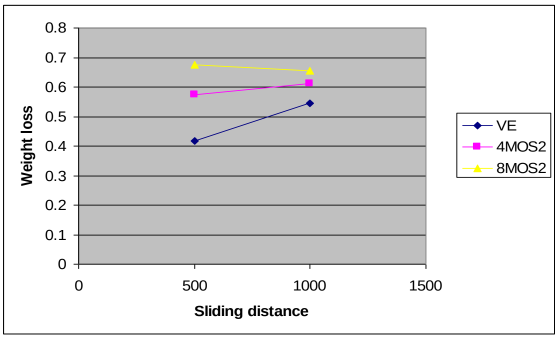

Fig 3.14:comparison of V-E with V-E+MOS_2

3.4.4Wear loss

The variation in specific wear losses of composites worn at load 23N and 36N against abrading distances of 500m and 1000m respectively is shown in the above graphs for the 36N load and load of 23N.As previous experimentations on this field reveal that the wear volume is linear with the sliding distance. The composites exhibited relatively high initial wear rates, when surfaces are new, which decreased gradually with increase in abrading distance. This is due to asperities and heterogeneity being rapidly worn until a uniform smooth surface is produced. Wear volume increases with the increase in sliding distance and wear volume decreases with the addition of fillers. In this experimental study from the graphs the wear losses is linear with the sliding distance on the load of 36N. In case of 23N load the 4%TiO2 shows the less wear losses with the neat Vinyl Ester and the MoS2 has lesser wear resistance and Al2O3gives the satisfactory results. In case of 36N load the TiO2 has higher wear resistance and 8%Al2O3 has lesser wear resistance.

4. CONCLUSION

The aim of this was to investigate the influence of fillers [Al_2O_3 ,TiO_2 ,MoS_2] on the dry sliding wear and abrasive wear behaviour and mechanical behaviour of glass fiber reinforced Vinyl Ester composites.The wear performances of glass fiber reinforced composites were strongly proportional to the applied load, sliding velocity, distances etc.It is found that with an increase in abrading distance, the wear rate is increased. The wear volume loss is increased in V-E composites with increase in abrading distance. The hardness of the specimens increases by increasing the filler materials.The tensile and the flexural properties have improved by increasing the filler content. This study in overall it shows thatTiO_2 with both 4% and 8% filler composite shows higher wear resistance, though the Al_2O_3 has shown satisfactory results too

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