INFLUENCE OF Al_2O_3NANO FILLER ADDITIONS ON THREE BODY ABRASIVE WEAR BEHAVIOR OF CARBON FIBER/EPOXYCOMPOSITES

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Abstract

In this study, effect of alumina nano-filler on Three-Body Abrasive wear performance of carbonfiber/epoxy resin composite is evaluated. Carbon fiber/epoxy composite samples without filler and with 0.1%, 0.2%, 0.4% and 0.7% filler additions are fabricated by 'VARTM' method. Specimens from the fabricated plates are cut and Three-Body wear investigations arecarried out using Rubber Wheel Abrasive Test Rig in accordance with ASTM G65. Tests are conducted for abrading distances of 250 m, 500 m, 750 m and 1000 m. Three-body abrasive wear studies were conducted and results show decrease in wear loss with increase in nano-filler percentage for varying abrading distances. A comparison between wear rates of different filler content is graphically represented.Also surface morphology is done to investigate the nature of damage at the compositesurface.

***Keywords*:** *Al_2O_3Nano filler, Epoxy, Three-Body Abrasive Wear, SEM.*

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1. INTRODUCTION

Polymer composites have widespread interest in various engineering applications[1,7]. Carbon fiber reinforced epoxy composites are being increasingly used because of their low weight, engineering flexibility, low density, and anti-corrosion properties in automobile, aeronautical and marine applications [4]. According to some studies polymer composites reduces component weight up to 50% if aluminum is substituted by polymer composites.Theshape, size and distribution of fillers in the matrix and the adhesionin the interface has a influence on mechanical behavior of the composites[3]. The mechanical strength, modulus, and thermal conductivity of the polymer composites can be improved using filler reinforcements in the polymer matrix[10,9,12].

The epoxy based materials are having a wide range of applicantshat include coatings, adhesives and in manufacture of composite materials using carbon and glass fiber reinforcements[5]. Epoxy resins in general have excellent adhesion, heat resistance, good chemical and exceptional mechanical properties. Also it can posess very good electrical insulating properties[6].

Alumina fillers(Al_2O_3) come from the family of inorganic compounds. It is usuallystated to as alumina, corundum as well as other terms, reflecting its extensive occurrence naturally and used in manufacturing. In the manufactureof aluminium metal it has greatest significant, though it has applications as abrasive because of its hardness and it has high melting point hence it can be used as refractory material.It is cost effective and has excellent dielectric properties, good thermalConductivity[15]. It has been used with polymer composites to study the mechanical behavior[8].

Among the different forms of wear, abrasive wear is the utmost significant since it contributes to more than 50% of the overall cost of wear. Abrasive wear phenomenon arecome across in vanes, pumps which deal with industrial fluids,gears, bearings in subjected to heat, chute liners abraded by coke, mineral ores and coal etc [7, 16, 14, 11]. Abrasive wear is mainly triggeredas a result of hard particles moving along the surface of partthat are enforced against.. There are mainly two types off wear: two-body and three-body abrasive wear. In case of two-body wear, the hard particles cause wear due to one surface sliding over the surface of the other. In three-body abrasion wear, two solid surfaces roll as well as slide over each other and the particles are trapped between the two surfaces. As per the literature when the three-body abrasion is compared with two-body abrasive wear the material removal rate in less in three body wear. It is observed that in three-body abrasion the loose abrasives abrade the two sliding surfaces between to an range of about 10% of the time in sliding, where as they spend approximately about 90% of the period in rolling [17].

Three body abrasive wear is more practical and compared to two-body problemit appears to have been given less attention. In the last decade, many studies on composites materials exposed to abrasive wear are presented [17,18,13].

Though, A decentquantity of work has been stated on the three-body abrasive wear performance of composites with polymer matrix as referenced in [18, 19], Hence an attempt has been made in this work to understand the role of alumina filler on the three-body abrasive wear performance of carbon fiber/epoxy resin composites.

2. EXPERIMENTAL

2.1 Materials

Composites plates are prepared using Carbon fabric as reinforcement and epoxy resin is used as matrix material. The hardener used is Araldite HY 951. Al_2O_3nanopowder of 150nm to170nmis used as filler material.

2.2 Sample Preparation

Fabrication was done by "VARTM" method and composites are cured in a hot air circulating Owen. The low temperature epoxy resin (HTR212) and suaiable hardener (HY 951) were mixed in a ratio of 3:1 by weight as suggested. Then Carbon fiber mat are placed in the mould and vacuumbag is placed over the carbon fabric layers and the edges are sealed. 8 layers of Carbon fabric were used to get the required thickness of 2.5 mm, which was maintained by using stoppers of 2.5 mm thickness. Once the edges are sealed vacuum pump is connected to one end and the other side is provided with ports to which the resin reservoir is connected. Once the vacuum pump is switched –ON- the resin is sucked into the mould. The excess resin is drawn out of the mould by the vacuum pump. Once the resin impregnates the fabric layers, the composite is allowed to cure in the mould for 24 hours and then it is post cured in a air circulating Owen for 4 hours at 180 degree C. The procedure was repeated to fabricate 4 more plates with the addition of alumina nano fillers as the filler material in steps of 0.1%, 0.2%, 0.4% and 0.7% respectively. Specimens were cut in agreement with ASTM-G65.

3. THREE-BODY ABRASIVE WEAR TEST

Abrasive Wear Test

The tribologicalbehavior of Carbon fiber/epoxy composite withAluminanano filler and without Alumina nano filler were investigatedby a Dry Sand Abrasive Tester in accordance with ASTM G65. Specimens of size 75mm x 25mm were weighed (Initial Weight) and were held against the rotating wheel of diameter 200 mm.

Abrasives of grade AFS-60 silica sand having angular shape with sharp edges are used. The abrasive particles were fed at the contact facesat the interface of the rotating rubber wheel and the specimen to be tested. A rotational speed of 200 rpm is maintained for conduction of tests. The abrasivesare fed at a rate of 250±5 g/min. The test samples are prepared for the tests by cleaning the surfaces.A high-precision digital weighing machine is used for weighing the initial weight of samples (having accuracy of 0.1 mg) then the sample is mounted in the sample holder. Abrasive particles are fed from the hopper through a nozzle between the rotating abrasive wheel(cholorobutyl rubber tyre) andtest specimen. Then the test sampleis pushed against the rotating rubber wheel. A lever arm is used to apply a specified force whereas a meticulous flow of abrasive particles abrade the surface of test sample. The abrasive wheel rotatesin such a way that its face in contact moves in the path of sand flow.After the finish of the set test period, the sampleis removed from the holder, carefully cleaned and weighed for the final weight. The difference in weight of specimen before and after the abrasion test is determined. The tests were carried out at 24 N and 48 N loads and the sliding velocity is kept constant as 2.15 m/s. Moreover, the abrading distances were varied in steps of 250m from250 m to 1000m. For the second (i.e., longer duration testinvolving say distance of 500m) the abrasion test were carried out on the same wear track where first (i.e., 250 m) shorter runs were involved. The wear was measured by the loss in weight, After the wear test, the sample was again cleaned. The difference in the final weight and the initial weight gives the wear loss in g.

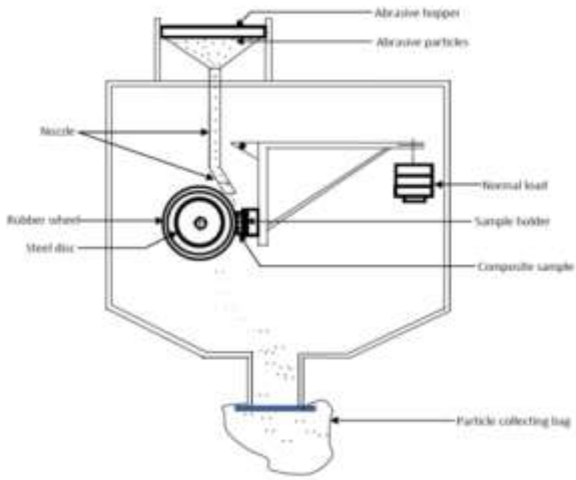

Fig 3.1: Schematic diagram of Abrasive Test Rig.

4. RESULT AND DISCUSSION

4.1 Wear Loss

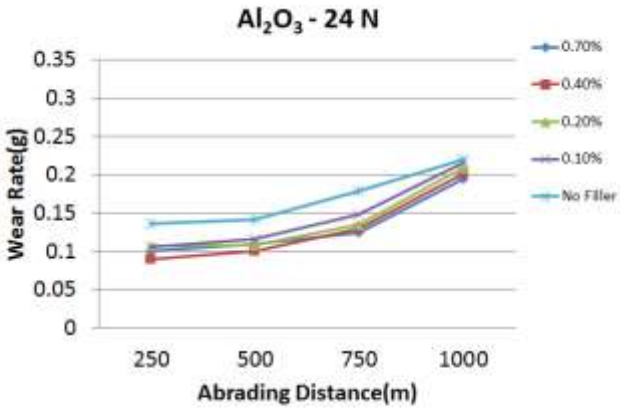

Fig. 4.1.1: Wear Loss Vs Abrading Distance at 24NLoad.

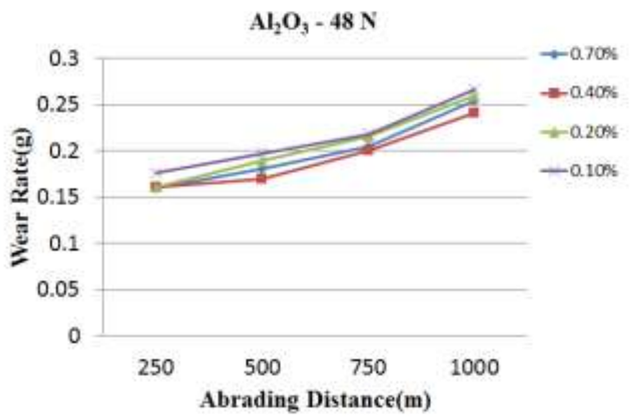

Fig. 4.1.2: Wear Loss Vs Abrading Distance at 48NLoad.

Fig.4.1.1 and fig.4.1.2shows the wear loss in grams is dependent on abrading distance. It is observed that wear loss increases with the increase in abrading distance(m) and with additions of alumina nanofiller wear loss reduces.Carbon fiber reinforced epoxy composite without alumina filler shows greater wear loss for the abrading distance of 1000m and load 24N. Carbon fiber reinforced epoxy composite with 0.4% aluminanano filler show lesser wear loss compared with that of composite without alumina additives. This indicates that the nanofiller has altered the wear behavior to produce better wear resistance in the alumina nanofiller reinforced composite specimen. With increase in load, at 48 N a similar pattern is observed. Wear loss reduces with increase in filler content as seen in fig.4.1.2. At abrading distance of 1000m the composite with 0.4% aluminanano filler shows lesser wear compared to composites without filler and composites with 0.4% filler.Further increase in alumina content(0.7 %) there is a increase in wear due to the poor interaction of epoxy resin with aluminanano filler.

There by it is seen that the Carbon fiber reinforced epoxy composite with 0.4 % of aluminanano filler shows the better resistance to wear than carbon fiber/epoxy composites with0.1 % and 0.7% of alumina filled carbon fiber reinforced epoxy composite.

4.2 SURFACE MORPHOLOGY

SEM micrographs: there are many contrivancessuggested to demonstrate how material removal takes place from the surface of the composite material during abrasive-wear process. These mechanisms comprise fatigue,fracture and melting. Sincethere arecomplications involved in abrasion, it is difficult to suggest that a particular mechanism totallyis responsible for all the wear loss. Generally, the abrasive wear progressioncomprisesof four diverse mechanisms like micro-ploughing, micro fatigue, micro cutting, and micro-cracking. From the SEM pictures the three-body abrasive wear processes that are responsible for the foremost wear mechanisms are detected qualitatively.

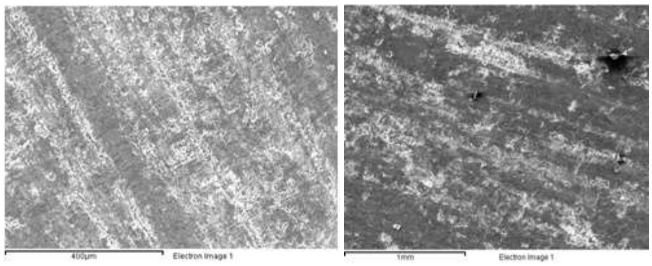

Fig 4.2 (a):- SEM Micrograph At 100X . (i): SEM image of the specimen without alumina filler. (ii):SEM image of the specimen with 0.2% of alumina nano filler.

Fig. 4.2(a) (100X magnification) shows the SEM picture of carbon fiber/epoxy composites without filler and carbon fiber/epoxy composites with 0.4 % of alumina nano filler surface abraded for load 24N. In SEM image of the specimen without alumina filler fig.4.2(a)(i) shows the furrows in the abrasion direction.Very fine fibrils is seen which is nothing but the Wear debris expurgated from the epoxy and it seems like they are adhered to the face of the tested specimen. The white parallel marks on the image are the worn out surface of the matrix material and fiber when the abrasive particles come in contact in abrading condition. The damage of the fiber is not visible due to hidden in matrix. The image of carbon fiber reinforced epoxy with 0.4 % filler fig 4.2(a)(ii) shows less furrows with discontinuous parallel lines in abrading direction is clearly visible. Image indicates composite surface is darker compared to that of the composite without filler. The damage to the matrix here is less due to the addition of filler when load is applied. Dark spot in the image is the blow hole formed during fabrication work.

Fig.4.2 b) (200X) the micrograph shows the worn out surface which has marks of parallel ploughing in the direction of abrasion. For the specimen without filler from fig.4.2(b)(i), the ploughing marks are much deeper and are continuous. With the percentage of nano fillerincreases in the composite,micrograph image of specimen with 0.4% of alumina nano filler from fig.4.2(b)(ii), shows lesser ploughing marks, which are discontinuous with the abrading direction. These ploughing marks are clearer in next higher magnification.

It is seen in Fig 4.2(c) the clear picture of the damaged surface of the composite where the matrix materials surface has been damaged. The composite without filler fig.4.2(c)(i), indicates more wear in the matrix material. From the image of the specimen without filler it is noticed the fracture of the reinforcementandmatrixis similarkind of wear.The interface of the matrix material is removed from the fiber. The image with alumina filler fig.4.2(c)(ii) indicates discontinuous parallel ploughing marks. The white spots in the surface indicate the damage of matrix surface. With the applied load and abrading distance here in this specimen the damage to the matrix material and fiber is lesser. This is because of the addition of the filler, surface become harder and less affected to abrasive particles which comes in their way.

Further increase in magnification as in Fig.4.2(d)(i) (1000X) the micrograph of the specimen without filler indicate the damage to matrix and following removal of epoxydue to the of micro cracksformation and propagation at the composite surface. Also the detachment of epoxy matrix from the interface of fiber surface witnessed in case of specimen with applied load of 24N. The matrix appears to be in clusters form leaving a gap between them, which show the cracks and damage of fiber. Fibers are not clearly visible due to the merging of matrix material. At the left corner of the image the black mark shows the damaged fiber surrounded by a matrix. Image with 4% of the alumina filler fig.4.2(d)(ii) shows matrix material has been detached from the carbon fiber but still it covers the fiber and prevent it from damage. The white portions, in the image show micro cracks with damage to the matrix material. Small thin curvy lines noticed in the image are the micro cracks with fibers which are exposed to the environment. Due to the better interaction of matrix with filler lesser damage to the matrix is occurred. The increase in alumina filler content the material removal and micro crack has been reduced. Composite without filler has shown deeper grooves of matrix damage in the direction of the abrading distance, damaging the carbon fiber. The filler has played an important role for matrix in composite with 4% of alumina providing less damage to the matrix and more resistance towards abrasive particles.

5. CONCLUSIONS:

The foremost intension of this experimentis to increase the wear resistance of the composites using Alumina nanofiller because it has good wear resistance properties.Some of the significantinterpretationswere made from the study are.

- The three-body abrasive wear lossis observedto be differing in trend with increase in filler content in carbon fabric/epoxy resin composites.
- The three-body abrasive wear loss is dependent on the abrading distances and the load applied for all composite specimen tested.
- With addition of weight percentage of aluminananofiller is perceived to be advantageous to the performance of the composite during abrasive wear. There is decreasein tracks by plowing at higher abrading distances.
- From the experimental results it is also witnessed that there is decrease in wear rate with increasing filler percentage.composite having 0.4% of Al_2O_3nanofiller show less wear rate compared to other composites.

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