Influence of fillers on tribological behaviour of glass-coir reinforced epoxy composites – An ANN Approach

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Abstract. Composite materials are widely used in many industries today because of its properties. Some of the unique properties are corrosion resistance, high stiffness, strength and strength to weight ratio. Most of the metal exhibit the same properties but when weight plays a pivotal role, composites are suitable. In the current study, glass, coir, epoxy and MoS2 are used as materials. Fabrication of composites were done using vacuum assisted hand lay-up method. After fabrication, different experiments were performed to study the tribological behaviour of hybrid composites using ASTM Standards. From the experimental study, it is clear that composites with fillers played a pivotal role when compared with unfilled one. Filler percentage were varied between 0-6%. Significant improvement was observed after adding the filler. Hybrid composites with filler showed better wear and frictional resistance when compared with unfilled one. Artificial neural network method was also employed for validation. From ANN, it was clear that, experimental results were mapped with the output of ANN.

Key Words: Glass Fiber, Coir Fiber, Artificial Neural Network, Wear, MoS2 filler

1. Introduction

Synthetic composite materials were widely used in the field of aerospace, sports, medicine, civil, automobile and military applications etc., because of its properties. Many researchers are conducted different experiments on glass fibers whereas very few were used MoS2 as fillers. The current study has been carried out to reduce the cost of material by adding one more natural reinforcement. Coir fiber used as reinforcement in the current study along with glass fibers. After adding natural fiber, properties were reduced by 10-15% when compared with only synthetic fibers. TiO2/MoS2 fillers were also used and the impact increased the performance of the composites.

A P Harsha [1] et.al studied the erosive behaviour of GFRE composites and they found that, weight loss at 60-degree impingement angle was more compared with other angles. Bidirectional glass fibers showed better erosion resistance compared with uni-directional. Ranganatha S R et al [2] used CFRE composites for study and they found that, Al2O3 fillers exhibit better properties when compared with unfilled one. 2% Al2O3 fillers showed better resistance when compared with unfilled and different proportions of fillers. Amar Patnaik et al [3], conducted experiment on GE with fillers and the team found that, incorporation of silica, alumina and pine dark will increase the tensile, flexural and impact strength of the composites and also silicon carbide showed better resistance and properties when compared with other fillers. Zhenyu Jiang et al., [4] used artificial neural network approach used to predict the wear properties of the composite’s materials. For ANN software, experimental parameters were considered as input and ANN trained thoroughly till get the accurate results. K Sabeel Ahmed et al [5], carried out experiment on sliding behaviour of SiC/Al2O3 filled jute epoxy composites. They found that, coefficient of filler increases with increase in load and sliding velocity. Al2O3 filler filled composites showed low coefficient of filler and wear loss compared with SiC.

Although a great deal of work has been reported in the literature which discuss the mechanical and wear behaviour of fiber reinforced polymer composites with and without filler, however a very less work has been done on effect of MoS2 filler on mechanical and wear behaviour of bi-directional glass
fiber reinforced epoxy composites. Against this background, in the present investigation, composites samples are made by using simple vacuum assisted hand-lay-up technique with varying weight fraction of bi-directional glass fiber, coir fiber and MoS2 filler. The effects of fiber loading and filler on the tribological behaviour of epoxy composites are studied.

2. Materials And Experimental Setup

Bi-Directional glass fiber, randomly oriented coir fiber, hardner, epoxy resin and TiO2/MoS2 powders were used as materials for the above study. For the present study vacuum assisted hand lay-up method is employed for the fabrication of composites materials. Figure 1 below explains flow chart followed for the fabrication.

**Fig 1:** Manufacturing flow chart of hybrid composites with and without TiO2/MoS2

Step by step procedure of vacuum assisted hand lay-up method explained below with figures.

- Glass fabric is cut according the dimensions required plus a tolerance of 10 mm with the help of scissors as shown in figure 2.
- For testing purpose, we require shape of the specimen either square or rectangle with 3mm thickness. A smooth granite surface is cleaned, made free from dust and other particles thoroughly using wax. A sealant is placed along the periphery of the worktable as shown in figure 3.
- Objective is to fabricate glass/carbon/coir/hybrid composites and suggest a suitable filler% . With this as agenda, by varying the different proportions of matrix and fillers, composites are fabricated. Firstly, a small quantity of resin applied on the work bench and spread to create a thin layer of resin over which glass fabric reinforcement is placed. Subsequently resin and reinforcement layers are stacked one above the other and smoothed out till we achieve the required thickness (figure 4).
- Once the specimens are prepared, its equally important to achieve a constant mixture of resin and reinforcement. Firstly, a thin film with pinpoint holes distributed equally throughout the specimen (as shown in figure 5).
- Over the thin film, a dense matte is applied which absorbs the extra resin if any.
- The entire workbench is covered with sheet adhered to the sealant around the periphery so as to create a vacuum space (figure 6 & 7).
- One of the side is connected to the vacuum machine to suck out all the air. The vacuum thus
created will force a pressure of about 14psi over the specimens which helps in flattening it. The extra resin being sucked by the matte film as shown below. The vacuuming machine is run for about 2 hours at a stretch (figure 8).

- Once vacuuming is completed, next step is curing. Once specimen is taken out of vacuum, it will be kept in room temperature for 24 hours followed by oven for 2 hours. Once curing completed, the extra material around the sides are trimmed (Figure 9).

![Figure 2(a & b): Dimensioning of glass fiber](image)

![Figure 3. Sealant on the work bench.](image)

![Figure 4. Stacking of Fibres and Epoxy](image)

![Figure 5: Application of Porous Plastic film](image)
Different materials fabricated for the current study was glass-coir reinforced with epoxy without TiO2/MoS2 filler, with 2% filler, 4% filler and 6% fillers. In the current study, wear and friction test was carried out using two body abrasion test rig at Ducom Bangalore. Specimen prepared as per ASTM G99. Silicon carbide abrasive papers are used to abrade the specimen at a constant speed of 200 rpm. Load of 20 and 40 N are used for the current study. The test is conducted for 2 mins at a speed of 200 and 400 rpm.

3. Results and discussion
Figures 10 represent wear loss as a function of load for different percentages of MoS2/TiO2 filled composite materials. From the graph it is clear that wear loss increases with increase in load. Wear loss of filled composites is lower than the unfilled one for a sliding distance of 6000m. The glass/carbon fiber strengthened the composite while the filler acts as lubricant together providing enhanced wear resistance. The presence of filler particles on the surface acts as effective barriers to prevent large scale fragmentation of epoxy.

From figure 10, it is clear that, GC-E hybrid composites showed better wear resistance after the incorporation of fillers. Increase in load will also increase the wear loss whereas addition of fillers, will reduce the wear loss since fillers acts as a lubricant and improve the wear resistance of the composites. Also from figure it is evident that, GC-E composite with 4% MoS2 filler showed better wear resistance (least wear loss of 0.0651g at 20N load) when compared with unfilled composites which yield to maximum wear loss of 0.0969 g at 40N load.
Figures 10 represent the specific wear rate as a function of sliding velocity. From the figure it is evident that, specific wear rate decreased predominantly as the percentage of filler increased. Normally composites consists of two wear modes

- Polymer matrix wear – Matrix deformation and cracks in the matrix
- Fiber wear – Fiber sliding wear/cracking/rupture/pulverizing.

Due to transfer film formation on the counterface because of the addition of fillers, specific wear rate reduces. As MoS2 is self-lubricant by nature, wear loss of filled composites is related to the formation and development of transfer film. This result in better wear resistance.

COF of the GC-E samples are tested at constant sliding distance of 6000m for different loading conditions. Figure12 shows co-efficient of friction as a function of load. As the load increases coefficient of friction decreases. Figure 12 represents coefficient of friction as a function of load for 20 and 40 N respectively. It is clear from the graph that, coefficient of friction decreases with increase in load. Also coefficient of friction in case of MoS2 and TiO2 filled hybrid composite is higher when compared with unfilled hybrid composite. 6% MoS2 filled GC-E composite showed maximum coefficient of friction of 0.519 at 20N load whereas unfilled composite at 40N load showed least coefficient friction of 0.151.
4. Artificial Neural Network

4.1 Procedure:
ANN is basically used to determine the predictive value and to avoid the number of experiments that researchers used to do in order to get the results. Here with the available output of the experiment and the available input which are nothing but the variables considered for conducting the experiments. In the present study, MATLAB R2019a original software for modelling. Following steps are followed to predict the value.

   STEP 1: use the command “nftool;” in the command prompt.
   STEP 2: After entering the command, we can able to notice the tool where we need to upload the input and target file. Input file are the parameters considered while doing the experiment like load, filler content, fiber content, impinging angle, density etc, sliding distance, speed etc. whereas output parameters are the experimental results like tensile strength, modulus, wear rate, weight loss, COF, flexural modulus, erosive wear etc.
   STEP 3: After uploading the input and output file, next step is to test and validate. Here we need to select the number of samples for testing and validation.
   STEP 4: After testing and validation, the next step is to train. Different algorithm can be used here for the purpose of training.
   STEP 5: Network was trained using Levenberg Marquardt algorithm. In this step we can generate the regression graph, training graph and validation check.
   STEP 6: After training, we can save the program and generate the graph which gives clearly the error that is variation in the target and output value.

4.2 Artificial Neural Network Results:
A linear regression plot for LM algorithm between the output and the corresponding target are represented in figure 13. The value of R is 0.99772 for the response. This value will give a linear fit where the target and the output will match exactly. Figure 14 represent performance plot which gives training, testing and validation errors. Best validation performance has occurred at 3rd iteration (validation error will be zero/minimum and it will increase thereafter).

   To test the performance, 35 datasets are used in this study. MoS2, TiO2, feed rate, time, speed and sliding velocity are used as input variables and COF/specific wear rate or wear loss are used as target parameters. It can be observed from the figure 15 that, the predicted value from the ANN are almost nearer to the COF test results. From the results of ANN, it is clear that experimental results and ANN results are proceeded in correct manner.

Figure 13. Regression plot for LM algorithm
5. Conclusion

The main purpose of this research project is to develop a new class of material which can be used in the field of medical and aerospace engineering. Different materials are fabricated by adding different proportions of MoS2 & TiO2 fillers. The materials fabricated in this study are GC-E. For these materials different proportions of fillers are mixed with matrix at the time of fabrication to improve the properties of the materials. Study also performed for prediction and validation of results respectively.

- MoS2 incorporated filler showed better wear and frictional resistance when compared with unfilled and TiO2 filler filled GC-E composites.
- MoS2 filler addition will enhance the COF property. This is due to the structure of MoS2 which forms a thin black colour film that provides Cushioning effect.
- ANN Study reveals that, actual results from the experiment were mapped with the ANN results. The results from the ANN were almost similar to experimental results.

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Dr. Srikantappa A S was honoured by Taluk Kannada Sahitya Parishat Srirangapatna recognising his services in the field of education and Honoured with Best Teacher Award by District Kannada Sahitya Parishat Mandya recognising his services in the field of education.