EFFECT OF FLY ASH AS FILLER ON MECHANICAL & FRICTIONAL PROPERTIES OF JUTE FIBER REINFORCED COMPOSITE

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Abstract - ***Experimental study is carried out on the influence of fly ash fillers on mechanical and tribological properties of woven jute fiber reinforced polymer hybrid composite. Composites were prepared using hand layup method with weight percentage of fly ash as filler material varying from 2% to 10% with 3 ply [0/90]s woven jute fiber as reinforcement having weight percentage of 40%. Considerable improvement in hardness of the composite upon increasing the filler content was observed however the tensile property decreased. The tribological property obtained using pin on disk wear apparatus showed considerable increase in wear resistance of the composite material upon increasing the fly ash as filler material.***

Key Words: *Fly ash, woven jute fiber, hybrid composite*

1. INTRODUCTION

Natural fibers exhibit several advantageous properties when used as reinforcement for composites. They posses low-density, resulting in relatively light weight composite having higher specific properties [1, 2]. Natural fibers have significant cost advantages when compared with synthetic fibers such as glass, carbon, nylon, etc. Among all the natural fibers used as reinforcement in composite materials, jute seems to be a promising material because of its relatively low cost and commercial availability [3]. It also has higher strength and modulus upon comparing with plastic and is a good replacement for conventional fibers in many applications.

Verma et al. [4] and Mohan et al. [5] have investigated the mechanical properties of jute/glass hybrid composites in both polyester resin and epoxy resin. Chawla and Bastos [6] investigated the influence of the volume fraction of untreated jute fibers in polyester resin fabricated by the leaky mould technique on modulus of elasticity, impact strength and maximum strength.

Winfield [7, 8] analyzed the use of jute-reinforced plastics to low cost housing. In his study jute fabric is directly used as reinforcement. Khan et al. [9] developed environmental friendly jute fabric composites and investigated the influence of woven structure on the mechanical properties of the composite. In these composites, it was observed that mechanical strength and modulus in the warp direction are higher when compared to the weft direction.

Apart from this, plain-woven jute fabric composites in the warp and weft directions exhibited superior mechanical properties to those of non-woven jute fabric composites. Currently in India, 90 million tons of fly ash is being generated annually, dumped in 65,000 acres of ash ponds. This huge quantity produces challenging problems, like health hazards and environmental issues [10]. Fly ash comprises of fine particles of silica, alumina, calcium and magnesium oxides [11].

Fly ash is formed at temperatures ranging from 920–1200°C and is collected as precipitator ash [12]. The properties of polymers can be modified using fibers and fillers so that they posses high strength/high modulus property.

At present, researches are being carried out to develop newer FRP composites with different combinations of fibers and fillers in order to make them usable under different conditions [13]. The size, shape, volume fraction and specific surface area of the particles added in polymer have influenced the mechanical properties of the composites to a greater extent [14].

It is observed that 30 wt% of E-glass in the glass fiber reinforced polymer composite without filler material yields better results [15]. Composites properties depend on the size, shape and other physical reinforcements [16].

Limited work has been carried out on woven jute fiber in polymer composites as reinforcement. Moreover hybridization effect of woven jute composites attracts the researchers in respect of the mechanical properties. Hence this study on Hybrid woven jute composite deals with the influence of fillers in mechanical properties.

2. EXPERIMENTAL DETAILS

2.1. Materials

For the present experimental investigation, Jute fibers were extracted from healthily grown jute straws by retting process. Jute strands were prepared with spinning mills, which were woven as warp and weft to produce the woven fabric as shown in Fig.1 and its specifications is mentioned in Table 1.

Fig. 1. Woven Jute mat

The woven fabric Posses the following properties as shown in the table 1.

Table 1. Specification of Woven Jute mat.

No.of yarns per 10cm		Twist of yarn (turns per 3 cm)	Surface weight (g/m2)
53 weft	53 warp	6	370

Unsaturated polyester resin has been chosen for matrix for its good cross-linking tendency and processability. For 100 ml of resin, 0.75 ml of MEKP (Methyl Ethyl Ketone Peroxide) and 0.65ml of Cobalt Naphthenate were taken at ambient temperature as per the manufacturer's recommendations. The matrix, catalyst and accelerator were procured from Raja Polymers (P) Ltd., Kanyakumari, India. The distinctive properties of the polyester resin were listed in Table 2.

Table 2. Properties of unsaturated polyester resin matrix.

Appearance	viscous liquid
Specific gravity	1.08
Viscosity	110 cps

Fly ash usually refers to ash produced during combustion of coal. The fly ash used in this research was collected from a thermal power station which is located at Tuticorin, India. In this Thermal power plant Coal is used as a fuel, during the combustion process the fly ash was collected using electric precipitators. The collected coal was reduced to nano size by ball milling process for 8 hours in Center for Composite Materials, Kalasalingam University, Krishnankoil, India.

2.2. Preparation of composite specimen

The compression molding technique was adopted for the fabrication of composites. A known weight of woven jute mat arranged in 3 ply [0/90]s was spread in the mould of size of 300 x 150 x 3 mm with weight percentage of 40%. Extreme care has been taken for the orientation of the warp and weft of the mat. Metered quantity of unsaturated polyester resin was poured in the die with the mixture defined in the material which forms the matrix. The resin solution was degassed prior to pouring to remove the air bubbles formed. A grooved roller is used to remove the air bubbles after the pouring process. The mould was kept under pressure for 24 h. This results in the fabrication of woven jute polymer composite specimen.

Similar to the above process, samples having weight percentage of 2, 4, 6, 8 and 10 of nano fly ash were fabricated upon varying the matrix weigh percentage and keeping the woven jute mat weight percentage as a fixed one. The resin and fillers were metered and mixed thoroughly using motorized stirrers to enclose the nano fly ash inside the polyester resin wrapper. This results in a fabrication of 6 composite specimens of size 300 x 150 x 3 mm with the following designation as shown in the Table 3.

Table 3. Designation of the composite specimens

Sl.No.	Specimen Description	Designation
1	40 % Fiber + 60 % Resin	FA0
2	40 % Fiber + 58 % Resin + 2 % Fly ash	FA2
3	40 % Fiber + 56 % Resin + 4 % Fly ash	FA4
4	40 % Fiber + 54 % Resin + 6 % Fly ash	FA6
5	40 % Fiber + 52 % Resin + 8 % Fly ash	FA8
6	40 % Fiber + 50 % Resin + 10 % Fly ash	FA10

3. TESTING

3.1. Tensile Testing

Specimens were prepared as per the dimensions of ASTM D3039 standard using Bosch angle cutter with carbide wheel. The dimensions of the test specimen were as shown in Fig. 2. Aluminum end tabs were bonded to the specimen for proper gripping and to ensure failure in the gauge length. Tests were conducted on closed loop servo hydraulic MTS 810 Material Test System using data acquisition software Test Works-II as per ASTM D3039 [17].
Specimens were mounted at a grip pressure of 4.1MPa. Load was measured using a load cell of 50kN and strain using clip-on type MTS extensometer having a gauge length of 25mm. A rate of loading of 5 mm/min was used for testing.

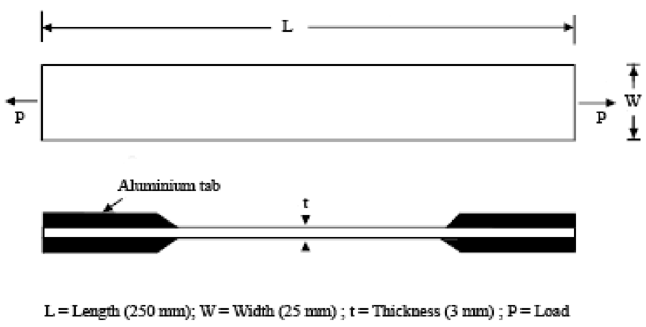

Fig. 2. Dimensions of the tensile test specimen (ASTM D3039)

3.2.Hardness testing

Brinell hardness test of the composites were conducted according to EN 1534 (2000) in Llyod testing machine. The measurements were done using a steel ball intender of diameter 10mm with a load of 3kN. After 20 seconds the maximum load of 3kN was reached and the load was maintained for 25 seconds, which was gradually decreased to zero within 15 seconds. The diameter of the remaining indentation formed was measured using Brinell microscope.

3.3. Wear testing

The tribological properties of the composites were studied using a pin-on-disc tribometer. The disc was made of hardened high carbon steel EN 24 (HRC 62, Ra 0.3 μm). The normal and friction force were measured using a force transducer fixed to the arm. The friction force data was obtained using computer based data acquisition system.

Wear test was conducted at a normal load of 40 N. Tests were performed at sliding velocity of 1.5 m/s under dry condition. The tests were conducted up to a sliding distance of 2 km. The initial mass of pin was measured using an electronic balance. After the test, the mass of the pin was measured after cleaning it.

Five tests were conducted for each sample and the average values of measured friction force, and mass loss were used for analysis. The specific wear rate K0 in mm3/Nm was calculated using the formula in equation(1)

$$k_0 = \frac{1000(m_1 - m_2)}{\rho N S} \quad (1)$$

m_1 and m_2 are the mass of the pin before and after testing in grams, ρ is the density of the sample, N is the normal load in N and S is the sliding distance in m.

4. RESULTS AND DISCUSSION

4.1. Tensile Strength

The result of the tensile test conducted on the fabricated composite specimen are displayed in the graph shown in the Figure 3. The results reveals that the tensile strength at yield of the composite specimen containing no fly ash filler was found to be 32.3 MPa and it had a declining trend upon adding the fly ash as filler.

When the weight percentage of the fly ash filler increased to 10% the tensile strength reduced to 10.4% reaching 28.94 MPa.

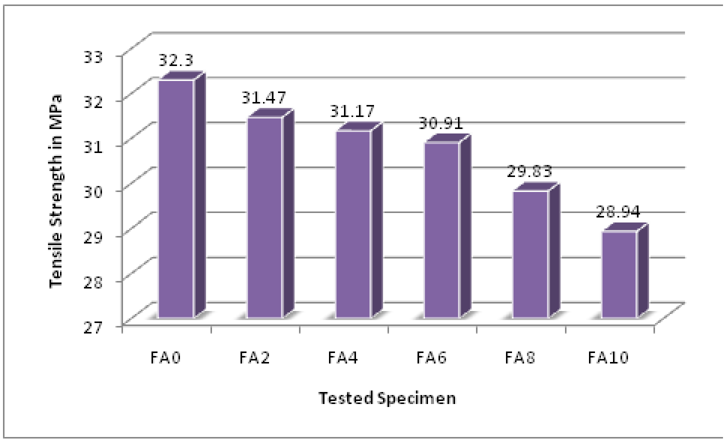

Fig. 3. Tensile strength of the specimen

This decrease in tensile strength upon increasing the filler content may be due to the voids that may have been created by the air entrapment by the nano sized fly ash. This phenomenon makes this composite unsuitable for structural applications.

4.2. Hardness.

The results of Brinell hardness test performed on the fabricated are displayed graph shown in the figure 4. The Brinell hardness (HB) of the specimen with no fly ash filler was found to be 95 N/mm2. The hardness value got increased to a percentage of 30.52% upon the influence of filler to 10% to a value of 124 N/mm2.

This huge increase in the hardness value is because of the Carbon content present in the fly ash. This resulted in a hard material which can be applied in areas where compressive loading plays a vital role in structural applications.

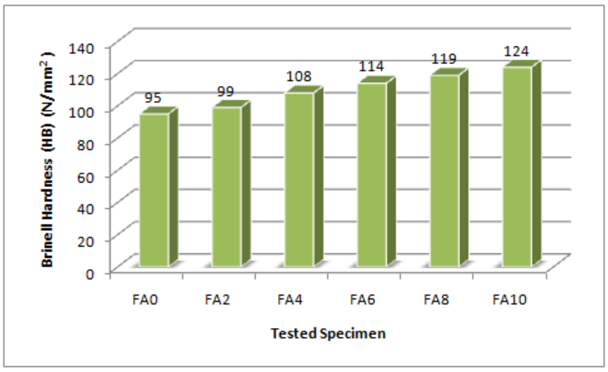

Fig. 4. Brinell Hardness of Tested specimen

4.3.Wear

The results of the wear test conducted on pin-on disk setup are presented in the graph shown in the figure 5. The specific wear for the composite specimen without the reinforcement of nano sized fly ash was observed to be 4.26 x 10-4 mm3/Nm.

When the filler content in the composite is increased to 10%, the specific wear rate of the specimen started reducing to 55.63% considerably.

The carbon content of the fly ash acts as a solid lubricant which results in a self lubricating material. This type of materials can be applied in the areas where friction has to be minimized.

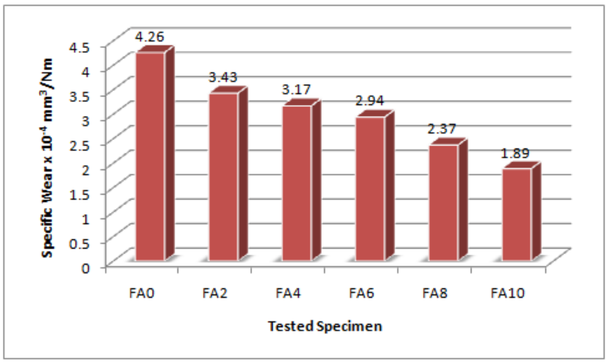

Fig. 5. Specific Wear of the tested specimen

5. CONCLUSION

In this work a self lubricating, low wear rate composite has been developed and their mechanical and tribological properties were investigated. From the results the following three major conclusions were drawn.

The tensile strength of the composite has decreased by 10.4 %, This is because of the air entrapment caused by the nano particles.

The hardness of the composite increases by 30.52%. This is because of the carbon content present in the fly ash. Also the particle size plays a vital role to increase the material density, which improves the hardness of the material.

The specific wear of the composite decreases by 55.63% and this is because of the carbon content present in the fly ash. Since carbon particles are well known solid lubricant, the composite will become a self lubricating material, which results in low wear rate.

The results of this research points out that, fly ash an industrial waste can be used effectively to produce light weight composites with good mechanical and tribological properties. Hence, the newly fabricated composite material can be used as an alternative material in automobile, electronics, machine tool, Construction, Aircraft and sports Industries.

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