SOLID PARTICLE EROSIVE WEAR BEHAVIOUR OF EULALIOPSIS BINATA FIBER REINFROCED EPOXY COMPOSITE

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ABSTRACT

In this investigation a new unexplored potential non-wood natural fiber, eulaliopsis binata (short fiber) is taken as reinforcement with epoxy as matrix material to examine the potential of the fiber as a reinforcement material. The incorporation of short eulaliopsis binata (sabai) fiber with different weight percentage (10,20,30,40) contributed towards enhancement of the tribological properties of the composite. The erosion wear behavior of composites was carried out by air jet erosion test apparatus with four different impingement angles (30º,45º,60º and 90º) and at four different impact velocities (48,70,82 and 109 m/s). The experimented composite showed semi-ductile erosion wear behavior with maximum wear rate at 45º impingement angle at lower velocities and maximum wear rate at 60º at higher velocities. The morphology and damage mechanism of eroded surfaces indicate failure of the composite due to micro cutting and micro-ploughing.

INTRODUCTION

A significant portion of engineering materials starting from daily products like household appliances, doors and windows to sophisticated products like aircraft and space ships are made of composite materials **[1]**. The biggest advantage of composite materials from designer's point of view is the tailor made option for specific application and properties requirement **[2]**. There are various opportunities for the designers to choose among different matrix materials like polymer, metal and ceramic and also on the reinforcement side starting from synthetic to natural fiber to design and develop a new class of composite. Looking at the present day demand and environmental legislation, the interest of researchers is being shifted towards natural fiber polymer based composite **[3]**. Sisal, jute, bamboo, wheat and flax straw, banana has been proved to be good reinforcing material in the polymer matrices **[4]**. The decline trend in the wood raw material from forest created an urge in the research community to find out alternative sources of new raw material for growing composite industry. In this paper, a new class of fiber (non-wood material) has been utilized to find out its potential as a reinforcement in polymer matrices. These composites because of their low cost, higher strength and modulus and above all the biodegradable properties have been the subject of intense study in comparison to synthetic fiber composites.

Eulalipsis binata (sabai grass), a perennial plant known for its high fiber quality belongs to poacceae family of plant kingdom **[5]**. This plant is generally available in the eastern part of India along with some asian countries such as china, Nepal, Pakistan, Myanmar, Thailand, Philippines, Malaysia. Eulalipsis binata fiber is used for making ropes, utility products and in textile industry **[6]**. These plants can be cultivated in degraded and up lands. The rainfall and manure is not necessary but availability of these can lead to better production of sabai pant. The sabai plant helps in conserving water in the soil which adds to the advantages such as low cost of the sabai grass fiber and good quality fiber. Their large-scale cultivation in barren hills and slopes have already been practiced and proved to have fast ecological benefits. The industry is associated with various activities of raising production of grass, processing of goods such as ropes, mats, carpets, sofa sets, wall hangings and other sophisticated, fashionable articles **[7]**. Being a renewable, sustainable fiber, this fiber possesses a tremendous potential in uplifting the economic status of the cultivators **[8]**.

The average fiber length and ash content of sabai fiber is more than that of bamboo fiber which is being used as a fibre **[9]**. Based on morphological characteristics, the sabai grass is quite comparable and even better in some characteristics than that of bamboo fiber **[10]**. In this present investigation, an attempt has been made to investigate the ability of the eulalipsis binata fiber as a reinforcement material to study the erosive wear characteristics of the polymer composite.

EXPERIMENTAL/COMPUTATIONAL DETAILS

Fresh sabai grass stems were collected from mayurbhanj district of odisha state in india. The upper and lower portion along the length of the fiber were cut and removed because up to certain length at these portions they were having less diameter. After cutting these portions we get a long fiber of uniform diameter. Again the fibers were cut into a length of short fiber i.e. 11mm (optimum fiber length from fiber pull out test). In this work Araldite LY556 was used as the epoxy resin with HY951 as the hardener with epoxy with a ratio of 10:1.

The composite samples were fabricated using a wooden mold by usual hand lay-up technique. At first, the weights of fiber and epoxy were calculated with the help of a weighing machine for different volume fraction of fiber. Then a mixture of calculated epoxy resin and hardener (ratio of 10:1 by weight) was formed by gentle stirring followed by mixing of the fiber. After proper mixing of powder and epoxy, the mixture was poured carefully into the mold. A mold release spray was applied throughout the inner surface of the mold before pouring so that the removal of composites was fast and easy. The mold was pressurized from the top by some weights and left for curing at room temperature for 24 hours. Care was taken to consider the loss of materials when they squeezed out of the mold due to application of pressure. This procedure was adopted for fabrication of composites which consists of 10, 20,30 and 40% weight fractions of fiber.

Figure 1: Samples (20*20*20 mm^3) cut from fabricated composite slab of size 150*5*60 mm^3

Sand particle erosion test were conducted on Air jet erosion test rig designed as per ASTM G76 standard with its various component shown in Figure 2. The test rig comprises of air compressor, sand hoper with particle feeder, air particle mixing chamber and accelerating chamber. A selected grade of sand particles was put in the hopper for flow of sand mass during experiment. The sand flow continuity to the sample is maintained by a conveyor belt system. A definite mass flow rate of (3 gm/min) is to be selected for the experiment. A vibrating system is used for the regular flow of sand particle without intermittent at fixed mass flow rate. The erodent particle passes through the air particle mixing chamber where sand particles were mixed with a definite pressure of air. Pressurized air is provided by compressor and regulated by the pressure knob such that definite pressure of air mixes with the erodent in mixing chamber. After mixing these pressurized sand particles are allowed to passes and accelerating through the nozzle of diameter 4 mm to strike the composite sample which is held on the sample holder so that erosion of sample takes place. The arrangement are provided for adjustment of angles of sample holder and particle velocity in the test rig. The Air jet erosion test rig has also been fitted with the rotating double disk arrangement to measure the impact velocity of erodent at various pressures particles striking the samples. The impact velocity at different air pressure measured by double disk method are 48, 70, 82 and 109 m/s for 1, 2, 3 and 4 bar pressure.

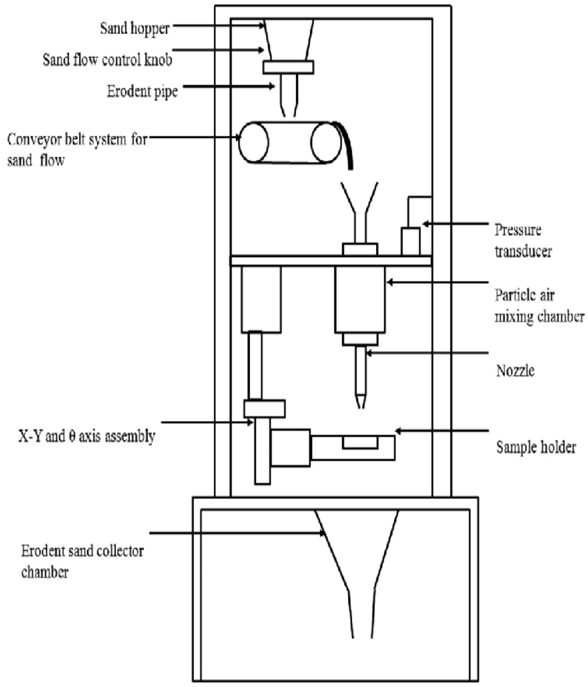

Figure 2: Schematic diagram of erosion wear tester.

The condition under which the erosion experiments has been conducted are given in Table-1. The test sample were cleaned with acetone, then dried properly before and after use and measure the weight to an accuracy of 1×10^{-3} gm by the use of electronic balance. The weight of test samples was measured prior and after each test to find out the weight loss (Δw). Each test sample were eroded for a total period of 15 min with succession of 3 min each for different impact velocities with different angle of impingement. The erosion rate is then calculated.

Table 1: Erosion wear test parameters

Test parameters	
Type of Erodent:	Silica particle
Shape and size of erodent:	Irregular; 200 ± 50
Hardness of silica particles (HV):	1420±50
Impingement angles (α°):	30,45,60 and 90
Impact velocity (m/s):	48,70,82 and 109
Erodent feed rate (gm/min):	3±0.2
Standoff distance (mm):	10

RESULTS

Figure (3-6) shows the variation of erosion rate of different fiber weight fraction composite with respect to various impingement angles (30-90°) and for different impact velocities (48-109 m/s). It was observed that maximum erosion rate takes place at 45° impingement angle at low velocities (48 and 70 m/s) and maximum erosion rate shifts to 60° at higher impact velocities (82 and 109 m/s). This experimental result shows the semi-ductile erosion wear behavior of composite. Minimum erosion rate takes place at 30° impingement angle for all velocities. In the present study, it has also observed that with increase in velocities, that is at 82 and 109 m/s the maximum erosion rate shifted towards 60° impingement angle from 45° angle. Due to this, semi-ductile behavior of the composite changes towards showing brittle behavior. It is further observed that irrespective of impact velocities and impingement angles, minimum erosion rate takes place for 20 wt. % fiber fraction composite and highest erosion rate takes place for 30 wt. % fiber fraction composite. However, 10 wt. % and 40 wt. % composites exhibited an intermediate erosion rate under all experimental condition. It has also been observed from experimental results that erosion rate of all fiber fraction composite increases with increase in impact velocity for all impingement angles.

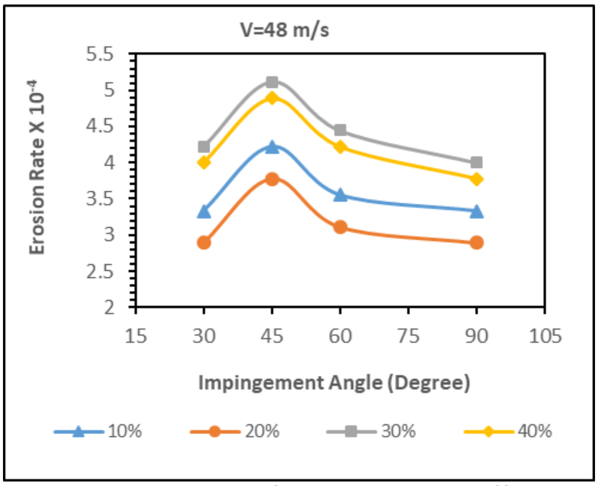

Figure 3: Variation of erosion rate with different impingement angles at 48 m/s impact velocity.

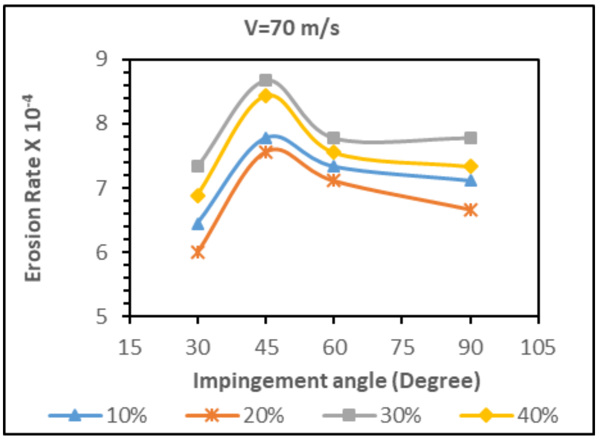

Figure 4: Variation of erosion rate with different impingement angles at 70 m/s impact velocity.

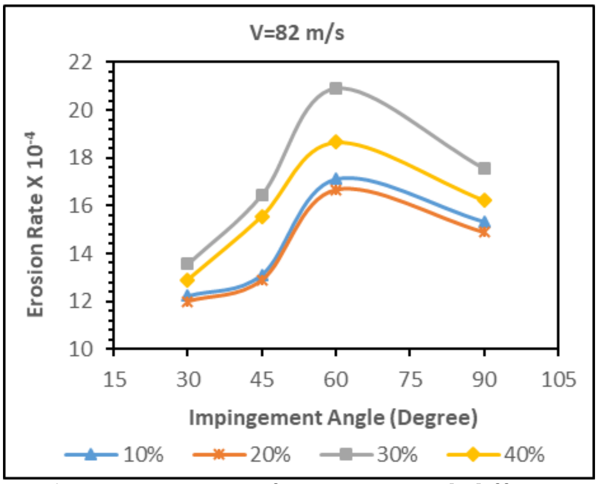

Figure 5: Variation of erosion rate with different impingement angles at 82 m/s impact velocity.

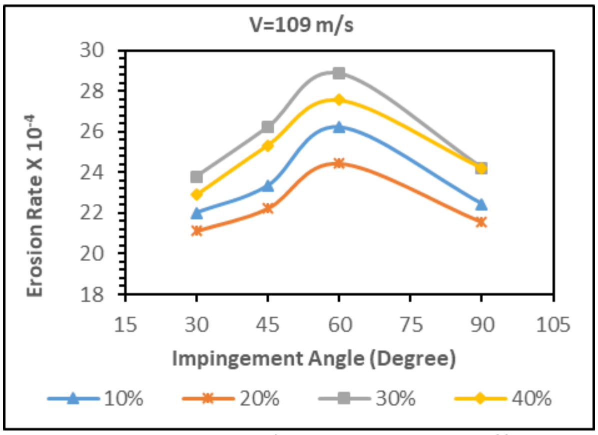

Figure 6: Variation of erosion rate with different impingement angles at 109 m/s impact velocity.

DISCUSSION

Figure 7(a,b) shows the micrographs of eroded surface for 48 m/s impact velocity, whereas Figure 8(a,b) is for the micrographs of the eroded surface at 82 m/s impact velocity. Fiber breakage and detachment of fiber from the surface is clearly visible. Formation of cavities due to fiber removal are also seen on the surface which leads to higher erosion rate. For 45° impact angle (Figure7(a,b)) though the fiber breakage is visible at some places but the impact angle and the velocity are not sufficient enough to detach it from the surface. This in term leads to lower erosion rate. Figure 8(a) shows the eroded surface at higher velocity at 82 m/s for 60° impact angle. It is seen that craters are being formed on the surface of the fiber. Chunks of materials from the surface are also removed. But still the fibers are intact within the body of the composite which leads to lower erosion rate. However, for 60° impact angle Figure 8(b) it is seen that extensive damage of the fiber surface occurs due to development of cracks on the entire surface of the fiber. Fibers are also seen to be removed due to micro cutting and micro ploughing. This might have happened due to development of higher compressive stresses on the surface because the angle of impact and velocity of impact at 82 m/s.

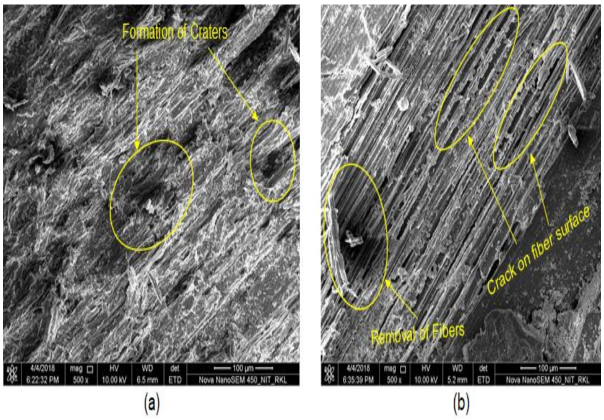

Figure 7: (a) Crater formation and **(b)** Breakage of the fiber at 48m/s velocity at an angle of 45^0 for 30 weight percent composite sample.

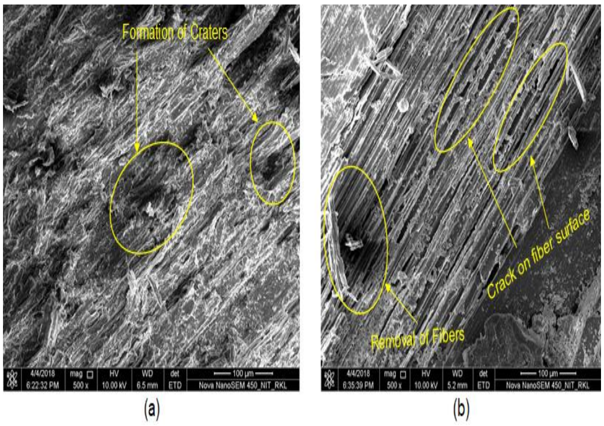

Figure 8: (a) Eroded surface and **(b)** Crack generation in the composite at 82m/s impact velocity at an angle of 60^0 for 30 weight percent composite sample.

CONCLUSIONS

- The Eulaliopsis Binata (EB) short fiber are successfully used as reinforcing medium to fabricate the composite.
- The influence of impingement angle on erosion wear of EB Fiber composite exhibits pseudo semi-ductile erosive wear behavior with maximum erosion rate at 45° impingement angle at lower impact velocities and maximum erosion rate shifted to 60° impingement angle for higher impact velocities. This sifting of maximum erosive angle from 45° to 60° indicates behavior of the composite from semi ductile to semi brittle nature.
- The morphology of eroded surface of composite samples indicates that material removal along with surface damage takes place due to micro-cutting and micro-ploughing. The fiber in the composite subjected to sand particle erosion encountered intensive de-bonding and breakage of fiber which were not supported enough by the matrix depending on the impact angle and velocity of impact.
- The composite can be used to produce desert roof structure, surfing boats, sport equipments and can also be used for low cost housing purpose.

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