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Mechanical and Erosive Wear Behavior of Rubber Wood Particulate Reinforced Epoxy Composite

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Abstract

Natural fibers have many advantages like biodegradable, recyclable, easy availability and low cost along with high specific strength and mechanical properties which are comparable to synthetic fibers, creating interest among researchers worldwide for their suitable use in composite industries. Rubber wood is one such natural fiber whose potential as reinforcement in polymer composite is not yet explored till date. The present work based on the study of the mechanical properties and solid particle erosion wear behavior of epoxy/rubber wood composite. Composites were fabricated by the hand-lay method by incorporating various weight fraction of rubber wood particulates starting from 10-40 wt. % (RWC1-RWC4) with an increment of 10 wt. %. The erosive test was performed on the composites with the help of air-jet erosion tester having various operating parameters such as impact angle (30° to 90°) and abrasive particle velocity (48 m/s to 109 m/s). The results concluded that epoxy/rubber wood composite is semi ductile in nature. The worn surface morphology of the wear test of composite samples were analyzed with scanning electron microscopy (SEM).

Keywords: Rubber Wood, Erosion wear, Hand lay-up, SEM;

1. Introduction

Nowadays Fiber-reinforced composites become as an emerging material in our day to day life due to its good stiffness and enhanced strength compared to traditional materials [1,2]. However, in recent years; the natural fiber has been used for the application in research areas as a reinforcing material for replacement of synthetic fiber in polymer matrix composites (PMCs). Different researchers have studied the various properties of polymer /natural fiber composites like mechanical, friction and wear behavior over the synthetic fiber composites. In recent years, the tribological wear behavior basically, abrasive and erosive wear, are creating most of the damaged in the industrial and other components. However, many studies have been conducted by various authors, which gives that the study of the erosion behavior of the natural fiber composites is important criteria before designing any product which operating under the tribological conditions. The erosive wear design of the components is based on the various parameters [36]. Erosion is a type of wear in which material removal takes place due to impingement of particle, Slurries, fluids and gases. This plays a major cause of failure of machine component and different parts in various industries, automobile, aerospace sectors where components are subjected to impingement of various medium with significant velocity [7,8]. The present work focuses on the mechanical properties and erosive wear behavior of the rubber wood/epoxy composite with varying weight percentage. The results of the tests are analyzed and compared.

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2. Material and Methods

Rubber wood particulate was used for the preparation of composite. Latex, which is an extract from Rubber wood, is used for the production of rubber. Generally, extraction of latex can be done for up to 25-30 years of the economic life of the tree. After that farmers cut down the tree and well dried. Dried stem of Rubber wood can be used for the furniture industry, household applications. Here, in the present research, particulate fiber was extracted from dried stem of Rubber wood for possible reinforcement in polymer matrix composite, Fig. 1. (a-d).

The epoxy resin LY556 (diglycidyl ether of bisphenol A) having a density of 1.2 gm/cm^3 was used as the matrix material. The resin and hardener of grade HY 951 were used to mixed in proportion of 10:1 (wt. %) for well curing of composite structure.

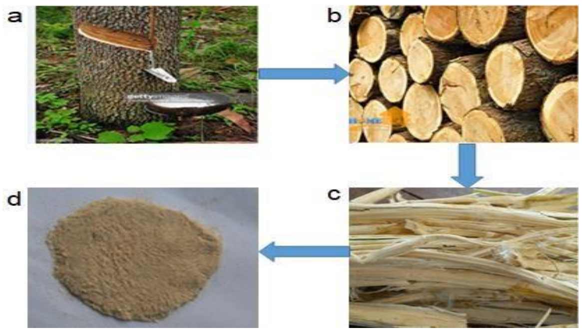

Fig. 1. (a) Green latex Rubber tree; (b) Dried stem of Rubber tree; (c) Crushed layer of stem; (d) Particulate fiber of Rubber wood.

2.1. Fabrication Process of Composite

Rubber wood composites (RWC) were fabricated by simple Hand-lay-up method having 10-40 wt.% of fiber with a step of 10 wt. percent. The amount of fiber and epoxy were calculated by using the rule of mixture according to mold dimension. For fabrication of composite, a calculated amount of epoxy resin and hardener (ratio of 10:1 wt.%) of respective grade were taken in the glass jar. The mixture was stirred thoroughly and kept in the vacuum chamber for possible removal of air bubbles. A calculated amount of fiber was added to the mixture of epoxy and hardener and mix thoroughly in the glass jar. The mixture was left in the mold up to 48 hours for proper curing at room temperature. Then, fabricated composite was taken out from the mold and again post-cured for up to 24 hours. Fig. 2. Shows the fabricated composite with mold. Further, specimen of tensile, flexural and erosion wear testing experiments were cut in the required dimensions.

Fig. 2. Fabricated composite with mold

3. Experimental Setup

3.1. Fabrication of Composite

The Tensile and Flexural test was conducted on INSTRON H10KS universal testing machine (UTM) with an applied load of 10 KN and a crosshead speed of 2mm/min. Tensile and flexural test samples of different fiber wt. % (RWF1-RWF4) were prepared as per ASTM standard, Fig. 3.

Fig. 3. Samples of Tensile test

3.2. Erosion wear test

A sand blast-type machine, Air jet erosion test apparatus, was used for erosive wear test as per ASTM G76 standard. Test apparatus and components are shown in Fig. 4 (a,b). The test apparatus was designed to be representative of an erosion wear rate with various operating parameters like erodent particle sizes, erodent particle flow rate, particle velocities, and impingement angles which are indicated in Table 1. Samples for erosion wear test were cut in the dimension of 25mm X 25mm X 5 mm from the fabricated composite slab. Samples before and after Erosion wear test are illustrated in Fig. 5 (a,b).

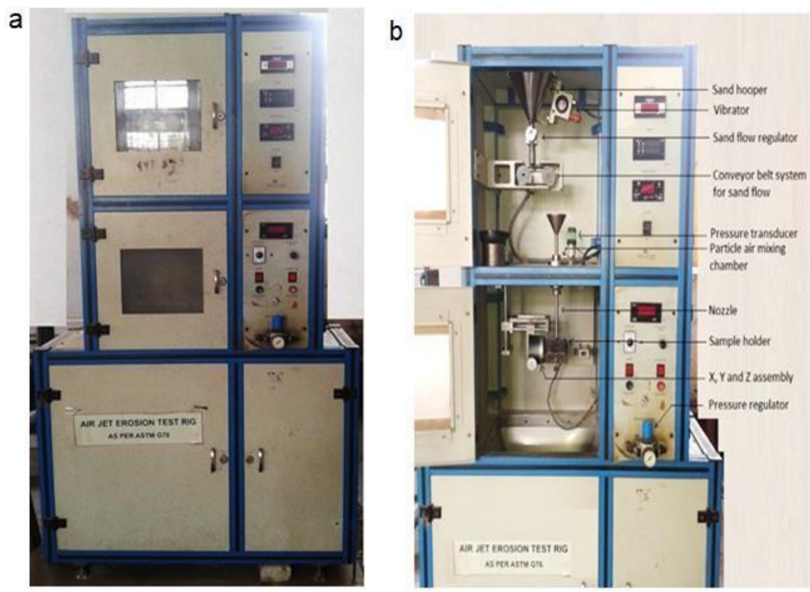

Fig. 4. (a) Air jet erosion test rig (b) Components of Test rig

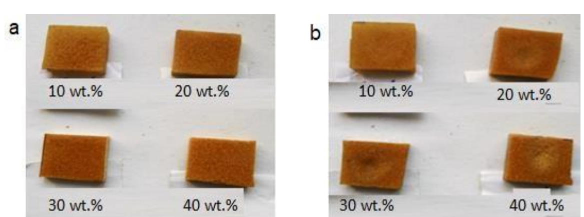

Fig. 5. (a) Samples before Erosion test; (b) Samples after Erosion test

Table 1. Test conditions for erosive wear studies

Erodent:	Silica particle
Erodent shape:	Irregular

Erodent size (μm):	200±50
Hardness of erodent particle (HV):	1420±50
Impact angles (α°):	30,45,60 and 90
Particle velocity of impact (m/s):	48,70,82 and 109
Flow rate (gm/min):	3±0.2
Operating temperature (°C):	27 ^{0}C
Sample distance from nozzle (mm):	10

4. Result and Discussion

4.1. Tensile and flexural strength of composite

It had been found that at 30 wt.% fiber fraction composite (RWC3) have maximum tensile and flexural strength in the order of 25.35MPa and 36.15 MPa respectively. Tensile and flexural properties of the composite are shown in Table 2. The date in Table 2 demonstrates that strength is increased when fiber wt. percent increases from 10 to 30 wt.% fiber fraction composite. It has been seen that further increase of fiber wt.%, decrease the strength of composite from 30 to 40 wt.% composite. The possible cause to reduce the strength is lower compatibility between fiber and matrix at higher fiber fraction composite. A Similar result also found by Acharya et al. [9].

Table 2. Tensile and flexural strength of composite

Design notation of composite	Fiber Weight Fraction (%)	Tensile Strength (MPa)	Tensile Modulus (GPa)	Flexural Strength (MPa)	Flexural Modulus (GPa)
RWC1	10	19.5	0.845	23.80	1.98
RWC2	20	22.71	1.275	27.95	2.14
RWC3	30	25.35	1.624	36.15	3.05
RWC4	40	20.52	0.921	31.25	2.51

4.2. Solid particle erosion wear study

Figure 6. (a-d) represents the variation of erosion rate of composite (RWC1-RWC4) with different impact angles (30-90°) at various velocities (48-109 m/s). It has been seen that the maximum erosion rate occurs at 45° impact angle for all velocities and fiber wt. fraction composites. The prior investigation reported that material behaves ductile, semiductile and brittle erosion wear behavior as maximum erosion rate takes place at 15-30°, 30-60° and 90° respectively [10]. The present analysis of experimental result reveals that the fabricated composites behave as semi-ductile erosive wear behavior as the maximum erosion rate takes place at 45° impact angle. Similar results have been reported by [11,12]. It had been also examined that maximum and minimum erosion rate appeared on RWC4 and RWC1 respectively, irrespective of impact velocity and impingement angle.

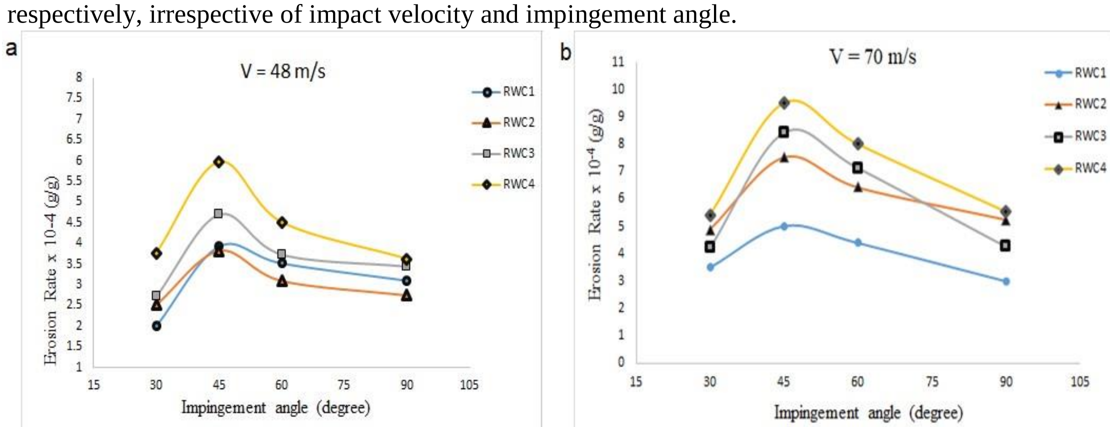

Fig. 6. (a,b) Variation of erosion rate with impact angle at 48 m/s and 70 m/s respectively.

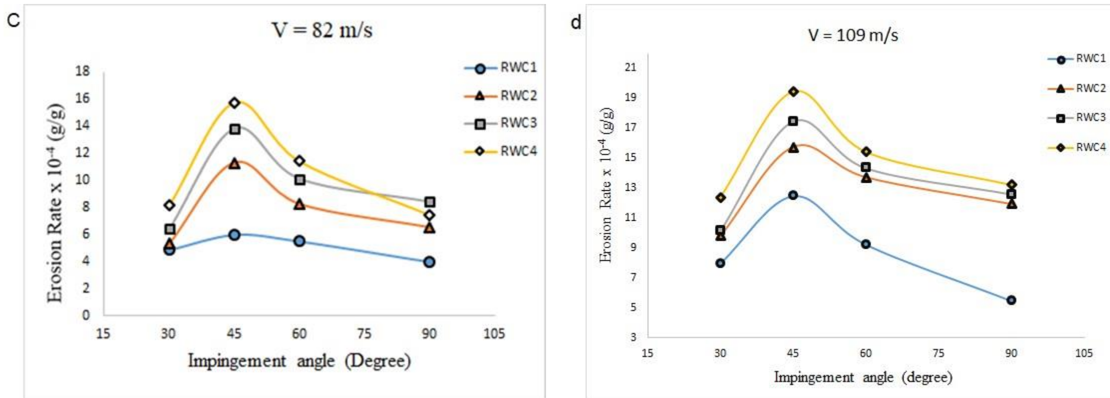

Fig. 6. (c,d) Variation of erosion rate with impact angle at 82 and 109 m/s respectively.

The impact angle and particle velocity has great significant effect on the erosion rate of the composites. For all kind of material, as the steady state condition reached, erosion rate (E_r) can be expressed in the term of power function of impact velocity [13], by equation($E_r = kv^n$). Where, "k" is the proportionality constant and "n" is the velocity exponent. Both the value of "n" and "k" can be obtained using power law equation with least square fitting method. The value of "n" of the composites gives the information regarding the behaviour of the material. If the value comes in-between 2-3, then the behavior of the material can be found as ductile in nature. However, if the value is in the range of 3-5, then it represents the brittle nature of the material. The velocity exponents found for the present case for 30°, 45°, 60° and 90° impact angles are in the range of 1.482-1.695, 1.361-1.778, 1.159-1.809 and 0.705-1.778 respectively. This reveals that Rubber wood/epoxy composite is a semi-ductile in nature.

4.3. Surface morphology

Morphology of eroded surfaces of Rubber wood particulate filled epoxy composite, as shown in Figure 7 (a,b), was examined by Scanning electron microscope. It has been observed that material removal takes place due to micro cutting, micro ploughing and micro scooping. Also, microcracks are appeared on the eroded surfaces due to high-velocity impact. By observation of eroded surfaces, it has been seen that maximum erosion occurs at 45° impingement angle in respect to 60° impingement angle, Figure 7 (a,b). It has been observed that both micro-cutting and ploughing mechanism are responsible for the erosion of the composite samples. Fig (a) shows the formation of the crater and subsequent dislodging of particulates from the eroded surface which leads to higher erosion at 45° angle of impingement. At 60° (Fig. b) though shows the formation of the crater at some places but the removal of particulates from the surface is minimum, that is de-bonding between matrix and particulates does not occur. Hence erosion is less.

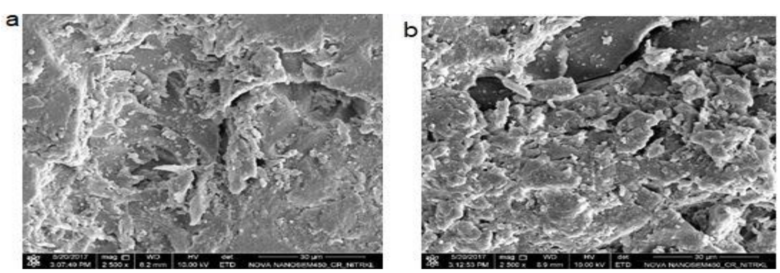

Fig. 7. SEM micrograph of eroded surfaces of 30 wt.% fiber fraction composite at impingement angles of, (a) 45° (b) 60°

5. Conclusion

- Rubber wood particulates can successfully be used as a reinforcing medium with polymer matrix for the fabrication of composite.
- Composites at 30 wt. % fiber fraction (RWC3) have maximum tensile and flexural strength in the order of 25.35MPa and 36.15 MPa respectively.
- The erosion rate of rubber wood/epoxy composites is maximum at 45° impact angle.
- The composites reveal semi-ductile in nature.

- The erosion rate of the composites is lower at low velocity. However, it increases with an increase in velocity.
- The velocity exponents found for 30°, 45°, 60° and 90° impingement angles are in the range of 1.482-1.695, 1.361-1.778, 1.159-1.809 and 0.705-1.778 respectively. The value of velocity exponent “n” shows that Rubber wood filled epoxy composite behaves in a semi-ductile manner.
- The surface morphology of the eroded surface revealed the micro-cutting and micro-ploughing mechanism.

Acknowledgments

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