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Study of Mechanical Properties of Wood Dust Reinforced Epoxy Composite

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Abstract

Composites based on natural fibre reinforcement have generated wide research and engineering interest in the last few decades due to their small density, high specific strength, low cost, light weight, recyclability and biodegradability and has earned a special category of green composite. In this paper, sundi wood dust reinforced epoxy composite were processed with seven different % filler wt. The tensile and flexural tests were performed at three different speeds to study the mechanical behaviour of the composites. From the observation it was found that the mechanical property increases up to certain filler % age and then properties gradually decrease. The microstructure of the composites is also studied to analyze the change using scanning electron microscopy.

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Keywords : Epoxy based composites; wood dust; tensile property; flexural property; speed variation.

1. Introduction

In the past few decades, research and engineering interest has been shifting from unanimous materials to polymeric composite materials. Polymers and their composites have generated wide interest in various engineering fields including tribological applications, in view of their better strength and comparatively small density as compared to monolithic metal alloys [Kranthi and Satapathy (2010); Nielsen and Landel (1994)]. Due to

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environmental concerns, the natural fibre composites, also known as green composite, have shown a growth of interest because of their recyclability and biodegradability. Environmental awareness among all over the world also provided reasons for the focus of the attention towards the use of green fibre polymer composite.

Environmental awareness among all over the world also provided reasons for the focus of the attention towards the use of green fibre polymer composites. The availability of the natural fibres of plant origin in abundance has also been a reason for the study in this area. Specific properties of natural fibre composite such as light weight, low cost, renewable in nature, high specific strength and modulus have widened the usage over other materials [Thakur et al. (2012); Bhowmick et al. (2012)]. A major advantage is that they can be easily disposed of at the end of their life cycle by compositing or by recovery of their calorific value in a furnace which is not possible in synthetic fibre such as for glass. Also in automobile industry the use of wood based natural fibre composites enhance the mechanical strength and acoustic performance, reduce material weight and fuel consumption, improve biodegradability and production cost for the auto interior parts [Herrera-Franco and Valadez-González (2004)]. Almost all of the commonly available natural plant fibres that are cheap and abundant in nature are being used for reinforcement in combination with non-biodegradable matrix materials such as unsaturated polyester, epoxy resin, polyethylene and polypropylene [Ashori (2008)]. Among these, epoxy resins are very versatile in nature. They are one of the most important classes of thermosetting polymers which are widely used as matrices for fiber-reinforced composite materials and as structural adhesives. They are amorphous, highly cross-linked polymers and this structure results in these materials possessing various desirable properties such as greater tensile strength and modulus, uncomplicated processing, fine thermal and chemical resistance, and dimensional stability [Song et al. (2000)].

Different works on the application of natural fibres like banana, pissava, coconut coir, agave, as the reinforcements in polymer matrix have been carried out. The woven banana fibre reinforced epoxy composites showed a very stable mechanical behaviour under different loading and speed condition [Sapuan et al. (2006)]. The epoxy based pissava fibres composite has rich silicon content on the surface and large dispersion in their mechanical properties [Nascimento et al. (2012)]. The flexural modulus of coconut fiber polypropylene matrix composite can be improved by using adequate fiber granulometry and extruder screw speed and that of agave fibre reinforced epoxy composite were significantly high due to alkali treatment of the fibre [Ishizaki et al. (2008); Mylsamy and Rajendran (2011)]. The flexural strength and tensile strength of date wood palm flour based polyethylene composite was decreased by increasing the filler content while the flexural modulus was increased [Mirmehdi et al. (2014)]. The internal recycling of poly (vinyl chloride)-based composites was influenced by wood fibre filler, resulting with increase in number of cycle, the flexural strength is also increased [Augier et al. (2007)].

In this work, natural filler based epoxy composite from wood dust is developed and its mechanical behaviour under various testing speed and % of filler wt. is investigated and comparative study is done. Also the microstructure of the composite is studied.

2. Materials and experimental details

2.1 Materials and Composite fabrication

In this work the low temperature curing epoxy resin (Araldite LY 556) chemically belonging to the 'epoxide' family and corresponding hardener (HY 951) are mixed in a ratio of 10:8 by weight. The sundi wood dust (SWD) is obtained during the cutting of sundi tree wood. The principal organic constituents of sundi wood are cellulose, glucomannan, xylan and lignin. The sundi tree belongs to Michelia montana tree species family and easily available in Eastern part of India.

The sundi wood dust (SWD) particles (collected from North eastern part of India) with average particle size 2 µm and density 0.779 gm/cc after cleaning and drying are reinforced in epoxy resin (density 1.26 gm/cc) to prepare the composites. The dough (epoxy filled with SWD) is then mechanically stirred and gradually poured into the vacuum glass chamber of required dimension of 125 mm×25 mm×5 mm, coated beforehand with glass paper. The whole mixture in the chamber is cured for 24 - 48 hours at room temperature and after that the filler reinforced specimen is used to study the various mechanical behaviours.

2.2 Experimental design

Design of experiment is a powerful analysis tool for modeling and analyzing the influence of control factors on the output. The most important step in the design of experiment lies in the selection of the control factors. Therefore, many factors are included so that non-significant variables can be known at the earliest opportunity. The tensile and flexural tests using composites are carried out under different operating conditions considering two parameters, viz., filler content and speed at seven level and three levels respectively as listed in Table 1. In a conventional full factorial experiment design, it requires 7*3= 21 runs to study two parameters at mixed levels.

Table 1. Levels of the variables (control factors) used in the experiment.

	Levels							
Control factors	1	2	3	4	5	6	7	Units
Filler content	0	2.5	5	7.5	10	12.5	15	wt.%
Speed	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	mm/min

2.3 Tensile test

The tensile test was carried out according to ASTM D 638-03 using universal testing machine with grip capacity of 100 kN. The testing was performed at ambient temperature of 24 °C and relative humidity of 53%. Seven different % filler wt. specimens (as 0%, 2.5%, 5%, 7.5%, 10%, 12.5% and 15%) were tested at three different speeds of 1 mm/min, 2 mm/min and 3 mm/min. The standard specimen was mounted by its ends into the holding grips of the testing instrument. The machine is designed to elongate the specimen at a uniform rate and using extensometer the instantaneous applied load and the resulting elongation are measured continuously and cumulatively.

2.4 Flexural test

The three point flexural tests of composites are carried out using Universal testing machine as per ASTM D 790-03 at 24 °C and 53% relative humidity. The specimens of each filler contents were tested at three different crosshead speeds of 1 mm/min, 2 mm/min and 3 mm/min. The sample of rectangular cross section rests on two supports and is loaded by means of a loading nose midway between the anchors. The loading nose and anchors have cylindrical surface. The flexural modulus is calculated from the slope of the initial portion of the load deflection curve.

Also the microstructure images of the composites are taken by scanning electron microscope for analyzing the filler distribution in the resin. The images are taken at the magnification of 1000 times for the length of 10 µm at 10 kV of power supply.

3. Results and discussion

3.1. Tensile test results

The tensile test was carried out using seven different filler content samples at three different speeds. The variations of maximum load versus filler content and tensile stress at maximum load versus filler content are shown in figure 1(a) and (b) respectively. The variation of tensile modulus and tensile strain at various speed for different filler content are shown in figure 1(c) (d) respectively.

From the results, it can be observed that as the filler weight % increases, maximum load, tensile modulus, tensile stress and strain value increases and becomes maximum at 10% filler content by wt. and then these properties decreases and becomes minimum at 15 % filler wt. except for tensile modulus value which attains its minimum value at 0 % filler wt.

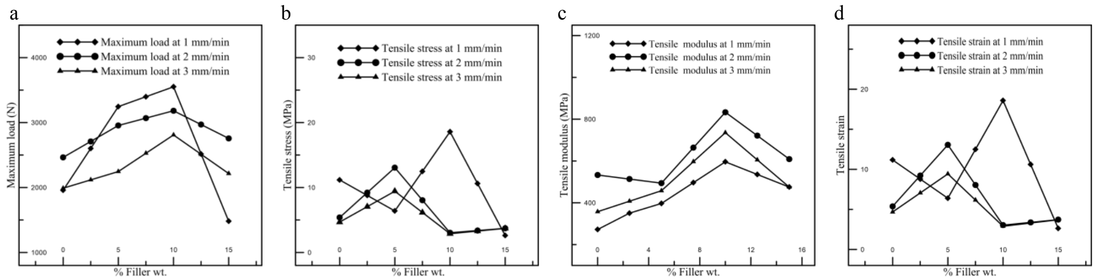

Fig. 1. (a) Maximum load vs. % filler wt .at various speed; (b) Tensile stress at maximum load vs.% filler wt. at various speed; (c) Modulus vs % filler wt. at various testing speed; (d) Tensile strain at maximum load vs. % filler wt. at various speed.

The maximum and minimum values of load with speed of 1 mm/min are found at 10 % and 15 % filler wt. respectively. Their respective values are 3550.36 N and 1482.08 N. The maximum and minimum values of tensile stresses with speed of 1 mm/min are 28.29 MPa and 10.83 MPa at 10 % and 15 % filler wt. respectively. The maximum and minimum strain values are 19.10 and 2.69 respectively at 10 % and 15 % filler wt. with speed of 1 mm/min respectively. For 2 mm/min speed the maximum and minimum modulus values are found at 10 % filler wt. and the maximum and minimum modulus values are found 0 % filler wt. at 1 mm/min speed and the values are 19.10 MPa and 2.69 MPa respectively. The maximum value of the stress is found at higher % age of filler with low speed. This is due to the fact that the fillers get time to reorient themselves and results in higher value of the stress whereas in case of higher speed the maximum value of stress is reached at a lower % age of filler.

3.2 Flexural test results

The flexural test is carried out for seven different % filler wt. at three different speeds. The variation of flexural stress, modulus and strain vs. filler content at different speed are shown in figure 2(a), (b) and (c) respectively.

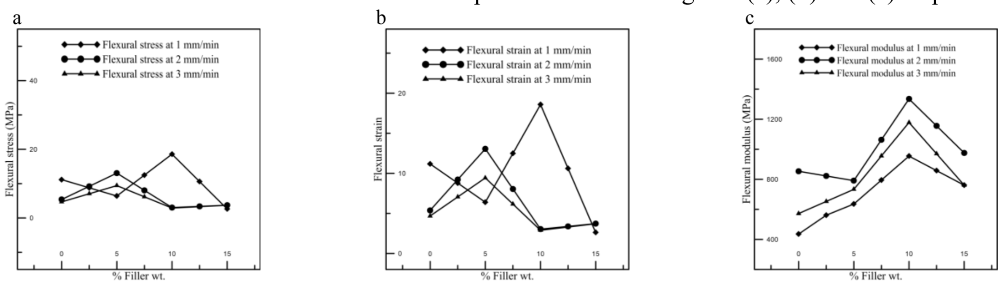

Fig. 2. (a) Flexural stress at maximum load vs.% filler wt. at various speed; (b) Flexural strain at maximum load vs. % filler wt. at various speed; (c) Flexural modulus vs. % filler wt. at various speed.

From the results, it can be inferred that as the filler wt. % increases, flexural modulus, flexural stress and strain value increases and becomes maximum at 10% filler wt. And then properties start decreasing and become minimum at 15 % filler wt. except for modulus value which attains its minimum value at 0 % filler wt.

The maximum and minimum values of flexural stress are 47.65 MPa and 18.24 MPa respectively for 10 % and 15 % filler wt. with 1 mm/min speed. The maximum and minimum flexural strain values are 2.61 and 18.58 respectively for 10 % and 15 % filler wt. with 1 mm/min speed. The maximum and minimum values of flexural modulus are 1335.20 MPa and 435.70 MPa respectively for 10 % and 0 % filler wt. and speed of 2 mm/min and 1 mm/min respectively. As discussed in the case of tensile properties regarding the maximum stresses and its relationship with speed of testing, the same is also true for the flexural properties.

At higher % age of filler the observed drop in tensile and flexural behaviours of the composites occurs due to the agglomeration of the filler molecules around the matrix which prevents the proper curing of the composite and the same can be observed in the scanning electron microscope images. The filler particles are seen scattered in 2.5 % filler wt. sample as shown in figure 3(a). For 10 % filler wt., specimen filler particles are started forming clusters and mechanical properties are at the highest value as shown in figure 3(b). For higher filler wt. %, the clusters are started engulfing the resin resulting isolation of resin and hardner resulting in incomplete curing of composite as shown in figure 3(c) and (d) respectively.

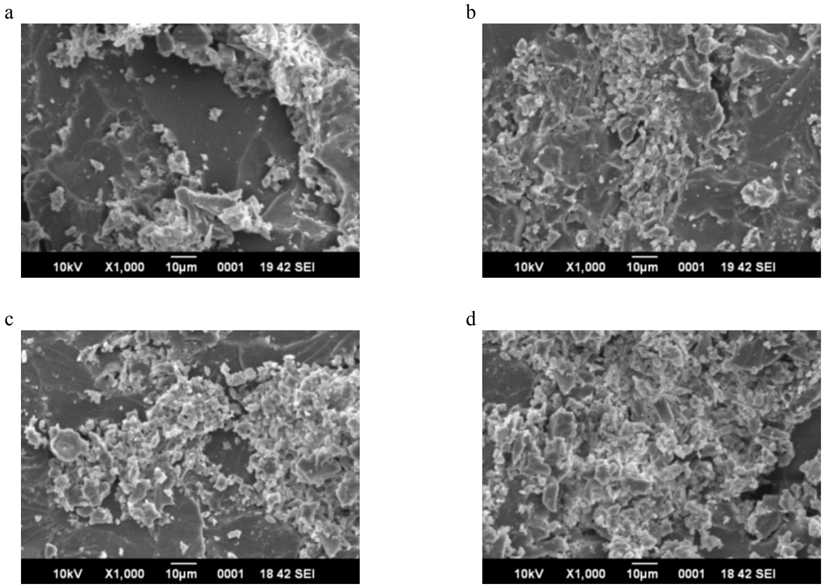

Fig. 3. SEM images of specimen of epoxy with (a) 2.5 % filler wt.; (b) 10 % filler wt.; (c) 12.5 % filler wt.; (d) 15 % filler wt.

4. Conclusion

The mechanical bevaviour of sundi wood dust reinforced epoxy composite is studied under the variation of filler content and speed. The experimental results support that successful fabrication of sundi wood dust reinforced epoxy composites is possible and that sundi wood dust possesses good filler characteristics as it improves the tensile and flexural properties of the polymeric resin. The maximum load, tensile stress and strain, and flexural stress and strain values are found to be maximum and minimum at the filler wt. of 10 % and 15 % respectively with speed of 1 mm/min. but the tensile and flexural modulus values are found to be maximum and minimum at 10 % filler wt. with speed of 2 mm/min and at 0 % filler wt. with speed of 1 mm/min respectively. The best mechanical properties are observed for 10 % filler wt. and speed of 1 mm/min and 2 mm/min speed.

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