Improving the mechanical properties of jute fiber woven mat reinforced epoxy composites with addition of zinc oxide filler

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Abstract. The present work is to prepare the jute fiber reinforced epoxy composites by changing the number of layers of jute fiber mat and adding the various content of zinc oxide filler. The composites were prepared by compression molding techniques and investigates the tensile, flexural and impact properties according to ASTM standard. The results reveal that increasing the number of jute fiber mat layer was increased the mechanical properties. The maximum strength was obtained in double-layer composites. By incorporation of zinc oxide filler, the filler content gradually increased the mechanical strengths which increased the bonding effect between fiber and matrix. The maximum mechanical strengths were obtained for composites containing the 25% of zinc oxide filler. More than the 25% of zinc oxide filler was decreased the mechanical properties due to lower the resin content and bonding between fiber and matrix.

Keyword. Jute fiber composites; Zinc oxide filler; mechanical properties; compression molding technique

1 Introduction

The natural fiber reinforced polymer composites are widely used in various applications, such as automobile parts, aerospace, construction and aviation [1]. These materials fit to the concept of circular economy to convert the biomass waste to value-added products. Changing of the weight content of the natural fiber in the composites manufacturing was improving the mechanical, dynamic and thermal properties. The natural fibers, such as jute, sisal, snake grass [2], Sansevieria ehrenbergii [3], pineapple leaf fiber, coir fiber, etc, are widely used to prepare the polymer composites for characterization.

The fillers have been used to mix with polymer to develop the filler and fiber-reinforced polymer composites for improving the properties. The polypropylene composites were made with continuous and short jute fiber by varying weight ratios from 20 to 40%. The Maleic Anhydride grafted Polypropylene (MAPP) coupling agent was mixed with resin before making composites. The tensile and flexural strength of continuous fiber and coupling agent mixed composite were found to be higher than the neat resin [1]. The polypropylene composite made up of chopped jute fiber showed higher mechanical properties at a fiber content of 30 wt% [3]. The chemically treated jute fiber composites showed higher mechanical properties than the untreated fiber composites. The NaOH and silane treated jute fiber showed higher bending strength [4]. The polypropylene composites reinforced with jute fabric showed higher tensile strength at 40 % fiber volume fraction [5]. The polyvinylchloride coated plane weave jute fiber in polyester composite showed higher tensile and flexural strength at a coating concentration of 200 g/m2 [6]. The epoxy composite was made up of woven jute mat with various coconut shell fillers. The composite with a 30 % weight content of filler showed better mechanical properties [8]. The Bi woven Jute fabrics were used to prepare the epoxy composite with *Portunus sanguinolentus* shell powder. The maximum mechanical properties of 55 MPa (Tensile strength), 5.45 MPa (Flexural strength) and 6.21 J (Impact strength) were obtained for chemically treated powder [9].

The unidirectional jute fiber was used to prepare the epoxy composite at 52 % of fiber content and compared the mechanical properties with bamboo fiber composites. The higher mechanical properties were found for jute fiber composite. The unidirectional jute fiber was used to prepare the epoxy composite at 52 % of fiber content and compared the mechanical properties with bamboo fiber composites. The improved mechanical properties were found for jute fiber composites, such as tensile strength of 216 MPa and flexural strength of 158 MPa [10]. The length of jute fiber, such as 10, 20, 30 and 40 mm was used to prepare the epoxy composites with and without NaOH treated fiber and at various weight fractions 0%, 5%, 10%, 15%, 20% and 25% [11]. The jute fiber was treated and coated with NaOH and polylactide for composites development. The mechanical properties were improved by increasing the coating thickness [12].

The injection molding technique was used to prepare the jute and flax fiber polypropylene composite. The jute fiber reinforced polypropylene composite showed higher tensile strength than the flax fiber reinforced polypropylene composite [13]. The rose and

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padauk wood dust was mixed with epoxy resin for preparing the jute epoxy composites. The 10 percent padauk wood filler mixed with jute epoxy composite showed higher mechanical properties [14]. The hot press technique was pursued to prepare the Polypropylene-MAPP/flax composites. The maximum tensile strength was found in longitudinal and transverse directions at 60% fiber content [15]. The fillers of zinc oxide and titanium dioxide were used to prepare the jute epoxy composites. The addition of filler showed in increasing the thermal stability and mechanical properties [16]. The present work is to investigate the mechanical properties of zinc oxide filler reinforced jute epoxy composite at various filler and fiber content.

2 Experimental

2.1 Fabrication of Composites

The jute fiber mat composite laminate was developed by hand lay up method followed by compression cold press technique. The jute mat was cut into 220 mm length × 220 mm width according to mold size. The epoxy and hardener were mixed in a ratio of 10:1 ratio for 5 minutes. The polyethylene thin sheet was placed on the mold for easy removal of the plate. The jute mat was dipped in the resin and placed on the female die mold. The steel roller was rolled over each layer for removing the air bubbles in the resin. The closed mold was kept in a hydraulic press at 15 bar pressure for 8 hours. The casted composite was removed from the mold and it was placed in a hot air oven for 1 hour at 45°C. The single, double and tribble layer jute mat was used to prepare the composites, and addition of zinc oxide filler of 5, 10, 15, 20, 25 and 30% weight content was mixed with double layer composites for preparing the filler with fiber-reinforced epoxy composites.

2.2 Mechanical Properties

The mechanical properties of tensile, flexural and interlaminar shear strength (ILLS) were studied according to ASTM standards. The tensile test was performed according to the ASTM D 638. The size of the specimen was 165 mm in length, 13 mm in width and 3 mm in thickness. The gauge length was 50 mm. The universal tenting machine (Model: DTRX-5 kN, Make: Deepak poly-Plast Pvt. Ltd, Load cell: 30kN) was used for the experiment with a cross head speed of 2 mm/min. The three-point flexural testing sample size was 120 mm (length), 12.7 mm (width) and 3 mm (thickness) [1-2]. The testing speed of the sample was 2 mm/min. The ILLS test was performed in UTM and the size of the samples was cut into ASTM D2344. The five identical specimens were tested for all mechanical tests and the average values were calculated for further discussion.

3 Results and discussion

3.1 Tensile Properties

Figure 1a shows the tensile stress versus strain curve of zinc oxide and jute fiber mat reinforced epoxy composites. Increasing the jute fiber mat increased the stress with strain. The epoxy composites containing two layers of jute fiber mat showed a higher tensile stress curve with strain. The three-layer composites showed less tensile stress than double-layer composites. The double-layer can absorb more stress during experiments due to the required level of matrix presented in the composites. However, increasing of the jute mat was more than double to reduced the quantity of matrix to lower the tensile stress. The double-layer composites with zinc oxide filler showed that increasing the filler content increased the tensile stress curve. The maximum tensile stress versus strain curve was obtained for double layer composite with 25% of zinc oxide filler content. The filler acted as a bonding agent between jute fiber and epoxy, which increase the tensile stress. However, with more filler content i.e 30%, the epoxy acted as more brittle and also less epoxy content [1, 3] that reduced the stress. Figure 1b showed the tensile properties of jute mat epoxy composites with and without zinc oxide. The percentage differences between the tensile stress of the composites are 3.5 (Single to double layers), 22.87 (Double to triple layers), 29.6 (25 to 5 % of zinc oxide), 23 (25 to 10 % of zinc oxide), 18.6 (25 to 15 % of zinc oxide), 3.8 (25 to 20 % of zinc oxide), and -14.8 (25 to 30 % of zinc oxide). Figure 1c shows the tensile modus of jute mat epoxy composites with and without zinc oxide. The percentage differences between the tensile modulus of the composites are 9.7 (Single to double layers), 16.08 (Double to triple layers), 27.7 (25 to 5 % of zinc oxide), 23 (25 to 10 % of zinc oxide), 11.18 (25 to 15 % of zinc oxide), 11.18 (25 to 20 % of zinc oxide), and -17 (25 to 30 % of zinc oxide).

3.2 Flexural properties

Figure 2a shows the flexural stress versus strain curve of zinc oxide and jute fiber mat reinforced epoxy composites. Increasing the jute fiber mat increased the flexural stress with strain. The double-layer jute fiber composite showed higher flexural stress than the single and triple layers. The more bending stress was transferred uniformly in the double-layer composite than in the other two. The double-layer composites with zinc oxide filler showed that increasing the filler content increased the flexural stress curve. The maximum flexural stress versus strain curve was obtained for double-layer composite with 25% of zinc oxide filler content. The filler acted as a bonding agent between jute fiber and epoxy, which increased the flexural stress. The more filler in epoxy composites led to brittle [1, 3, 7], which reduced the flexural stress. During the bending of the composite sample, the loading surface had compressive stress formation and bottom surface had tensile stress. The more filler acted as a load barrier member in the composites. Figure 2b showed the flexural stress of jute mat epoxy composites with and without zinc oxide. The percentage differences between the tensile stress of the composites are 27.97 (Single to double layers), 6.96 (Double to triple layers), 31.67 (25 to 5 % of zinc oxide), 23.62 (25 to 10 % of zinc oxide), 14.49 (25 to 15 % of zinc oxide), 5.17 (25 to 20 % of zinc oxide), and -21.68 (25 to 30 % of zinc oxide).

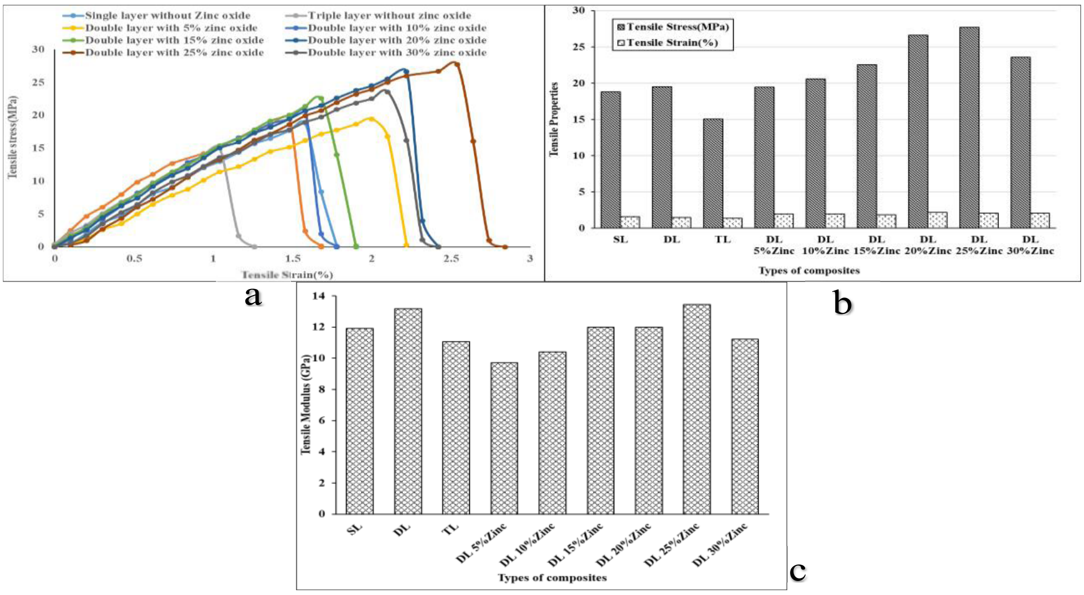

Figure 1. a) Tensile stress versus strain curve, b) Tensile stress and strain, and c) Tensile modulus of jute fiber mat reinforced epoxy composites with and without zinc oxide

Figure 2c shows the tensile modus of jute with and without zinc oxide. The percentage differences between the tensile modulus of the composites are 9.7 (Single to double layers), 16.08 (Double to triple layers), 27.7 (25 to 5 % of zinc oxide), 23 (25 to 10 % of zinc oxide), 11.18 (25 to 15 % of zinc oxide), 11.18 (25 to 20 % of zinc oxide), and -17 (25 to 30 % of zinc oxide).

3.3 Inter-laminar shear strength

Figure 3a shows the impact of zinc oxide and jute fiber mat reinforced epoxy composites. The impact strength of the composites was improved by increasing the number of jute fiber layers. The composites containing three layers of mat showed less impact strength than the double layers, and litter higher than the single layer jute mat composites. The double-layers composites had higher impact strength. The zinc oxide-filled double-layers epoxy composite showed an increase in the impact than the unfilled composite. Increasing the zinc oxide filler increased the impact strength due to the better bonding of fiber in epoxy with help of filler. The maximum impact strength was found in 25% of zinc oxide-filled composites. The percentage differences between the tensile stress of the composites are 50.3 (Single to double layers), 25 (Double to triple layers), 50.44 (25 to 5 % of zinc oxide), 40.27(25 to 10 % of zinc oxide), 40.29 (25 to 15 % of zinc oxide), 3.39 (25 to 20 % of zinc oxide), and -20.11 (25 to 30 % of zinc oxide).

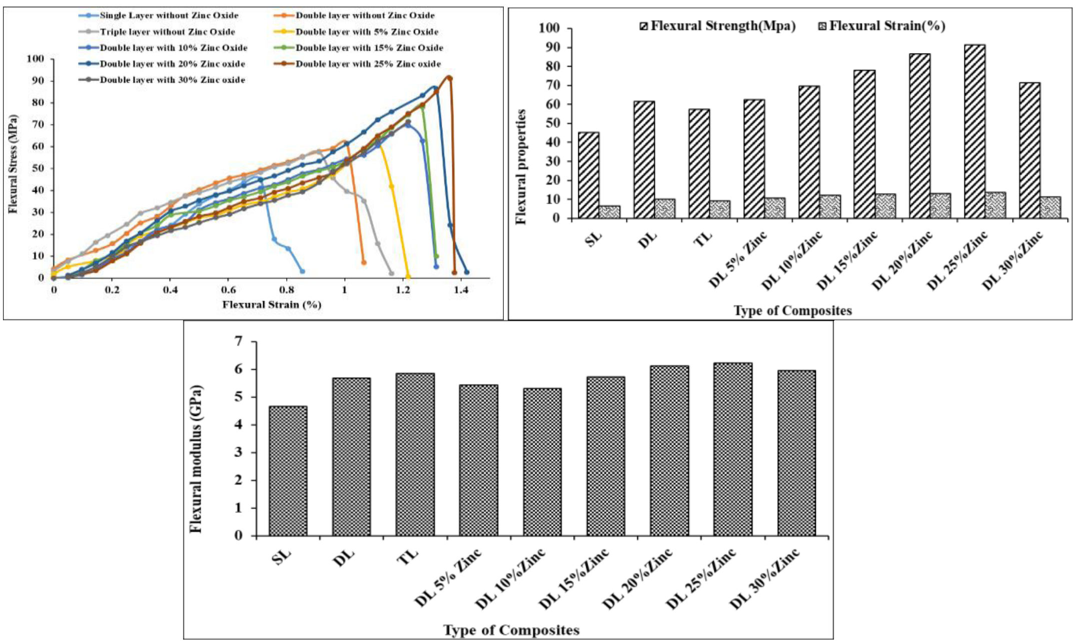

Figure 2. a) Flexural stress versus strain curve, b) Flexural stress and strain, and c) Flexural modulus of jute fiber mat reinforced epoxy composites with and without zinc oxide

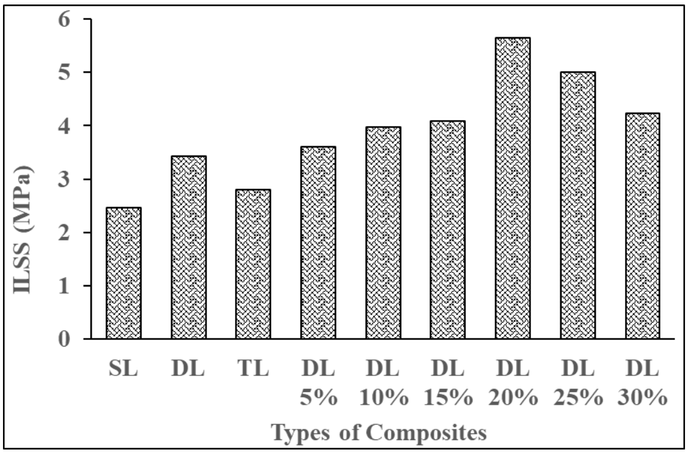

Figure 3. Impact strength of the jute fiber mat reinforced epoxy composites with and without zinc oxide

4 Conclusion

The jute fiber mat reinforced epoxy composite was prepared by compression molding techniques by changing the numbers of layers and, with or without zinc oxide filler. The tensile, flexural and impact strength were increased by increasing the jute fiber mat layers. Compare with single, double and triple layers, the double-layers composite showed higher mechanical properties due to the optimum level of matrix and fiber in the composite. Considering double-layer composites, the various percentagess of zinc oxide fillers were added to reinforced with epoxy for developed the composites. The more filler content increased the mechanical properties. The maximum strength was found for composites containing 25% of zinc oxide filler content. By increasing the filler content by more than 25%, there was a litter drop in mechanical properties due to the less resin content, which affects the bonding areas between fiber and matrix. Therefore, the double-layer jute fiber mat reinforced epoxy composites showed maximum mechanical properties at 25% of 25% of zinc oxide filler content.

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