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Investigation on Mechanical Behavior of Sisal Fiber Reinforced Polylactic Acid and Sisal/Epoxy Composites

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Abstract. Natural fibers have been found to be an alternative resource for synthetic materials. Natural composites are found to be a one hundred percent bio degradable product. Natural composites are also found to be having a great strength to weight ratio. In this process, hybrid sisal and polylactic bio composites are reinforced together by using the hand layup method. The ratio of sisal and polylactic element is in the ratio of 1:1 that are subjected to a compressive force with simultaneous heating process. Tensile strength and Flexural strength are evaluated as per the ASTM standards. Results shown that the there is good improvement in polylactic acid based biocomposite due to good interfacial between fiber and matrix.

Introduction

Industries such as aeronautical, marine, space vehicles and defense are lookout for composite materials having strength and low weight and that are intended to withstand varying load conditions that are forced on the products. Mostly synthetic polymer composites are used till date in various fields. Composites with reinforcements of natural fibers are being used as potential alternative to synthetic fibers reinforced composites in many engineering applications such as for packaging, automotive, furniture and construction industry (Omar Faruk, et al., 2014 [1]). This has been encouraged by the global concern for the eco-system and hence the subsequent need for eco-friendly materials (Temesgen Berhanu, et al., 2014 [2]). In a situation where the load-bearing capacity and dimensional stability under certain conditions like temperature and moisture are of secondary importance, bio-composites can replace engineering application of plastic products. Among these, polylactic acid (PLA) is a biobased polymer developed from renewable sources. It is usually produced from fermentable sugar and vegetable oils (G. Bexa, et al., 2017 [3]). PLA can be reinforced by natural fibers to produce fully biodegradable and environmental friendly bio-composites. According to Joseph et al (M. R. Sanjay, et al., 2016 [4]), thermoplastic polymers reinforced with natural fibers have stimulating mechanical properties. (T. Gurunathan, et al., 2015 [5]) exhibited that the increase of the content of agave fiber in natural composites based on polyhydroxybutyrate up to 30% can improve tensile and bending properties. (M. Feldmann, et al., 2016 [6]) has revealed that increasing the basalt fiber content in polylactic acid (PLA)-based composites improves the tensile, flexural, and impact properties. (Bax et al [12])(Furqan Ahmad, et al., 2015 [7]) study found that the addition of PLA in the rate of from 5% to 20% in flax fiber based composites improves tensile and impact properties. (Gamon et al [13]) (Sistanley Jones Lima Bispoa, et al., 2015 [8]) found that the increasing of themiscanthus fiber content from 10% to 40% in Polylactic acid does not adapt the melting temperature of the polymer. The study of (Anuar et al [14]) (Xuefeng Zhao, et al., 2014 [9]) showed that the rise of the kenaf fiber content in PLA improves the melting enthalpy of PLA. Different researchers explored the feasibility of using sisal fiber in thermoset polymer because of its low production cost and the ability of sisal fibers to be laminated and wound. In this work, it was studied how the sisal fiber modifies the properties of bio-composites based on PLA matrix. This study was carried out to investigate the effect of the sisal fiber content on the tensile and flexural behaviour of PLA based bio-composite.

Material and Methods

Sisal fiber is processed from Agave Sisalana widely cultivated in Southern Mexico. It is taken as woven fibre as shown in Fig. 1(a). It used for the preparation of bio-composites, as sisal fibre is very stiff. Polylactic Acid (PLA) is one of the known bio-polymer made of renewable resource. It is taken as pellets for the productions of bio composites, it has a high tensile strength and flexibility.

Fig. 1(a) Sisal fiber.

Fig. 1(b) Polylactic Acid.

The effects of various sisal fiber surface treatments on the mechanical properties of sisal thermoplastic composites were studied by many researchers. The most commonly used chemical treatments for sisal fibers are sodium hydroxide, isocyanate, permanganate, and peroxide.

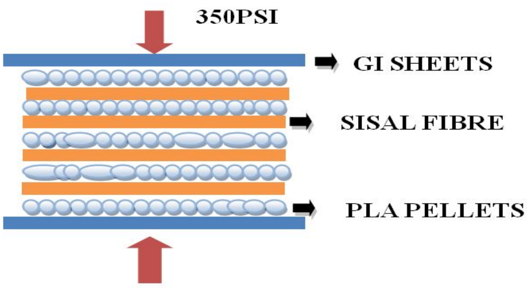

Fig. 2(a) Schematic representation of sisal PLA production.

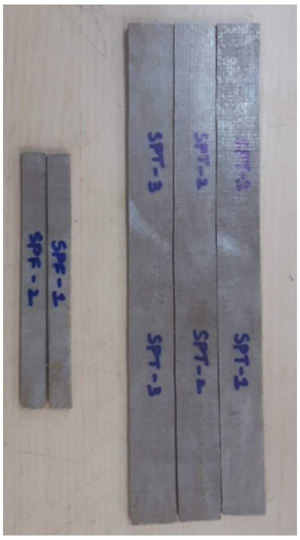

Fig. 2(b) Fabricated Specimen.

Akash et al. [10] studied the mechanical behaviour of hybrid sisal/hemp fiber-reinforced epoxy composites. The fibers were treated with 10% NaOH solution to improve the interfacial characteristics. The chemically treated hybrid composite showed maximal flexural and compressive properties at 40 wt% of sisal/hemp fiber content. The woven Sisal fibre is soaked in NaOH (Sodium Hydroxide) for 30 minutes, firstly it is washed in 3.5 litres of distilled water, then it is air dried overnight, and its kept in Hot air oven for 30 minutes at the temperature of 60 degrees celsius. Four layers of woven fibre and 200 grams of PLA pellets are uniformly sandwiched (40 grams between each layers) in between galvanized iron sheets as shown in Fig. 2(a). This combination is subjected to 350 psi at 180 degrees Celsius for 30 minutes then it is air cooled for 48 hours. The specimen is collected and machined for standard dimensions as shown in Fig. 2(b).The Table 1 consist of the tests performed and machines used, also the dimensions of the specimens based on ASTM standards and test speed.

Table1 Standards used for determination of Mechanical behaviour.

Test	ASTM standard	Machine	Test Speed	Specimen size (mm)
Tensile test	D3039	INSTRON® 3382	Cross-head speed of 5mm/min	250 × 25 × 3
Flexural test	D790	Tinius Olsen's® model IT503	Feed rate of 1.2 mm/min	127 × 12.5 × 3

Results and Discussions

Fig. 3(a) compares the flexural behaviour of Sisal PLA and Sisal Epoxy on the basis of ultimate load. At the start of test, the values of Sisal PLA are found to be just over the values of Sisal Epoxy. It is identified later in the test that the ultimate flexural load of Sisal PLA which breaks at 0.105 KN is comparatively higher than Sisal Epoxy which breaks at 0.080 kN. The breakage value is obtained which proves that sisal PLA is comparatively better than sisal epoxy when it comes to flexural properties.

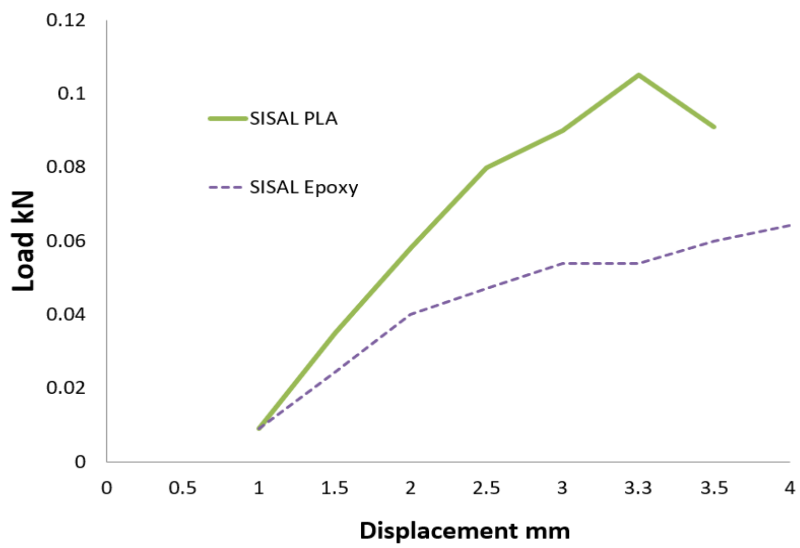

Fig. 3(a) Flexural behaviour of Sisal PLA and Sisal Epoxy.

The Fig. 3(b) depicts the load displacement curves of tensile test between sisal pla and sisal epoxy composites. Though both the composites present the similar values of UTL initially, the sisal epoxy breaks at 1.83 KN which is much lesser than the breaking value of Sisal PLA which is 2.775KN. Due to exposure of heat the polylactic acid has bounded strongly with the fibre. Thus, increasing adhesiveness and removing de-lamination property of specimen. So the absence of delamination proves that the bonding of polymer has not failed. Fiber breakage and fiber pullout are seen in the fractured specimen.

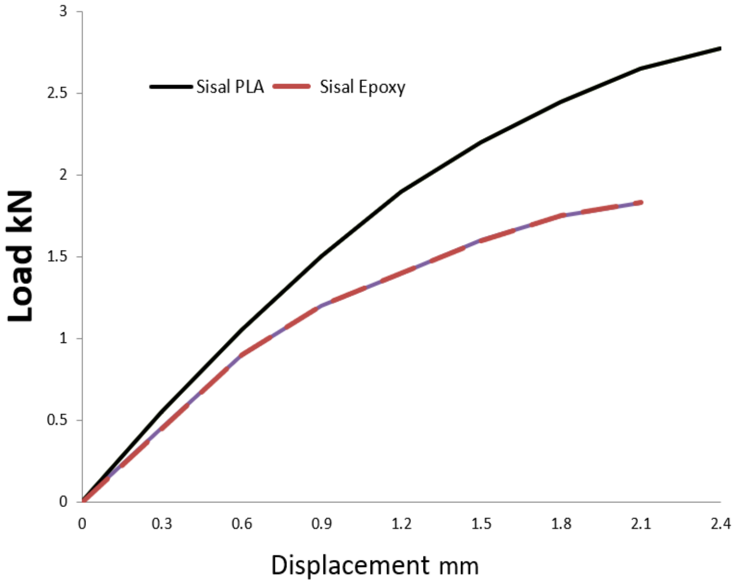

Fig. 3(b) Tensile behaviour of sisal PLA and Sisal Epoxy.

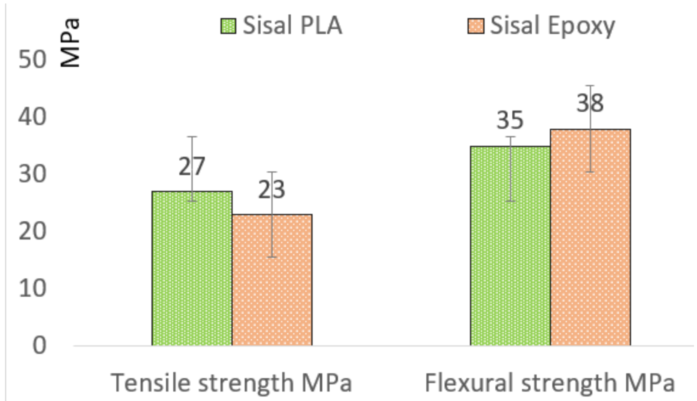

Fig. 3(c) Comparison of Tensile Strength and Flexural Strength of Sisal laminates.

Interfacial strength of the Sisal PLA laminate helps in improved performance than the sisal epoxy composite. Mechanical interlocking occurs to a better extent when the fibre surface is rough and increases the interfacial shear strength. Further PLA at 185degree Celsius for a production time of 30 mins, produced good crosslinking between carbon bonds. These was earlier investigated reported by (Takeshi Semba et al [17]). In their, hereported that the Improved compatibility would arise from the formation of crosslinks initiated by the peroxide in addition to the interactions of the ester groups. Therefore, the crosslinked system is a highly well-suited blend system, which utilize the distinct material property of PLA phases through enhanced interfacial adhesion results in improved mechanical behavior.

Conclusion

This work investigated the influence of polylactic acid matrix on the properties of sisal fiber reinforced PLA composites. Compression molding method was carried with prescribed standard temperature and time for better results. The tensile and flexural properties of PLA Sisal composites reinforced with different exhibited increased trend than epoxy-based sisal composites. Similarly, flexural behavior arise from the conducted test results shows no delamination in breaking of laminate. Interfacial bonding between the PLA matrix and alkaline treated sisal fiber improves the strength of the PLA based composites than the epoxy-based laminates.

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