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Saroj Devi
Department of Fabric & Apparel Science, Institute of Home Economics, University of Delhi, New Delhi, India

Charu Gupta
Department of Fabric & Apparel Science, Institute of Home Economics, University of Delhi, New Delhi, India

MS Parmar
NITRA, Ministry of Textiles, Govt. of India. New Delhi, India

Shankar Lal Jat
ICAR-Indian Institute of Maize Research, IARI, Pusa Campus, New Delhi, India

Correspondence
Saroj Devi
Department of Fabric & Apparel Science, Institute of Home Economics, University of Delhi, New Delhi, India

Enhancing the mechanical toughness of epoxy-resin composites using natural corn stalk fibre as reinforcements

Saroj Devi, Charu Gupta, MS Parmar and Shankar Lal Jat

Abstract
The effect of epoxy resin on reinforced corn stalk fibre blended with cotton and polyester in different proportions were studied, According to tensile test results it was found that P2 sample which is blended with cornstalk/ polyester (50:50) fibre with epoxy resin composite have highest tensile strength i.e. 13.46 MPa followed by cotton blended reinforced corn stalk natural fibre (50:50) with tensile strength 10.72 MPa. Flexural strength of specimen P2 (corn stalk/polyester (50:50)) was higher than that of rest specimens. When Corn stalk fibre blends ratio increased with polyester and cotton fibres the flexural strength decreased. It was observed that the flexural strength values decreased with the increase in weight% of corn stalk fibre. The flexural strength in case of 100% corn stalk reinforced composite specimen has lesser than other five composites specimens. Effect of the epoxy composites on the elongation at the break on different corn stalk blend with cotton and polyester fibre reinforced composites showed that there is a slight difference in the values of different blends. Composite made up with corn stalk/cotton (50:50) have higher elongation (3.82%) than the other composites, followed by cornstalk/cotton (70:30) and cornstalk/polyester (70:30) blended fibre composites. 100% corn stalk fibre has less elongation than the other comparable fibre composites. The decrease in the elongation at break is explained in terms of adherence of the filler to the matrix leading to stiffening of the fibre composite. Cornstalk fibre blended with polyester has higher impact strength than the cotton and 100% cornstalk fibre composites. This may be because of polyester have higher strength than the cotton and cornstalk's single fibre. Although 100% corn stalk fibres comparatively have less impact strength than rest of the composite. The strength of composite mainly depends on the volume fraction of the fibre as well as the thickness of the composite material. Samples with ≈0.6-0.10 mm thickness can be used as light valued textile applications. Sample C1 (corn stalk/cotton 70:30) have the highest maximum load at break followed by P1 sample (corn stalk/polyester 70:30).

Keywords: Mechanical toughness, epoxy-resin composites, natural corn stalk fibre

Introduction

Corn (*Zea mays* L.) stover, which refers a combination of corn stalk (stem) and leaf, is a kind of abundant and renewable agricultural residue. It could also be a sustainable and low-cost source for energy and chemicals in future. There are many traditional practices prevalent in India for management of crop residue like feeding animals, mulching soil, as bio-manure, thatching for rural homes, fuel for domestic and industrial use etc. Likewise, residues from groundnut are burnt in brick and lime kilns. Residues of cotton, oils seed crops, pulses, coconut shells, chilies, rapeseed and mustard stalks, sunflower and jute are utilized as fuel in homes (Pathak *et al*., 2010) [1]. Crop residues burning not only influence the atmospheric air qualityincluding climate but also the human health (Satyendra *et al*., 2013) [2]. It is environmentally unsafe to burn crop residues as it leads to release of harmful gases and smoke which can cause health problems to human beings.

Crop residue management is major issue of agriculture worldwide. This bio-waste can be used as value to the farmers. There has emerged a need to conduct a research to up cycle a product of value to the community to overcome this problem of agricultural crop residue. There is a need to find a way by which crop residue can be efficiently utilized for sustainability of environment, good human health as well as economic viability to farmers.

A lot of attention is being attracted for reinforcement from natural fibres currently. The fibre reinforced composites include fibre as reinforcement and a polymer as a matrix. Their special advantage is their low density, low cost, biodegradability, good mechanical properties etc.

They are advantageous because of lack of health hazards and non-abrasive nature (Sreenivasan, 2012) [3].

Natural fibers give stiffness and strength to the composite and are easily recyclable. They are potential replacement for man-made fibres as natural fibres from conventional and unconventional source are renewable material. Corn is one of the fastest growing crops in India where predominantly hybrid cultivars are grown. These hybrid corn cultivars have potential for enhanced biomass production and thus mostly preferred by the farmers in the country. The collection of the corn stalk is much easier as compared to the rice and wheat and thus has potential for its utilization in making biodegradable fibres. To prepare composites materials using corn stalk fibre and its blends.

Kakroodi, 2013 [4] found that the natural fibers reinforced composites have wide range of advantages such as high stiffness to weight ratio, lightweight, and biodegradability which makes them suitable for various applications in building industries. Van de Weyenberg *et al*., 2003 [5], showed that sisal fiber reinforced composite have good properties of thin-walled elements such as high strength in tension and compression. It give it a wide area of application such as structural building members, pipes strengthening of existing structures, permanent formwork, tanks, facades and long span roofing elements. Bamboo fiber on the other hand can be used for structural concrete elements as reinforcement, in roofing components in order to replace asbestos, while sisal fiber and coir fiber composites are being used (John *et al*., 2008) [6]. In construction applications like sheets (both plain and corrugated) and boards Natural fiber reinforced concretes products are being used as they are light in weight and are suitable for use in roofing, ceiling, and walling for the construction of low-cost houses (Kalia *et al*., 2011) [7].

Materials and Methods

Corn stalk fibre blended with cotton/ polyester composites making

The Composite Material samples were developed by using 100% extracted fibre as well as blending with other fibres like polyester and cotton. The blending percentage of extracted fibre with polyester and cotton is given below.Reinforcing fibre (corn stalk fibre) were carded one time and the matrix (polyester) fibres once separately in NITRA laboratory carding machine. Required ratio (50% polyester and 50% corn stalk fibre) were weighed and later carded together to blend the fibres. The blended fibres were carded again to obtain uniform mixing of reinforcing and matrix fibre. Fibre web was cut into 10 x 12-inch size mat. A single layer of the mat was placed between silicon applied transparent sheets. Resin and hardener were mixed in the required ratio and applied on mats with a brush in a uniform manner. Molding was done at 150°c for 10 minutes.

Table 1: Corn stalk fibre blending with cotton polyester in different percentage

S. No.	Corn Stalk fibres	Polyester fibre	Cotton fibre
1	100%	-	-
2	70%	30%	30%
3	50%	50%	50%

Testing of the developed composite material

Composite material made with blending the fibre with polyester and cotton in different percentages as well as 100 per cent corn stalk fibres were analysed for properties which are tensile strength, elongation at break; flexural strength and impact strength. The different tests performed for the above mentioned properties are as a follows:

Standard Test Method for Tensile Strength (ASTM D-638) Properties of Composites

This test method covers the determination of the tensile properties of unreinforced and reinforced plastics in the form of standard dumbbell-shaped test specimens when tested under defined conditions of pretreatment, temperature, humidity, and testing machine speed.

Testing Machine-a testing machine of the constant- rate-of-crosshead- movement type.

Test Specimens preparation

Five test specimens were prepared by die cutting machine in both the directions from the material. The width of the narrow section of the die was 6.00 ± 0.05 mm (0.250 ± 0.002 in.).

Test Procedure

Before the Testing, test Specimens were conditioned in accordance at 23 ± 2 °C and 50 ± 5% relative humidity for 40 h prior to test in accordance with Procedure. The width and thickness of each specimen were measured using the applicable test methods. Poisson's Ratio was determined at a speed of 5 mm/min. the specimen was placed in the grips of the testing machine; Grips were tightened evenly and firmly. Biaxial extensometer or the axial and transverse extensometer was attached in combination to the specimen. The test was run at 5 mm/min out to a minimum of 0.5% strain before removing the extensometers.

Calculations

$$\text{Tensile strength (N/mm2 or MPa)} = \frac{\text{Maximum load (N)}}{\text{Cross sectional area (Width x thickness)}}$$

Flexural Strength Test (ASTM D-790)

This test method determines the flexural properties of unreinforced and reinforced plastics, including high-modulus composites. This test method is generally applicable to both rigid and semi rigid materials. These test methods utilize a three-point loading system applied to a simply supported beam.

Test Procedure

Method 1A three point loading system was used to test the specimen. Micrometers of least count 0.025 mm [0.001 in.] were used for measuring the width and thickness of the test specimen. Test specimens were conditioned at 23 ± 2 °C [73.4 ± 3.6°F] and 50 6 5% relative humidity for 40 hrs prior to test in accordance with Procedure. The gage length and speed (5mm/min) was set accordance to specimen. Readings were noted down and calculated according to width and length of the specimen.

Flexural Strength

S= 3PL/2*bd*2

Where:

s = stress in the outer fibers at midpoint, MPa [psi],

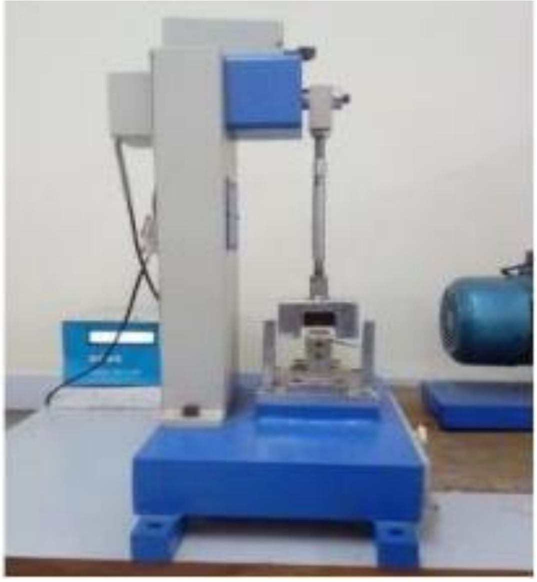
P = load at a given point on the load-deflection curve, N [lbf],

L = support span, mm [in.],

b = width of beam tested, mm [in.], and

d = depth of beam tested, mm [in.].

Unit =N/mm^2 or MPa



Universal testing machine for Tensile and Flexural Strength Impact tester

Fig 1: Instruments used for testing of composites

Izod Impact (Notched) ASTM D256

"Izod Impact Testing (Notched Izod) ASTM D256 is a common test to understand notch sensitivity in composites. Notched Izod Impact is a single point test that measures a materials resistance to impact from a swinging pendulum. Izod impact is defined as the kinetic energy needed to initiate fracture and continues the fracture until the specimen is broken. Izod specimens are notched to prevent deformation of the specimen upon impact. This test can be used as a quick and easy quality control check to determine if a material meets specific impact properties or to compare materials for general toughness.

Test Procedure

The specimen is clamped into the pendulum impact test fixture with the notched side facing the striking edge of the pendulum. The pendulum is released and allowed to strike through the specimen. If breakage does not occur, a heavier hammer is used until failure occurs. Since many materials (especially thermoplastics) exhibit lower impact strength at reduced temperatures, it is sometimes appropriate to test materials at temperatures that simulate the intended end user environment.

Specimen size

The standard specimen for ASTM is 64 x 12.7 x 3.2 mm. The most common specimen thickness is 3.2 mm (0.125 inch), but the preferred thickness is 6.4 mm because it is not as likely to bend or crush. The depth under the notch of the specimen is 10.2 mm.

The standard specimen for ISO is a type 1A multipurpose specimen with the end tabs cut off. The resulting test sample measures 80 x10 x 4 mm. The depth under the notch of the specimen is 8 mm.

Data

ASTM impact energy is expressed in J/m or ft-1b/in. Impact strength is calculated by dividing impact energy in J (or ft-1b) by the thickness of the specimen. The test result is typically the average of 5 specimens.

ISO impact strength is expressed in kJ/m2. Impact strength is calculated by dividing impact energy in J by the area under the notch. The test result is typically the average of 10 specimens. The higher the resulting numbers the tougher the material."

3. Results

Effect of Epoxy resin on Tensile strength of corn Stalk fibre reinforced composites

It is important to know that to get good tensile, flexural and impact strength properties need the optimum fibre loading (Bledzki *et.al.* 2007). So, the effect of epoxy polyester on reinforced corn stalk fibre blended with cotton and polyester in different proportions were studied (Fig.2). According to test results there has been found that P2 sample which is reinforced with cornstalk blended with polyester (50:50) fibre epoxy composite have highest flexural strength followed by C2 (cotton blended reinforced natural fibre (50:50)). From the results it has been found that with percentage increase of blended fibre i.e. cotton or polyester the strength of composite material also increases. This may be because polyester and cotton have high strength than the unconventional corn stalk natural fibre. A supportive study was conducted by Girisha *et.al.*, found that the strength of hybrid composite increases with increasing the volume% of fibres in composite and hybridization has also increased the mechanical properties. 100 percentage natural fibres without blending with other fibers it has less tensile strength.

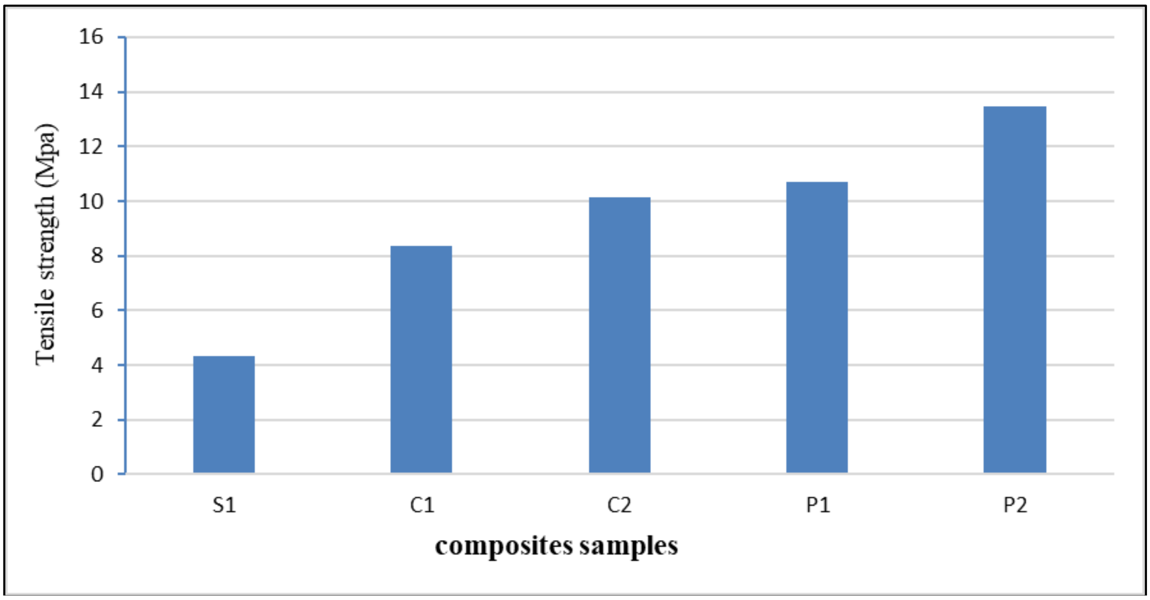


Fig 2: Effect of Epoxy resin on Tensile strength of corn stalk fibre blended with cotton and polyester fibre in (different proportions) reinforced composites S1- 100% cornstalk fibre C1-cornstalk fibre (70) + cotton (30) C2- cornstalk (50) +cotton (50) P1- cornstalk (70) + polyester fibre (30) P2- cornstalk (50) + polyester fibre (50)

Effect of Epoxy resin on Flexural Strength of corn Stalk fibre reinforced composites

The flexural strength is one of the important factors in Natural fibre reinforced composites and Fig.3. shows the variations in the flexural strength of composites with the effect of different blend ration of cotton and polyester with natural corn Stalk fibre. It can be seen from the Figure that flexural strength of specimen P2 is higher than that of rest specimens. When Corn stalk fibre content increases in blend of polyester and cotton fibres the flexural strength decreases. (Sukhdeep Singh *et.al.* analysed as with the addition of natural hemp fibers Flexural strength decreases. The flexural strength in case of 100% corn stalk (S1) reinforced composite specimen has lesser than other five composites specimens. Palanikumar *et al.* (2012) conducted a study on the sisal-jute-GFRP composite materials and results indicated that the addition of sisal and jute in the glass fiber composite materials make the composite hybrid and it improves the properties.

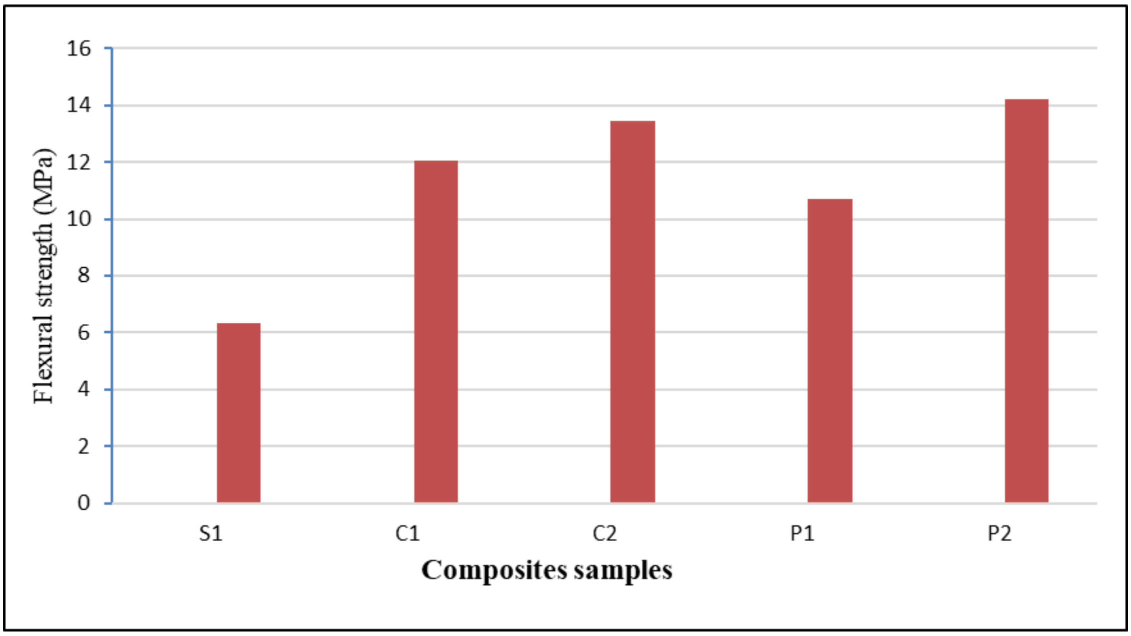


Fig 3: Effect of Epoxy resin on Flexural strength of corn stalk fibre blended with cotton and polyester fibre in (different proportions) reinforced composites S1- 100% cornstalk fibre C1-cornstalk fibre (70) + cotton (30) C2- cornstalk (50) +cotton (50) P1- cornstalk (70) + polyester fibre (30) P2- cornstalk (50) + polyester fibre (50)

Effect of Epoxy resin on Elongation at break of corn Stalk fibre reinforced composites: Effect of the epoxy composites on the elongation at break on different corn stalk blend with cotton and polyester fibre reinforced composites is shown in Fig.4.

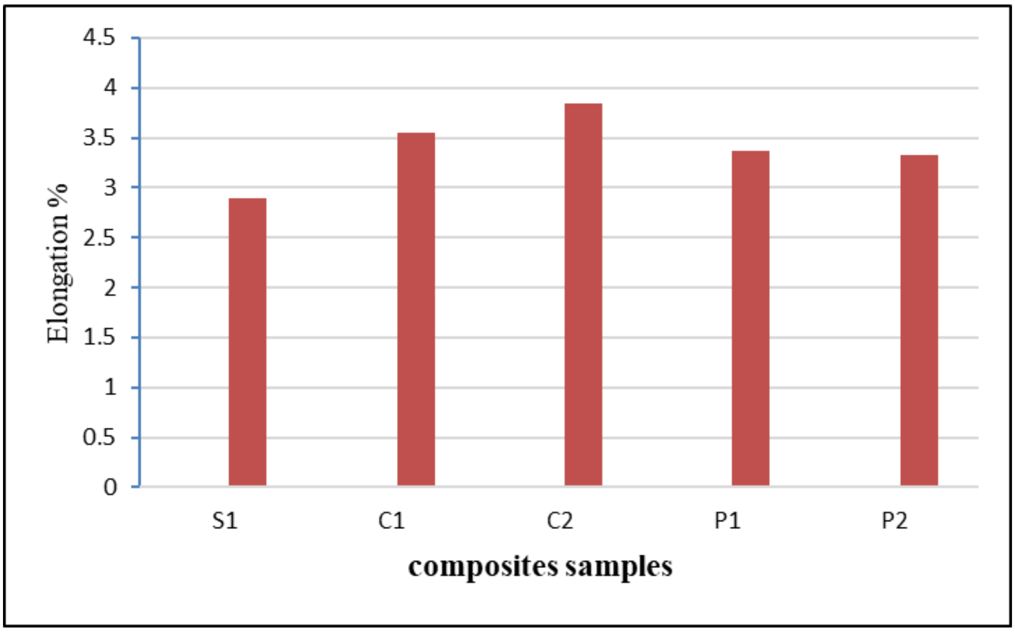


Fig 4: Effect of Epoxy resin on Elongation of corn stalk fibre blended with cotton and polyester fibre in (different proportions) reinforced composites S1- 100% cornstalk fibre C1-cornstalk fibre (70) + cotton (30) C2- cornstalk (50) +cotton (50) P1- cornstalk (70) + polyester fibre (30) P2- cornstalk (50) + polyester fibre (50)

There is slightly difference in the values of different blends. Composite P1 which is made up with corn stalk/cotton (50:50) have higher elongation% than the other composites, followed by C1 (cornstalk/cotton (70:30) and C2 composites sample. 100% corn stalk have less elongation than the other comparable fibre composites. Decrease in the elongation at break is explained in terms of adherence of the filler to the matrix leading to stiffening of fibre composite. (Ekebafe *et al.* 2010) [10].

Effect of Epoxy resin on Impact strength of corn Stalk fibre reinforced composites

As shown in the Fig.5, it is clear that cornstalk fibre blended with polyester have higher impact strength than the cotton and 100% cornstalk fibre composites. This may be because of polyester have higher strength than the cotton and cornstalk's single fibre. It is clear from the Fig.5 that 100% corn stalk fibres comparatively have less impact strength than rest of the composite. Strength of composite mainly depends on volume fraction of the fibre as well as thickness of the composite material. Samples have 0.6-0.10mm thickness so it can be use as light valued textile applications. Easwara Prasad *et.al.*, carried out study on untreated and 5% NaOH treated sisal fiber reinforced polyester matrix composites as per their study found that impact strength of both untreated and 5% NaOH treated sisal fiber reinforced polyester matrix composites increases with increase in their fiber volume fraction and thickness. this kind of plant fiber reinforced composites can used as Mudguards, name and number plates, panels and insulators in electrical industries, Engine guard in automobiles; and Light doom, switch gear.

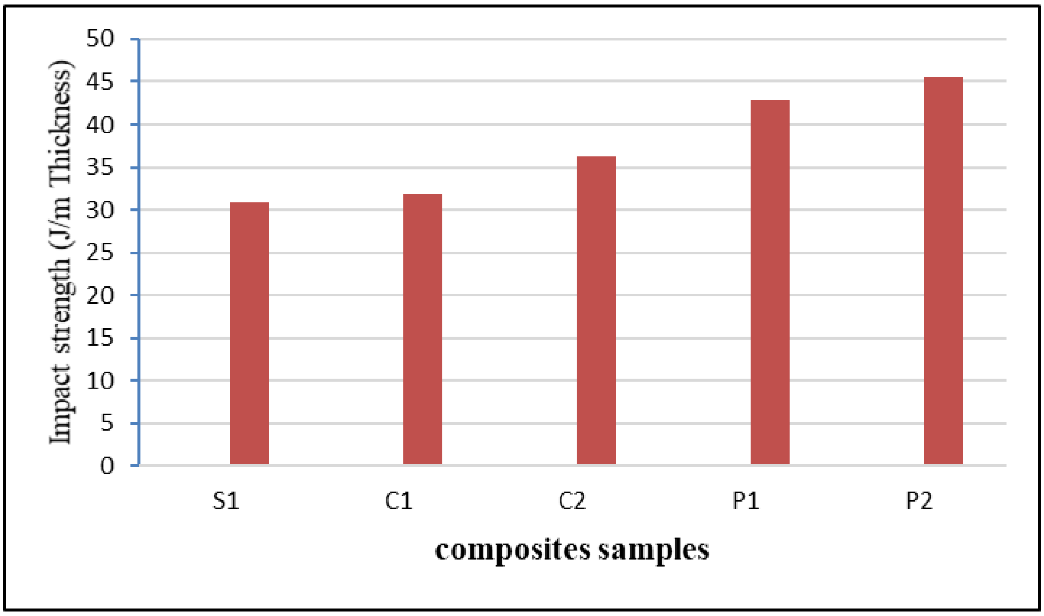


Fig 5: Effect of Epoxy resin on Impact strength of corn stalk fibre blended with cotton and polyester fibre in (different proportions) reinforced composites S1- 100% cornstalk fibre C1-cornstalk fibre (70) + cotton (30) C2- cornstalk (50) +cotton (50) P1- cornstalk (70) + polyester fibre (30) P2- cornstalk (50) + polyester fibre (50)

Sample marking

Dye cutter

Sample cutting

Prepared sample

Sample thickness measurement

Sample width measurement

Conclusion

According to tensile test results it was found that sample which is blended with cornstalk/ polyester (50:50) fibre with epoxy resin composite have highest tensile strength followed by cotton blended reinforced corn stalk natural fibre (50:50) with tensile strength. The strength of hybrid composite increases with increasing the volume of fibres in composite and hybridization has also increased the mechanical properties. Samples with $\approx$0.6-0.10 mm thickness can be used as light valued textile applications. There is a positive correlation between the load application and strength of the composite material as higher the load application higher will be the strength of the composite material. The results showed that the friction coefficients declined with the rise of applied load and the wear resistance maximized under normal orientation, indicating these reinforced polyester composites may have potential application as friction materials in environmentally friendly.

References

1. Pathak H, Bhatia A, Jain N, Aggarwal PK. Greenhouse gas emission and mitigation in Indian agriculture – A review, In ING Bulletins on Regional Assessment of Reactive Nitrogen, Bulletin No. 19 (Ed. Bijay-Singh), SCON-ING, New Delhi, 2010.
2. Satyendra T, Singh RN, Shaishav S. Emissions from crop/biomass residue burning risk to atmospheric quality. International Research Journal of Earth Sciences, 2013; 1:24-30.
3. Sreenivasan VS, Ravindran D, Manikandan V, Narayanasamy R. Influence of fibre treatment on mechanical properties of short sansevieria cylindrica/polyester composites; Materials and design. 2012; 37:111-121.
4. Kakroodi AR, Kazemi Y, Rodrigue D. Mechanical, rheological, morphological and water absorption properties of maleated polyethylene/hemp composites:

effect of ground tire rubber addition. Composites Part B: Engineering. 2013; 51:337-344.

5. Van de Weyenberg I, Ivens J, De Coster A, Kino B, Baetens E, Verpoest I. Influence of processing and chemical treatment of flax fibres on their composites. Composites Science and Technology. 2003; 63(9):1241-1246.
6. Bijay S, Shan YH, Johnson BSE, Yadvinder S, Buresh RJ. Crop residue management for lowland rice-based cropping systems in Asia. Adv Agron. 2008; 98:118-199.
7. Kalia S, Kaith BS, Kaur I. (Eds.). Cellulose fibers: bio- and nano-polymer composites: green chemistry and technology. Springer Science & Business Media, 2011.
8. Bledzki AK, Zhang W, Chate A. Natural fiber reinforced polyurethane microfoams. Compos Sci Technol. 2001; 61:2405-2411.
9. Ramesh M, Palanikumar K, Reddy KH. Mechanical property evaluation of sisal–jute–glass fiber reinforced polyester composites. Composites Part B: Engineering. 2013; 48:1-9.
10. Ekebafe LO, Imanah JE, Okieimen FE. Physico-mechanical properties of rubber seed shell carbon-filled natural rubber compounds. Chemical Industry and Chemical Engineering Quarterly. 2010; 16(2):149-156.