Wear performance and Mechanical properties of Unidirectional Sisal/Carbon/Flax Hybrid Reinforced Epoxy Composites

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Abstract. This current work rate the mechanical properties, wear resistance and frictional force of unidirectional hybrid fiber orientation composites. The orientation of fibers done by manually according to the size of fabricated plate and thickness of plate. In these research sisal/carbon and sisal/carbon/flax hybrid fiber reinforced composites are selected. Selected different combinations of hybrid fiber reinforced composites are shaped by using compression molding techniques. After that property of mechanical, wear resistance and frictional force were studied by using experimental study to discover their tensile, compressive, impact properties, wear resistance and frictional force due to the effect of unidirectional hybrid fiber combinations. The results of this study indicates that unidirectional sisal/carbon/flax hybrid combinations shows the better tensile strength, compression strength, impact strength, wear resistance and frictional force.

Keywords: Hybrid fiber, epoxy resin, compression molding, Unidirectional
1. Introduction
Nowadays fiber reinforced composite materials are used in following structures like space ship and air ship. The use of composites has been easy way to introduce new materials, and to enhance in fabrication process and growth of new logical and experimental methods. Flax fiber is the strongest natural fibers and its household history is long and rich and it has complex assembly of cellulose, hemicelluloses and lignin. There are many factors determining fiber properties and any alteration of those factors has an impact on fiber quality and quantity. Properties such as tensile strength, absorptive and biological activity. Sisal fiber is strong, durable material and it’s discovering important source of composites. Mechanical properties of fiber reinforced polymer composites are influenced by factors such as matrix, fiber-matrix interface, volume and weight fraction, fiber aspect ratio, fiber orientation etc. Carbon fibers are manufacture from polyacrylonitrile process. A 10 percent of carbon fibers manufactured from rayon and petroleum pitch process. By comparing the elements, steel has 29 million psi of tensile module. Comparatively carbon fibers are ten time stronger than steel and aluminum. Natural fibers are comparatively low cost, low density, high mechanical properties and biodegradable. Due to poor resistance to moisture the inherent use of reinforcement is gradually reduced. The properties of natural fiber have more mechanical properties. The plant fibers are in need to undergo physical / chemical treatment to generate the reactive hydroxyl groups and its modified structure. The limitations of synthetic fibers are hard to recycle and it has very good mechanical properties. The orientation of fiber angle 90° shows the better results of mechanical properties [1-13]. The properties of mechanical and thermal properties of short hemp fiber/glass fiber reinforced poly propylene hybrid composites were studied [14]. The combination of hemp and glass fiber has high thermal properties and water absorption resistance. The mechanical and physical properties of palm/glass fibers hybrid reinforced polyester composites were studied [15]. The tensile properties of ridge gourd/glass fiber reinforced phenolic composites were studied [16]. The glass fiber has high tensile properties when it’s added as hybrid fibers. The fiber glass reinforced hybrid composites produce better mechanical performance and it produced better flexural properties of silk fiber reinforced composites [17]. The tensile, flexural, impact and compressive strength of sisal/glass fiber hybrid composites were studied [18-20]. This result which increases the properties of glass fiber. The carbon and glass fabric layers show higher tensile stress and strain [21-23].

2. Materials and Methods

2.1. Sisal/Carbon/flax fiber
Sisal is a natural fiber which extracted from the Agave sisalana and lengthy fibres used for making twine and ropes [24]. Sisal fibers are biodegradable, highly durable, low maintenance, less wear and it have maximum renewable energy. It produced by decortications method by compressing the sisal leaves in rotating wheel with blunt knives. Flax fibers extracted from bast seeds and it does possess good tensile strength, absorptivity and biological activity [25]. Carbon fibers are made by organic polymers and form by 90% of carbon atoms and 10% from rayon process.

2.2. Resin Matrix/Hardener
Epoxy resin that used for cures when it combined with a hardener. The grade LY556 of epoxy was used in this to provide high stiffness. Hardener of the grade HY-951 used with epoxy. Fiber reinforced matrix prepared by using the mixture of epoxy resin and hardener 10:1 ratio [26-29].

2.3. Chemical treatment process
To produce high quality fibers, the alkali treatment is used. For this we used sodium hydroxide (NaOH) for etiolute and removing the impurities on the surface of natural fibers. Sodium hydroxide pellets and distilled water are used to prepare the 5% NaOH solution. While increasing the mentioned NaOH percentage it leads affect the fiber properties. Sisal and flax fibers immersed in the solution for 2hour separately. Then it is cleansed with flow water. It was placed in oven for 3hours at 80°C [30-31].
2.4. Composite fabrication process

Mold is made of EN90 steel and its measurements of 250 x 250 x 5 mm. The mould is refined from the mould plate. The weight ratio of epoxy resin, hardener and fiber is 10:1 and 250 grams respectively. The sisal, carbon, flax fibers are arranged layer by layer for orientation on mold surface manually after that epoxy resin applied manually on it and to roll the fiber by using rollers. Applied hydraulic press for 30 minutes at the temperature and 35 kg/cm² of pressure. The 45 minutes of curing time is applied before get it from the mould. Then it is post cured for 3 hours at room temperature. This same procedure was followed for each fabricated plate [32-34].

3. Experimental tests

3.1. Tensile strength test

Tensile test is used to calculate tensile strength of the specimen. It tested by using computerised universal testing machine with standard of ASTM D3039. The dimensions of specimen taken are 250 x 25 mm and crosshead speed of 2 mm/min. The test is carried out until the specimen fractures out with a specific tensile load applied on it.

![Figure 1. Tensile test specimen and experimental layout](image1)

![Figure 2. Tensile testing layout](image2)

![Figure 3. Tensile testing fractured specimen](image3)

3.2. Compressive strength test
Compression test used to calculate compressive strength of the fiber reinforced specimen. It tested by using computerised universal testing machine with standard of ASTM D3410. The dimensions of specimen taken are 140 x 12mm and crosshead speed of 1 mm/min. The test is carried out until the specimen fractures out with a specific compressive load applied on it.

![Figure 4. Compressive strength specimen](image1)
![Figure 5. Compressive strength specimen and experimental layout](image2)
![Figure 6. Compressive strength fractured specimen](image3)

### 3.3. Charpy Impact test

Charpy impact test were carried out on impact test machine as shown in Figure 4 and the ASTM D256 of standard used in this. Generally sisal fibers possess good impact absorbing properties.

![Figure 7. Impact test specimen](image4)
![Figure 8. Impact test setup and fractured specimen](image5)
3.4. Wear test
In this research we are using pin-on-disc wear tester to calculate the wear and frictional force under sliding conditions. Commonly available material samples are bearing steel, tungsten carbide or alumina (Al₂O₃).
Disk range: 100 to 200N
Wear disc diameter: up to 165mm
Wear range diameter: up to 100mm
Disc speed used: up to 2000 rpm
Load applied: up to 200 N
Frictional force applied: up to 200 rpm
Disc plate materials: Stainless Steel
Thickness: up to 8mm

Figure 9. Wear test specimen
Figure 10. Wear test setup

4. Results and discussion
The variations of the mean tensile strength of hybrid combinations as shown in below fig. the graphs have been plotted taking tensile strength of fibers and elongation at break. The combinations of fibers used are sisal, carbon and flax. In these combinations, there is a considerable increase of tensile strength 49.23 MPa and percentage of elongation at break is 7.2% in sisal/flax/combinations. The increase the length of sisal fibers content possesses the unexpected tensile strength compared to the others. The test results are shown and discussed in this section. To test the tensile strength 3 samples of specimens are taken. Among these the (uni directional of sisal/carbon/flax) shows maximum tensile strength. The superior qualities of carbon fibers when blended with natural fibers its shows max tensile behaviour due to limited brittleness characteristics.
Figure 7 shows the graphical representation of tensile strength of cured sisal fiber reinforced composites based on their different compositions. Within these the compositions of (uni directional of sisal/carbon/flax combinations) shows higher tensile strength of 49.23 MPa. Design parameters of compressive strength and modulus are equally compared. Due to lower compressive strength when we involved these composites continuously to the flexure means it made to high bending and failure. The test results are shown and discussed in this section. We take 3 experiments for find out the compressive force. Uni directional of sisal/carbon/flax shows the maximum compressive strength. The axial compressive strength of carbon fibers when blended with naturally fibers it increases due to the distribution of load evenly on their composites, so it shows maximum compressive strength compared to others.

Figure 8 shows the compressive force of cured sisal fiber reinforced composites on their multiple compositions. Within the combination of (uni directional of sisal/carbon/flax combinations) shows maximum compressive strength of 190.8 MPa.

Figure 11. Tensile test results

Figure 12. Compressive test results
The composite laminate with sisal/carbon/flax shows more impact resistance while less compared to sisal/carbon laminate. The hybridization effect is examined that sisal/carbon/flax shows highest value of 13.18 J, while compared to other laminate is 10.16 J. It is observed that there is no much difference between the other laminates due to increase length of sisal and flax fibers it shows higher impact resistance. The performance mostly affected due to void fractions and mechanics of sliding fraction of laminates. The test results are shown and discussed in this section. To test the impact strength 3 samples of specimens are taken. Uni directional of sisal/carbon/flax have higher impact strength. The more ductile fracture hybridization of carbon fibers with other fibers it raised with drop of fracture energy. So it shows the maximum impact strength compared to others.

Figure 9 shows the impact energy of sisal fiber reinforced composite material on their multiple combinations. Among these the combination (uni directional of sisal/carbon/flax combinations) shows maximum impact strength of 13.18 Joules.

![Impact Energy Chart](image)

**Figure 13. Impact test results**

The important required factors for wear resistance is surface finish, lubrication, load, corrosion, temperature and the material surface and the intrinsic properties like strength, compression, hardness, impact etc. The wear test results are shown and discussed in this section. In this we take 3 trials of specimens for testing wear and frictional force. Among these the (uni directional of sisal/carbon/flax) shows minimum wear and frictional force. Carbon fibers have the ability to absorb energy in the form of heat. Wear is increased in 125 microns on 20% fiber. After increasing the quantity of sisal fiber results to gradually reduces the wear performances. Therefore the combination of sisal/carbon/flax shows better wear results compare to others.

Figure 10 shows the wear and frictional force of cured sisal fiber reinforced composites on their multiple combinations. Uni directional of sisal/carbon/flax combinations shows lower wear of 22 microns and frictional force of 3.13 N compared to other one.
5. Conclusions
In the present work evaluates three trails based on unidirectional hybrid combinations of sisal/carbon and sisal/carbon/flax were achieved as per American Society for Testing and Materials standards used to test the strengths. The following result shows the final investigation of hybrid fibers reinforced epoxy composites. The mechanical properties of tensile strength and compressive strength shows the higher value of 49.23 MPa and 190.8 MPa in the sisal/carbon/flax of uni directional sample gives higher value compared to other samples. Generally, sisal and carbon fibers have good impact absorption and its shows the maximum impact value of 13.18 joules in the sisal/carbon/flax (uni directional) compared to others. The wear resistance and frictional force of treated sisal/carbon/flax fiber reinforced composites show low wear of 22 microns and frictional force of 3.13N.

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