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Mechanical Behaviour of Hybrid Composites Prepared using Sisal-Pineapple-Kenaf Fibre

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Abstract: *Variety of application use fibre reinforced composites because of their intrinsic properties in mechanical strength, renewability and low production cost compared to conventional materials. Natural fibres are environmentally friendly their use will not break the budget when used as an alternative to the regular materials. Reinforcement used in polymer is either man-made or natural. Man-made synthetic, metallic, semi-synthetic, polymer fibres have superior specific strength but their high cost of production limits its application and feasibility to make composites. Recently there is a rise in use of natural fibres from various natural resources which are available abundantly. Composites based on natural fibres have their advantages of cost in making the fibres from different vegetables, wood, animals and minerals. In this work a thorough and systematic inquiry regarding better utilization of sisal fibre for making value-added products has been carried out. Various hybrid composite test specimens as per ASTM were prepared with natural fillers such as sisal-pineapple-Kenaf fibres by using hand layup method. The physical and mechanical characteristics of prepared hybrid composite with sisal fibre, pineapple fibre and kenaf fibre are the main objective the research. The various mechanical properties of the hybrid composites like tensile strength, rupture strength, impact strength, shear strength, hardness, and wear strength are studied by standard experiment methods. The experimental results were discussed. The experiments exposed that the use of sisal fibre when compared with similar fibres in a composite increase the most of the physical properties like tensile, rupture, wear properties of the material where as impact strength of the material is lowered. Surface morphology of the sisal fibre after tensile loading is studied microscopically.*

Keywords: Hybrid Composites, Experimental, sisal fibre, pineapple fibre, Mechanical behaviour.

I. INTRODUCTION

Composites materials gained their exclusive attention due to its light weight, high specific modulus and strength in critical applications. The development of composite materials and their use in making complex intricate design and production technologies is the most important development in material science. Composite materials have a variety of benefits over regular materials such as light weight, durability, tensile strength, impact strength, rupture strengths, stiffness and fatigue characteristics. Due to these numerous superior properties, they are extensively used in the machine parts like drive shafts, tanks, pressure vessels, automotive, combustion engines, thermal management, railway coaches and aircraft structures and power plant structures.

Composites are made up of chemically distinct multiphase materials separated by distinct interface that exhibit better combination of properties compared to the constituent materials. Composite material is a combination of robust load-carrying material (known as reinforcement) imbedded with weaker materials (known as matrix) differing in composition on a macro scale. The arrangement of the phases relative to each other can be controlled during processing so that a desired property of composite can be achieved. Composites can be used where combination of property. The degrees of control over material property is typified by hybrid composites is transforming engineering design.

Many investigators have done their research work on hybrid composites made up of natural fibres and found out the mechanical properties and compared those with conventional and other composite materials.

Gupta, et.al studied the mechanical behavior of hybrid composites which are made up of polyester with natural fillers and found out with the tests that hybrid composites have better strength as compared to single glass fibre composites[1].

Ramesh, et.al investigated and compared the properties of sisal-glass fibre reinforced polymer to be having more superior tensile properties than jute-glass fibre reinforced polymer while jute- glass fibre fared better in flexural test [2].

Idicula, et.al investigated both the dynamic and static mechanical behaviour of short banana-sisal reinforced polyester composites made up of various ratios of banana and sisal in volume. The tensile strength and flexural strength were maximum and impact strength to be minimum for the 3:1 ratio of banana and sisal fibres [3].

Girirsha, et.al studied hybrid composites composed of untreated and treated sisal-banana, sisal-bamboo and banana-bamboo fibres. It has been found that composites using hybrid fibres shows increase in the tensile strength [4].

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Rao, et.al fabricated and examined the mechanical properties of mono-composites made up of vakka, sisal, bamboo and banana fibres. Composite made up of sisal fibre had more tensile strength than other composites [7].

Yousif, et.al worked on the study of flexural properties of sodium hydroxide treated kenaf fibre reinforced epoxy composites. Treated kenaf fibres show a 36% increase in flexural strength [8].

II. MATERIALS AND METHODS

The following materials were used to produce hybrid composite in this project:

A. Sisal fibre
B. Pineapple fibre
C. kenaf fibre
D. Unsaturated isophthalic polyester resin
E. Catalyst
F. Accelerator

A. SISAL FIBRE

Sisal fibres are extracted from leaf of a succulent plant called Agave Silsalana. Every leaf contains of several long, straight fibres which may be removed in a process known as decortication. During decortication, the leaves are beaten to get rid of the pulp and plant material, leaving the tough fibres behind. Sisal fibres are obtained from the outer skin of leaves, discarding the inner pulp. The characteristics of the fibres rely upon the properties of the fibrillar structure and also the lamellae matrix. The fibre is composed of many elongated fusiform fibre cells that taper towards the end. The fibre cells are coupled together by means of middle lamellae, which consists of hemicelluloses, lignin and pectin.

Fig. 1 Sisal Fibre

B. PINEAPPLE FIBRE

Pineapple fibre is extracted from the leaves of pineapple plant. The leaf should be cut first from the plant. Then the fiber is forcefully pulled or split away from the leaf. Most leaf fibers are slender and have stiffness to some extent. Each strand of the pineapple fibre is hand scraped and is knotted one by one to create a continuous filament to be hand-woven and then made into a piña fabric.

These fibres are multi-cellular and lignocellulosic. Fibre-reinforced composite structures are taking the central stage in virtually every sphere of material science, lingo cellulosic natural fibres like pineapple fibres come as viable and exuberant substitutes for the expensive and non-renewable artificial synthetic fibres.

The main advantage of using pineapple fibre is it can be added with other allied fibers to improve their quality and application. Moreover pineapple fibres are waste products from pineapple cultivation, the cost is minimal.

Fig. 2 Pineapple fibre

C. KENAF FIBRE

Kenaf is known as Hibiscus cannabinus has a cellulosic source with both economic and ecological advantages. Kenaf has good mechanical properties and takes only 150 days to grow quickly to harvest. The kenaf fiber has lower density than those of man-made synthetic fibres and has high tensile strength to weight ratio.

Fig. 3 Kenaf fibre

D. UNSATURATED ISOPHTHALIC POLYESTER RESIN

Unsaturated polyester resins are perfect for dimensionally stable mold construction which wets out quickly and can be applied with hand due to its very less corrosive property. Catalyst like Methyl Ethyl Ketone-Peroxide can be mixed with this resin at a rate of 1.25%. It is important to catalyze the resin correctly as under-catalyzation will result in a resin that would not harden. Over catalyzation can result in a significantly weakened resin.

Isophthalic polyester resins are undoubtedly of a higher-grade and offer substantially higher strength, better flexibility and chemical resistance.

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E. METHYL ETHYL KETONE PEROXIDE (MEKP)

MEKP is highly explosive organic peroxide; MEKP is thermally unstable which may undergo self-accelerating decomposition. Dilute solution of 60% MEKP available as Lupersol DDM is used as an initiator or additive for room temperature cure of unsaturated polyester resins. Exothermic chemical reaction happens between MEKP and polyester resin which releases heat energy and makes a chemical bond to harden or cure the resin.

F. COBALT NAPHTHENATE

Cobalt naphthenate is used as a promoter added to resin formulations to produce the curing reaction and control curing times within desired parameters. It can cure resin rapidly at room temperature.

G. PROPERTIES OF NATURAL FIBRES USED

Table- I: Mechanical Properties of Natural fibres used

Fibres / Properties	Sisal fibre	Pineapple fibre	Kenaf fibre
Density (kg/m^3)	1500	1520 –1560	1450
Young's Modulus (MPa)	9000 – 22000	34500 – 84500	53000
Diameter (μm)	15 – 30	25 – 34	14 – 33
Tensile Strength(MPa)	510 – 635	413 – 1627	930

H. CHEMICAL COMPOSITION OF NATURAL FIBRES USED

Table- II: Chemical Composition of Natural fibres

	Sisal fibre	Pineapple fibre	Kenaf fibre
Cellulose (%)	47 – 78	73.4	31 – 57
Hemi – cellulose (%)	10 – 24	7.1	21.5 – 23
Lignin (%)	7 – 11	10.5	15 – 19
Ash content (%)	0.5 – 1	2	2 – 5
Pectin (%)	10	-	-
Silica (%)	0.5	-	2.2

I. METHOD OF PREPARATION

The fabrication of hybrid composite laminate is done by hand layup method. Sisal fiber, pineapple fiber, kenaf fibre are used as reinforcement and unsaturated isophthalic polyester resin is taken as matrix material with natural fillers (sisal, pineapple, kenaf). This mix consists of the isophthalic polyester resin, cobalt naphthenate as promoter, Methyl Ethyl Ketone Peroxide as catalysts. The addition of promoter to resin will not cause any reaction to make the resin cross linking until catalyst is added to the mix. Isophthalic polyester epoxy resin, cobalt naphthenate and MEKP are mixed in equal ratio of by weight. The natural fibers of sisal, pineapple and kenaf are also taken in equal ratio by weight. The mold for the test specimen is cleaned and a mixture of petroleum jelly and white spirit is applied on to the mold surface with a sponge so that the mixture can act as a release agent. The fibres are mixed well together and are placed on the mold. The mix of resin, promoter and catalyst is now painted on the fibers evenly. Any air bubbles trapped in must be removed by using a firm roller. The process is repeated until a thickness of 3mm for the hybrid composite material. A uniformly distributed load of 25kgis kept over the composites and left untouched for 24 hours. After the curing period the test specimens of standard dimensions are cut for mechanical test as per American Society for Testing and Materials international standards. The following composition is used to fabricate the hybrid composite.

Table- III: Composition of all materials used to make the hybrid composite

S. No.	Material	Weight Composition
1	Sisal fibre	10%
2	Pineapple fibre	10%
3	Kenaf fibre	10%
4	Unsaturated isophthalic polyester resin + Cobalt naphthenate + MEKP	70%

III. TESTS PERFORMED

The following test are done for the prepared composite to determine its mechanical properties,

A. Tensile Test
B. Rupture Test
C. Shear Test
D. Impact Test
E. Hardness Test
F. Wear Test

IV. RESULTS AND DISCUSSIONS

A. TENSILE STRENGTH OF COMPOSITES

A test sample in shape of dog-bone rectangular cross section is used in universal testing machine as per the American Society of Testing and Materials. Tensile strength of the hybrid composites are found out using 500 kN universal testing machine. Here tension loads are applied axially to the test specimen gradually until the specimen yields. The value of tensile strength obtained is

TENSILE TEST (MPa)	22.05

B. RUPRURE TEST OF COMPOSITES

The modulus of rupture is determined by one point loading method and it is found out by using the following formula.

Modulus of Rupture = $\frac{P \times L}{bd^2}$

Where P - Load

L –Effective length of the test specimen

b–Breadth of the test specimen

t–thickness of the test specimen

The value of Modulus of Rupture obtained is

MODULUS OF RUPTURE (kN)	0.22

C. IMPACT STRENGTH OF COMPOSITES

The loss of energy during impact is the energy absorbed by the specimen during impact. The values are furnished in the following table.

IMPACT STRENGTH(J)	2

D. SHEAR STRENGTH OF COMPOSITES

The shear strength of composites gives the bonding between the different fibres from which the hybrid composite is made of. The value of shear strength obtained is

SHEAR	1.92

E. HARDNESS (BRINELL HARDNESS) OF COMPOSITES

Brinell Hardness of the fibres is found out by using the following formula.

$$BHB = F/A$$

Where F - Test Force

A- Surface area of indentation

The value of hardness obtained is 52 HB

F. WEAR STRENGTH

Wear strength of the composites measures the ability of the composite to scuffs and scrapes that occur during its use. The composite panels are subjected to a wire brush which scrubs back and forth for 50 times. The depth of abrasion is measured. The value of wear strength is

WEAR (% loss)	1.71%

G. MICROSCOPIC STRUCTURAL VIEW OF SISAL FIBRE

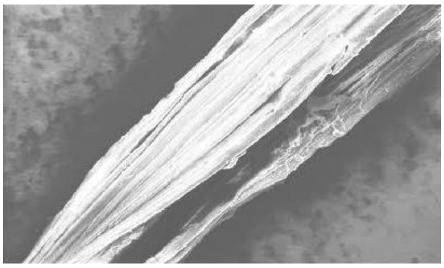

Fig.4 Sisal fibre – Microscopic view

Fig.4 shows microscopic view of sisal fibre using scanning electron microsope before it is to used in preparing hybrid composite. Fig.5 shows microscopic view of the sisal fibre after the prepared hybrid composite is subjected to tensile test. On close examination of the surface of the fibre, it is found that fracture surface is unevenand rupturedue to large deformation.

Fig.5 Microscopic view of sisal fibre failed due to tension

H. TABULATION OF EXPERIMENTAL RESULTS

Table- IV: Mechanical Properties of prepared hybrid composite

Mechanical Properties	Values
Tensile strength	22.05MPa
Rupture Strength	0.22kN
Impact Strength	2J
Shear Strength	1.92
Hardness	52HB
Wear Strength	1.71% loss

V. CONCLUSION

Various mechanical properties such as tensile strength rupture strength, impact strength, shear strength, hardness and wear strength of hybrid composite prepared with sisal, pineapple and kenaf fibre was experimentally found by various tests. The microscopic view of failed sisal fibre is captures using scanning Electron Microscope. The experimental test for tensile strength reveals that the combination of sisal-pineapple-kenaf fibres improves the tensile strength of the composite material. The rupture strength test also shows that there is a considerable improvement in the property of material. However the use of sisal has diminished the impact strength but can be compensated by the high impact strength of pineapple fibres. An increase in shear strength and hardness are observed from the results of their respective experiments. Wear loss is greatly reduced due to the rough nature of sisal fibres which is used in making the hybrid composites.

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