SUSTAINABILITY OF SISAL/JUTE HYBRID POLYMER COMPOSITE FOR PRODUCTION OF AUTOMOBILE BODY PARTS.

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ABSTRACT
This research investigated the sustainability of sisal/jute hybrid polymer composite for automobile application. Sisal/Jute hybrid polymers composite are of low cost, light weight, as well as possess satisfactory mechanical properties, easy making, availability and user friendly. Sisal/Jute fibres have been proven alternative to synthetic fiber and also advancing with a substantial potential to displace conventional mild steel in the automobile industry. In this research work, hybrid composites have been developed using hand layup technique based on percentage combination of Sisal and Jute fibers in the form of laminates prepared from Unsaturate polyester resin. The prepared laminate samples were subjected to tensile, flexural, impact and compressive, tests to evaluate their strength which was based on orientations and fibre percentage combination. Sisal/jute hybrid polymer composite demonstrated fairly good mechanical properties that could absolutely substitute conventional mild steel used in automobile body.

Keyword: Sisal, Jute, Hybrid, sustainability, Automobile

1.0 Introduction
The worldwide automotive production rate is increasing and estimated to reach 76 million cars annually by 2020.Nigeria has capacity to produce 380,000 cars per year [7] .It is estimated that a 25% reduction in car weight would be equivalent to saving 250 million barrels of crude oil. Composite has emerged as the solution of attaining high strength to weight ratio. Advanced technology in the field of petrochemical-based polymers has brought many benefits to mankind. It is becoming more evident that the ecosystem is considerably disturbed and damaged as a result of the non-degradable plastic materials for disposable items [18]. There is a growing urgency to convert agricultural by products and surpluses of the crops into new, profitable products. The need to develop technology allied with environmental preservation has created a renewed interest in the scientific world to study the viability of using natural fibres as reinforcement agents in biopolymer matrices.

The incorporation of several different types of fibres into a single matrix has led to the development of hybrid bio-composites. The behavior of hybrid composites is a weighed sum of the individual components in which there is a more favorable balance between the inherent advantages and disadvantages. Also, using a hybrid composite that contains two or more types of fibre, the advantages of one type of fibre could complement with what are lacking in the other. As a consequence, a balance in cost and performance can be achieved through proper material design. The properties of a hybrid composite mainly depend upon the fibre content, length of individual fibres, orientation, extent of intermingling of fibres, fibre to matrix bonding and arrangement of both the fibres. The strength of the hybrid composite is also dependent on the failure strain of individual fibres. Maximum hybrid results are obtained when the fibres are highly strain compatible, [16].

Sisal with the botanical name *Agave sisalana*, is a species of *Agave* native of southern Mexico but widely cultivated and naturalized in many other countries. It yields a stiff fibre used in making various products. The term sisal may refer either to the plant's common name or the fibre, depending on the context. It is sometimes referred to as "sisal hemp", because for centuries hemp was a major source of fibre, and other fibre sources were named after it. The sisal fibre is traditionally used for rope and twine, and has many other uses, including paper, cloth, wall coverings, carpets, and dartboards. Sisal plants, *Agave sisalana*, consist of a rosette of sword-shaped leaves about 1.5–2 metres (4.9–6.6 ft) tall. Young leaves may have a few minute teeth along their margins, but lose them as they mature. The sisal plant has a 7–10 year life-span and typically produces 200–250 commercially usable leaves. Each leaf contains an average of around 1000 fibres. The fibres account for only about 4% of the plant by weight. Sisal is considered a plant of the tropics and subtropics, since production benefits from temperatures above 25 degrees Celsius and sunshine. The increasing use of sisal in a variety of industries demands a thorough understanding of the properties of the fiber. Traditionally Sisal fibers can be classified into a variety of grades which include; the lower, medium and higher fibers, which are used for paper, rope and carpet making, respectively. Sisal has however found new applications in a variety of industries which include; the medical field [15], the automotive and Building industry [12]. Apart from the sisal plant which constitutes 4% of the sisal leaf, the sisal industry generates a lot of biomass commonly referred to as sisal waste. According to [5] the sisal plant leaf is a composite structure that is made up of three types of fibers: structural, arch and xylem fibers. Every sisal fiber contains numerous elongated individual fibers (fiber-cells). Each individual fiber-cell is made up of four main parts, namely the primary wall, the thick secondary wall, the tertiary wall and the lumen. Sisal leaves can be harvested from the age of 2 years. Harvesting can continue for 9 to 12 more years. The use of sisal fiber as a textile fiber by mankind began during forties, [19] Sisal fibers are one of the most extensively cultivated hard fibers in the world and it accounts for half the total production of textile fibers. The reason for this was due to the ease of cultivation of sisal plants, which demand shorter renewing times, and is fairly easy to grow in all kinds of environments. A large quantity of this renewable resource remains under-utilized. As can be seen, the cross section of sisal fibres is neither circular nor fairly uniform in dimension. The lumen varies in size but is usually well defined. The longitudinal shape is approximately cylindrical. The cell walls consist of several layers of fibrillar structure consisting of fibrillae. In the primary wall, the fibrillae have a reticulated structure. In the outer secondary wall (S1), which is located inside the primary wall, the fibrillae are arranged in spirals with a spiral angle of 40^o (for sisal fibre) in relation to the longitudinal axis of the cell. The fibrillae in the inner secondary wall (S2) of sisal fibres have a sharper slope, 18 to 25^o. The thin, innermost, tertiary wall has a parallel fibrillar structure and encloses the lumen. The fibrillae are, in turn, built up of micro-fibrillae with a thickness of about 20 nm. The micro-fibrillae are composed of cellulose molecular chains with a thickness of 0.7 nm and a length of a few mm [6].

Jute is a long, soft, shiny vegetable fibre that can be spun into coarse, strong threads. It is produced from plants in the genus *Corchorus*, which was once classified with the family Tiliaceae, more recently with Malvaceae, and has now been reclassified as belonging to the family Sparrmanniaceae. The primary source of the fibre is *Corchorus olitorius*, but it is considered inferior to *Corchorus capsularis*. "Jute" is the name of the plant or fiber that is used to make burlap, Hessian or gunny cloth. The word 'jute' is probably coined from the word jhuta or jota, an Oriya word. Jute is one of the most affordable natural fibers and is second only to cotton in amount produced and variety of uses of vegetable fibers. Jute fibers are composed primarily of the plant materials cellulose and lignin. It falls into the bast fibre category (fiber collected from bast, the phloem of the plant, sometimes called the "skin") along with kenaf, industrial hemp, flax (linen), ramie, etc. The industrial term for jute fiber is *raw jute*. The fibers are off-white to brown, and 1–4 metres (3–13 feet) long. Jute is also called the *golden fiber* for its color and high cash value

The term hybrid effect has been used to describe the phenomenon of an apparent synergistic improvement in the properties of a composite containing two or more types of fibre, [8]. The selection of the components that make up the hybrid composite is determined by the purpose of hybridization, requirements imposed on the material or the construction being designed. The problem of selecting the type of compatible fibres and the level of their properties is of prime importance when designing and producing hybrid composites. The successful use of hybrid composites is determined by the chemical, mechanical and physical stability of the fibre / matrix system.

2.0 Literature Review

[20] developed sisal fibre and its composites. The properties of sisal fibre itself interface between sisal fibre and matrix, properties of sisal-fibre reinforced composites and their hybrid composites have been reviewed. It is observed Sisal and glass fibres can be combined to produce hybrid composites which take full advantage of the best properties of the constituents. Almost all the mechanical properties show positive hybrid effects.

[13] studied the characterization and Synthesis of nano sisal fiber reinforced composite, the study compared the tensile properties of sisal nano fibre reinforced polymer composites to glass fibre reinforced polymer composites, chemically treated fibres were characterized by X-ray powder diffraction to measure the crystallite size and to find the morphology and inorganic materials of the nano powder, using Scanning Electron Microscope (SEM), test results observed shows that the tensile strength of sisal nano fibre reinforced polymer composites have high strength compared to glass fiber reinforced polymer composites.

[14] investigated the behavior of cylindrical FML hollow shafts subjected to static torsional loading. In their research work they used the FML hollow shafts with glass fibers reinforced with epoxy resin at different fiber orientations prepared using filament winding machine. To examine the effect of fiber orientation, FML hollow shafts of 0/90°, 60/30°, ± 45° and ± 55° fiber orientations were considered. Both the experimental and numerical results showed FML hollow shafts with 0/90° fiber orientation possessed higher torsional strength as compared to FML hollow shafts with 60/30°, ± 45° and ± 55° fiber orientation. Torsional buckling occurred at around 10°–15° angle of twist and torque reduced drastically once the FML hollow shaft experienced buckling. In FML hollow shafts of FRP thicknesses 2 and 2.5 mm, torsional buckling occurred beyond 15° angle of twist and cracking of FRP in different layers was observed before failure of the shaft. At 15° angle of twist, the maximum torque exhibited by FML hollow shaft of 0/90° fiber orientation with FRP thickness 1, 2 and 2.5 mm was 9.69, 15.27 and 21.55 Nm respectively.

[10] investigated on the Mechanical Characterization of Banana/Sisal Fibre Reinforced Poly Lactic Acid PLA Hybrid Composites for Structural Application; The test results obtained evident that the tensile strength properties of the treated banana/sisal fibre reinforced PLA biocomposites materials were significantly higher than those of untreated banana/sisal fibre reinforced PLA biocomposites. The treated fibers with NaOH were having the best mechanical properties than pure PLA and untreated fibre bio-composites. The chemical treatment also improved fiber matrix interaction by removal of lignin and hemicellulose, which led to the better incorporation of fiber with the matrix.

[11] investigated the mechanical properties such as compression strength and modulus, chemical resistance and thermal characteristics of the unsaturated polyester resin based kapok/sisal hybrid composites developed by the hand lay-up technique at room temperature. The variations in mechanical properties of these composites were evaluated as a function of fabric/fiber content and different volume ratios of fabrics. The addition of a relatively small amount of sisal fiber to kapok reinforced polyester matrix enhancing the compressive properties of the

resulting hybrid composites. A significant improvement in compressive properties of these hybrid composites were observed after NaOH treatment. Among all the resultant hybrid composites those with fabrics ratio of 1:3 demonstrated improved compressive properties. The chemical resistance of these hybrid composites to different chemical reagents and water was been studied in his research.

3.0 Materials and Method

The materials used for the preparation of the composite were: unsaturated polyester resin (matrix), methyl ethyl ketone peroxide (catalyst), cobalt naphthalene (accelerator), Vaseline (releasing agent) bought from Pascal Scientific Laboratory, Akure, Ondo state. Sisal plant fiber was obtained from Ogbemena garden, in Nneni town, Anambra State. Jute plant was obtained from Tiawo Farm, Owode, Ogun state Nigeria. The productions of the various composite materials were carried out through hand lay-up technique. Sisal and jute fibre strands were reinforced in unsaturated polyester, Methylethylketone catalyst and Cobalt accelerator at a ratio of 10:1:0.5. Each composites were loaded in 0.40 volume fraction, arranged in the orientation of $90^0/90^0$, $90^0/\ 0^0$,-$45^0/45^0$and in fibres combination percentage ratio sisal to jute of 50:50, 67:33, 33:67, with reference to a control sample of nil fibre (resin alone) and mild steel sample. The casting of the composites samples were cured under room temperature/ consolidate with a roller load weight of 50g, at 4hrs before samples were removed from the mould. Then, specimens were further cured in the air for another 12hrs after removing from the mould.

Hand Layup Method

The productions of the various composite materials were carried out through hand lay-up technique. Sisal and jute fibre strands were reinforced in unsaturated polyester, Methylethylketone catalyst and Cobalt accelerator at a ratio of 10:1:0.5.

The different composites were produced in the form of laminates for tensile, flexural, compression, impact, bending and torsional test. Each composites were loaded in 0.40 volume fraction, arranged in the orientation of $90^0/90^0$, $90^0/\ 45^0$, $0^0/0^0$, $-45^0/45^0$, $30^0/\ 60^0$, and in fibres combination percentage ratio sisal to jute of 50:50, 67:33, 33:67, sisal alone, jute alone etc with reference to a control sample of nil fibre (resin alone) and mild steel. The casting of the composites samples were cured under room temperature/ consolidate with a roller load weight of 50g, at 4hrs before samples were removed from the mould. Then, specimens were further cured in the air for another 12hrs after removing from the mould.

Test specimens were subjected to mechanical test as per ASTM standards using Instron 3369 Universal testing machine - The tensile test – ASTM D638, ASTM D790 three-point flexural tests, ASTM C790 compression test and Impact Test. All the specimen samples preparations and the mechanical test were carried out at room temperature of about 37^0C.

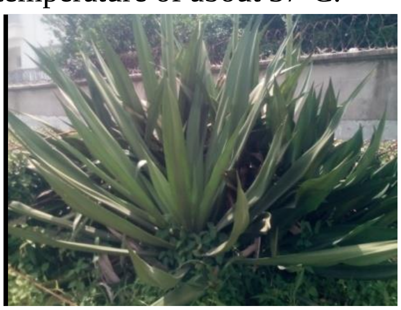

Figure 1. Picture of Sisal Plant.

Figure 2: Jute plant.

Fig.3 Extracted sisal fibre

Fig.4. Extracted Jute fibre

Figure 5: Compression test samples

Figure 6:Flexural test samples

Figure 7:Tensile test samples

Figure 8:Impact test samples

4.0 Results and Discussions

Tensile Test Result

Reference: Mild steel, Tensile Strength 400MPa

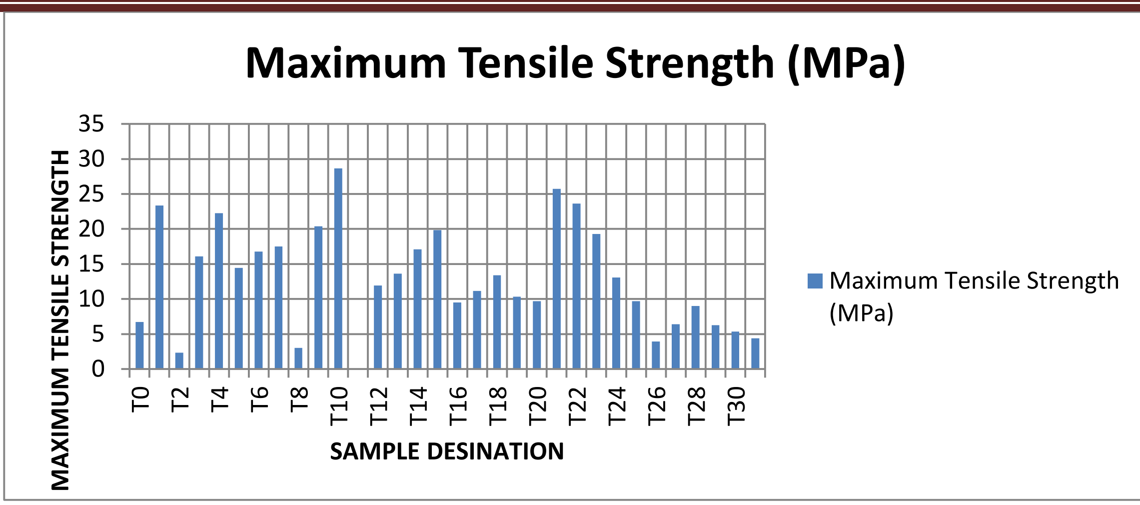

Figure 9: Graph of Tensile Test Samples of Sisal/Jute Fibres Percentage Combination Prepared at 0.4 Volume Fractions Using Unsaturated Polyester Resin result

Flexural Test Result

Reference: Mild steel, Flexural Strength 300MPa

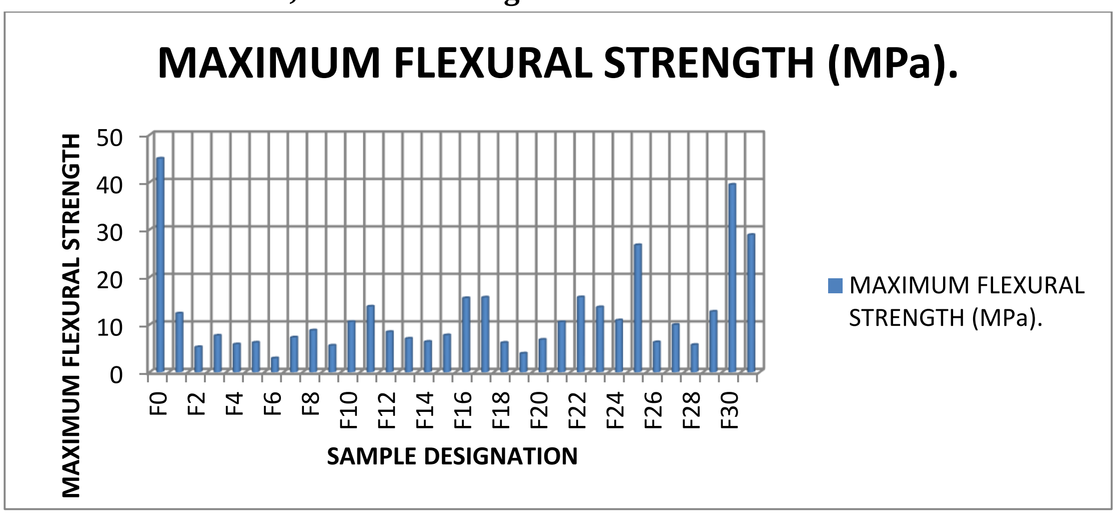

Figure 10 : Graph of Flexural Test Samples of Sisal/Jute Fibres Percentage Combination Prepared at 0.4 Volume Fractions Using Unsaturated Polyester Resin result

Impact Test Result

Reference: Mild steel, Impact Strength 29.5 Joule

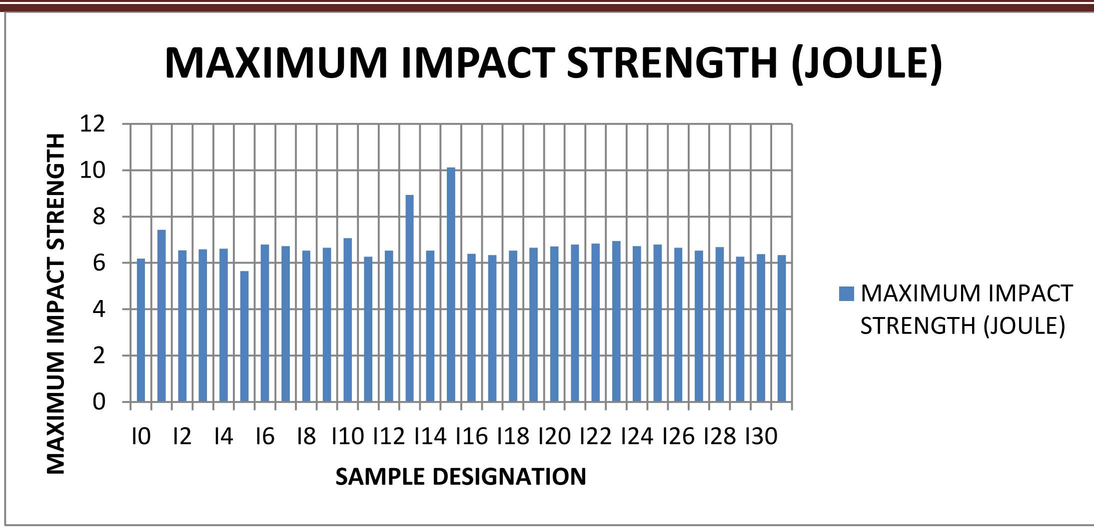

Figure 11: Graph of Impact Test Samples of Sisal/Jute Fibres Percentage Combination Prepared at 0.4 Volume Fractions Using Unsaturated Polyester Resin result.

Compressive Test Result
Reference: Mild steel, Compressive Strength 300MPa

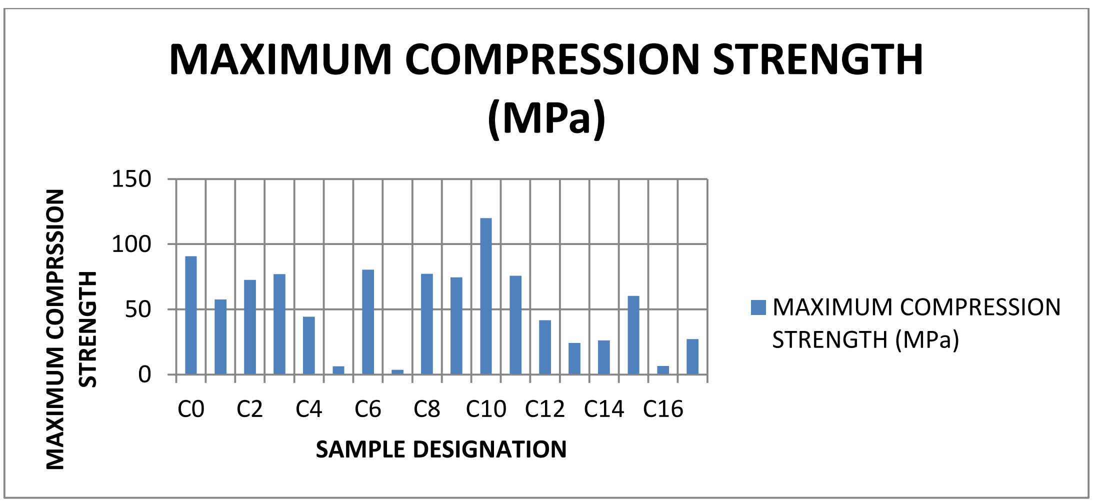

Figure 12: Graph of Compression Test Samples of Sisal/Jute Fibres Percentage Combination Prepared at 0.4 Volume Fractions Using Unsaturated Polyester Resin result.

The prepared laminate samples were subjected to tensile, flexural, impact and compressive, tests to evaluate their strength which was based on orientations and fibres percentage combination. Sisal/Jute hybrid fibres reinforced in unsaturated polyester resin, demonstrated a maximum tensile strength of 29.7MPa on sample designated T10 laid at $90^0/90^0$ orientation and (33:67) sisal/jute percentage combination, highest flexural strength of 39.5MPa on sample designated F30 laid at $90^0/45^0$ orientation and (100:0) sisal/jute percentage combination, maximum impact strength of 12 Joule on sample designated TSL16 laid at $45^0/-45^0$ orientation and (67:33) sisal/jute percentage combination, maximum compressive strength of 120MPa on sample designated C10 at $90^0/45^0$ orientation and (33:67) sisal/jute percentage combination

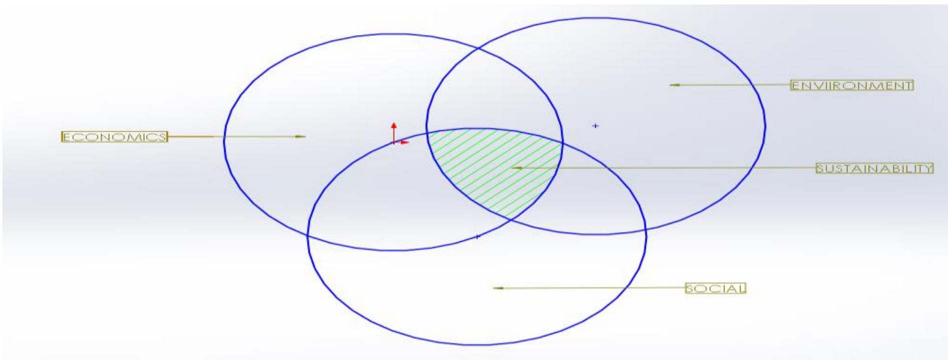

Figure 13: Sustainability analysis of sisal/Jute Hybrid Polymer composite

Economic: Sisal/Jute hybrid polymer composite when used in automobile body parts would be a source of income.

Environment: Sisal/Jute hybrid polymer composite are biodegradable, they are not cancergenic unlike glass fibers.

Social: There are no laws bounding the production of sisal/jute hybrid polymer composite and we can target not only Nigeria but the entire West Africa as our market.

sisal/jute hybrid composite for automobile body in line with sustainable development goals.

goal 8: good jobs and economic growth and goal 9: industry and innovation

Comparison of Mild steel thickness to Sisal/Jute

A body part in Mild Steel is 1.2mm in thickness. Then the thickness of a Sisal/Jute Polymer (S/JP) composite moulding by Hand Lay-up of comparative stiffness will be:

S/JP_{Th} = Conventional material x (Factor for for SJP/Factor for conventional material)

Factor for SJP = 6.8 (adopted from Table, Courtesy: Owens Corning Fibers)

S/JP_{Th} = 1.2 x (6.8/3.2) =3.24=3mm

Figure 14: Finished Chassis panel weighs 421grams

The chassis panel of an automobile was successfully developed using Sisal/Jute Hybrid Polymer composite. The chassis panel has a light weight of 421grams when compared to the weight of Toyota Camry 2000 model of 650grams and possesses good mechanical properties (tensile strength of 38MPa, Compressive strength of 120MPa, Impact strength of 12 Joul) and it is expected be durable with the overall cost of production of $6 which is far cheaper when compared to Glass fibre reinforced/conventional steel/ carbon reinforced polymer chassis panel of a Toyota Camry that cost $15 in the market.

Conclusion

It was observed that increase in percentage combination of sisal fibre exhibited superior tensile and Impact strength while increase in percentage combination of jute fibre exhibited superior flexural and compressive strength, Sisal/Jute hybrid fibres reinforced in unsaturated polyester resin, demonstrated a maximum tensile strength of 29MPa on sample designated T10 laid at $90^0/90^0$ orientation and (33:67) sisal/jute percentage combination, maximum flexural strength of 40MPa on sample designated F30 laid at $90^0/45^0$ orientation and (100:0) sisal/jute percentage combination, maximum impact strength of 12 Joule on sample designated TSL16 laid at $45^0/\text{-}45^0$orientation and (67:33) sisal/jute percentage combination, maximum compression strength of 120MPa on sample designated C10 at $90^0/45^0$ orientation and (33:67) sisal/jute percentage combination. The tensile strength of composite depends to a large extent on the interfacial bonding strength between the matrix and fibre reinforcement, the orientation of fibre, and the inherent properties of the composite ingredients. Improvement in the mechanical properties of the sisal/jute hybrid composite helps the composite to withstand more stress while being used in automobile body (Interior, semi-exterior and exterior).

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