Experimental of Flexural and Hardness Property of Palm-Sisal Reinforced Epoxy Resin Hybrid Composite Materials

Asmamaw Tegegne[1], Melese Shiferaw[2]
[1]Department of Manufacturing Technology, Federal Technical Vocational Education and Training Institute, Ethiopia
[2]Department of Manufacturing Engineering, University of Gondar, Ethiopia

***Abstract* -Hybrid Natural fiber composite material is made from two or more natural fibers to achieve better mechanical properties than single fiber composites. In Ethiopian large amount of unused natural fibers resources including palm, sisal and others are available. These can replace synthetic fiber composite materials. Carry out research to change the natural fibers in to use full engineering products is essential for industrial development. Experimental methodology of research was conducted to develop palm and sisal fibers reinforcements with epoxy resin matrix hybrid composite for the purpose of determining the flexural and hardness property that is required in vehicle internal body parts. In the production of hybrid composite specimens for flexural and hardness tests, various parameters including sequence of fiber layers effect (palm-sisal-sisal-palm (PSSP), palm-sisal-palm-sisal (SPSP), and sisal-palm-palm-sisal (SPPS)), angle orientation of fibers(0^o-45^o -0^o -45^o, 0^o -0^o -0^o -0^o, 0^o -90^o -0^o -90^o), weight concentration of fibers (weight ratio) and also different alkali (NaOH 6% and 10%)concentration treated fiber effect were considered. Flexural strength test was conducted on three point sampling size universal testing machine and hardness testing was conducted using Rockwell scale "A" hardness tester. From test results, the 6% NaOH treated chopped composites showed higher flexural strength (66MPa.) with weight concentration of 5%palm-20%sisal- and 75% epoxy. The hardness number of 6% NaOH alkali-treated fiber with weight concentration of 5%palm, 20%sisal and 75% epoxy chopped fiber number was110.344 and was the highest hardness comparing to hardness of other specimens. From the research results it is possible to conclude that using palm-sisal hybrid fibers as reinforcement in polymer matrix could successfully develop a composite material with high strength to weight ratio and rigidity for automobile interior parts applications and the naturally obtained fibers may play a great role in economic development.**

***Keywords*- hybrid, composite, flexural strength, matrix, hardness, Rockwell hardness tester**

I. INTRODUCTION

Composite materials have been developing since many years and play a greater role in replacing the metallic and other engineering materials as they attain relatively similar properties in service. Synthetic fiber composites are common in production line of many industries. However the naturally obtained fibers are not consumed yet. In view of researcher[1], in the consuming of synthetic fiber composite materials, there is a dramatically surge in interest of eco-friendly materials and technology in industrial sectors and hybrid bio composite from natural resources. All synthetic composite materials products have environmental impacts. It is either small or huge depending on the root causes and raw materials used in the production process. These will be including process or services which may involve energy consumption, natural resource depletion, solid waste generation, air pollution, land degradation and global warming issue.

According to that of[2], recently growing environmental impact associated with production, disposal and recycling of synthetic fiber based polymer composites triggers the development of eco-friendly composite for various applications such as automotive, marine, chemical, infrastructure, sporting goods, etc. From literatures and self-experience it is visible that among many natural fibers like palm, cotton, flax, banana and hemp, oil, jute, kenaf, sisal are highly consumed as they are abundantly available, cheaper and eco-friendly.

They possess very good and satisfactory mechanical properties. This time sisal fiber [2] plays a key role to fabricate a varied range of structural and non-structural industrial products with different polymer matrixes.

In the work of [3] it is also explained that the uses and problems of synthetic fiber as, solid waste disposal has become a burning problem. Garbage wastes such as plastic grocery bags, food packaging materials, bottles, containers, etc. are affecting environment and become sources of pollution in urban and rural(special road side) areas due to non-biodegradable nature. At the same time, the emission of greenhouse gases during combustion [3] is a serious global-scale problem. To keep the environment safe and green, it is important to reduce the use of such pollution-causing garbage. Now a day many countries banned plastic grocery bags production and utilization as they are main source of pollution.

Researchers[1,4] explained thatnatural fibers have attracting the interest to engineers, researchers, professionals and scientists all over the world as an alternative reinforcement for fiber-reinforced polymer composites, because of its superior properties such as high specific strength, low weight, low cost, fairly good mechanical properties, non-abrasive, eco-friendly and bio-degradable characteristics than human made or synthetic composite materials. Also[5] has discussed that natural fibers are potential replacement for synthetic fibers in automotive and aerospace engineering applications due to the low carbon footprint associated with them, reduction of the resonant amplitude of the vibration in a machine component design process. It is also underlined [5] that damping associated with fiber-reinforced composite structure is higher than conventional metal structures due to the viscous -elastic behavior, fiber-matrix interaction and the damping due to damage.

As discussed in literature[6], environmental awareness and sustainability concept attracts researchers and scientists towards utilization of natural fibers as reinforcement in polymer-based composites. Wood fibers, leaf, seed etc. are natural fibers highly used in the composite industry. These fibers often contribute greatly to the structural performance of plant and when used in plastic composites can provide significant reinforcement. Natural fiber composites can also be [6] very cost-effective material for application in building and construction areas (e.g. walls, ceiling, partition, window and door frames), storage devices (e.g. biogas container, post boxes, etc.), furniture (e.g. chair, table, tools, etc.), electronic devices (outer casting of mobile phones), automobile and railway coach interior parts (inner fenders and bumpers), toys and other miscellaneous applications (helmets, suitcases)

The increasing environmental concerns and awareness for greenhouse effect and biodegradability [7] have been the main driving force for the shift from synthetic fiber reinforced composites to natural fiber reinforced composites for various non-structural applications. This is because the development and use of natural fiber composites in these applications have least effects on the environment. Natural fibers such as sisal are light-in weight, low cost, non-toxic, naturally available, renewable, recyclable and biodegradable in nature[7]. According to [10], Sisal fiber is one of the most widely used natural fibers and is easily cultivated. It is a hard fiber extracted from the leaves of the sisal plant (Agave sisalana)[10] and is fully biodegradable and highly renewable resource of energy. The material is chosen to improve the various strength properties of the structure to obtain sustainability and better quality structure. There are three types of fibers in sisal, arch fibers, conducting fibers and structural.

In the studies of [11] it has been mentioned that, sisal fiber reinforced epoxy composites can been prepared by hand lay-up technique followed by static compression, using various fiber weight fractions. Mechanical properties, thermal properties, water absorption properties and dynamic mechanical analysis of sisal composites were investigated [11] and improved mechanical and other properties wear achieved. Researcher [11] explained that composites hand lay-up technique was used to fabricate the composites by reinforcing sisal fibers into the epoxy matrix as result of quantitative parameter and flexural strength flexural modulus were calculated analysis using equation [11]:

$$flexural\ strength(\sigma f) = \frac{3FL}{2bd^2} \qquad (1)$$

$$flexural\ modulus(E) = \frac{mL^3}{4bd^3} \quad , \qquad (2)$$

Where F is the ultimate failure load (N); L, the span length (mm); b and d, the width and thickness of specimen in (mm) respectively; and m, the slope of the tangent to the initial line portion of the load is placement curve.

In view of[9]a combination of two or more types of fibers in a single polymeric matrix (also known as a hybrid composite), produces greater stiffness and strength in comparison with individual reinforced polymer composites. It has been explained that [9] commonly, one type of fiber in the hybrid composite has a low modulus and/or lower cost, whilst the other type has a higher modulus and/or higher cost. Low modulus and inexpensive fibers make hybrid composites more tolerant to damage and reduce overall costs, while the more expensive fiber with a high modulus provides load-bearing capabilities and composite stiffness. Accordingly, hybrid composites can provide a high stiffness and strength, improve the impact and fatigue resistance, provide high fracture toughness, and simultaneously cut the weight and/or total cost [9]. Author [9] carried out an experiment on the effect of NaOH treatment on the flexural strength jute fiber that is related to sisal fiber, the flexural test or three-point bending test was carried out on UTM for the specimens prepared as per the ASTM D790 standard. According to [9] experimental result 5% NaOH treated jute fiber reinforced polyester composites showed the maximum flexural strength of 44.71 N/mm^2 over 38.6 N/mm^2 showed by 10 %, NaOH treated jute reinforced polyester composites. In this work Flexural strength was determined from the formula given below [9].

$$\sigma f = \frac{3PL}{2bdh^2} \qquad (3)$$

Where

σf = flexural strength P = Maximum applied load (N),

L = span length of the specimen (the distance between the two supports). b = width of the specimen,

H = thickness of the specimen.

Palm fibers are also one of the reinforcing materials for polymer matrix composites. Concerning the date palm, the world wide annual production of date palm tree is 42% more in comparison to coir and 20–10% more compared to hemp and sisal. Each stem of palm tree is surrounded by a mesh of single cross fibers which appears as a natural woven mat of fibers with different diameters. In the work of [12] three-point bending flexural tests according to ASTM D790 standard with the crosshead speed of 2.0 mm/min were applied on upper and lower surface of each six replicate specimens of pure epoxy composites and each DPF/epoxy composite and the failure was calculated when bending of specimen reach up to corresponding critical point [12].According to researcher [12], the amount of date palm fiber increases up to 5% the flexural strength also increases. But when it is above 50% the strength becomes reduced due to the reduction of matrix.

The sisal palm hybrid composite may attain high strength to weight ratio, moisture absorbing ability, pollution free property or are environmentally eco-friendly and recyclability.

Ethiopia has much amount of natural fiber resources which can be used as a reinforcement material replacing synthetic composite materials fibers like carbon, glass fiber and others .From the experience and from literatures it is possible to understand that for many years in the past, most researchers focused their attention on synthetic composites reinforced materials like glass, carbon, and ceramics. But these materials are depleted and are sources of different environmental pollution; have less economic benefits and most are non-recyclable and non-degradable. It is because of this , today natural fibers get more attention and become attractive than synthetic fibers as they attain good specific properties, relatively low prices , are recyclable and have low density with relatively high strength. However, there is a limitation on researches of natural fibers utilization and mechanical property analysis. More over palm-sisal hybrid composite utilization and property analysis is not widely applicable. The applications of such composites are not widely distributed. Carry out research and study the mechanical properties of these fibers are the basic criterion for introducing to the industries in order they scale up and use for many purposes. Carry out research on properties like flexural strength and hardness is important to produce parts for internal automotive body parts like roofing and floor, which is exposed to bending and scratching loads.

Thus this research is focused on investigating of flexural and hardness property of hybrid fiber-reinforced epoxy resin composite material fabricated from locally available palm-sisal plants suitable for automobile interior part applications. The development of fibers from locally available palm and sisal plants to produce hybrid composite material to determine the hardness and flexural strength for further engineering application like in automobile industry were the key issues investigated in this work.

II. MATERIALS AND RESEARCH MATERIALS METHODOLOGY

A. Materials

To carry out the research the following materials were used. The some of the matrix materials were purchased in the local market.

Epoxy resin, which is light in weight and resists alkalis, acids, stress cracking and is low moisture absorption, **was** used as a matrix in the hybrid composite directly. **Hardener (HY-95) was used** as curing agent and as a catalyst to facilitate the curing time. It is the specific selection and combination of the epoxy and hardener components that determine the final characteristics and suitability of the epoxy coating for a given environment. Wax was another material which was used as a mold releaser due to its collapsibility after use. NaOH solution was used for fiber treatment. For alkaline solution treatment distilled water was employed and finally natural fibers which were extracted from palm and sisal plants at the local area were used as reinforcements in the hybrid matrix composite produced.

B. Methodology

To conduct the research experimental methodology with both qualitative and quantitative approaches was used. Purposive sampling was selected and 54 specimens for three point samples based on the four parameters namely, angle orientation, weight concentration, lamination/ layering, effect of alkali treatment were prepared. The samples were prepared to analysis mechanical properties (bending strength and hardness) of palm and sisal hybrid fiber reinforced epoxy composite. The procedure followed to prepare the specimens was extraction of the natural fibers from palm and sisal, preparation of epoxy resin and conducting of mechanical property test.

In extracting palm and sisal fibers manual mechanical extraction method (fig.1 and 2) with the help of serrated knives was used. In the process, fiber was extracted by rasping the leaves with a blunted knife and placed on the working table until the resinous materials were removed and fiber strands are obtained. A bunch of fibers were mounted or clamped on a stick to facilitate segregation. In this method, almost the entire extraneous matter was removed leaving only the fiber strand. Decorticated fibers were washed before drying in the sun or by hot air. Proper drying is important as fiber quality depends largely on moisture content. Thus extracted fibers from palm and sisal were dried in air with the help of sun light for 72 hours.

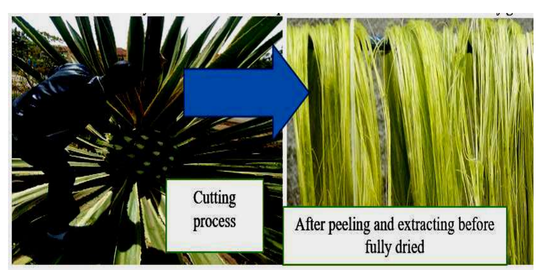


Fig.1. Extraction process of sisal fiber

Fig. 2.extracted sisal fiber after washed by pure water and dried

The extraction process of palm fiber is different from that of the sisal fiber. The extraction was done after studying the physical properties of palm as displayed in table 1.

TABLE 1 PHYSICAL PROPERTIES OF PALM FIBER [13]

Fiber	Physical properties of palm fiber			
	Density,(gr/cm^3)	**Elongation,(%)**	**Tensile strength,(MPa.)**	**Young's Modules,(Gpa.)**
Palm leaf stalk	1-1.2	2-4.5	97-196	25-5.4
Palm leaf sheath	1.2-1.3	2.84	220	4.8
Palm petioli	0.7-1.55	25	248	3.24
Palm fruit	1.09	28	423	6-8
Coir	1.15-1.2	30	175	4-6
Pineapple leaf	0.86-1.6	14.5	144	400-627

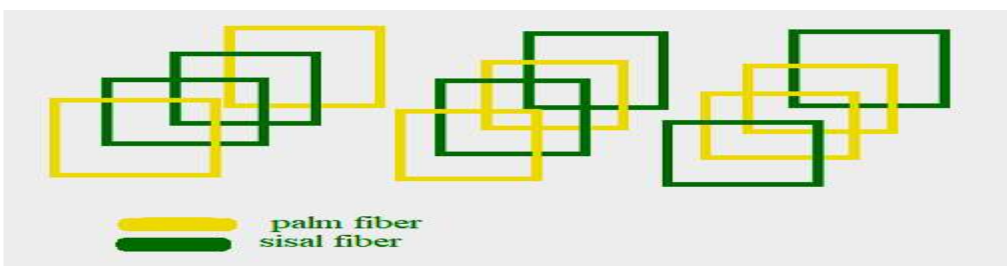
Processes of preparation include cutting and collecting of the palm leaf, peeling and drying of the fiber in air. After extraction of the fibers from both plants specimens for analysis were prepared using the tools, equipment and apparatuses. Hand layup method of composite fabrication was selected as it was the only possible easiest way available during the research process.

Digital balance for measuring the weight ratio of fiber and epoxy, syringe for subtracting hardener to mix with epoxy, bucket for treatment solution preparation, brush used for hand lying of fiber, scissors for cutting the fiber in order to prepare chopped fiber, table used as workbench, manual pressing mold die used for compressing the specimen matrix during mixing were tools and devices used in the fiber preparation. Digital Photo camera was used to take picture for analysis.

The matrix used to fabricate the specimen was epoxy density 1.13 g/cm^3 at 25°C that was mixed with hardener density 0.97 to 0.99 g/cm^3. The weight ratio of mixing epoxy and hardener was as per the supplier norms.

The specimens were prepared based on different techniques (as discussed above based on four parameters). Accordingly, based on a sequence of fiber layers, the lamina consisting of two layers of palm fibers and two layers of sisal fibers with an equal amount of mass 30/70(15 palm-15 sisal- 70 epoxy and other mass concentrations) were prepared. The three-point sampling technique was selected with different sequences (fig.3) of fiber layers.

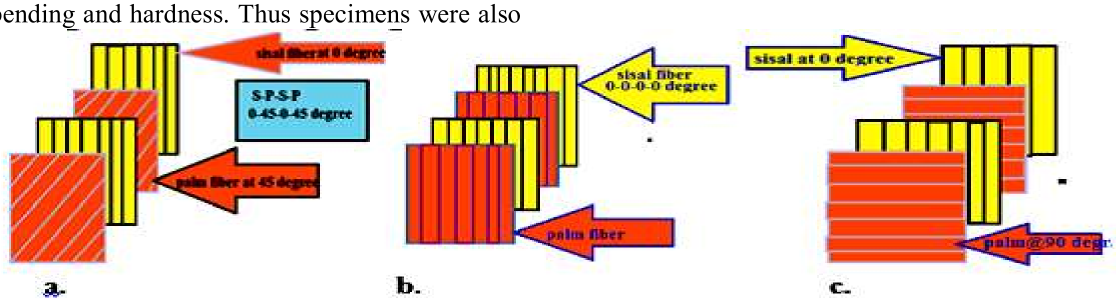
PSSP- palm- sisal-sisal-palm, PSPS- palm- sisal-palm-sisal, SPPS- Sisal-palm-palm-sisal four layers in each and 3 samples each were made in sequence of layer arrangement.



a) palm- sisal-sisal-palm b) palm- sisal-palm-sisal c) Sisal-palm-palm-sisal

Fig.3. Fiber sequence layer arrangement

It is thought that angle of orientation of fibers in the fabricated composite may show an effect on mechanical strength basically on bending and hardness. Thus specimens were also prepared based on different angular orientations of fibers (Fig.4).



Angle of S-P-S-P(a.0º-45 º -0º -45º,b.0º -0º -0º -0º, and c.0º -90º -0º -90º)

Fig.4. Angular orientation of fibers in the prepared composite

Samples based on angular orientation were prepared based on the schematic displayed in table 1.

Samples were also prepared based on concentration of fibers (weight ratio).This was done to check the effect of fiber concentration on the mechanical property. Different mass concentration chopped fibers were used for sample preparation. The10P-10-S-80E, 5P-20S-75E and 30P-30S-40E concentration was prepared (concentration in weight percent).

The fibers were treated using alkaline solution (Sodium Hydroxide (NaOH)) as it enhances the surface morphology of natural fibers. Commonly recommended concentration of the alkaline solution for treatment is 6% and 10% NaOH. The treatment of both palm and sisal fibers with this solution took 4 hours (fig.5 and 6).

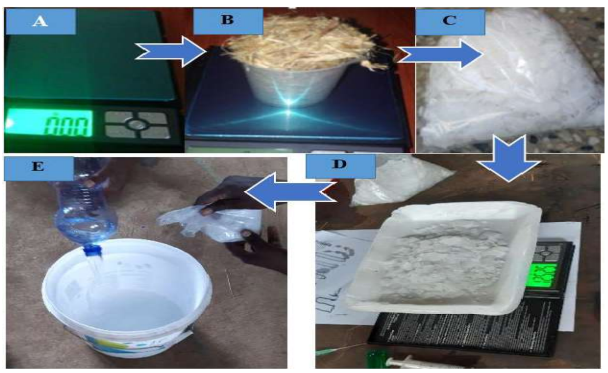


Fig.5. Sequence (flow) of fiber treatment

A , digital balance, B ,measuring of chopped fiber. C, NaOH, D, measuring of NaOH and E . preparation of solution using distilled water

Fig.6. Treated fiber after dried in sunlight; A , treated with 6%,NaOH, B , treated with 10%NaOH.The surface of the fiber was changed its color and morphology after NaOH solution treatment in different concentration.

After all the above processes the mold for layup was prepared from MDF and specimens were prepared. Epoxy and chopped fibers were mixed and lamina according to ASTM standard was prepared using hand layup method. Vacuum sacking pump was used to remove the excess air and resin was also removed. This can create homogeneity of the composite sample. The thickness of the lamina was limited to 4mm and the size was 170mmx81mm. After drying, the edges of the specimen were neatly cut using saw as per the required dimensions. And test samples were cut to the required sizes prescribed in the ASTM standards and made ready for test.

III. EXPERIMENTAL ANALYSIS

While carried out the analysis, effect of mass fraction of the fiber and sample size determination of the specimens was considered. According to ASTM standard for bending strength and hardness test of composite fiber material, the dimension of the specimen is recommended as ASTM D790 (77x12.5x4) mm [14]. According to ATSM D790-2003 standard is recommended [15], for flexural test and the tests were performed for a span-to-thickness ratio of 32:1.

To determine the flexural stress, flexural strain, etc. each sample loading can be done at the rate of 0.01 mm/ sec and test data was stored by the machine console.

While testing the diameter of the supporting roller was 10mm, the distance between the two supporting rollers was 112mm.(fig.7), and the test loading size was 150mmx35mmx3.5mm. [15].

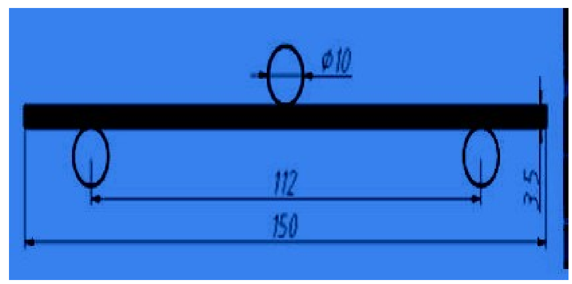


Fig.7. Three point bending test

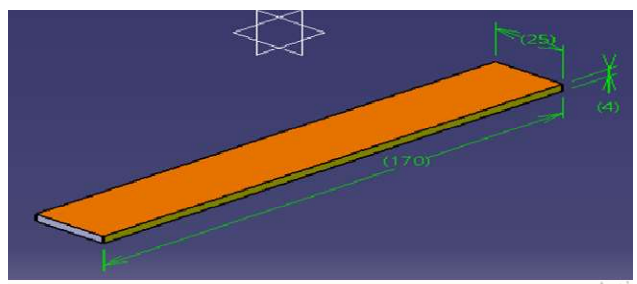


Fig.8 Sample specimen as ASTM D790 standard size in (mm)

Sample specimens prepared for mechanical testing were prepared based on ASTM D790 [15] standard for this purpose (fig.8).The testing schematic is displayed in fig.9.

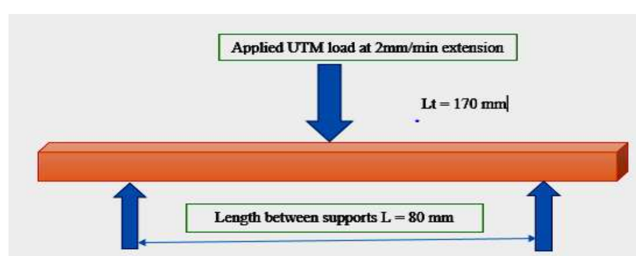


Fig.9. ASTM D790 flexural strength test mold size

In the fig L = length, W = width, t = thickness.

When preparing the mold the volume was determined using the equation

V = L*W*t + volume of void (4)

The mass of composite was calculated based on analysis of fractional volume of composite.

Taking the values of the physical properties of sisal fiber and palm fiber the volume of the composite was calculated as:

VC = VP+VS+VE (5)

Where: VC= volume of composite

VP = volume of palm fiber;

VS = volume of sisal;

VE = volume of epoxy.

Vc= m c/ρ c= m palm/ ρ palm +m Epoxy/ρ Epoxy + m Sisal/ρ Sisal

But the mass of composite was calculated as: Mcf = Mp+Ms+Me = 1 where Mcf = mass fraction of composite.

Based on the analysis using the above equations the results obtained for bending test are displayed in table(2).As seen in the table the matrix (Epoxy) mass is higher than the fibers.

TABLE 2 SUMMARIZED CALCULATED MASS OF COMPOSITE FOR BENDING TEST

Designation	Composition			Mass of composite, gram			Sum
	Palm,%	Sisal,%	Epoxy,%	Mass, P	Mass, S	Mass of matrix	Sum
1	10	10	80	7.775	7.775	62.2	77.75gram
2	5	20	75	3.887	15.55	58.32	
3	30	30	40	23.37	23.37	31.1	

Based on the values given in table 2 volume fraction of the fiber and the matrix content of the composite (Vf, Vm) was calculated as

$$Vf = \frac{Vf}{Vf+} = \frac{Vf}{Vc} \quad (6)$$

As a result: Vf+Vm=1

Let ρf and ρm are density of fiber and density of matrix respectively then $m = \frac{v}{\rho}$

ρm = Density of Matrix (g/cc)

Vf = Volume of fiber (cm^3)

The mass density of the composite was calculated as:

$$\rho = (Vf * \rho f + Vm * \rho m)/Vm \quad (7)$$

A composite laminate containing 10 wt% of palm fiber, 10wt% of sisal fiber in 80 wt% epoxy resin was taken as a sample for 1gram of hybrid composite and analysis result is given in table3.

TABLE 3 ANALYSIS RESULT OF 1 GRAM SMALL HYBRID COMPOSITE

	Palm fiber	Sisal fiber	Epoxy
Mass, gm	0.1	0.1	0.8
Volume m^3	1.125	1.415	1..2
Density g/cm^3	0.0889	0.076	0667

Based on the equation mentioned above for weight fraction analysis the weight fraction of gram concentration for hybrid composite was calculated and the result is displayed in table4.

TABLE 4 WEIGHT FRACTION GRAM CONCENTRATION HYBRID COMPOSITE

Weight concentration designation,%	Volume fraction composition (cm^3)			
	palm	Sisal	Epoxy	Vc
10P - 10S - 80E	0.0889	0.0706	0.667	0.8265
5P – 20S - 80E	0.0444	0.1413	0.5833	0.8265
30P – 30S – 40E	0.2667	0.212	0.3333	0.8265

The result in the table shows that the volume of the composite is equal in all arrangements of various concentrations of the fiber and matrix.

The stiffness matrix, strain, and strength of composite lamina were also calculated from the theory of composite lamella using the formula [16]:

$\frac{1}{Ec} = \frac{1}{E1} + \frac{1}{2} + \cdots \frac{1}{En}$ (8)

Accordingly $\frac{1}{Ec} = \frac{1}{Ep} + \frac{1}{Es}$

For laminate analysis equal mass of palm and sisal fiber in different layers of the laminate was considered for analysis and result was displayed in table (5).

TABLE 5 SUMMARIZED CALCULATED ELASTIC PROPERTIES OF EACH ANGLE PLY LAMINATE

property	**Hybrid Palm-Sisal-Epoxy resin composite layer**		
Angle	00	450	900
Exx(MPa)	3375	3415	3370
Eyy(MPa)	3370	3513	3370
Ezz(MPa)	3370	3513	3370
vxy	0.27	0.271	0.27
vxz	0.263	0.271	0.263
vyz	0.27	0.27	0.27
Gxy(MPa)	1072	1328	1072
Gxz(MPa)	1072	1328	1072
Gyz(MPa)	1566	1548	2600

From the table it is possible to understand that the young's module and shear modulus are higher in the arrangement of 0^o-45^o-90^o orientation. This tells that the stiffness of the hybrid composites is better in such orientation.

For better understanding and determination of stiffness [17], stiffness matrix that serves as a connection between the applied loads and the associated strains in the laminate was calculated. From the analysis it was understood that the 0 and 90^o angle orientation of fibers arrangements have the same effect on the stiffness of the hybrid palm- sisal composite in which the values after analysis are the same and at the 45^0angle orientation at some points the values were 0 implies that stiffness is not strong as a result of which the material deflects due to applied load in service.

After stiffness analysis of the samples from theoretical point of view, mechanical test for flexural analysis was carried out using UTM which has highly integrated testing packages that can be configured to meet different testing needs like tension, compression, and flexural test. The tested specimens for flexural test are displayed in fig.10.

Fig.10. Specimen after flexural strength test

As seen in fig. 10 some of the specimens were sheared and broken. This may be due to the excessive applied load beyond the required value.

A mathematical modeling (fig.11) from UTM setup was used for quantitative analysis to determine flexural strength of the hybrid composite.

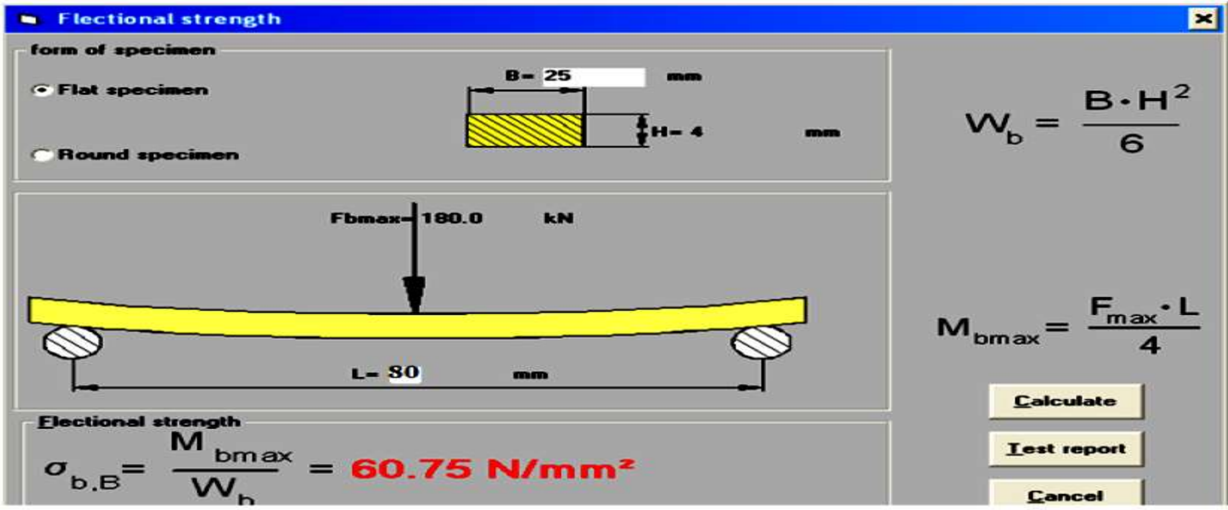


Fig.11. Mathematical modeling form of UTM flexural strength setup

In addition to flexural strength testing hardness of the samples was tested. The specimens were exposed to hardness test in order to determine the resistance to permanent deformation including indentation, wear, abrasion, scratch. Rockwell hardness testing with RHA scale was carried out in light of the fact that the Rockwell testing machine offers a quick and practical operation and can likewise minimize lapses emerging from the administrator. Fig.12. shows the 3D model of the specimen for hardness test.

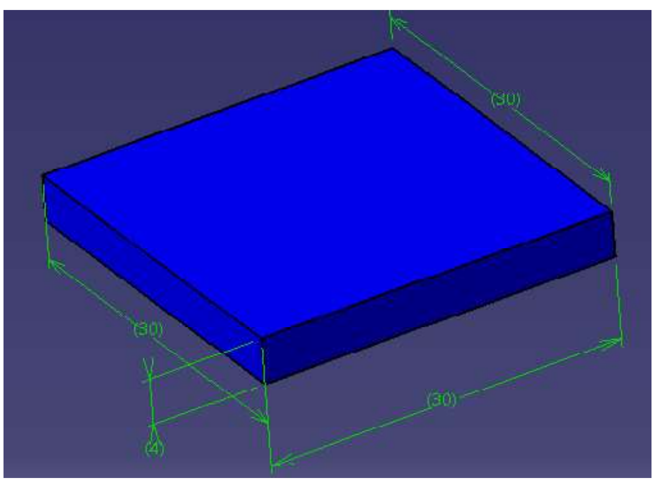


Fig.12. Dimension of hardness test specimen (all dimension in mm) by CATIA V5 according to ASTM D-785 [18]

IV. RESULT AND DISCUSSION

A. Flexural test result

In the three-point bend test to measure the flexural strength of the composites, the load applied at the middle point of the specimen was done at a speed of 0.5mm/min; the span length was 80mm (Fig.12.).The purpose of the test was to use the data obtained from the test to select elements that resist bending load without inflection.

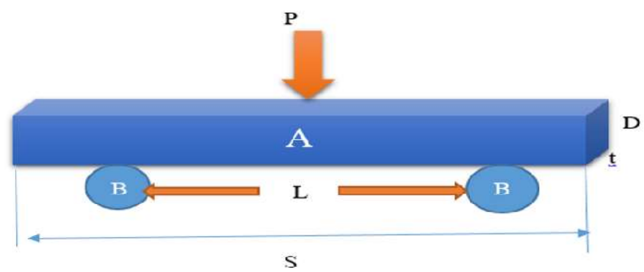


Fig.12. Three-point bending (flexural) test

P: load probe, A: specimen, D: depth of specimen, B: support, t: thickness L: support distance (span) and S: overall length of specimen

Under three-point bending when the load P is applied at mid-span of a rectangular specimen of span L between two rollers, the highest flexural strength is determined by:

$$\sigma bf = \frac{3LP}{2b*d^2} \quad (9)$$

The deflection of the specimen by considering specimens as a beam (Dc) from the center as illustrated in Fig.12 can be expressed as:

$$Ec = \frac{rL^2}{6d} \quad (10)$$

The maximum flexural strain ε_f also calculated from:

$$\varepsilon f = \frac{6*Ec*d}{L2} \quad (11)$$

The bending elastic modulus (E) is determined from the slope of the Load-deflection curve in a linear mathematically expressed as:

$$E = \frac{M*L^3}{4*(db*dd^3} \quad (12)$$

Where

σbf =E= calculated fracture stress (flexural strength), MPa ;

P = load at a given point on the load-deflection curve, N;

Ec = is the maximum deflection at the center of the specimen, mm ;

m = is the slope of the tangent to the straight-line portion of the load-deflection beam;

L = distance between support span of specimen, mm;

b = width of the specimen tested, mm;

d = t = depth of the specimen, mm;

r = strain, mm/mm.

σbf= is the maximum strength of the material and it is also given in MPa;

The flexural test results are presented in fig.13.

The value of elongation or deflection was 2% of the span length of the specimen. Due to that the span length of 80mm elongation was 0.02*80mm = 1.6 mm.

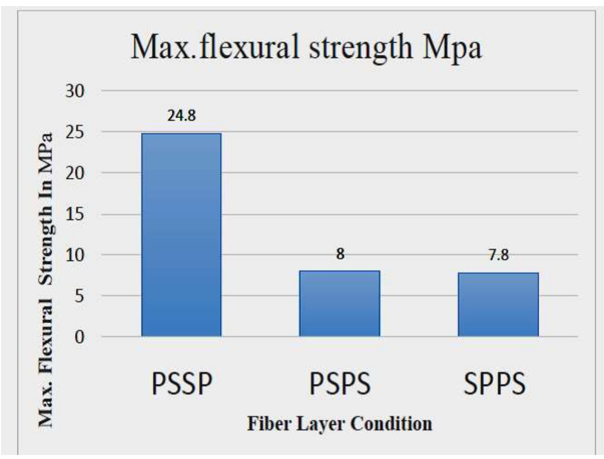


Fig.13. Flexural strength comparison between layers

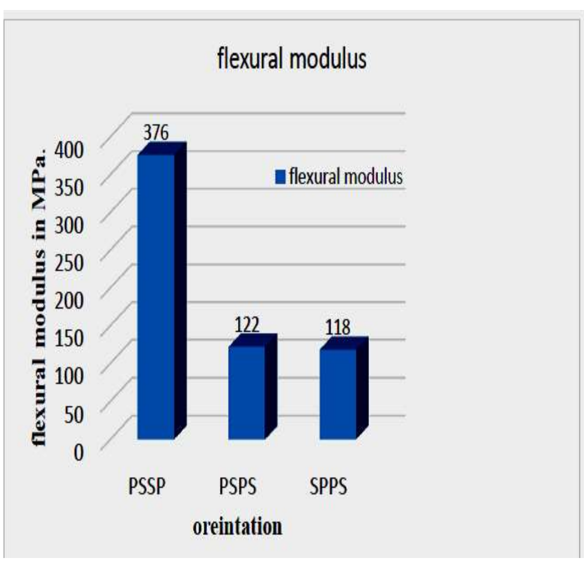


Fig.14. Flexural modulus comparison between layers

As seen in fig.13 and fig.14 the maximum flexural strength and flexural modulus of PSSP lamination layer was 24.8MPa and 376Mpa.respectively. But the PSPS and SPPS laminations have lower strength than PSSP. This was due to the low bonding strength and composition of the matrix. Besides this, the two laminates were obtained maximum elongation property. This was because of the long fiber alignment and lower matrix bonding structure. Lower strength of the composite also was due to the problem associated with the fabrication problem in that the fiber was slipped and affected compressibility and formation of bonding with matrix. This was also connected with the absence of vacuum chamber fabrication possibility. Untreated palm and sisal fibers

poor mixing property that was observed during fabrication was also evidence for lower strength of the two laminated hybrid composite samples. The untreated fibers contained some cellulose remnants which affect the mixing capability with the matrix as a result of which strength become low.

Fiber angle orientation effects were also tested to analyze the hardness and flexural strengths of the fabricated palm-sisal fiber hybrid composite. The samples were prepared based on SPSP arrangement in a 15%sisal-15%palm and 70% and other matrix weight ratio. The result is displayed in fig.15. Orientation of the angles were 0°-0° -0° -0°,0° -45° -0° -45° and 0° -90° -90° -90°.

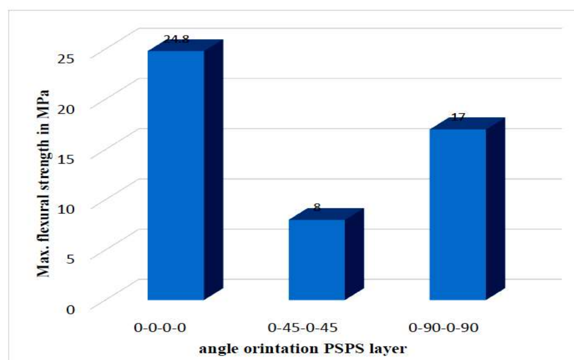


Fig. 15.Effect of angle orientation on flexural strength

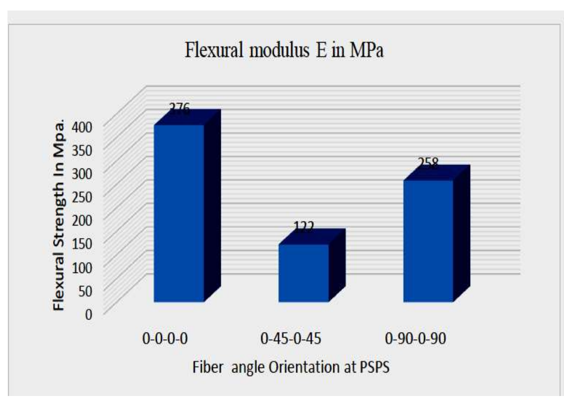


Fig. 16. Effect of fiber angle orientation on flexural modulus

As seen in fig.15 and fig.16 the 0° -0° -0° -0°, angle orientation provided higher flexural strength and flexural modulus than the other angular orientation arrangements. Very low flexural strength was observed at the 0° -45° -0° -45°.This is because the slippage of fibers at of cellulose in the untreated fiber could also influence on the binding and mixing capability of the fiber with epoxy. Alignment of 0° -0° -0° -0° orientation during fabrication was much lower than the other two angular arrangements. The 0° -4 ° -0° -45° orientation showed the lowest flexural strength and modulus implies that the fibers were not stable and the binder could not reach to all the parts and no equal distribution of compression force due to the hand layup method used for fabrication. As mentioned above the presence fibers in such arrangements could also be the cause for the degree of strength.

Test was also carried out to determine flexural strength and flexural modulus of the hybrid composite prepared from chopped randomly distributed palm-sisal fiber. The weight concentrations were 10S-10P-80E, 5P-20S-75E, 30P, 30S, and 60E. As observed in fig.17 and 18 the 5P-20S-75E weight concentration showed higher flexural strength and flexural modulus than the other two concentrations. This strength is property of the 0°-45° -45° -45° chopped angular orientation type composite which is evident for the effect of chopping fibers in improving the mechanical properties of composites.

Comparing to the strength obtained based on layer dependent and angular orientation factors, the strength obtained based on weight concentration in both variables is much better. The 5P-20S-75E weight concentration was provided much appreciable result than the other concentration implies that the lower the palm fiber and the lower the epoxy (matrix concentration) the better the strength than the rest. This is also the good indicator that the binder could distribute in a manner that all chopped sisals were wetted and mixed well, effect of surface area on the boding characteristics of epoxy(matrix) is better on chopped fibers than the longitudinal or layer by layer fiber arrangements ,where lower flexural strength and modulus was observed. Curing time of the chopped fibers after mixing with the epoxy was very fast which means economical. The flexural modulus is much higher than the other cases mentioned above indicates that composite materials fabricated in this condition has lower deflection problem in service.

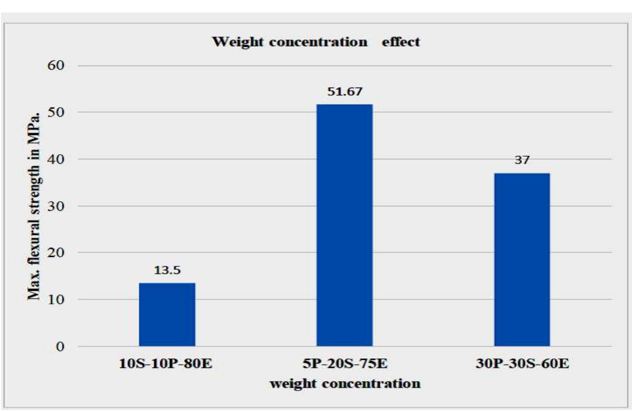


Fig.17. Effect of weight concentration of flexural strength

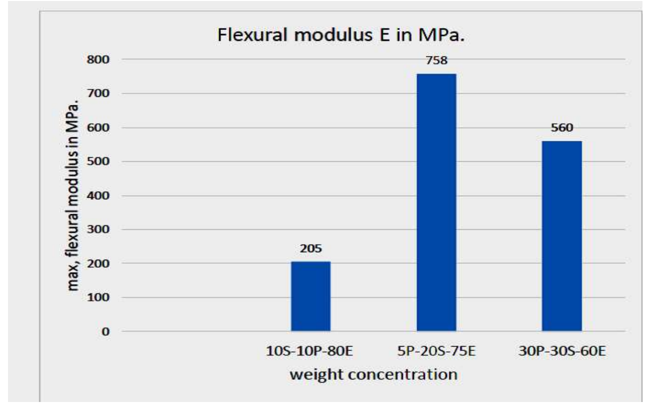


Fig. 18. Effect of weight concentration on flexural modulus

To improve the bonding capacity of fibers and to increase the flexural strength as well as flexural modulus of the fabricated composite fibers were treated by 6% and 10% NaOH solutions. The obtained maximum flexural strength and flexural modulus for chopped fibers treated by6% NaOH were 66 Mpa. and 1000Map respectively.

Fibers treated by 10NaOH solution showed lower result that maximum flexural strength was55 Mpa and flexural modulus was 836Mpa.The results are better than the untreated fiber composites. Her it is possible to underline that the cellulose content was removed and bonding property of fiber matrix was improved. However when the NaOH concentration increases the fibers could be dissolved and concentration of matrix increases which lead to reduce deflection resistant of the hybrid composite and it is also necessary to study which type of fiber was not resist the solution.

As mentioned above Rockwell (RHA) hardness test was conducted to determine the scratch sensitivity (hardness)of the fabricated palm-sisal fiber-epoxy matrix hybrid composite .The 10S-10P-80E, 5P-20S-75E, 30P, 30S, and 60E 6% solution treated chopped randomly oriented type total of 6 samples were tested and the total mean hardness number obtained was HRA110.344.This hardness was for 5P-20S-75E type sample which is the same material that has maximum flexural strength and flexural modulus. This confirms that such material developed in a way that has been developed in this particular research is better and can be used for the interior parts of automobile where compression stress and scratch are common loads applied to the parts in service.

Comparing to the previously developed hybrid composites like untreated sisal banana epoxy (61.1Map flexural strength [19], hybrid sisal banana polystyrene (57.85Mpa flexural strength and 2690 MPa flexural modulus [20]),the newly developed palm-sisal- epoxy from chopped randomly oriented 6% solution treated type hybrid composite is better in flexural strength and can be adapted to the real industrial application.

V. CONCLUSION

In this paper the flexural strength and hardness property analysis of hybrid palm-sisal- epoxy resin composite material was presented. Extraction and fabrication process of palm-sisal fiber reinforced epoxy resin hybrid composites with different percentage of fiber weight concentration, fiber layering orientation, angle arrangement under-treated and untreated fiber condition was developed using hand layup fabrication method. This was conducted based on the ASTM standard of D790 for flexural strength analysis and ASTM D-785 for hardness analysis.

From the experimental test results, it was observed that the hybrid palm-sisal fiber reinforced epoxy resin composite material has good mechanical properties. From the result it is possible to conclude that 6%NaOH solution treated types of fibers have better strength (66 Mpa and 1000Mapflexural strength and flexural modulus respectively) than the untreated fibers. More over chopped type randomly oriented fibers showed better quality including hardness of RHA=110.344.

In angular orientation system of production process the 0^o-0^o-0^o-0^o layer is better in strength, while in a chopped randomly oriented type the 0^o-45^o-45^o-45^o orientation is better in general mechanical properties because interlinked composite fibers increase rigidity and compression strength. This composite product can be used in simple automotive internal (roofing, floor and dash board) body parts.

REFERENCE

[1] N.R. And All, Natural Fiber For Green Technology In Automotive Industry*: A Brief Review IOP Conference Series,* 2018.

[2] K. Senthilkumar, N. Rajini, M. Chandrasekar, M. Jawaid, SuchartSiengchin, Mechanical Properties Evaluation of Sisal Fiber Reinforced Polymer Composites*: A Review. Construction And Building Materials,* 2018,pp 713–729.

[3] G.M. Arifuzzaman Khan, M. Terano, M.A. Gafur, M. ShamsulAlam, Studies on the Mechanical Properties of Woven jute fabric Reinforced Polymer(l-lactic acid) Composites. *Engineering Sciences,* 2016,pp. 69 –74.

[4] M. Sanjay, G. Arpitha, and B. Yogesha, Study on Mechanical Properties of Patural-Glass fibre Reinforced Polymer Hybrid Composites: *A review. Materials today: proceedings,*2(4-5):2015, pp.2959-2967.

[5] J. M Rajesha, N Rajini, Free Vibration Characteristics of Banana/Sisal Natural Fibers Reinforced Hybrid Polymer Composite Beam. *Procedia Engineering 144,* 2016, pp. 1055 – 1059.

[6] R.S. Soma Dalbehera, Industrial Design, Study on Mechanical Properties of Natural Fiber Reinforced Woven Jute-Glass Hybrid Epoxy Composites. *Advances in Polymer Science and Technology*, 2015: p. 1 -6.

[7] D.O.B. and all, *Effect* of Alkali Treatment on Mechanical Properties of Sisal Woven Fabric Reinforced Epoxy Composites.American Journal of Engineering Research (AJER), **6**(6): 2017, p. pp-93-96.

[8] H.S. SyafiqahNurAzrieSafri, Mohammad Jawaid, KandasamyJayakrishna, Impact behviour of hybrid compo sites for structural applications*: A review Composites Part B*, 2018. Part B 133: p. 112-121.

[9] M. AjithGopinath, Elayaperumal A, Experimental Investigations on Mechanical Properties of Jute Fiber Reinforced Composites With Polyester ond Epoxy Resin Matrices. *Procedia Engineering*,97: 2014, p. 2052 – 2063.

[10] D. S.Yazhini, Studies on Bond And Flexural Strength of Sisal Fibre Rope Reinforced Concrete. IJESC, .**8**(3):2018.

[11] K. Srivastava, Properties Of Sisal Fibre Reinforced Epoxy Composite. Indian Journal of Fibre& Textile Research, 41: 2016, pp. 235-241.

[12] M.A. MohamHamdyGheith, WaheedullahGhori ,Naheed Saba, Flexural, Thermal and Dynamic Mechanical Properties of Date Palm Fibres Reinforced Epoxy Composites.journal of material research tectnology, 1: 2019. Pp. 853–860.

[13] E.R. Pradeep P, Suthan R. and Jayakumar V, Characterization of Palm Fibers For Reinforcement In Polymer Matrix,vol.11(12), 2016: pp. 1819-6608.

[14] P.C. Saha, N. Modak, Three Point Bending Test Of Fibre Reinforced Particulate Composites.**7**(4): 2016.pp. 2229-5518.

[15] M.H. Tao Yang, XuejuanNiu and Yu Du, Experimental Investigation of The Three-PointBending Fatigue Properties of Carbon Fiber Composite Iaminates. *AMS*1(1): 2016.

[16] M. Berthelot, Mechanics of Composite Material and Structures, 2015.

[17] J.M. Berthelote, Mechanics of Composite Material and Structures, 2017.

[18] R.N. ChandanChawan, Analysis of Impact & Hardness Behavior and Comparison Study of Sisal and Jute Hybrid Composite,IJSRD3(07): 2015pp. 2321-0613.

[19] G.M. Sivakandhan, N. Tamiloli, L. Ravikumar, Studies on Mechanical Properties of Sisal and Jute Fiber Hybrid Sandwich Composite Materials Today,10 : 2019.

[20] D.T.R. KotreshSardar, Shivakumar, Fabrication and Investigation of Bending Test on Hybrid (Sisal and Banana) Fiber Reinforced Polyester Composite Material3(6):2014.