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Fabrication and Testing of Reinforced Natural Fiber

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Abstract: In recent decade, bio composite materials are synthesized using natural cellulose fibers as reinforcements together with matrix, which have attracted the attention of researchers due to their low density with high specific mechanical strengths, availability, renewability, degradable and being environmental-friendly. The present work attempts to make an improvement in the current existing methodology and materials used to have better mechanical properties as well as to enhance the compatibility between fibers and the matrix using the required resin and hardener. The bio-composites are prepared with the unsaturated polyester matrix (laminate) and fibers such as dry grass, cow hair, coconut coir and nano compositions of copper oxide using wet hand lay-up method with appropriate proportions to result in fiber structure. Mechanical properties such as tensile strength, impact strength and hardness are calculated for the fabricated fiber samples.
Keywords: Fiber, Reinforcements, Resin, Nano-Composites, Bio-Composites.

I. INTRODUCTION

Over the last thirty years composite materials, plastics and ceramics have been the dominant emerging materials. The volume and number of applications of composite materials have grown steadily, penetrating and conquering new markets relentlessly. Modern composite materials constitute a significant proportion of the engineered materials market ranging from everyday products to sophisticated niche applications. While composites have already proven their worth as weight-saving materials, the current challenge is to make them cost effective. The efforts to produce economically attractive composite components have resulted in several innovative manufacturing techniques currently being used in the composites industry. It is obvious, especially for composites, that the improvement in manufacturing technology alone is not enough to overcome the cost hurdle. It is essential that there be an integrated effort in design, material, process, tooling, quality assurance, manufacturing, and even program management for composites to become competitive with metals.

The composites industry has begun to recognize that the commercial applications of composites promise to offer much larger business opportunities than the aerospace sector due to the sheer size of transportation industry. Thus the shift of composite applications from aircraft to other commercial uses has become prominent in recent years. Increasingly enabled by the introduction of newer polymer resin matrix materials and high performance reinforcement fibers of glass, carbon and aramid, the penetration of these advanced materials has witnessed a steady expansion in uses and volume. The increased volume has resulted in an expected reduction in costs. High performance FRP can now be found in such diverse applications as composite armoring designed to resist explosive impacts, fuel cylinders for natural gas vehicles, windmill blades, industrial drive shafts, support beams of highway bridges and even paper making rollers. For certain applications, the use of composites rather than metals has in fact resulted in savings of both cost and weight. Some examples are cascades for engines, curved fairing and fillets, replacements for welded metallic parts, cylinders, tubes, ducts, blade containment bands etc. Further, the need of composite for lighter construction material and more seismic resistant structures has placed high emphasis on the use of new and advanced materials that not only decreases dead weight but also absorbs the shock & vibration through tailored microstructures. Composites are now extensively being used for rehabilitation/ strengthening of pre-existing structures that have to be retrofitted to make them seismic resistant, or to repair damage caused by seismic activity. Unlike conventional materials (e.g., steel), the properties of the composite material can be designed considering the structural aspects. The most widely used meaning is the following one, which has been stated by Jartiz "Composites are multifunctional material systems that provide characteristics not Obtainable from any discrete material. They are cohesive structures made by physically combining two or more compatible materials, different in composition and characteristics and sometimes in form".

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The weakness of this definition resided in the fact that it allows one to classify among the composites any mixture of materials without indicating either its specificity or the laws which should given it which distinguishes it from other very banal, meaningless mixtures.
For the sake of simplicity, however, composites can be grouped into categories based on the nature of the matrix each type possesses. Methods of fabrication also vary according to physical and chemical properties of the matrices and reinforcing fibers

A. Metal Matrix Composites (MMCs)

Metal matrix composites, as the name implies, have a metal matrix. Examples of matrices in such composites include aluminum, magnesium and titanium. The typical fiber includes carbon and silicon carbide. Metals are mainly reinforced to suit the needs of design. For example, the elastic stiffness and strength of metals can be increased, while large co-efficient of thermal expansion, and thermal and electrical conductivities of metals can be reduced by the addition of fibers such as silicon carbide.

B. Ceramic Matrix Composites (CMCs)

Ceramic matrix composites have ceramic matrix such as alumina, calcium, alumina silicate reinforced by silicon carbide. The advantages of CMC include high strength, hardness, high service temperature limits for ceramics, chemical inertness and low density. Naturally resistant to high temperature, ceramic materials have a tendency to become brittle and to fracture. Composites successfully made with ceramic matrices are reinforced with silicon carbide fibers. These composites offer the same high temperature tolerance of super alloys but without such a high density. The brittle nature of ceramics makes composite fabrication difficult. Usually most CMC production procedures involve starting materials in powder form. There are four classes of ceramics matrices: glass (easy to fabricate because of low softening temperatures, include borosilicate and alumina silicates), conventional ceramics (silicon carbide, silicon nitride, aluminum oxide and zirconium oxide are fully crystalline), cement and concreted carbon components.

C. Polymer Matrix Composites (PMC)

Most commonly used matrix materials are polymeric. The reasons for this are two-fold. In general the mechanical properties of polymers are inadequate for many structural purposes. In particular their strength and stiffness are low compared to metals and ceramics. These difficulties are overcome by reinforcing other materials with polymers. Secondly the processing of polymer matrix composites need not involve high pressure and does not require high temperature. Also equipments required for manufacturing polymer matrix composites are simpler. For this reason polymer composites developed rapidly and soon became popular for structural applications. Polymer composites are used because overall properties of the composites are superior to those of the individual polymers. They have a greater elastic modulus than the neat polymer but are not as brittle as ceramics. Polymeric matrix composites are composed of a matrix from thermo set (unsaturated polyester, epoxy or thermoplastic polycarbonate, polyvinylchloride, nylon, polystyrene and embedded glass, carbon, steel or Kevlar fibers (dispersed phase). The potential applications of polymer composites include consumer goods (sewing machines, doors, bathtubs, tables, chairs, computers, printers, etc), sporting goods industry (golf shafts, tennis rackets, snow skis, fishing rods, etc.), aerospace industry (doors, horizontal and vertical stabilizers, wing skins, fin boxes, flaps, and various other structural components), marine applications (passenger ferries, power boats, buoys, etc.), automotive industry (bumper beam, seat/load floor, hood radiator support, roof panel and land transport systems like cars, trucks and bus bodies, railway coach components, containers and two and three wheelers), construction and civil structures (bridges, columns doors, windows and partitions and for translucent roofing sheets, prefabricated modular houses and buildings etc.), industrial applications

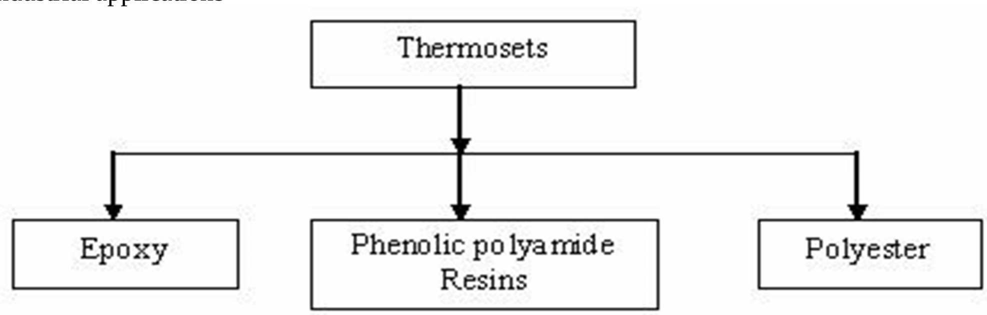

Fig1: Thermo-set resin

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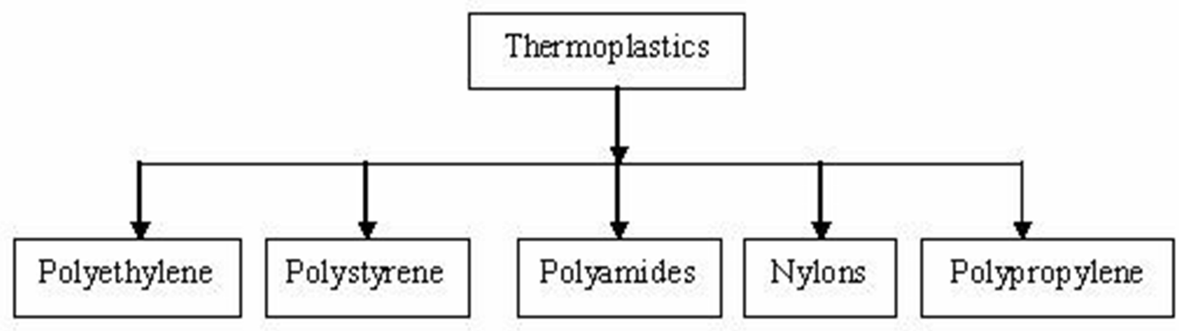

Fig2: Thermo-plastic resin

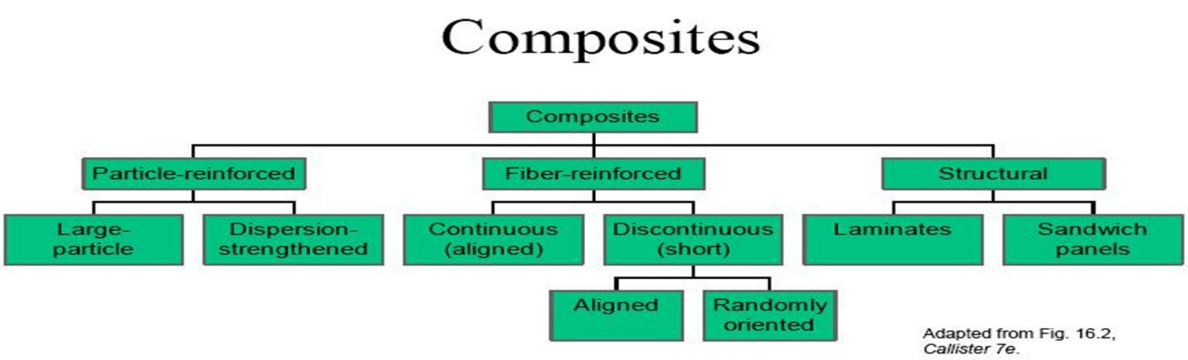

Fig3: Reinforced Based Composites

Resin is a viscous hydrocarbon secretion of many plants, particularly coniferous trees. Hardener is a curing agent for epoxy or fiberglass. Epoxy resin requires a hardener to initiate curing; it is also called as catalyst, the substance that hardens the adhesive when mixed with resin. It is the specific selection and combination of the epoxy and hardener components that determines the final characteristics and suitability of the epoxy coating for given environment.

Fig4: Epoxy resin(LY-556) Fig5: Hardener (HY-951)

Glass mate is a low modulus, neutral cure silicone sealant suitable for interior fixing of mirrors, coated glass or metal panels. A ready to use, one-part silicone sealant which is non-corrosive and odorless. Glass mate has excellent unprimed adhesion on most mirror coatings and has outstanding resistance to heat and humidity. It’s properties are unaffected by sunlight, ultra-violet radiation and temperature extremes.

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Fig6: Glass mate (310)

Fig7: Animal Hair

Table1: Properties of natural fiber

Plant Fibers	Density (Kg/m^3)	Tensile Strength (MPa)	Young's Modulus (GPa)
Jute Fiber	1300-1500	200-450	20-55
Sisal Fiber	1300-1500	80-840	9-22
Coconut Coir	1150-1250	106-175	6-8
Areca Nut	1050-1150	300-530	30-60

Animal fiber generally comprise proteins; examples mohair, wool, silk, alpaca, angora. Animal hair (wool or hair) are the fibers taken from animals or hairy mammals. E.g. Sheep's wool, goat hair (cashmere, mohair), cow hair, horse hair, etc. Silk fiber are the fibers collected from dried saliva of bugs or insects during the preparation of cocoons. Examples include silk from silk worms. Avian fibers are the fibers from birds, e.g. feathers and feather fiber. Nano materials are chemical substance or materials that are manufactured and used at a very small scale. Material with any external dimensions in the nanoscale.Nano materials are developed to exhibit novel characteristics compared to the same material without nanoscale features, such are increased strength, chemical reactivity or conductivity. In this work nano-material of copper oxide has been used as one of the filler material.

Fig8: Nano composition of Copper Oxide

These fibers have higher tensile strength than other fibers. Therefore, these fibers are used for durable yarn, fabric, packaging, and paper. Some examples are flax, jute, banana, hemp, and soybean. Fruit fibers are the fibers are collected from the fruit of the plant, e.g. coconut (coir) fiber.

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Fig9: Dry grass and coconut coir

II. LITERATURE REVIEW

M.Ananda Rao[1] says that the main objective of this paper is fabrication and analysis of mechanical properties of FRP composites, comparison of mechanical properties of Kevlar fiber mild steel. A Test piece with Kevlar fibers & Epoxy resin LY-556 are fabricated and various mechanical testing is done on both the test pieces and the results have to be compared. The fabrication is done using the dimensions according to the ASTM standard. The test pieces are tested using Universal Testing Machine. The main purpose of the paper is to determine the best FRP composite from the two test pieces by comparing the tensile strength, flexural strength and impact strength and compressive strength.

A.Kishore[2] studied about Epoxy (LY-556/HY-951) system filled with modified clay (MC) was synthesized by using mechanical shear mixing with the addition of hardener as tri-ethylene-tetra-amine (TETA). The effect of the fumed silica can be negated by the application of a shear force (e.g. mixing, brushing, spraying etc), allowing the liquid to flow, level out and permit the escape of entrapped air. The reinforcement effects of MC in the epoxy polymer on thermal, mechanical and vibration properties were studied. Curing study shows that the addition MC does not show any effect in the curing behavior of epoxy polymer. Thermo-gravimetry analysis (TGA) shows enhanced thermal stability for epoxy with MC fillers. The epoxy with MC fillers shows considerable improvement on tensile and impact properties over pure epoxy polymer. SEM studies shows that addition of clay significantly turns the epoxy system from brittle to ductile nature was played instrumental in scaling performance. The improvement in tensile and impact properties of nano-composites is supported with the fracture surface studies. Epoxy with MC fillers shows enhanced vibration characteristics than that of the pure epoxy polymer. FTIR studies indicated the formation of C-H bonds on the surface of the nano-composites.

Yan Li[3] presents a summary of recent developments of sisal fiber and its composites. The properties of sisal fiber itself interface between sisal fiber and matrix, properties of sisal fiber-reinforced composites and their hybrid composites have been reviewed. Suggestions for future work are also given. In the review they describe in detail about the properties of sisal fiber, Interface properties between sisal fiber and matrix; Properties of sisal-fiber-reinforced composites; Sisal/glass-fiber-reinforced hybrid composites; Price; Interface modifications; Treatment of sisal fiber; Alkali treatment; Iso-cyanate treatment; Peroxide treatment; Permanganate treatment; surface Treatment of fiber/matrix interfaces; Sisal/polyester composites; Sisal/epoxy composites; Sisal/phenol formaldehyde composites; Sisal/polyethylene composites; Sisal-fiber-reinforced thermo set matrices; Sisal-fiber-reinforced thermoplastics matrices; Processing methods; Properties of sisal fiber reinforced polyethylene; Properties of sisal fiber-reinforced polystyrene matrices; Properties of sisal-fiber-reinforced PVC composite; Sisal-fiber-reinforced rubber matrix; Sisal-fiber-reinforced gypsum and cement matrices; Sisal and synthetic hybrid-fiber composites; and they evaluate the Dynamic mechanical properties. The Electrical properties and Ageing properties, finally they conclude that different matrix systems have different properties. The mechanical and physical properties of sisal-fiber-reinforced composites are very sensitive to processing methods, fiber length, fiber orientation and fiber-volume fraction. Sisal and glass fiber can be combined to produce hybrid composites which take full advantage of the best properties of the constituents; almost all the mechanical properties have show positive hybrid effects.

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K. Murali Mohan Rao[4] aims at introducing new natural fibers used as fillers in a polymeric matrix enabling production of economical and lightweight composites for load carrying structures. An investigation of the extraction procedures of vakka (Roystonea regain), date and bamboo fibers has been undertaken. The cross-sectional shape, the density and tensile properties of these fibers, along with established fibers like sisal, banana, coconut and palm are determined experimentally under similar conditions and compared. The fibers introduced in the present study could be used as an effective reinforcement for making composites, which have an added advantage of being lightweight.

III. METHOD AND EXPERIMENTATION:

A. Fabrication Process

1) *Step 1: Selection of matrix material:* Epoxy LY-556 resin belonging to the Epoxide family was taken as the matrix. HY 951 was used as the hardener.
2) *Step 2: Selection of reinforcement and Natural fibers:* Natural fibers such as dry grass, cow hair, coconut coir and copper oxide were taken to fill as reinforcements in the Polymer composite
3) *Step 3: Selection of glass mate:* Glass mate 310 material is used it is easy to fabricate. It can absorb hardener and resin easily
4) *Step 4: Mixing process:* Take the glass mate and cut it with certain dimensions and then calculate the weight of glass mate then take resin double of the glass mate weight and take hardener $1/3^{rd}$ of hardener weight and then take filler materials 1% of all these weights then mix the filler material in the resin then arrange the base sheet, hardener, glass mate at one place and then start the fabrication process.
5) *Fabrication Processes of Composite Material:* Manufacturing of a composite material is to combine the polymeric resin system with the fiber reinforcement. Since the orientation of the fibers is critical to the end properties of the composite, manufacturing process is utmost important to align the fibers in desired direction. A good manufacturing process will produce a higher, uniform fiber volume fraction along with a higher production of a large volume of parts economically and have repeatable dimensional tolerances. The composite manufacturing techniques can be classified into two categories:

B. Open Mould Process

1) Hand lay-up process
2) Spray up process
3) Vacuum-bag auto clave process
4) Filament winding process

C. Closed Mould Process

1) Compression moulding
2) Injection moulding
3) Sheet moulding compound (SMC) process
4) Continuous pultrusion process

Hand lay-up technique is the simplest method of composite processing. The infrastructural requirement for this method is also minimal. The processing steps are quite simple. First of all, a release gel is sprayed on the mold surface to avoid the sticking of polymer to the surface. Thin plastic sheets are used at the top and bottom of the mold plate to get good surface finish of the product. Reinforcement in the form of woven mats or chopped strand mats are cut as per the mold size and placed at the surface of mold after Perspex sheet. Then thermosetting polymer in liquid form is mixed thoroughly in suitable proportion with a prescribed hardener (curing agent) and poured onto the surface of mat already placed in the mold.

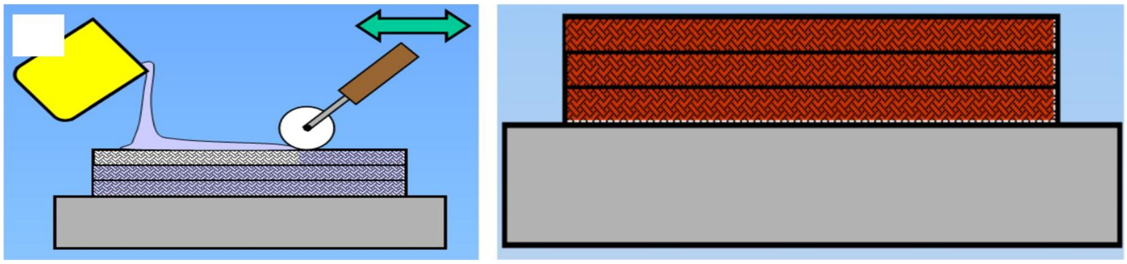

Fig10: Schematic Diagram of hand lay-up process and Orientation of fiber layers

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The polymer is uniformly spread with the help of brush. Second layer of mat is then placed on the polymer surface and a roller is moved with a mild pressure on the mat-polymer layer to remove any air trapped as well as the excess polymer present. The process is repeated for each layer of polymer and mat, till the required layers are stacked. After placing the plastic sheet, release gel is sprayed on the inner surface of the top mold plate which is then kept on the stacked layers and the pressure is applied. After curing either at room temperature or at some specific temperature, mold is opened and the developed composite part is taken out and further processed. The schematic of hand lay-up is shown in figure 1. The time of curing depends on type of polymer used for composite processing. For example, for epoxy based system, normal curing time at room temperature is 24-48 hours. This method is mainly suitable for thermosetting polymer based composites. Capital and infrastructural requirements less as compared to other methods. Production rate is less and high volume fraction of reinforcement is difficult to achieve in the processed composites. Hand lay-up method finds application in many areas like aircraft components, automotive parts, boat hulls, diase board, deck etc.

Fig11: Sample preparation by wet hand lay-up process

Fig12: prepared sample piece

D. Testing:

1) *Hardness test:* Hardness is the property of a material that enables it to resist plastic deformation, usually by penetration. However, the term hardness may also refer to resistance to bending, scratching, abrasion or cutting. Hardness is not an intrinsic material property dictated by precise definitions in terms of fundamental units of mass, length and time.

A hardness property value is the result of a defined measurement procedure. Hardness of materials has probably long been assessed by resistance to scratching or cutting. An example would be material B scratches material C, but not material A. Alternatively, material A scratches material B slightly and scratches material C heavily. Relative hardness of minerals can be

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assessed by reference to the Mohs Scale that ranks the ability of materials to resist scratching by another material. Similar methods of relative hardness assessment are still commonly used today. An example is the file test where a file tempered to a desired hardness is rubbed on the test material surface. If the file slides without biting or marking the surface, the test material would be considered harder than the file. If the file bites or marks the surface, the test material would be considered softer than file.

The above relative hardness tests are limited in practical use and do not provide accurate numeric data or scales particularly for modern day metals and materials. The usual method to achieve a hardness value is to measure the depth or area of an indentation left by an indenter of a specific shape, with a specific force applied for a specific time. There are three principal standard test methods for expressing the relationship between hardness and the size of the impression, these being Brinell, Vickers, and Rockwell. For practical and calibration reasons, each of these methods is divided into a range of scales, defined by a combination of applied load and indenter geometry.

E. Hardness Testing Methods

1) Hardness Testing
2) Rockwell Hardness Test
3) Rockwell Superficial Hardness Test
4) Brinell Hardness Test
5) Vickers Hardness Test
6) Micro-hardness Test
7) Mohs Hardness Test
8) Sclero-scope and other hardness testing methods

: A tensile specimen is standardized sample cross section. It as to shoulders and a gauge in between. The shoulders are large so they can be readily gripped, whereas the gauge section as a smaller cross section so that the deformation and failure can occur in this area A standard specimen is prepared in a round or a square section along the gauge length, Depending on the standard used. Both ends of the specimens should have sufficient length and surface condition such that are firmly gripped should have sufficient length and a surface condition such that are gripped during testing.

Fig13: specimens before testing

F. Equipment

he most common testing machine used in tensile testing is the universal testing machine .this type of machine has two crossheads; one is adjusted for the length of the length of the specimen and the other is driven to apply tension to the test specimen. the machine must have the proper capabilities for the test specimen being tested .There are main four parameters :force capacity ,speed precion and accuracy ,force capacity refers to the capacity refers to the capacity refers to the fact that machine must be able to generate enough force to fracture the specimen .

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Fig14: Universal Testing Machine

Alignment of the test specimen in the testing machine is critical because if the specimen is misaligned, either with an angle or offset to one side,the machine will exert a bending force on the specimen .the specimen. This is especially bad for brittle materials because it will dramatically skew the results.

G. Process

he test process involves placing the test specimen in testing machine and slowly extending it until it fractures. During this process, the elongation of the gauge section is recorded against the applied force. The elongation measurement is used to calculate the engineering strains. in order to study the plastic flow of materials, it is necessary to understand the concepts of true stress and true strain. in tensile test , during the test progresses, one region of the specimen begins to deform much quicker than the rest in order to calculate the stress there are two possibilities the original area or the actual area of the specimen at any instant of the load. when the stress is calculated on the basis of the original area, it is called the engineering or normal stress and if the original length is used to calculate the strain, then it is called the engineering strain

Nominal stress=P/A_0

Nominal strain=$(L-L_0)/L_0$

Where L is the length of the original gauge length under force P, and L_0 is the original gauge. If the stress and strain are calculated based on the instantaneous area and length at any instant of load, then it is the true stress and true strain.

Table 2: Parameters after testing

Parameter	Dry grass	Cow hair	Coconut coir	Copper oxide
Final gauge length(mm)	308	302	306	306
% elongation	8.0	2.0	6.0	6.0
Tensile load(KN)	25.11	29.04	21.76	24.29
Tensile strength(N/mm^2)	209.33	242.0	181.37	202.42

IV. RESULTS AND DISSUCUTION

In our work four samples composite fiber using four different filler materials are prepared using wet hand overlay method. The four filler materials namely coconut coir, dry grass, cow hair and powdered copper oxide in nano form. The main motto of this work is to determine the material properties of the reinforced fiber using natural and synthetic filler materials. These samples are subjected to different testing's such as Hardness, Impact test and Tensile test. Results were noted and tabulated. The results for the samples against Hardness are as follows:

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Table3: Results of hardness test

MATERIAL	LOAD		
	60N	100N	150N
Dry grass	57	54	54.5
Cow hair	78.5	78	78.1
Coconut coir	80	80.2	81
Copper Oxide	53.1	50.5	50

The results for the samples against Impact Test are as follows:

Table4: Results of Impact testing

MATERIAL	NO.OF DIVISIONS	IMAPCT STRENGTH IN JOULES
Dry grass	38	76J
Cow hair	37	74J
Coconut coir	38	76J
Copper oxide	37	74J

The results for Engineering stresses and strains as well as for True stresses and strains are calculated and stress strain curves for the corresponding values are also drawn.

Table5: Engineering Stresses and Engineering Strains

Dry grass		Cow hair		Coconut coir		Copper Oxide	
Stress	Strain	Stress	Strain	Stress	Strain	Stress	Strain
200	0.26	230.11	0.2	170.22	0.18	190.45	0.21
192.22	0.2	222.25	0.15	161.25	0.12	184.25	0.19
186.36	0.19	218.12	0.1	152.26	0.09	176.34	0.13
172.52	0.14	205.66	0.08	144.56	0.06	169.23	0.07

Table6: True Stresses and True Strain

Dry grass		Cow hair		Coconut coir		Copper Oxide	
Stress	Strain	Stress	Strain	Stress	Strain	Stress	Strain
209.33	0.6612	242.0	0.9685	181.37	1.0	202.42	0.9723
198.25	0.6011	233.15	0.8565	170.25	0.9121	191.02	0.8835
185.21	0.5125	226.22	0.7053	161.28	0.8535	184.52	0.7124
176.23	0.4522	215.55	0.6222	155.33	0.7847	172.03	0.6621

We can have a look at the specimens after they are subjected to tensile testing.

Fig15: Dry grass specimen


Fig16: Coconut coir specimen

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Fig17: cow hair specimen

Fig18: copper oxide specimen

V. CONCLUSIONS AND FUTURE SCOPE

In this work four samples of composite fiber with three natural filler materials and one synthetic filler material are prepared and are tested for Hardness, Impact and Tensile resistance. It has been noted that the tensile strength is recorded a higher value for the sample in which the filler material is cow hair (animal fiber) which is valued at 242.9 N/mm^2 . The sample with coconut coir has recorded a higher value when compared to the other specimens whereas the resistance to impact i.e., resistance to withstand shock loading is quite similar for all the samples. It has also been noted there is very less effect of the synthetic nano composition of Copper oxide as a filler material which didn't show good results compared to the other composites with natural fibers as filler material. It has been observed that the tensile strength for the sample with coconut coir is better than many plastic composites like PVC which has a tensile strength of 50Mpa. With further more investigations and testing's initiatives can be made to replace PVC with these composites made of natural fibers instead of using complete plastic.

In the future extension of this work computer models can be prepared and simulation can be done and those results can be compared with that of the practical values. Tests corresponding to thermal conductivity can also be studied. In an advance state the filler material instead of pieces can be made to form a matrix layer and can be placed as layers which could increase the strength much more.

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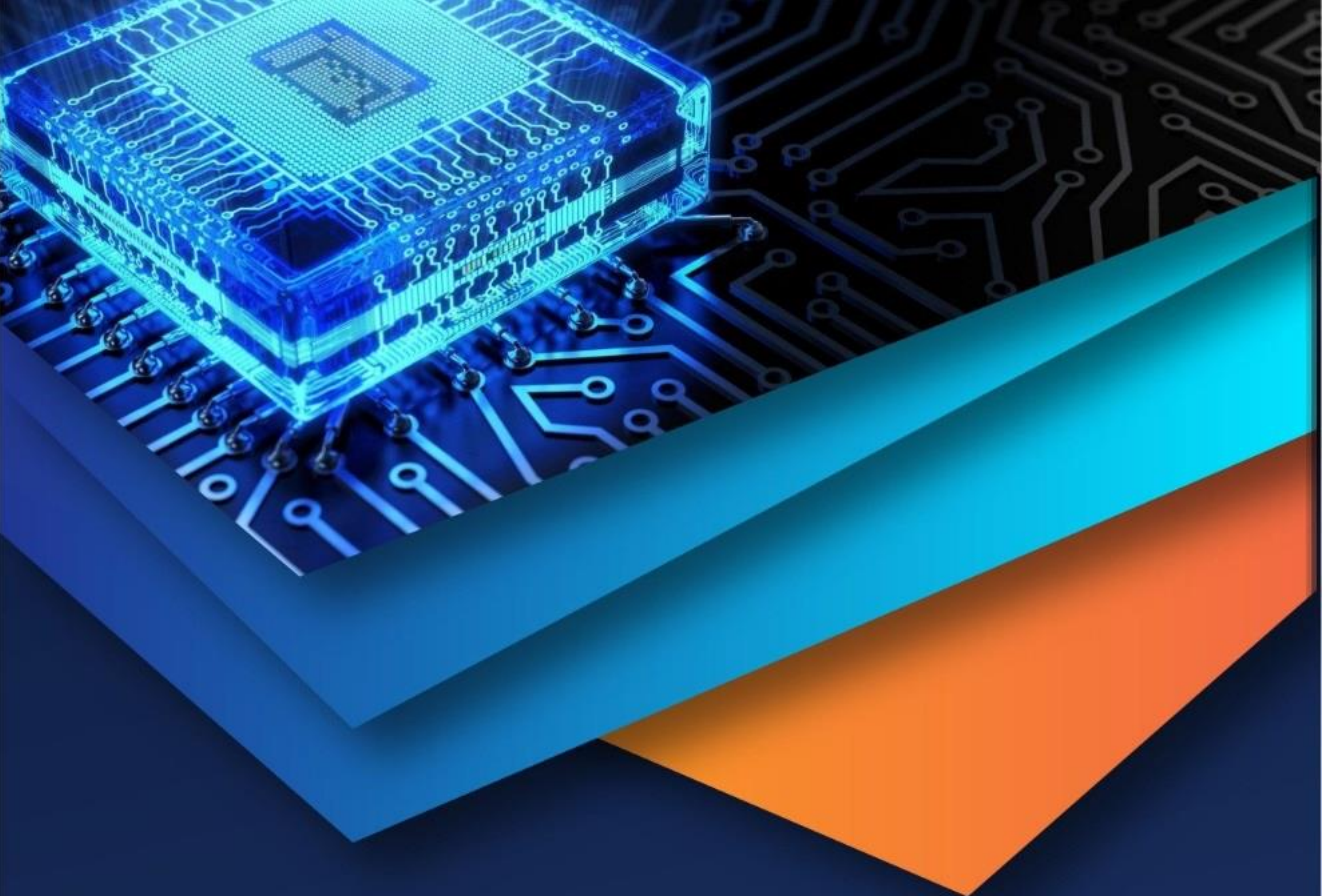

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