DEVELOPMENT OF HYBRID COMPOSITE AND INVESTIGATE THE EFFECT OF ENVIRONMENTAL CONDITIONS AND VOLUME FRACTION ON ITS MECHANICAL PROPERTIES

DISSERTATION-II

Submitted in partial fulfillment of the requirement for the award of degree

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By

AKSHAY THAKUR

(11506884)

Under the guidance of

MR.VIVEK SHEEL RAJPUT

(17842)

DEPARTMENT OF MECHANICAL ENGINEERING
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Supervisor Name : Vivek Sheel Rajput **UID :** 17842 **Designation :** Assistant Professor

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SR.NO.	NAME OF STUDENT	REGISTRATION NO	BATCH	SECTION	CONTACT NUMBER
1	Akshay Thakur	11506884	2015	M1572	7837486168

SPECIALIZATION AREA : CAD/CAM & Mechatronics **Supervisor Signature:** ___________________

PROPOSED TOPIC : FABRICATION OF A HYBRID COMPOSITE WITH CHARACTERIZATION OF ITS MECHANICAL PROPERTIES UNDER MOISTURE FOR DIFFERENT VOLUME FRACTION.

Qualitative Assessment of Proposed Topic by PAC		
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2	Project Feasibility: Project can be timely carried out in-house with low-cost and available resources in the University by the students.	7.00
3	Project Academic Inputs: Project topic is relevant and makes extensive use of academic inputs in UG program and serves as a culminating effort for core study area of the degree program.	7.40
4	Project Supervision: Project supervisor's is technically competent to guide students, resolve any issues, and impart necessary skills.	7.80
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PAC Committee Members		
PAC Member 1 Name: Jaiinder Preet Singh	UID: 14740	Recommended (Y/N): Yes
PAC Member 2 Name: Piyush Gulati	UID: 14775	Recommended (Y/N): Yes
PAC Member 3 Name: Dr. Manpreet Singh	UID: 20360	Recommended (Y/N): Yes
DRD Nominee Name: Dr. Amit Bansal	UID: 18697	Recommended (Y/N): Yes
DAA Nominee Name: Kamal Hassan	UID: 17469	Recommended (Y/N): Yes

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PAC CHAIRPERSON Name: 12174::Gurpreet Singh Phull **Approval Date:** 03 Oct 2016

ABSTRACT

From the past decade there has been a prominent growth in the field of composite materials giving good mechanical properties but accumulation of its waste and incapability to recycle or dispose composites based on synthetic fibers has increased environmental consciousness. This brings the need to develop and investigate composite materials based upon natural fibers because of their different attributes like low density, low cost, light weight, environment friendly, recyclability and biodegradability. Further mechanical properties of the materials can be enhanced by hybridizing different fibers within the matrix in which one fiber balance the deficiency of other fibers. As mechanical properties of composite materials are greatly influenced by fiber orientation and fiber volume fraction, this present study focuses on the development of hybrid composites and investigates the effect of fiber volume fraction and fiber orientations on the mechanical properties of the composites. Six different samples with different volume fraction, different fiber orientation and different fiber mixture were prepared using simple hand layup technique. Further water absorption behavior of developed composites was observed in order to identify weight gain percentages. It has been observed that fiber orientation and fiber volume fraction substantially influenced the mechanical properties of the fiber reinforced composites as tensile behavior shows that strength increases with increase in volume fraction and hybridization of jute-sisal fiber in epoxy based composites. Finally, a discussion on the mechanical properties obtained from experimental results is given along with identification of areas for extending the present research in the field of natural fiber reinforced hybrid composites.

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CERTIFICATE

I hereby certify that the work being presented in the dissertation entitled "**Development of Hybrid Composite and Investigate the effect of Environmental conditions and Volume Fraction on its Mechanical Properties**" in partial fulfillment of the requirement of the award of the Degree of master of technology and submitted to the Department of Mechanical Engineering of Lovely Professional University, Phagwara, is an authentic record of my own work carried out under the supervision of **Mr. Vivek Sheel Rajput, Assistant Professor,** Department of Mechanical Engineering, Lovely Professional University. The matter embodied in this dissertation has not been submitted in part or full to any other University or Institute for the award of any degree.

(Date)

Akshay Thakur

11506884

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

(Date)

Mr. Vivek Sheel Rajput

17842

HOD (ME)

___________The external viva-voce examination of the student was held on successfully

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Signature of Examiner

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLE

Table **Page No**

CHAPTER 1

1 INTRODUCTION

Composite materials are defined as combination of two or more different materials combined at macroscopic level with different physical and chemical properties. The composite made from two different constituents produce different properties from individual components. It is homogeneous at microscopic scale and heterogeneous at macroscopic scale.

In around 10000 B.C, the composites were present in the form of straw brick which were used as construction material. Then in around 4000 B.C; laminated composites were made from papyrus plant which was used for making writing material. Later in 1200 B.C, mangolas developed the modern composite bow. The bows were made using cattle tendons, wood and silk. The horn and antles were used to make the main body of bow because these materials are very flexible. The string of bow was made from tendon, horse hair and silk. The bows were so strong that one could shoot around 1.5km away.

Modern composite came into existence during second world war because the fighter planes were in very high demands and they were required to be light weighted yet strong also. The use of radar technology led to the development of glass fiber reinforced plastics which were used as a housing material for radar.

The best benefit associated with composite materials is that they generally show good quality of the individual components. In comparison to traditional materials composite materials are preferred for having good fatigue life, high energy dissipation, good resistance to corrosion and being less expensive [1]. Composites possess very high strength to density ratio and stiffness to density ratio. Some examples of composites are:-

1) Cement and gravel which are combined together to form concrete.
2) Bone is a composite material containing collagen fiber and hydroxyl apatite.
3) Wood which contain cellulose fibers in a matrix of lignin.

These materials are used in many applications such as bridges, building and structures of bathtubs, storage tanks, shower stalls etc. It has some industrial applications, medical field marine applications, wind power etc. In coming future there would be huge number of applications in spacecraft and aircraft.

1.1 CONSTITUENTS OF COMPOSITE

1.1.1 Matrix

It has major role to play in composite material where fiber reinforcement is provided and act as a adhesion to them. Two different materials or constituents are sandwiched together inside the matrix. It carries some load that is applied to a composite and also keeps the fibers in place. It also prevents friction between fibers. These are generally of four types discussed as-

Polymer matrix

These are classified as:

Thermoplastic matrix and thermosetting matrix

Metallic matrix

These are used where conducting properties are required. Metal can be made to flow around the fibers by heating them or by vacuum infiltration. Examples are aluminum, nickel, titanium etc.

Ceramic matrix

These are used where high temperatures are encountered. These can be vapor deposited on an already in plane fiber system or around the fibers and then carbonized by heating to a suitable temperature. Examples are boron carbide, silicon oxide etc.

Carbon matrix

These are used where even higher temperatures are encountered such as in space applications where carbon-carbon composite is used for fabricating the nose of the space module. These can sustain a temperature of around 3000 degree Celsius.

1.1.2 Reinforcement

It is a material which is lodged into a matrix. Reinforcement is used to change physical properties of the composites and provides structural strength. Its function is to increase load bearing capacity of the matrix along with increase in its strength and stiffness. It can be either continuous, or discontinuous in nature.

These are of following types-

Fibrous reinforcement

These are those which have very high length to diameter ratio that is aspect ratio (l/d).

Whiskers reinforcement

These are also fibers but are very short and rigid in nature.

Flakes reinforcement

These are spherioroidal in shape and they can be packed more densely in comparison to fibers, but due to surface defects their strength is lower than fibers.

Particulate reinforcement

These are the particles which may be metallic or non-metallic in nature which are added to matrix to improve its strength.

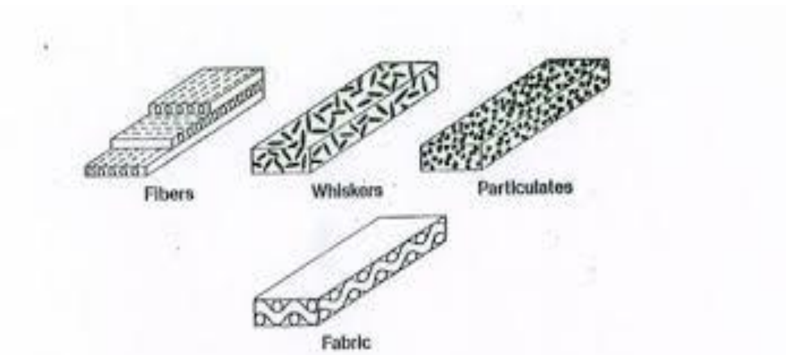


Figure 1: Types of Reinforcement [2]

1.2 CLASSIFICATION OF COMPOSITE MATERIAL

Fibrous composite material

Laminated composite

Particulate composite

Combination of above three**.**

1.2.1 Fibrous Composite

Polymers are known for their ductility rather than low stiffness. Composites like glass and ceramic are strong and stiff in spite of having brittleness also so we utilize great strength of the ceramic by neglecting the catastrophe. By aligning the fibers of a composite along direction of loading, the stiffness and strength are an average of those of the matrix and fibers, weighted by their volume fractions. But not all composite properties are just a linear combination of those of the components.

1.2.2 Laminated Composite

These are bounded together by layers of two different materials. To achieve a more beneficial material, lamination is done to join the best face of bounding material and layers. Strength, stiffness, low weight, corrosion resistance, wear resistance etc are the properties that can be achieved by lamination.

1.2.3 Particulate Composite

These composites are prepared by blending silica flour, glass beads and sand into a polymer during its functioning. Particulate composites have low efficiency in terms of strength but have some effective properties like low cost and good wear resistance. For example surface of road which is either concrete or macadam.

1.2.4 Combination of above Three

Multiphase composites are capable of exhibiting different and multiple properties of various types of reinforcement. For example reinforced concrete is both particulate and fibrous also.

1.3 FIBERS IN COMPOSITES

Fiber is a natural or man-made substance which is mainly longer in length as compared to its width. Fibers are used in the manufacturing of strongest engineering materials consist of different variety of fibers.

Advanced or hybrid fibers can be produced without expensing much of money in large amounts as compared to synthetic fibers. Generally there are two types of fibers used in composite materials; those are discussed as follow-

1.3.1 Man-made fibers

These are those fibers in which chemical composition, shape and properties are mainly enhanced during the manufacturing process. These fibers are also known as chemical fibers or advanced fibers. Man-made fibers generally consist of fibers which can be regenerated and synthetic fibers.

1.3.2 Synthetic fibers

These fibers come directly from synthetic materials like petrochemicals as compared to man-made fibers which came from available natural contents like cellulose or protein. Here fibers case comes into two categories: (i) discontinuous fibers also known as short fibers having ratio of length to diameter of 20 and 60, and (ii) continuous fibers also known as long fibers having mainly aspect ratio between 200 and 500.

Metallic fibers

The fibers which can be casted from ductile metals like gold, copper or silver and squeezed out from some brittle one like aluminum, nickel or iron are known as metallic fibers.

Carbon fiber

These are generally based on oxidized and via pyrolysis carbonized polymers like PAN (poly acryl nitrate), and final material we get is nearly pure carbon.

Silicon carbide fiber

Polymers are the basic polymer in silicon carbide fibers not hydrocarbons, where near around 50% of atoms of carbon are exchanged by silicon atoms and hence they are known as poly-carbon-silanes. The pyrolysis yields a formless silicon carbide, having mainly some other elements like titanium, oxygen, or aluminum but it has mechanical properties almost like carbon fibers.

Fiberglass

Purified natural quartz is used to make fiberglass. These are also man-made fibers which are made from specific glass and optical fibers that can be obtained from natural raw materials, silica fiber made from sodium silicate etc.

Mineral fiber

These fibers have least surface defects and hence can be particularly very strong.Taking example of asbestos which is a common mineral fiber.

Polymer fibers

These fibers come under the category of man-made fibers which follow synthetic chemicals instead of directly coming by purely physical process from natural materials.

1.3.3 Semi-synthetic fibers

These are those fibers which are generated from raw materials. These also posses a long-chain polymer structure and with the help of chemical processes these can be modified and partially degraded, in contrast to nylon or Dacron that are completely synthetic fibers which the chemist synthesizes by polymerization reaction from low-molecular weight compounds. Cellulose regenerated fiber is earliest semi synthetic fiber.

1.3.4 Cellulose regenerated fibers

These are another type of man-made fibers, developed from natural cellulose. It comes from various sources like rayon from tree wood fiber, Modal from beech trees etc.

1.4 Natural fibers

Natural fibers present in the shape of fiber. These are explained as the fibers which are produced by plants, animals, and geological processes. These fibers are growing interest due to different causes having their capability to exchange synthetic fiber reinforcement plastics at lower cost with enhanced sustainability, major factor affecting mechanical performance of natural fiber composites are [3]

1) Fiber selection

Selection of fiber is a major factor which affect mechanical properties because the fiber which we are choosing must be compatible with the matrix material.

2) Matrix selection

Matrix material plays an important role where two different materials are combined together inside the matrix. Its main function is to carry load and keeps the fiber in line which directly affect mechanical properties.

3) Interfacial strength

It refers to the strength of bond between matrix and fibers. It is desirable so that stress can be transmitted from matrix phase to fibers to achieve maximum overall strength.

4) Fiber orientation

Orientation of fibers mainly deals with further improvement in its properties. if fibers are oriented as compared to uni-direction, their load carrying capacity increases.

5) Composite manufacturing process

It involves different techniques or methods which are used to fabricate a composite material. Different techniques possess certain advantages and disadvantages and are selected according to their applications.

In India composite board has been developed as an alternative to medium density fiberboard which has been assessed for use in railcars. [4] In recent time the aircraft industry has also been adopting NFCs for interior paneling. They are classified according to their origin:

Plant Vegetable fibers

These are mainly based on placement of cellulose with lignin. Examples like cotton, hemp, jute, flax, ramie, sisal, banana, coir fiber, kneaf fiber, bamboo fiber, maize or corn fiber, kapok fiber, abaca fiber, raffia palm etc. these fibers are used in the production of paper and textile.

We have proposed mainly three types of fibers in our study. Those are sisal, jute and coconut coir.

Sisal fibers

It is a hard fiber extracted from sisal plant that grows in hot and dry areas. It is an environmentally friendly fiber as it is biodegradable. It is exceptionally durable and low maintenance with minimal wear and tear also does not attract dust particles and moisture. It also shows good impact and sound absorbing properties.

Figure 2: Sisal Fiber

Jute fiber

It has some unparalleled physical properties such as high tenacity, bulkiness, sound and heat insulation properties, high strength, less extensibility, low thermal conductivity etc.
These are strong, coarse and organic also. It is mostly used in packaging, textiles, non-textiles and agriculture sectors.

Figure 3: Jute Fiber

Coir fiber

It is found in hard internal shell and outer coat of coconut. Coir fibers show some special characteristics like thick, strong and also has high abrasion resistance. Generally used in making of mats, brushes and sacking.

Figure 4: Coir Fiber

Animal fibers

These are mainly obtained from animals like spider silk, sinew, wool fiber, camel hair, and fur like sheepskin, rabbit, beaver etc.

Mineral fibers

These consist of asbestos group. Asbestos is a naturally long occurring mineral fiber. These fibers show heat insulating properties. These are classified as asbestos based, glass wool, Rockwool or stone wool, ceramic wool.asbestoes based are further of three types that are: crocedolite, amosite, chrysotile.

1.5 Properties of Natural fibers [5]

Fiber type	Failure Strain (%)	Density (g/cm3)	Tensile strength (MPa)	Elastic modulus (GPa)	Elongation at break (%)
Jute	1.5-1.8	1.3–1.5	200–770	20–55	2.0–3.0
Sisal	2.0-2.5	1.5	100–800	9–22	3.0–7.0
Kenaf	-	1.4–1.5	930	53	1.6
Coir	15-30	1.2	180	4–6	30.0
Flax	1.2-1.3	1.5	350–1040	28–70	2.0–4.0
Hemp	1.6	1.5	690	30–70	1.5–4.0
Bamboo	-	0.6–1.1	140–230	11–17	4.0–7.0

Table 1: Properties of Natural fibers

1.6 Advantages and Disadvantages of Natural Fiber composites [6].

Advantages	**Disadvantages**
Low density and high specific Strength and stiffness.	Lower durability than for Synthetic fiber composites, but can be improved considerably with treatment.
Fibers are a renewable resource, for which production requires little energy, involves CO2 absorption, while returning oxygen to the environment.	High moisture absorption, which results in swelling.
Fibers can be produced at lower cost than synthetic fiber.	Lower strength, in particular impact strength compared to synthetic fiber composites.
Low hazard manufacturing Processes.	Greater variability of properties.
Low emission of toxic fumes when subjected to heat and during incineration at end of life.	Lower processing temperatures limiting matrix options.

Table 2: Advantages and Disadvantages of Natural Fiber composites.

1.7 Different techniques of fabricating composite with advantages and disadvantages

1.7.1 Hand layup method

The composition of this composite has been discussed as natural fibers along with epoxy resin by employing hand layup method for fabrication of fibers. GI sheet mould with demanded dimensions was used for producing samples according to ASTM standard [7]. Epoxy resin with hardener was chosen in a ratio of 10:1 by weight for fabrication of composite. Chopped sisal and jute fibers were used to prepare specimen [8].The polymers composites are fabricated by hand lay-up technique. Composite samples with various fiber loading (0, 12, 24, 36 and 48 wt %) were made and subjected to post curing for 24 hours at room temperature [9]. This technique is best suited for thermosetting polymer based composites. Any combination of fibers and matrix material can be used in this method and also capital and infrastructural requirement are less than the other methods. some of the drawbacks we face in this technique are like uniform distribution of resin inside fabric is not possible, formation of voids in the laminates, quality of final product depend upon skills of labor. One of the most important drawback we face in this method is less production rate and difficult to get high volume fraction of reinforcement. The process is suitable for fabrication of wind turbine blades, boat and architectural moulding etc.

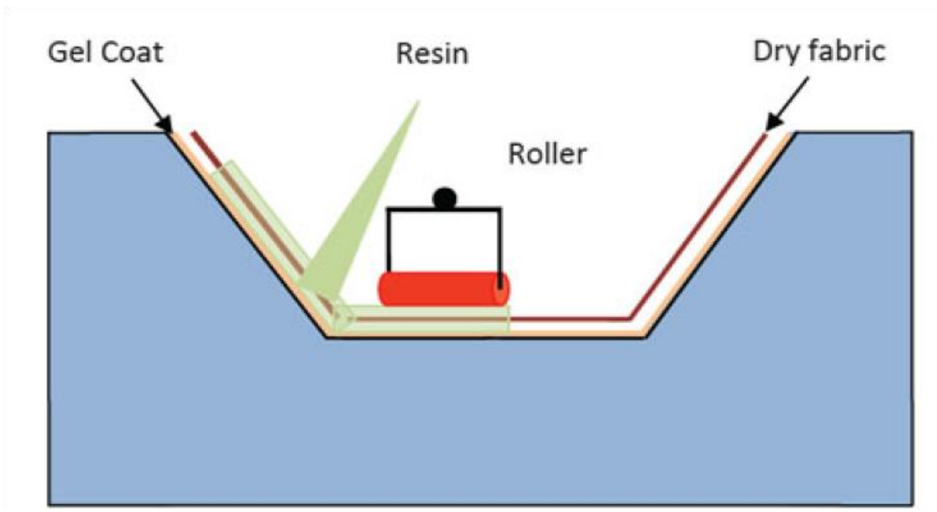


Figure 5: Hand Lay-Up Technique [9]

1.7.2 Spray lay-up method

This method consist a hand held gun to chop the fibers which are guided in a spray of catalyzed liquid resin provided at the mold to wet the reinforcement fibers, which are correspondingly chopped in same spray gun. Whole of the setup is left to cure under standard atmospheric conditions. The main application of this part is in lightly loaded structural panels e.g. caravan bodies, truck fairings, small dinghies etc. [10]. This method eliminates the major limitation of previous method by providing high volume fraction of reinforcement in composite and also suitable for small to medium volume parts. major concern related to this method are like it is not suitable for parts having high structural requirements, good surface finish can be achieved on one side only, short fibers can be used only in this process etc.

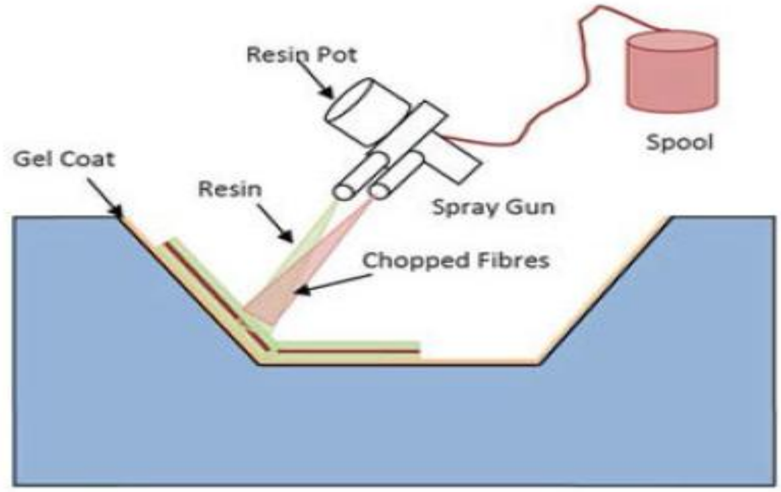


Figure 6: Spray Lay-Up Technique [10]

1.7.3 Vacuum Assisted Resin Infusion Moulding (VARIM).

This technique used the method of impregnation of dry reinforcement by liquid thermoset resin driven under vacuum, and this technique made to reduce the void content inside the molded composites. With vacuum bag moulding, the bags are used to evacuate the air from laminate and to generate the atmospheric pressure required for compaction over the mold [11]. This process helps in achieving higher fiber content laminates and lower void content than other method. It is costly method in terms of labor and bagging material.

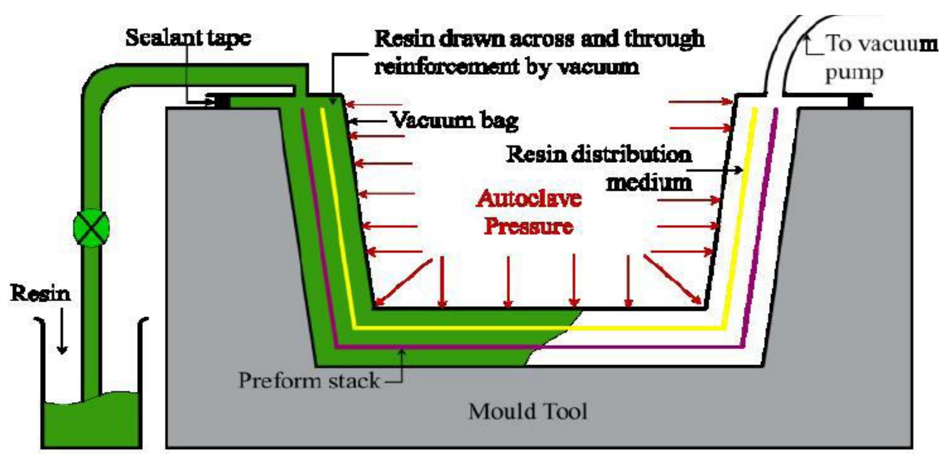


Figure 7: Schematic Illustration of the Vacuum Enhanced Resin Infusion Technology [12]

1.7.4 Filament Winding

This process is an automated one in which fiber tows in different orientations are transferred through a resin bath before wounded on to a mandrel and is commanded by fiber feeding mechanism and rotation rate of mandrel. Curing of wounded component is done in an oven or autoclave. This method is used in fabrication of hollow mostly circular or sectioned components. Some of the advantages it has are like it is fast and economic process, complex fiber pattern can be obtained etc but also has some leaks like resin with low viscosity is required in this process, it is limited to convex shaped components etc**.**

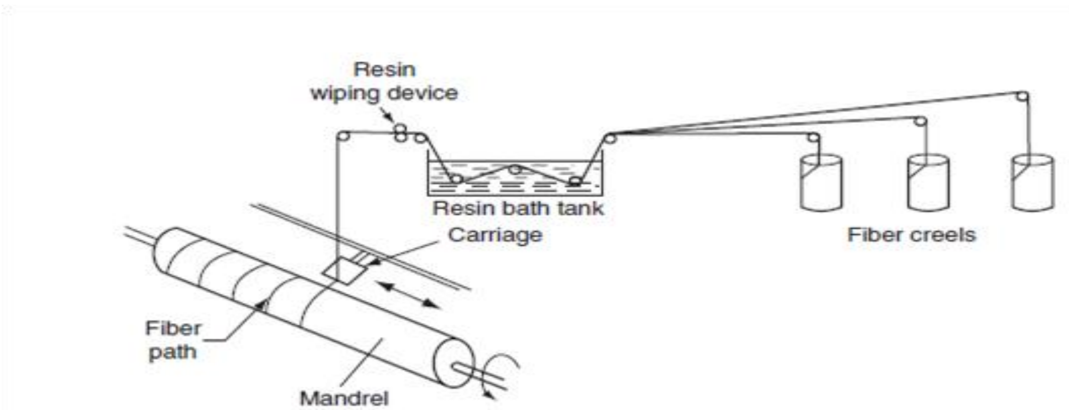


Figure 8: Filament Winding [2]

1.7.5 Pultrusion

It us a continuous process in which fibers are passed through a bath of liquid resin then fibers with wetted resin are passed through a heated die which impregnate and control the resin and then material is cured to its final shape. this process has advantages like suitable for mass production, fast and economic, surface finish of the product is good, resin content can be controlled etc but also have some problems like only suited for constant cross sections, die cost can be high etc. applications of this process can be seen in beams and girders used in roof structures, bridges, ladders etc.

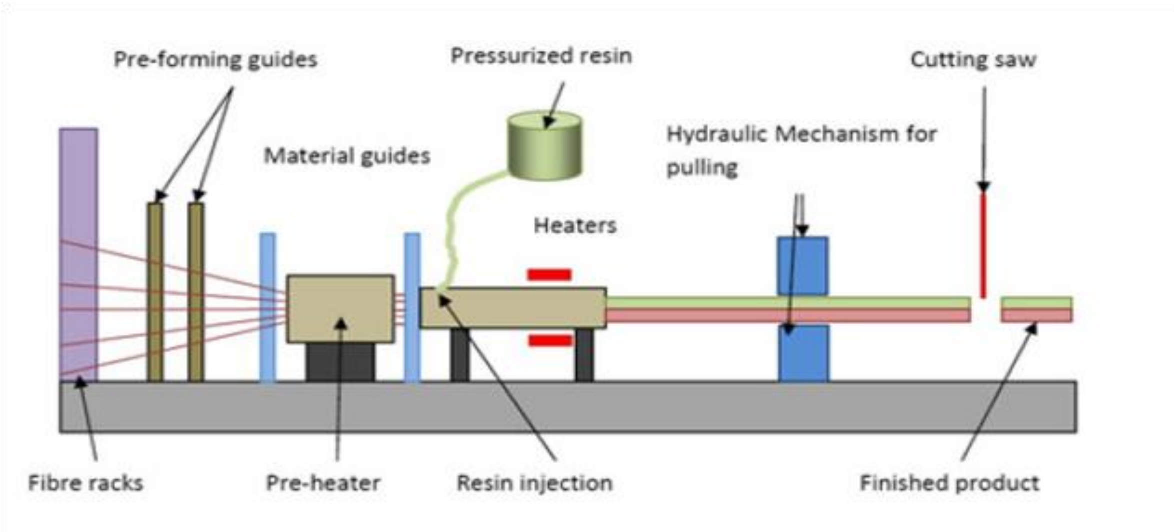


Figure 9: Pultrusion Process [10]

1.8 Volume fraction

Volume fraction is defined as ratio of volume of fiber to the volume of composite**.** Many researchers have observed that the fiber volume fraction is one of the major parameters in the determination of the mechanical properties of natural fibers [13]. The ratio of fibers and matrix used in a composite has a direct impact on its properties. Lack of fibers in material will deteriorate the properties of material and excess of it also decreases its strength due to lack of space for matrix to fully surround the bond with the fibers [14]. Fiber volume fraction is calculated as [15]:

$$VF = 1 - \left(\frac{W - Wf}{V \times \rho m}\right) \quad (1)$$

Where,

VF = volume fraction

W = weight of composite

W_f = weight of fibers

V = volume of composite

ρm = density of matrix.

Generally, three different methods for determining volume fraction are used which are given below:

1) Acid Digestion

2) Optical Micro-Scopy based

3) Resin Burning off.

1.9 Rule of mixture

This rule is used to predict various properties of the composite materials made up of continuous and unidirectional fibers. Various mechanical properties like density, modulus of elasticity, load, ultimate tensile strength, thermal conductivity etc can be predicted for composites. This rule can be applicable in different areas of simulation like FEM, abaqus, hypermesh, solidworks etc. The mathematical formulation is given below: [16]

$$E_c = fE_f + (1 - f)E_m \tag{2}$$

Where,

Volume fraction of fiber (f) = $\frac{Vf}{Vf+Vm}$

Material property of fiber (E_f)

Material property of matrix(E_m)

CHAPTER 2

2 LITERATURE REVIEW

Girisha.C et al. (2012)[17] investigated that manual hand layup method was used for fabrication of husk fibers and tamarind fibers by using epoxy resin and composite have been developed. For good adhesion, fibers were treated with NaOH solution and hybrid composite was made by using different percentage of fibers (10%,20%,30%,40%,50% by weight). Mechanical tests were performed to characterize these natural strengthened hybrid composites. It was reported that there was increase in fiber percentage ultimately increasing its tensile strength; however after a particular percentage this tensile strength gets decreased. A valuable variation in tensile and flexural strength was recorded when compared to untreated fiber for surface treated fiber composite.

Concluded that for 40 percent of addressed fiber, flexural strength was found to be maximum and the maximum impact energy for the composites reinforced with 50 percent of addressed fiber was observed.

K. Velmurugan et al. (2015)[18] Studied that jute and kneaf natural fibers were used for assembly of polymer matrix composite. These fibers are available in grate quantity in nature in many shapes. In this study to improve strength E glass fibers are used. Hand layup technique is used to fabricate this sandwich composite. This composite fabrication resulted in more tensile strength as compared to other natural composites such as coir, sisal, banana etc.

Resulted in improvement in mechanical properties like Tensile, flexural, compression and impact strength which are analyzed through different strength measuring experiments. Applications of this natural fiber reinforced polymer sandwich composite material can be seen in automobile sector, marine field and aero space industries.

Nino Serah Baby et.al (2016)[19] Inspired from natural fibers, we can use agricultural waste on commercial bases to make a composite of polymer reinforced with fibers. In this study manufacturing of composite having matrix of polymer was done by utilizing sisal fiber which shows superior impact strength in spite of having normal flexural as well as tensile properties rather than lignocellulosic fibers. The mechanical nature of natural hybrid composites is shown in this study. Evaluation of mechanical attributes of vinyl ester combined with sisal, glass, steel fiber and prosopis juliflora was done. Manual Hand lay-up technique was used for fabrication of different samples where the stacking of piles was alternate. This study is mainly concentrated on manufacturing of composite of polymer matrix with the help of natural fibers like sisal fiber, metallic fiber like steel fiber, non - metallic fiber like glass fiber.

The present work concluded in calculating the material characteristics by conducting different tests like tensile strength test, impact strength test and flexural strength test and a more beneficial hybrid composite was obtained.

S. Keck et.al (2016)[20] examination of mechanical and fracture mechanical behavior of composites reinforced with unidirectional aligned flax fiber was done experimentally and numerically. Mainly focused on determination of crack paths in compact tension samples under static and fatigue loading with three different fiber directions and their fatigue crack growth rate curves. The crack path is not only governed by the stress state as the marked orthographic behavior of these materials, but also affected by fiber direction and fiber volume fraction. So the standard samples are not applicable for stress intensity factor solution.

Consequently, to evaluate the stress intensity factor evolution extensive numerical simulation have been carried out along the growing crack in order to determine fatigue crack growth rate curves. Both young’s moduli and tensile strengths increases with increase in fiber volume fration.also formula to calculate the geometry correction factors for compact tension samples having fiber direction perpendicular to loading direction was proposed.

Flávio de Andrade Silva et.al (2009)[21] formulation of composites of cement fiber with the help of sisal fibers bounded with long unidirectional placed fibers and their physical mechanical attribute was characterized. In a self-compacted cement matrix, casting of corrugated flat sheets of these natural fibers was done with manual hand layup method and 3 MPa pressure was applied to compress them. For determination of the peak strength, crack and toughness of the composites, bending tests and direct tensile tests were performed. Water absorption test and drying shrinkage tests were performed to characterize the physical properties of the composites. To ensure its durability, calcined waste crushed clay brick and metakaolin were used to modify ordinary Portland cement matrix to take up the calcium hydroxide produced during the hydration process of Portland cement. Hot-water immersion test with accelerated aging conditions were used to determine durability of new composite.

it was found from physical tests that that both composite system were water repellent with negligible water escape. The resulted material when undergone through 6 months hot water test of about 60*C a multiple cracking behavior was found when applied to bending.

L.Q.N. Trana et.al (2014)[22] coir fibers properties were investigated for using it as a reinforcement in composite materials. the examination of the fiber internal structure consisting the organization of primary fibers, angles of micro fibril and fiber porosity was done by X-ray micro tomography and image analysis by SEM. Tensile tests were performed to determine mechanical attributes of coir fiber, having a integrated optical strain mapping system which determine fiber strain to develop more reliable values of strain and E-modulus at failure.

It was observed that fibers of coir have a lot of primary fibers and a lacuna at the core posses' high porosity of 22 to 30% and low defect sensitivity. Also resulted that these fibers posses high strain to failure and were not much strong and stiff which lead to increment in its toughness and also used as reinforcement in composites.

Girisha.C et.al (2012)[23] water absorption effect on the mechanical properties of composite of natural fibers having desired fibers like sisal and coir that were bounded with epoxy was analyzed and those undergoes through water immersion test. Natural hybrid composite such as coconut coir and sisal fibers was evolved and fiber of different weight fraction of about 20%, 30% and 40% were used for the manufacturing of this composite. By immersing samples in a water bath during water absorption test at 25 degree C and 100 degree C for unlike time durations. Evaluation and comparison of the tensile and flexural properties of samples that undergone through both aging conditions was done and calibrated against samples of dry composite.

Concluded that as fiber volume fraction increases, the percentage of moisture uptake also increases due to fibers of more cellulose content. It was also found that tensile and flexural properties of this material get reduced as we increase the moisture uptake percentage. At room temperature the water absorption pattern was obtained to follow fickian behavior for these composites, whereas at higher temperature the water uptake properties did not adopt this law.

Khouloud Cheour et.al (2016)[24] investigated that damping and mechanical properties of quasi-Unidirectional Flax fiber Reinforced Epoxy (UFRE) composite get effected by water content intake over a certain period of time defined as water ageing. Composite materials immersed under water for testing by using press platen process. There is a decrease in the bending moduli of the composite and an increase in loss factors with the increase of water intake. It was established that variations caused in case of loss factors are practically reversible but irreversible when bending moduli is considered.

Faris M. AL-Oqla et.al (2015)[25] reviewed the development in sector of intrinsically conductive polymers (ICPs) and conductive polymer composites (CPCs) consisting natural fibers. These natural fibers have some unique characteristics like electrical conductivity, mechanical strength, eco friendly and reusability which allow them to be used in different novel and present applications. Examination of consequences on dielectric properties of conductive fiber contents of fibers, size of fiber, different chemical treatment, and temperature as well as moisture content was done.

Observed that short natural fibers would enhance the dielectric reaction of the polymeric matrix, but decrease in dielectric loss factor could be possible due to chemical handling which directly affects these composites in passive manner.

Subbiah Jeeva.G et.al (2015)[26] examined the improvement in mechanical properties of composite material of natural fiber by using glass fiber as a base material. for that we have used micro powder also. Examination of effect of additives in composite was done by making four different specimens with coconut fiber, banana fiber, sisal fiber and titanium oxide powder respectively. Polyester resin was used as bonding material between fibers. Then the tensile strength and impact strength of samples was analyzed using ultimate testing machine.

The result so obtained was compared with the original sample having no additive show that there was decrease in tensile strength with samples that add additive of natural fibers like sisal, banana and coconut coir where as titanium dioxide as additive in composite material gave high tensile strength.

G. Navaneethakrishnan et.al (2015)[27] preparation of Glass fiber (GF) and Banana fiber (BF) reinforced silica nanoparticles filled epoxy bio-nanocomposite has been done for the evaluation of tensile strength and impact strength. Banana fibers which are received from banana stem have been nominated for their diameter variance and their different mechanical properties, having fracture morphology. In this work Glass and fiber of banana and powder of silica was combined to form a composite. Examination of fiber matrix adhesion, BF and GF ply interface bonding, and different modes of failure such as fiber breakage, matrix cracking, and fiber pull out and dispersion of silica nanoparticles was done with the help of scanning electron microscope (SEM).

It was reported that the prepared bio nanocomposites have been expected to have improved mechanical properties. On adding silica results in increases the modulus of elasticity and strength.Hybridized composite material having Banana fiber and glass fiber has proved to be perfect for making cost effective composite material also.

Magdi El Messiry et.al (2013)[28]Investigated environmental friendly, sustainable composite materials to solve the problems of recycling of agriculture waste, due to their high potential as a material with suitable strength, low weight and low deformation. Composite laminates were formed from Fiber and epoxy with desired directional properties. Mechanical properties were derived for composites from the properties of fiber and matrix with the help of the rule of mixtures. It was found that fiber volume fraction played a substantial part in the determination of the mechanical properties.

In this work taking fibrous structure constituent, random fiber, yarns or fabric the determination of fiber volume fraction was done which advice of using regular open structure yarn with lower packing density and less twist which will give better and low variability of these composite properties.

K.L. Pickering et.al (2015)[29] reviewed the mechanical performance of natural fiber composites because of their different advantages as compared to some others materials, like man-made fiber composites, having less impact on environment and economic also that shows their qualities in different fields and to increase their mechanical functioning, to broaden the potentiality and use of this type of materials. Elements that affect the mechanical functioning of NFCs were taken to count and details achievements made with those factors in this study.

This study concluded that the lower densities of NFCs results in better comparison for particular properties. There was great change in long and short term properties of natural fiber composites which help them in extending their range of applications in different sectors.

Maria Rosa Valluzzi et.al (2015)[30] effect of moisture and cycles of temperature on timber elements combined with different fibrous materials and matrices by using wet lay-up method was examined. It was done by multi-scale experimental approach having (i) classification of composite material by mechanical characterization(ii) determination of nature by mechanical bond tests at the composite-to-timber interface and micro structural investigation (iii) a bending test named four-point bending tests done on strengthened timber beams.

Resulted in better functioning of natural-fiber composites when compared with synthetic composites and effect of temperature and content of wood moisture on bonding was also noticed. This study also shows a path for using NFRPs in environmental situations.

Ariel Stocchi et.al (2013)[31] a new honeycomb core was prepared by using a natural-fiber reinforced composite having matrix of vinylester reinforced with jute fabric has introduced. Two types of compression-molding techniques were used for manufacturing 6mm and 10mm cell honeycombs. Lateral compression was used for best outcomes. Experimental tests were taken under flat wise compression so that composite elastic response and the core response could be characterized. Good elastic properties of the core were analyzed by finite element modeling and homogenization.

Concluded that flat wise compression tests reported the failure of core mechanisms were yarn pull-out and fiber breaking. From this study it was obtained that jute-reinforced cores have the capability to be a substitute to standard cores taking the uses that can bear compressive static load.

2.1 SCOPE OF STUDY

Composite based on carbon fiber and glass fiber are widely used these days in automotive and aerospace industries but one of the graveling we faced in using these fibers are that they are not reusable and non-biodegradable. In spite of having good mechanical properties, the accumulation of waste of these fibers are causing a serious threat to the environment.

So need is generated to make composites based upon natural fibers as they are renewable and bio-degradable giving good mechanical properties. Growing interest of using natural fibers in composites would lead to cost effectiveness and provide the researchers to utilize these natural fibers effectively and efficiently in the coming future. Further combining two or more fibers in a composite would take us to identify the properties integration of the hybrid composites.

Experiments would be performed to make new hybrid composites elaborating distinct and superior properties. Hybrid composites can be considered for their light weight applications and property response against moisture content.

2.2 OBJECTIVE OF THE STUDY

From the past decades there has been a massive growth in the development of hybrid natural fiber composites which exhibits good combination of fiber properties like high strength, less weight, moisture resistant, flexible, stiffness etc. Keeping in mind the current exploration of the research the following objectives are targeted in order to achieve the goals.

- Fabrication of hybrid composites made from natural fibers (sisal, jute) in combination along with the determination of their properties.
- Comparison of mechanical characterization of sisal/jute fiber reinforced epoxy based composites with jute reinforced epoxy based composites.
- To investigate the effect of volume fraction and orientation of fibers on mechanical properties of composite.
- To investigate the water absorption behavior of natural fiber reinforced composites.

CHAPTER 3

3. EQUIPMENT, MATERIAL AND EXPERIMENTAL SETUP

This chapter deals with the complete information about processing of composite and experimental procedures being used along with different test for determining its properties.

3.1 EQUIPMENTS

Different equipments which are used for formulation of this composite are discussed as:

3.1.1 DIE

A die of dimensions 32.5×9×7 cm is used having two metal plates in it for placing the composite inside them for compression. Upper part of the die is removable over which weight of desired quantity is applied for complete curing of the product.

Figure 10: Die

3.1.2 BEAKER

Two different beakers of desired volume are being used separately for pouring and weighing resin and hardener for their exact mixing ratio.

Figure 11: Beaker

3.1.3 MIXING JAR

A mixing jar is used to mix both the resin as well as hardener taken from their beakers for complete mixing.

Figure 12: Mixing Jar

3.1.4 WEIGHING MACHINE

This is available in civil laboratory of LPU and is used to measure weight of fiber , both resin and hardener in grams used for making composite.

Figure 13: Weighing Machine

3.1.5 HAND HEXA AND FILE

After marking and placing the samples in bench vice, hand hexa is used to cut them and file is used to avoid irregularities of the product.

Figure 14: Hexa and Flat File

3.2 MATERIALS

To make a hybrid composite material we used different natural fibers because of their different properties like high stiffness, less weight, high strength etc. and epoxy resin is used for its better adhesive properties as major ingredient. They are discussed below as:

1. Jute fiber
2. Sisal fiber
3. Resin
4. Hardener

Specimen of different natural fibers of jute and sisal are used. The selection of these natural fibers is done on the basis of literature review due to their properties and attributes.

3.2.1 Jute Fiber

There are 2 different types of jute fiber we deals with and those are capsularic jute which is white in color and olitorious jute which is brown or yellow in color. So we have used second type of fiber because of its properties best suited for our work.

3.2.2 Sisal Fiber

It is exceptionally durable and low maintenance with minimal wear and tear also does not attract dust particles and moisture. It also shows good impact and sound absorbing properties.

Figure 15: Jute and Sisal

3.2.3 RESIN

Lapox duralite epoxy resin which is a modified epoxy resin with thixotropic additives and is a thermosetting polymer that polymerizes and cross links of grade LPX DRAT-R1LB0416B is used due to its better adhesive properties.

Figure 16: Resin and Hardener

3.2.4 HARDENER

Duralite hardener of grade LPX DRAT-H0.8LB0416B is used which is suitable to cure duralite resin at ambient temperature. The bond prepared are suitable to achieve good adhesion with similar and dissimilar substrate like glass, ceramics, stone and metals.

3.2.5 Technical Data sheet of Lapox Duralite [32].

Duralite resin

Property	**Unit**	**Reference**	**Value**
Description	-	-	Opaque viscous liquid
Colour	-	-	Hazy white
viscosity@25*C	mPas	ASTM D 2196	35000-45000
Density	Gm/cc	ASTM D 792	1.1-1.2

Duralite hardener

Property	**Unit**	**Reference**	**Value**
Description	-	-	Brown viscous liquid
Colour	GS	ASTM D 1544	Max 8
viscosity@25*C	mPas	ASTM D 2196	30000-40000
Density	Gm/cc	ASTM D 792	0.9-0.98

Mix properties

Property	**Unit**	**Reference**	**Value**
Mixing ratio	Pbw	-	100:80
Mix viscosity	mPas	ASTM D 2196	35000-40000
Pot life	minutes	ASTM D 2471	50-65
Peak exotherm temperature (PET)	*C	ASTM D 2171	Max-65

Table 3: Technical Data Sheet of Resin and Hardener

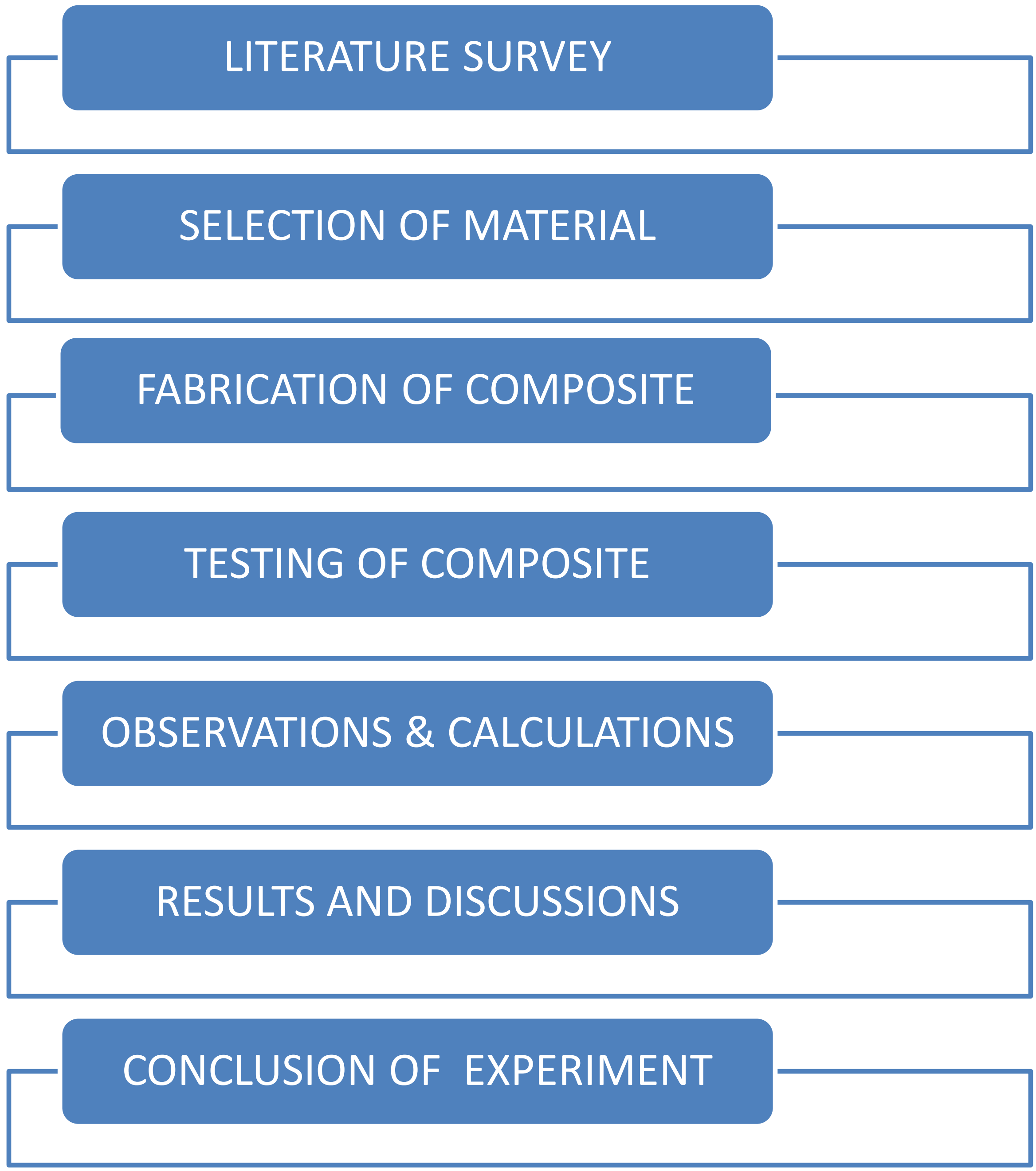
3.2.6 Advantages and Disadvantages of epoxy resin:

There are certain advantages and disadvantages of the matrix material i.e. epoxy resin which we are using for fabrication of natural fiber composite. Some of them are discussed below.

Advantages	**Disadvantages**
1) Good mechanical properties. 2) Good thermal resistance. 3) Low shrinkage during curing. 4) Resistance to water, chemical and solvents.	1) Somewhat Toxic in nature. 2) Limited temperature application ranges to (170°C). 3) High thermal coefficient of expansion. 4) Moisture absorption affecting Dimensional properties.

Table 4: Advantages and Disadvantages of Epoxy

3.3 RESEARCH METHODOLOGY



3.4 FABRICATION OF COMPOSITE

Fabrication of different samples of composite is done by conventional hand layup method. Complete description of whole of the project is given below:

STEP 1. Procurement of Material

Materials used in this composite are assembled from different sources such as:

Jute fiber from Phagwara (Punjab).

Sisal fiber from Chander Prakesh and Company,Jaipur (Rajasthan).

Resin and Hardener from Atul polymers, Jalandhar (Punjab).

STEP 2. Composition of Samples

For making different samples of jute and sisal fiber the composition is shown as:

SAMPLE	FIBER	WEIGHT OF FIBER(gm)	WEIGHT OF EPOXY (gm)	TOTAL WEIGHT OF COMPOSITE(gm)	DENSITY OF EPOXY(gm/ cm^2)	VOLUME FRACTION
S1	JUTE(unidirectional)	28.41	162.42	190.83	1.2	22%
S2	JUTE(unidirectional)	47.34	120.5	167.84	1.2	42.6%
S3	JUTE+ SISAL	28.5+19= 47.5	139.5	187	1.2	43%
S4	JUTE+ SISAL	29.5+20.5 =50	124	174	1.2	49%
S5	JUTE+ SISAL (fiber orientation)	29.5+21.5 =51	119	170	1.2	51%

S6	JUTE(bi-directional)	16.8	109.2	126	1.2	22%

Table 5: Composition of different Samples

STEP 3. Procedure of Manufacturing

1) Natural fiber composite of jute and sisal fiber was made by hand-layup technique where a wooden die of dimensions 32.5×9×7 cm is used having two metal plates in it for placing the composite inside them for adequate compression.

2) Uni-directional, bi-directional jute fibers and sisal fiber are taken by maintaining their weight and mixing ratio of resin and hardener.

3) According to the samples, 4-5 layers of fiber are used with epoxy. composite is fabricated using hand- layup method provided a thin plastic sheet as a releasing agent so that epoxy should not flow to the walls of the die causing a problem in opening the die and placed under weight of 100kg for 48 hours at room temperature.

4) After removing the weight, sample is taken out of the die and is weighted on weighing machine for final weight of the composite. Thickness of the final sample is measured with the help of micrometer.

5) Marking and cutting of different samples is done according to the ASTM standards for tensile, flexural and impact testing.

3.5 EXPERIMENTAL WORK

Experimental work has been carried out on hybrid composite for analyzing the effect of volume fraction on its mechanical properties. Various test performed on different machines are:

Tensile Test- Universal Testing Machine (UTM).

Flexural Test- Universal Testing Machine (UTM).

Impact Test- Impact Testing Machine (CHARPY TEST).

Testing of Samples

In this case study, we did three types of testing of composite for obtaining the effect of environmental conditions and volume fraction on its mechanical properties.

3.5.1 Tensile Test

Tensile test of the natural fiber composite is done on all the samples according to the ASTM-D638 test standard to determine tensile strength, yield strength or yield point, percentage elongation, percentage reduction in area, modulus of elasticity where the cross head speed is 5mm/min. samples were hold in the jaws of tensile testing machine setup in universal testing machine.

Sample specifications are-

Directional Features.	Total Length of Sample (mm)	Tab Length of Sample (mm)	Width of Sample (mm)	Thickness of Sample (mm)
Uni-Directional Jute Fiber	250	50	15	3-7
Bi-Directional Jute fiber	250	50	25	3-7
Hybrid (Jute+ Sisal)	250	50	15	3-7

Table 6: Specifications of Tensile test samples

Six different samples were made for investigating tensile properties having different volume fraction and fiber orientation along with effect of hybridization on these properties. S1 and S2 are single fiber composites having different volume fraction, S3 and S4 are hybrid composites (jute, sisal) having different volume fraction where as S5 and S6 are fiber oriented composites.

Figure 17: Tensile Test Samples before Testing.

Figure 18: Tensile Test Samples after Testing

Figure 19: Tensile Testing on UTM.

3.5.2 Flexural Test

Flexural test is used to determine the capability of the material to withstand bending before achieving its breaking point. This test is carried out according to the ASTM-D790 on three point bend test setup in UTM machine having span length of 50mm and cross head speed of 10mm/min. it is calculate as:

$$\text{Flexural strength} = \frac{3PL}{2BD^2}\text{, N/mm}^2 \quad (3)$$

Where, P = Max Peak Load (N)

L = Span length between the movable support (mm)

B = Width of sample (mm)

D = Depth of sample (mm)

Sample specifications are –

Directional Features.	**Total Length of Sample (mm)**	**Width of Sample (mm)**	**Thickness of Sample (mm)**
Uni-Directional Jute Fiber	150	15	3-7
Bi-Directional Jute fiber	130	15	3-7
Hybrid (Jute+Sisal)	150	15	3-7

Table 7: Specifications of Flexural test samples

Six different samples were made for investigating flexural properties having different volume fraction and fiber orientation along with effect of hybridization on these properties. S1 and S2 are single fiber composites having different volume fraction, S3 and S4 are hybrid composites (jute,sisal) having different volume fraction where as S5 and S6 are fiber oriented composites.

Figure 20: Flexural Test Samples before Testing

Figure 21: Flexural Test Samples after Testing

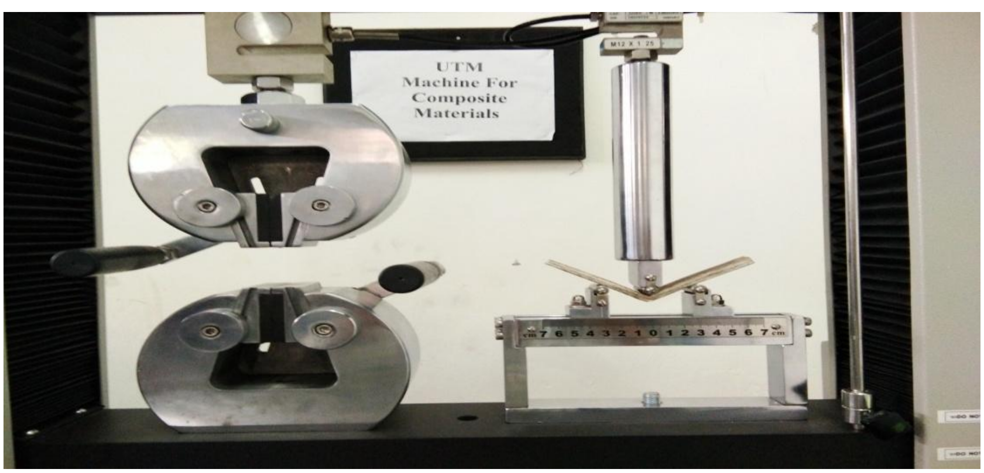


Figure 22: Flexural Testing on UTM.

3.5.3 Impact Test

This test is used to determine the amount of energy absorbed by material during fracture. charpy impact test which is also known as charpy v-notch impact test comes under ASTM-D370 has been used to perform this test in which a sample usually v-notched placed horizontally in which notch is positioned in opposite direction of striker(hammer) is struck and broken by a single blow. This absorbed energy gives material's toughness and act as a tool to temperature dependent ductile-brittle transition.

Sample specifications are –

Directional Features.	**Total Length of Sample (mm)**	**Width of Sample (mm)**	**Thickness of Sample (mm)**	**Length of positioning of notch (mm)**	**Depth of notch (mm)**	**Angle of notch (degree)**
Uni-Directional Jute Fiber	63.5±2	12.7±0.20	3-7	31.80±1	2.54	22.5
Bi-Directional Jute fiber	63.5±2	12.7±0.20	3-7	31.80±1	2.54	22.5
Hybrid (Jute+Sisal)	63.5±2	12.7±0.20	3-7	31.80±1	2.54	22.5

Table 8: Specifications of Impact test samples

Six different samples were made for investigating impact properties having different volume fraction and fiber orientation along with effect of hybridization on these properties. S1 and S2 are single fiber composites having different volume fraction, S3 and S4 are hybrid composites (jute, sisal) having different volume fraction where as S5 and S6 are fiber oriented composites.

Figure 23: Impact Test Samples before Testing

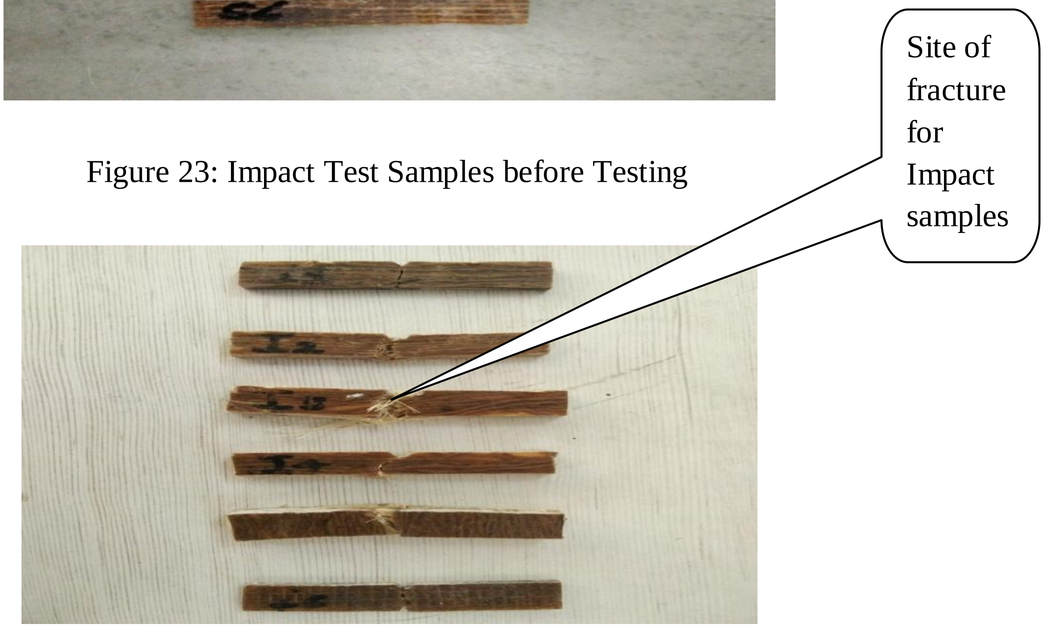


Figure 24: Impact Test Samples after Testing

Figure 25: Impact testing

3.5.4 Water absorption Test:

For investigating the effect of environmental conditions, water absorption test was carried out on natural fiber composite. Six samples were prepared having different volume fraction, different fiber mixture in order to investigate water absorption behavior. Samples were cut in dimensions of 76.2×25.4×6mm according to ASTM- D570-98. Initial weight of samples was measured on weighing machine before dipping in normal water for 24 hours time duration.

After 24 hours, samples were taken out of water and excess water was removed with the help of dry cloth or tissue paper. Samples were weighted again for moisture absorption in them. Moisture absorption was calculated by weight difference of samples before dipping and after dipping in water and its percentage was calculated by given formula [33]:

$$\mathbf{Mt} = \frac{\mathbf{Wt - Wo}}{\mathbf{Wo}} \times \mathbf{100} \tag{4}$$

Where, Mt = moisture content in sample

Wt = weight at immersion time (after water absorption).

Wo = original weight of sample (before water absorption).

Sample specifications are –

Directional Features.	**Total Length of Sample (mm)**	**Width of Sample (mm)**	**Thickness of Sample (mm)**
Uni-Directional Jute Fiber	76.2	25.4	3-7
Bi-Directional Jute fiber	76.2	25.4	3-7
Hybrid (Jute+Sisal)	76.2	25.4	3-7

Table 9: Specifications of Water Absorption test samples

Figure 26: Water absorption samples before immersion

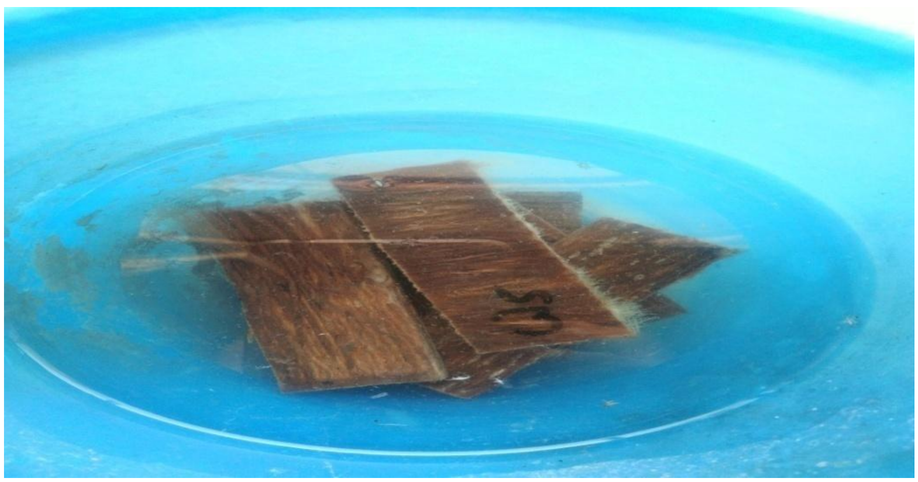


Figure 27: Samples during Immersion

Figure 28: Samples after Immersion

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Mechanical characterization of composites.

In this present study six different samples were prepared having different volume fraction and orientation along with the effect of hybridization on mechanical properties. All specimens were prepared, cut and tested as per ASTM standards. This chapter discusses the results obtained from tensile, flexural and Impact testing of the composites and effect of volume fraction and fiber orientation on mechanical properties.

4.1.1 Tensile properties: All tensile specimens were tested according to ASTM-D638, table 10 shows the tensile strength obtained for different samples.

Samples	Volume fraction	Orientation	Tensile strength (N/mm^2)
S1	22%	Uni-directional	32.918
S2	43%	Uni-directional	38.232
S3	43%	Uni-directional	41.856
S4	49%	Uni-directional	42.306
S5	51%	90-45-0-45-90	36.428
S6	22%	Bi-directional	45.731

Table 10: Shows Tensile Strength of different Samples.

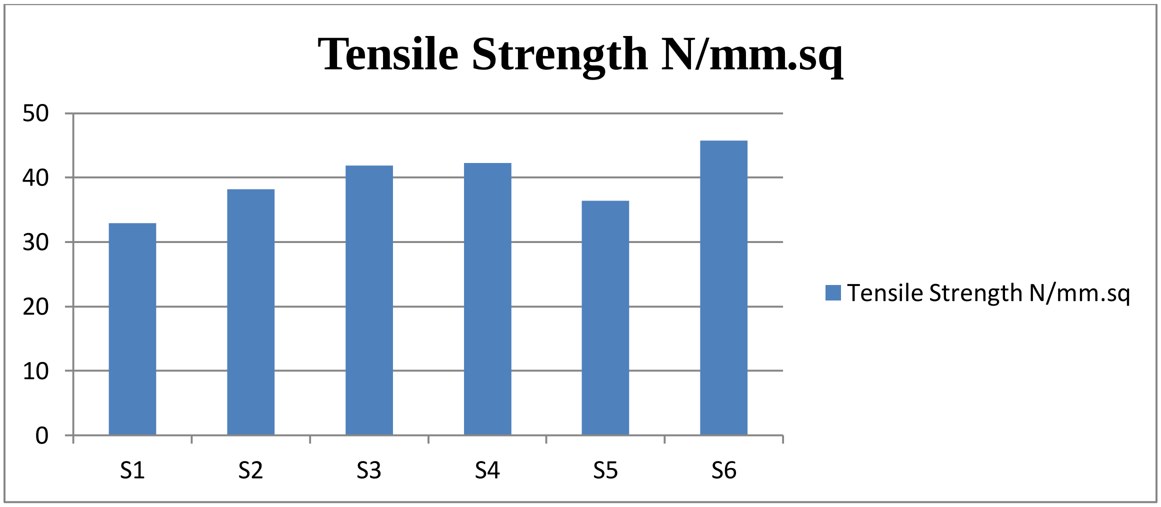


Figure 29 Shows Graphical representation of Tensile Strength for different Samples.

From the experimental results of each specimen, it was observed that maximum tensile strength of 45.731 N/mm^2 was given by sample S6 having volume fraction 22% with bidirectional fiber orientation and minimum tensile strength of 32.918 $N/mm^2$was given by sample S1 having volume fraction 22% with unidirectional fiber orientation. Figure 29 shows the graphical representation of tensile behavior of different samples along with tensile strength values. Furthermore effect of volume fraction, fiber orientation and hybridization are required to be discussed step wise in order to analyze tensile behavior of all specimens in details as given below:

Effect of volume fraction on tensile strength: A comparison has been made between samples S1 and S2 both having unidirectional fiber orientation but different volume fraction as shown in table 10. It was observed that as volume fraction increases from 22% to 42.6% the tensile strength of sample increases from 32.918 N/mm^2 to 38.232 N/mm^2 which shows fiber fraction plays a vital role in composites in carrying a load under tension. Same results were obtained in case of comparison of S3 and S4 hybrid composites made from jute and sisal which shows that tensile strength increased from 41.856 N/mm^2 to 42.306 N/mm^2 as volume fraction of fiber increases from 43% to 49%. Figure 30 shows a graphical representation of comparison of tensile strength of specimens having different volume fraction.

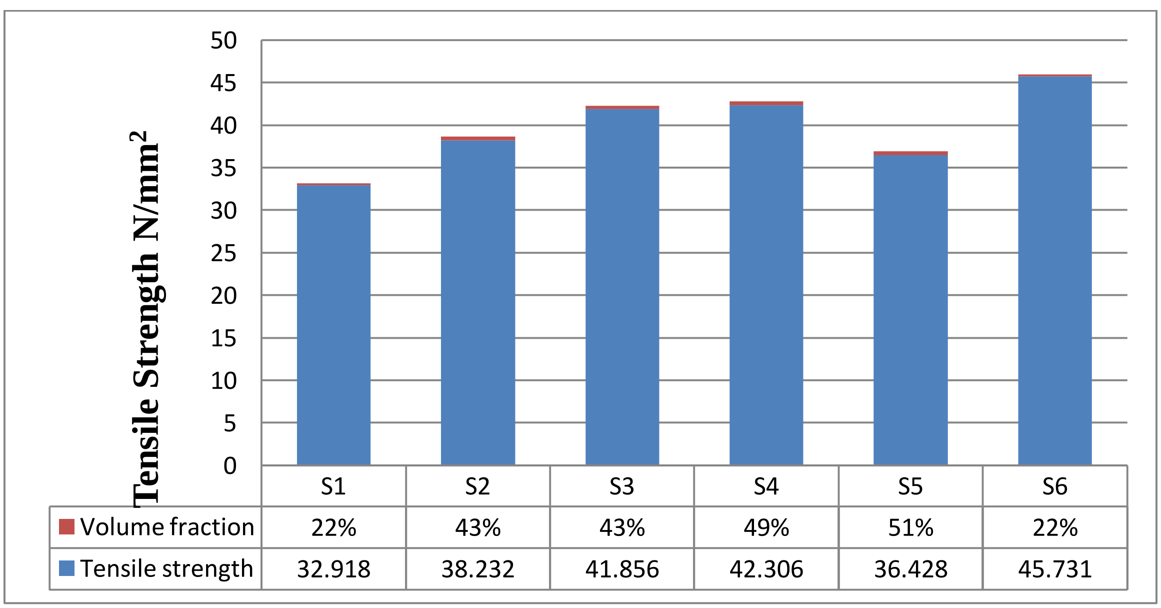


Figure 30: Shows comparison of tensile strength of samples having different volume fraction.

Effect of Hybridization on tensile strength: It was observed from the experimental results that hybrid composites are capable of bearing more loads under tension as compared to un-hybrid composites. A comparison has been made between S1 and S3 in which tensile strength increases from 32.918 N/mm^2 to 41.856 N/mm^2 as jute fiber composite (S1) replaced by jute-sisal fiber mixture in sample S3. Furthermore a comparison was made between S1, S3 and S4 which shows that hybridization of sisal-jute and increase in its volume fraction provides substantial increase in tensile properties of the samples as given in Table 10. A graphical representation of comparison of samples S1, S2 and S3 with tensile properties is given in Figure 31.

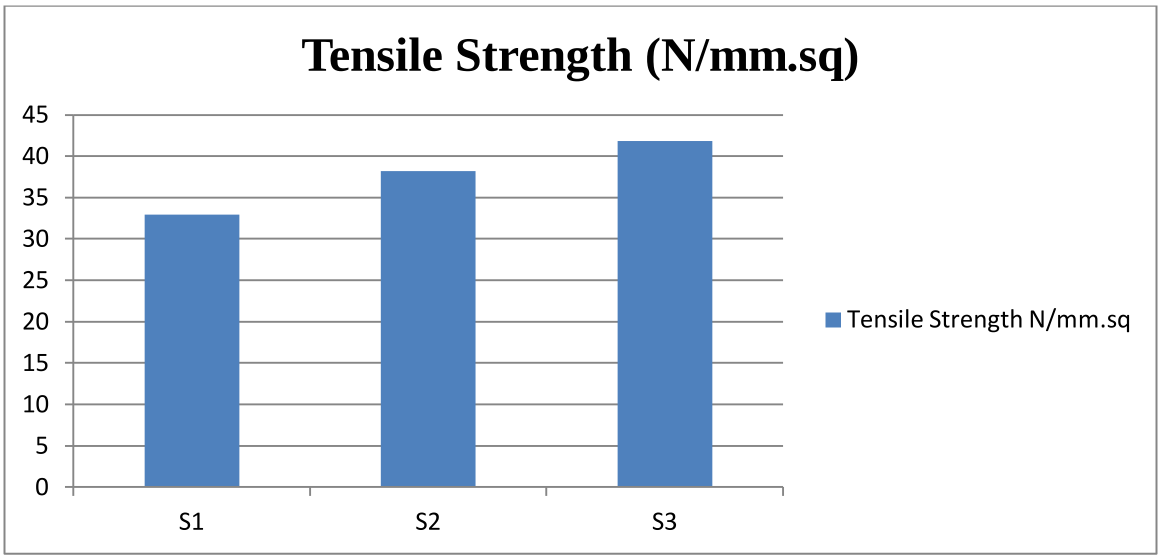


Figure 31: Shows comparison of Tensile strength of Samples.

Effect of Fiber orientation on tensile strength: A comparison has been made between samples S1, S6 having different orientations in which it was observed that bi- directional orientation of fibers in composites (S6) provide better strength as comparative to uni-directional orientation of fibers in composites (S1). As shown in table 10, sample S6 gives better tensile strength of 45.731 N/mm^2 as comparative to sample S1 which gives 32.918 $N/mm^{2.}$ Further comparison has been made between Samples S1,S5,S6 which shows that hybrid of sisal and jute (S5) orientated with [90,45,0,45,90] provides good tensile strength as compared to unidirectional(S1) and bi-directional(S6) composites. Figure 32 shows a comparison of tensile strengths of samples S1, S5 and S6 having different orientation.

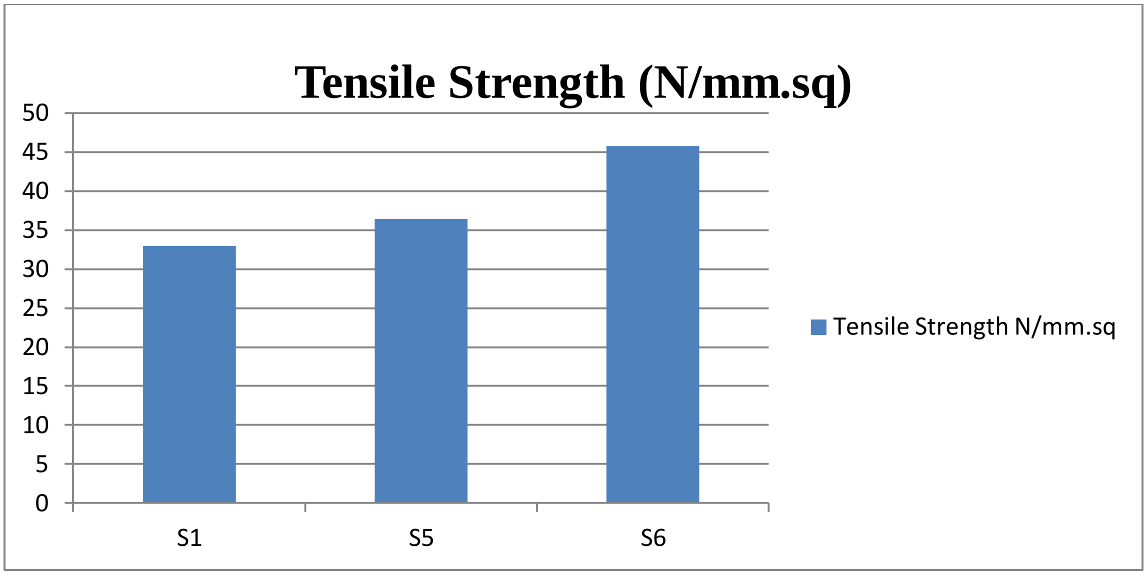


Figure 32: Shows a comparison of tensile strengths of samples S1, S5 and S6 having different orientation.

4.1.2 Flexure properties: All flexural specimens were prepared and tested as per ASTM standards D790-02, table 11 shows Flexural strength obtained for different samples.

Samples	Volume fraction	Orientation	Flexural strength (N/mm2)
S1	22%	Uni-directional	61.654
S2	43%	Uni-directional	32.683
S3	43%	Uni-directional	53.418
S4	49%	Uni-directional	35.647
S5	51%	90-45-0-45-90-	31.625
S6	22%	Bi-directional	63.019

Table 11: Shows Flexural Strength of Samples

It was observed that maximum flexural strength was obtained in sample S6 having volume fraction 22% and bi directional orientation of fibers where as minimum flexural strength was obtained in case of sample S5 having volume fraction 51% and [90, 45, 0, 45, 90] orientation of fibers in composites. Figure 33 represents the comparison of flexural strength for all samples having different volume fraction and fiber orientation.

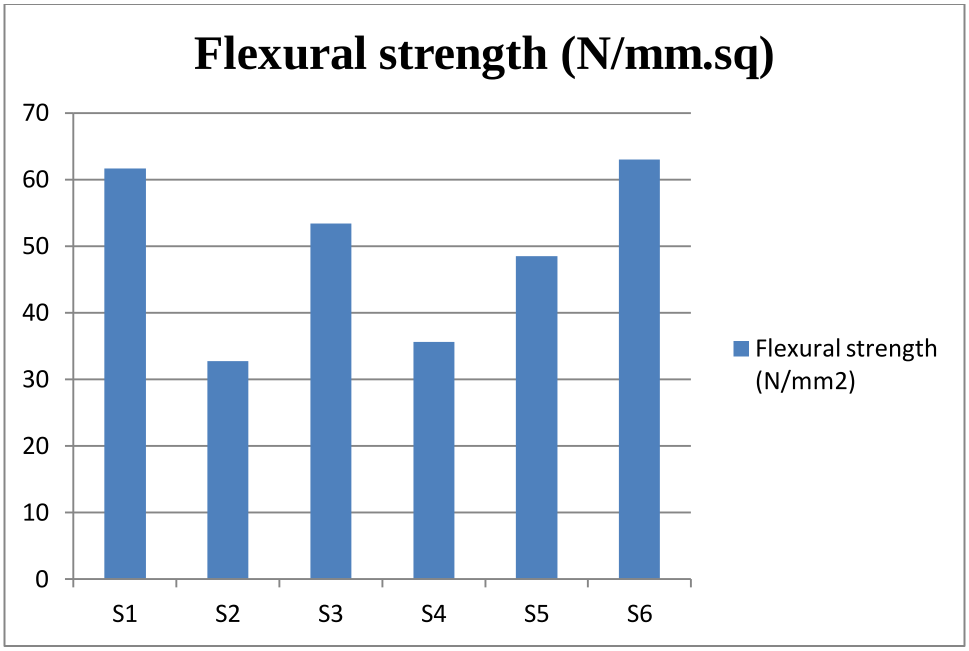


Figure 33: Shows Flexural Strength of all Samples.

Furthermore it was observed that flexural strength of samples decreases with the increase in volume fraction as in case of S1, S2 and S3, S4. Figure 34 shows the decrease in the value of flexural strength from 61.654 N/mm^2 to 32.683 N/mm^{2}as volume fraction increases 22% to 43%.

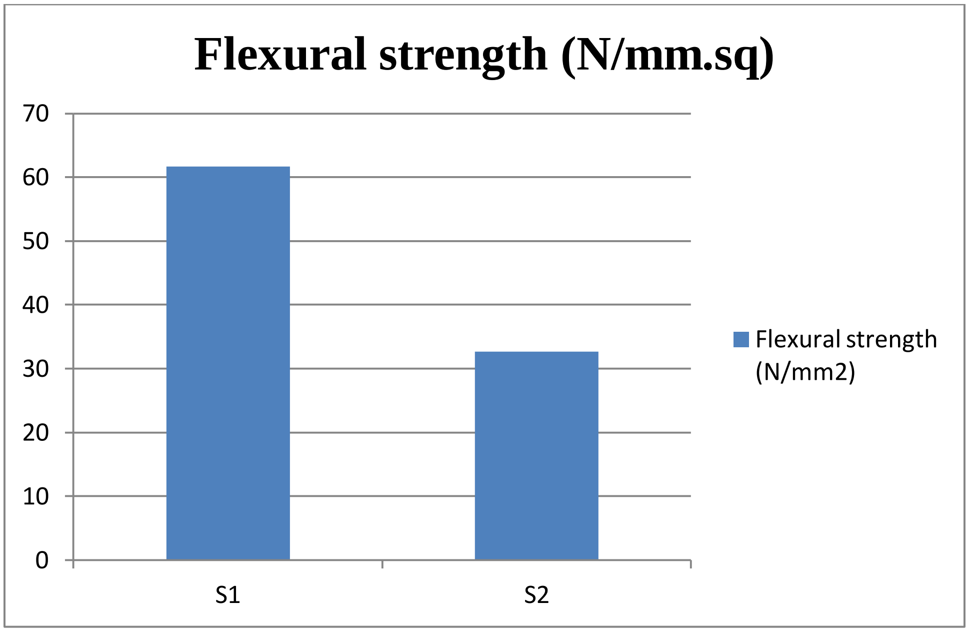


Figure 34: Shows Decrease in Flexural Strength.

4.1.3 Impact Properties:

All impact samples were prepared and tested as per ASTM standards A370, table 12 shows Impact strength obtained for different samples.

Samples	Volume fraction	Orientation	Impact strength (J)
S1	22%	Uni-directional	16
S2	43%	Uni-directional	20
S3	43%	Uni-directional	22
S4	49%	Uni-directional	7
S5	51%	90-45-0-45-90-	15
S6	22%	Bi-directional	2

Table 12: Shows Impact Strength of Samples

It was observed that maximum impact strength was obtained in sample S3 having volume fraction 43% and uni-directional orientation of fibers where as minimum impact strength was obtained in case of sample S6 having volume fraction 22% and bi-directional orientation of fibers in composites. Figure 35 represents the comparison of impact strength for all samples having different volume fraction and fiber orientation.

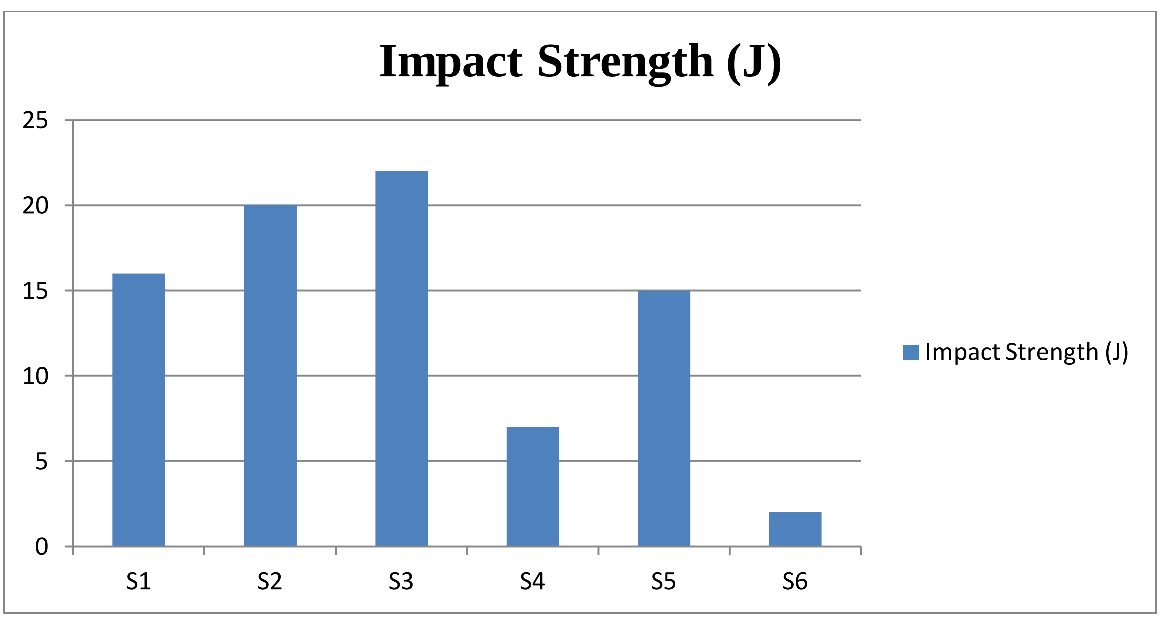


Figure 35: Shows the comparison of Impact strength for all samples.

Furthermore it was observed that impact strength of samples S1 (uni-directional) jute reinforced epoxy based has more strength of 16(J) whereas sample S6 (bi-directional) jute reinforced epoxy based composite has less impact strength of 2(J) although both are having same volume fraction. Figure 36 shows the comparison between uni-directional and bi-directional jute at same volume fraction.

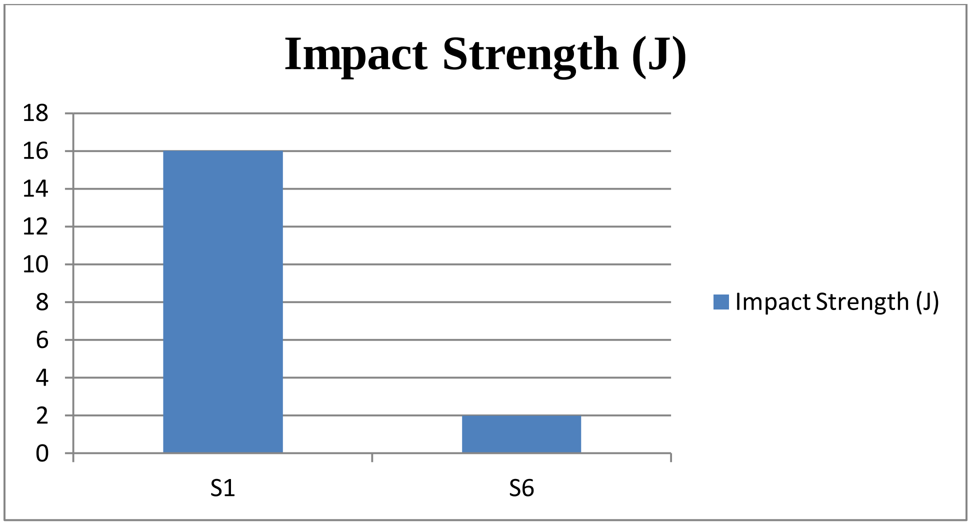


Figure 36: Shows the comparison between uni-directional and bi-directional jute reinforced epoxy based composite at same volume fraction.

A comparison has been made between sample S1 and S2 which shows that increase in volume fraction of fiber significantly increases the impact strength of the composites.

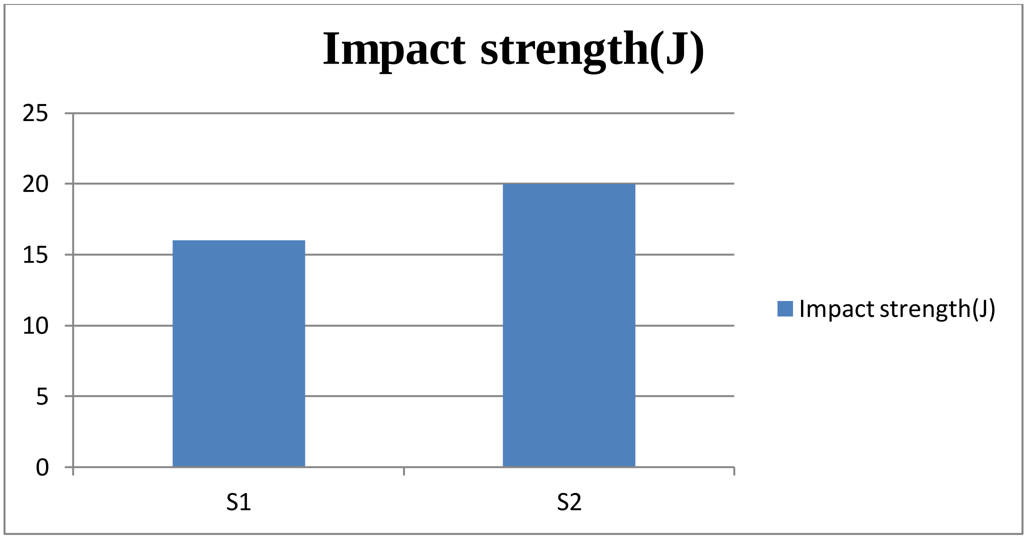


Figure 37: Comparison of Impact Strength between S1 and S2

Furthermore, comparison has been made between S1 and S3 in which impact strength increases from 16 J to 22 J because of hybridization of jute/sisal reinforcement whereas S1 is uni-directional jute reinforced composite only. Figure 38 shows the comparison between uni-directional and hybrid samples at different volume fraction.

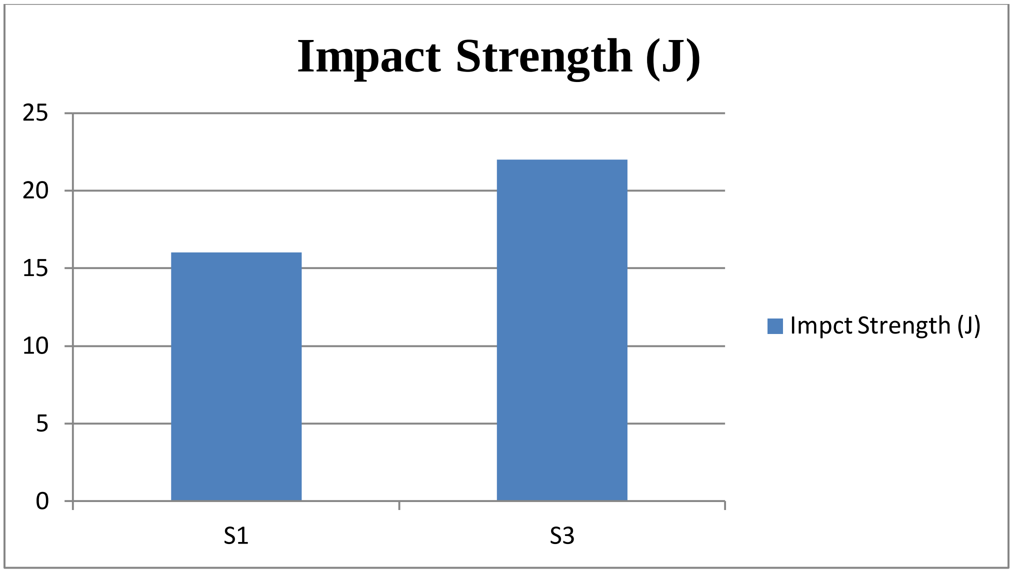


Figure 38: Shows the comparison between uni-directional (jute) and hybrid (jute/sisal) samples.

4.2 Water absorption analysis:

Water absorption behavior of different samples was analyzed according to ASTM- D570-98.Table 13 shows the variations in weight and percentage of water uptake.

Samples	Weight before Immersion (gm)	Weight after Immersion (gm)	Orientation	Percentage of water uptake (%)
S1	0.012	0.014	Uni-directional	16.666
S2	0.010	0.012	Uni-directional	20.222
S3	0.014	0.016	Uni-directional	14.288
S4	0.013	0.015	Uni-directional	15.388
S5	0.012	0.016	90-45-0-45-90-	33.333
S6	0.006	0.008	Bi-directional	33.333

Table 13: Shows variations in weight and moisture content of Samples

It is observed from the table that samples having fiber orientation (S5 and S6) have maximum moisture content as compared to hybrid samples (S3, S4) and uni-directional jute reinforced epoxy based composites samples (S1 and S2).

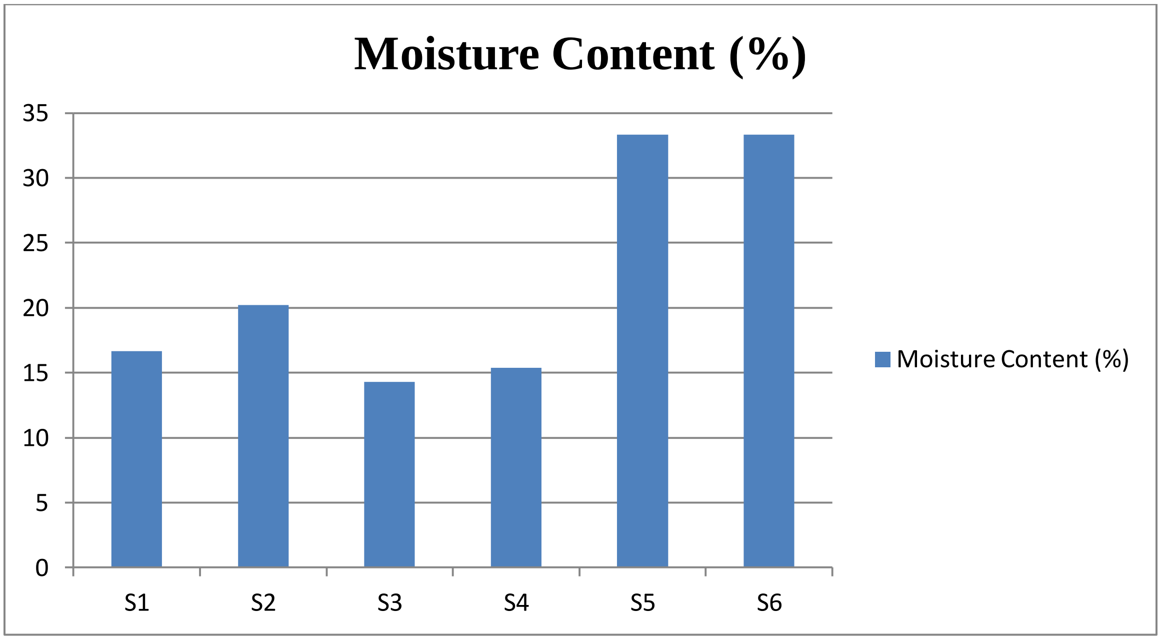


Figure 39: Shows Moisture Content in Samples

CHAPTER 5

5.1 CONCLUSION

The present experimental study of evaluating the effect of fiber volume fraction, fiber orientation on mechanical properties and investigating water absorption behavior of jute/epoxy based composites and jute-sisal/epoxy based hybrid composites along with their comparison leads to the following conclusions:

1. Fabrication of Natural fiber reinforced composite using hand layup technique was successfully done for jute-sisal/epoxy based composite and jute/epoxy based composites.
2. Present study revealed that natural fiber reinforced polymer composite shows good mechanical properties which can be further increased by doing hybridization of two or more natural fibers in a polymer matrix.
3. Tensile strength of developed composites increases with the increase in volume fraction of fibers as tensile properties greatly influenced by the tensile strengths of individual fibers in the composites.
4. It can be observed that tensile strength of hybrid composite (sisal–jute/epoxy) increases when compared to single jute/epoxy based uni-directional and bi-directional composites.
5. Maximum tensile strength of 42.306 N/mm^2 has been observed in hybrid composite having high percentage of fiber volume fraction 49% comparative to other composites.
6. Maximum flexural strength of 53.418 N/mm^2 observed in jute/sisal (Volume fraction 43%) fiber hybrid composite with unidirectional orientation.
7. Results indicated that impact strength of composites influenced by fiber composition within the matrix as impact properties of developed composites increases with increase in fiber volume fraction as well as by hybridizing sisal-jute fiber in epoxy based composites.
8. Water absorption behavior indicates that its rate increases with the increase in fiber volume fraction as observed in sample S1 and S2.

9. Water absorption percentage decreases in case of hybrid (jute/sisal) composite indicates that jute fiber volume fraction dominates in the water absorption characteristics of composites.

5.2 FUTURE SCOPE

There is a wide scope of research in the field of natural fiber based hybrid composites. So present work can be further extended to evaluate some of the objectives as given below:

1. Different fabricating techniques can be used to optimize the mechanical characterization of composites by varying fiber volume fraction and fiber orientations.
2. Different fiber orientation can be considered for evaluating efficient mechanical behavior of hybrid composites.
3. Evaluation of thermal and cryogenic properties can be done to identify its range of applications.
4. Effect of moisture on mechanical properties can be determined in order to identify the mode of failure.

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