ISSN : 2455-9679
Impact Factor : 3.805

IJRTSM

INTERNATIONAL JOURNAL OF RECENT TECHNOLOGY SCIENCE & MANAGEMENT

"MECHANICAL PROPERTIES OF EPOXY COMPOSITE REINFORCED WITH SISAL FIBER"

Brijesh Kumar Singh [1], ***Arun Patel*** [2]

[1] *M Tech Part Time Scholar& Department of Mechanical Engineering,NIIST, Bhopal, Madhya Pradesh, India*
[2]*Head & Associate Professor& Department of Mechanical Engineering,NIIST, Bhopal, Madhya Pradesh, India.*

ABSTRACT

This work explores the possible utilization of sisal fiber i.e. a natural fiber, in the form of short fiber in polymer composites and assesses its reinforcing potential. The research reported in this thesis broadly consists of three parts: The first part has provided the description of the materials used, processing steps and various experimental programs. The second part includes various physical and micro-structural characteristics of a series of epoxy based composites reinforced with short sisal fiber in different weight proportions. This part also report on the different mechanical properties like tensile strength , compressive strength and flexural strength of the fabricated samples with respect to the fiber content. Third part also reports on the effect of sisal fiber inclusion on sliding wear characteristics of epoxy based composite. This experimental investigation on short sisal fiber/epoxy composites has led to the following specific outcomes: sisal fiber possesses ample reinforcing potential to be used as a filler material in epoxy matrix composites. Successful fabrication of epoxy matrix composites reinforced with short sisal fiber is possible by simple hand-lay-up technique. These composites possess low amount of porosity with reduced density, low water absorption rate, improved compressive and flexural strength and reduced loss of material because of wear.

Key Words: *Epoxy, Sisal fiber, Polymer matrix composite, Properties, Scanning electron microscopy, Density, Voide content, Water absorption behavior*

I. INTRODUCTION

1.1 General Objects and Limits

It is difficult to draw a building material to assess the strengths and weaknesses of metals, plastics and clay because each of these terms covers all families of objects where the scope of buildings is usually as wide as the differences between the three classes. Comparison in general terms, however, may point to some of the obvious advantages and disadvantages of different types of assets. At the simplest level then:

Plastics have very low material content. They have good chemical resistance for a while but have no thermal stability and have only a moderate resistance to environmental degradation. They have bad mechanical properties, but they are easily made and assembled.

Clay materials can be of low size (although some are very dense). They have high heat resistance and are resistant to many types of attacks (abrasion, wear, rust). Although they are extremely strong and durable due to their chemical composition, they are all shy and can only be built and molded with difficulty.

Metals are mostly medium to high in size. Many have good thermal stability and can be made to resist corrosion by bonding. They have useful properties and high hardness, and are moderately easy to join. It is largely due to their inefficiency and resistance to cracking that metals, as a class, became (and remained) popular materials.

On the basis of the above comparisons it can be seen that each category has certain internal advantages and

ISSN : 2455-9679
Impact Factor : 3.805

disadvantages, although the polymer presents fewer problems to the designer than steel or clay vessels.

1.2 Introduction to Consolidation Materials

The scarcity of common materials has forced the scientific community to work on another matter of material and after intensive research they came out with a composite material. A compound is defined as any combination of two or more different elements. If you look at this definition, it will include bricks, concrete, wood, bone and modern man-made compositions such as plastic reinforced with long or short wire. The man-made combination took a huge market fifty years ago, when low-rise building combined with high strength and durability was a concern. Apart from the above definition of integration, in addition three other methods must be met before we can call an asset a combination. First of all, all the elements that make up a combination must be present in the right proportions. Second, all components used to make a composite must have different properties so that the composite structures differ significantly from the sand structures formed by the impact of any single component which must not first control the composite structures. Finally, synthetic compounds are usually produced by deliberate mixing and combining of elements in various ways [1].

Combined materials increase the range of designers across all engineering branches. Compounds are grouped in a way that will help us make the most of their beauty while minimizing the effects of their failures. This process of excellence can free the designer from the problems associated with the selection and production of standard materials. They can use solid and lightweight materials, with structures designed to fit specific design requirements. And because it is so easy to make complex designs, a complete rethinking of a composite design can lead to both cheaper and better solutions [2]. Compound materials create expertise that can be acquired by the materials scientist and his clients, a design engineer.

Also, according to the same definition, two or more different categories mean that they must have a chemically intermediate phase and it is also important that the specification of these components is possible in any way. Between the two distinct elements there should be a continuous phase that usually occurs in large quantities in the compound, though not always. This continuous phase is called the matrix. A common theory is that it is the matrix characteristics that are developed when another component is produced to integrate. Some elements are known as the reinforcement phase. In many cases reinforcement is harder, stronger and stronger than the matrix, although there are some exceptions. The geometry of the reinforcement phase is one of the major constraints in determining the performance of reinforcement; in other words, composite machine structures are a function of the shape and size of the reinforcement.

The separation of composites can be done in two different phases, first on the basis of the matrix material as shown in Figure 1.1 where there may be metal composites, ceramic matrix composites and polymer matrix compounds. It is evident that the polymer matrix has also been divided into thermoset compounds and thermoplastics compounds**.** properties of composites are a function of the shape and dimensions of the reinforcement.

Classification of composites can be made in two different categories, first on the basis of matrix materials as shown in figure 1.1 in which it can be metal matrix composites, ceramic matrix composites and polymer matrix composites. It is observed that polymer matrix is further categorized as thermoset composites and thermoplastics composites.

II. LITERATURE REVIEW

Human beings are exclusively depends upon plants and its fibers for their requirements. In this regards, use of natural fibers are increasing gradually in industrial and human applications. Composite are prepared either by synthetic fibers or by natural fibers. Now going with eco-friendly, decomposable and monetary scenario natural fibers are flagrantly used in place of synthetic fibers. The natural fiber possesses various unique characteristics. Its properties may vary with change of source of generation, because natural fibers are produced in different environmental conditions. The land, water, sun intensity and air vary with change of location & natural conditions are varying place to place and season to season which affect the inbound properties of natural fibers based composites. There is a long list of natural fibers available in nature which is being used by various researchers to develop new class of composite material.

The use of natural fiber as a filler material in composite was earlier reviewed **by Saheb and Jog [5]** in late 90's as natural fiber reinforced composites was emerging area at that time in the field of polymer science. Among the various advantage offered by natural fibers like low density, high specific properties, biodegradable and non-abrasive, the natural fibers had certain limitations as well. They are incompatible with most of the matrix and had moisture absorption behavior. They presented the natural fiber reinforced composites with special reference to the type of fiber, treatment of fibers and interface of fiber and matrix.

ISSN : 2455-9679
Impact Factor : 3.805

Komuraiah et al. [6] presented the chemical composition of natural fibers and the effect of it in various mechanical properties. They reported that the main components of natural fibers are cellulose, hemi cellulose, lignin, pectin and wax. Out of this wax is highly undesirable as it reduce the adhesion between fiber and polymer. They further studied that the composition of these natural fibers were primarily dependent on the geographical location where the plants are grown up. They concluded that all fiber has the same constituents but the compositions of each constituent vary with fiber and their way of grown up.

Mohammed et al. [7] reviewed widely used natural fiber reinforced polymer composites and their applications. They also discussed the effect of different chemical treatments applied to the natural fibers when they reinforced in various polymers. Impacts of surface modification on various properties like water absorption, tribology, viscoelastic behavior, relaxation behavior, flames retardancy, and biodegradability properties of NFPCs were also discussed in their article.

Machado et al. [8] present an overview of physical and mechanical properties of natural fiber reinforced composites. They studied the effect of service condition on the properties of such composites. They studied the behavior of composites when it was used for short term application and for long term application.

Fan and Fu [9] in their study first classified the type of natural fiber that can be used for construction purpose. Then on the basis of identification of various applications in construction site, they explore the hierarchical structure of such natural fibers.

Gopinath et al. [10] performed experimental study with jute as reinforcement material in epoxy and polyester matrix. They fabricated composites with maximum filler content of 18 % by weight with both the polymers and evaluated different mechanical properties like tensile strength, flexural strength, impact strength and hardness. In their study they reported that epoxy as matrix material had better compatibility with jute as compared to polyester as matrix material and hence epoxy based composites has better mechanical properties when compared to polyester based composites.

Pereira et al. [11] reported the variation in impact resistance provided by epoxy matrix composites reinforced with aligned and continuous jute fiber. The maximum percentage of jute fiber is incorporated in epoxy was 30 % by volume in their analysis. They measured the impact energy absorbed by material with Charpy impact testing machine. In their study they found that the amount of energy absorbed by composite increases with increase in fiber volume fraction. They further compared their result with different published results and found that energy absorbed with jute as filler material is better that most of the natural fiber i.e. Ramie, coir and Curaua.

Mohanty et al. [12] used jute fiber as reinforcement after modifying its surface. This surface modification involves dewaxing, alkali treatment, cyanoethylation and grafting. After the chemical treatment of fiber, Fourier-transform infrared spectroscopy and thermogravimetric analysis were performed on it. They concluded that with surface treated fiber in Biopal, tensile strength is increased by 50%, bending strength is increased by 30% and remarkable increase of 90% is reported in impact strength when compared to neat Biopal. They found that treatment of surface will increase the adhesion between fiber and matric with the help of scanning electron microscopy. This is the main reason of increase of various mechanical properties.

Similarly **Kumar et al. [13]** reduces the moisture content of the fiber by providing it with alkali treatment using NaOH solution. They found that, this preprocess of fiber reduces the wettability and thickness of fiber as has low moisture absorption. This certainly increases the adhesion between fiber and matrix. They concluded that usage of treated fiber will certainly increase the mechanical properties of the composites.

On the same note, **Basak et al. [14]** treated the surface of jute fiber and observed improvement in physical appearance of the jute fiber. They reported that there is no significant improvement in the mechanical properties of treated fiber reinforced epoxy composites.

Another natural fiber which is of interest currently and is extensively used is basalt fiber which has exceptional properties over glass fiber. The protuberant benefits of these composites comprise high specific mechano-physico-chemical properties, biodegradability and non-abrasive qualities. Keeping that in mind **Dhand et al. [15]** presents a review of basalt fiber used as a reinforcement material. In their work, they combined the work performed by various researchers and also present the classification of basalt fiber. They further include the detail of properties obtained by various researchers which includes mechanical, thermal and chemical resistant properties.

Amuthakkannan et al. [16] concentrate their study on the length and content of basalt fiber in polymer composites. They tried to establish the relationship between mechanical properties and length and content of fiber. They performed their study with polyester resin and performed various destructive tests on the fabricated composites. Further they also examined the failed composites under scanning electron microscopy. It is always necessary to have good interfacial bond between fiber and polymer to improve the physical properties of the composites. Apart from physical properties, various mechanical and thermal properties of the composites were also dependent on the interfacial bonding and also on fiber length and orientation.

Pak et al. [17] investigate basalt fiber/polypropylene composites and evaluate dynamic mechanical and thermal analysis. They studied the grafting effect of maleic anhydride polypropylene on the basalt fibers which ultimately improves the bonding strength and thermomechanical properties of the composites.

Bauer et al. [18] used continuous basalt fiber and present a probable polymer composite for high performance application. They provide a unique combination of mechanical and functional properties as low cost. They procured the fiber from different vendors and investigated their composition, physical parameters and probable defects. Later they establish structure-property relationship for the most potential fiber sort out after introductory analysis.

Muñoz et al. [19] used flax fiber with epoxy matrix upto 50 wt% of fiber using resin transfer moulding. They studied the effect of flax fiber in water absorption behavior of the epoxy matrix. Later they performed tensile and flexural testing of water immersed specimens and evaluated the result. Their analysis revealed that fiber gets swelled due to water absorption and this will actually beneficial as far as mechanical properties of composite is concerned. **Huang et al. [20]** work on the response of impact or shock load on the flax/epoxy composites. The outcome of their study was that the cross-ply samples retained their structural integrity at peak pressures that were sufficient to break unidirectional samples.**Haggui et al. [21]** provided a complete set of static and fatigue loading data of thermoplastic composite fabricated using liquid resin infusion. They studied the fatigue tensile behaviour by estimating the material stiffness degradation. The fatigue results obtained were than concluded in an S-N curve in their later work.

Campana et al. [22] studied the impact of processing at high temperature upon mechanical properties of fabricated composites. They found that post curing of composites at temperature slightly decreases the tensile properties of the matrix used in polymer composites. They further observed that interfacial adhesion between fiber and matrix not play major role in improving the mechanical properties of the composite. They concluded that the probable reason for that is the intrinsic weakness of the material.

Perremans et al. [23] analyzed the damping behavior of the flax fiber composites. They further found that the measured value is inferior when compared to the theoretical value which is mainly because of the limited compatibility between the fiber and matrix. To enhance the compatibility between fiber and matrix, three different types of chemical treatment were performed on fiber by them. The chemical treatment done by them enhances the mechanical properties of the composites and the improvement and benefit of chemical treatment were reported in their work.

Luo et al. [24] used corn fiber in three different forms in polyactide matrix. They used untreated fiber, alkali treated fiber and fiber with sizing treatment. Than they evaluated the mechanical and thermos-mechanical properties of three different set of composites and found that sizing-treated corn fiber give better properties followed by alkali treated fiber and untreated fiber. They concluded that the main reason of difference in properties is because of the interfacial adhesion between fiber and matrix. From SEM analysis, they found that untreated fiber show poor adhesion between fiber and matrix which improves when fibers were alkali treated and further improves when fibers were sizing-treated.

Kumar et al. [25] also studied the mechanical properties of corn fiber reinforced polymer composites but with polypropylene matrix. Also in-spite of modifying the fiber surface, they modified the surface of polypropylene by adding Maleic anhydride grafted polypropylene to it. With modified matrix, they found improvement in mechanical properties which was the outcome of experimental finding conducted using Taguchi method and analyzed by ANOVA optimization method.

Youssef et al. [26] used recycled low density polyethylene with corn husk (powder form) in their study. The composites were fabricated by melt compounding followed by compression moulding. The effect of filler content of crystallization behavior, mechanical, and swilling properties were investigated in their study. They also found the similar increasing trends in the tensile strength of fabricated composites with filler content, though hardness marginally with filler content decreased according to their study. They further evaluated the thermal behavior using differential scanning calorimetry of the composites and reported improvement in the thermal stability of composites.

Luo et al. [27] utilized the different part of the corn stalk in their study for fabricating composites. They performed mechanical testing on different composites and found that the properties were affected by the composition in terms of cellulose, hemicellulose and lignin fractions. In their study, they found that with increase in cellulose and lignin content, flexural and tensile strength of composites increases whereas the corn fiber part with high hemi cellulose content show poor mechanical properties. Compiling their result, they concluded that the stem or cob part of the corn

ISSN : 2455-9679
Impact Factor : 3.805

was the more suitable corn fiber for the preparation of composites because this part contains more cellulose and lignin and low hemi cellulose content.

Mechakra et al. [28] in their work used Alfa fiber in its short form in polypropylene matrix for fabrication of composite material. They used different surface treatment methods for the modification of the surface of fiber for better adhesion between fiber and matrix body. Among the various treatment methods, they found alkali treatment of fiber is best with optimum concentration. They performed SEM analysis, to show the modified surface of fiber and its interaction with matrix body. Further, the treated fiber when incorporated in polypropylene matrix, it shows remarkable improvement in tensile strength and Young's modulus. They also reported in the improvement in acoustic properties of the composites when raw fiber were replaced with treated fiber.

Du et al. [29] fabricated thermoset based pulp fiber composites with a combination which consist four type of pulp fiber and two types of thermoset polymers. The fiber and matrix used in their investigation are hardwood and softwood high-yield pulp (HYP), Kraft pulp, and whatman cellulose fibers and two matrixes include unsaturated polyester and vinyl ester. They performed the FTIR and TGA analysis of the composites and presented the result obtained by the analysis and draw some interesting conclusion from their analysis. A natural fiber i.e. kenaf fiber which is industrial crop in Malaysia and also grown commercially in some other part of the world is considered to be important reinforcement material to be used as automotive and construction materials.

Rashid et al. [30]studied the dry sliding wear behaviour of sugar palm fiber reinforced in phenolic resin. Their analysis revealed that the applied normal load and treatment made the most significant contribution to the volume, while the sliding speed had no significant effect on the wear results.

Kalapakdee et al. [31] studied the Composites of preferentially aligned pineapple leaf fiber (PALF) in a thermoplastic elastomer Santoprene. PALF filled Santoprene composites were first prepared by melt mixing on a two-roll mill with different PALF contents. Tensile and tear properties in directions parallel and perpendicular to the fiber axis were measured. They observed that the modulus at 10% strain and tear strength in the longitudinal direction increased significantly with increasing PALF content (up to 15%), while tensile strength and elongation at break decreased. The effect of PALF content was less significant in the transverse direction. In addition, compression molding temperature also affected all these properties but to different extents. The two most affected properties were modulus and tear strength in the longitudinal direction as concluded by the authors.

Sair et al. [32] used a combination of polyurethane and hemp fiber to develop a new set of material. They concentrate their study to evaluate water absorption behavior, thermal conductivity and mechanical properties of the composites in context to fiber content. The output of their work follows the trend that mechanical properties increases with fiber content whereas thermal conductivity decreases. Both the factors are favorable for the developed material to be used in building insulation. **Sepe et al. [33]** did pre-treatment of hemp fiber to improve the bonding between fiber and epoxy matrix. They compared the mechanical behavior obtained with and without fiber treatment and shows that silane treated hemp fiber improves the tensile and flexural properties of the composites. For analyzing the bonding of fiber and matrix they also observe the sample under scanning electron microscopy and perform Fourier transform infrared spectroscopy.

Khan et al. [34] performed the experimental and numerical study of fracture behavior of bamboo fiber reinforced epoxy composites. They used NaOH treated fiber in their study. Treatment of fiber increased the tensile strength of the composites. They performed fracture analysis with fiber of varying length and observe the effect of change in length of property of composites. The outcome of their study shows that with increase in fiber length, fracture toughness of the composite increases when the content of the fiber remain constant.

Roy et al. **[35]**evaluated the mechanical properties of the coir fibers in their study. Tensile strength, Young's modulus and elongation at break of virgin coir fibers were found to be 152 MPa, 5.3 GPa and 36%, respectively. Coir fibers were treated with ultraviolet (UV) radiation and were found to improve the mechanical properties significantly. The surface of the fiber was mercerized (alkali treatment) using aqueous NaOH solutions (5–50%) at varied time and temperature. Pretreatment with mercerization of coir fiber showed significant improvement in the mechanical properties of the coir fiber-based composites. They also studied the water absorption behaviour and found that it increases with fiber content and soaking time. Further, they concluded that water absorption percentage decreases when treated fiber were used.

Ramesh et al. [36] were also fabricated banana fiber reinforced polymer composites with thermoset polymer epoxy and experimentally determined its mechanical properties. All the composites were fabricated using hand lay-up

ISSN : 2455-9679
Impact Factor : 3.805

technique and the fractured surface were studied under scanning electron microscopy. **Jorden et al. [37]** improves the interfacial bonding between banana fiber and LDPE matrix with the help of chemical treatment. They used two different techniques for fiber treatment i.e. peroxide treatment and permanganate treatment. With two different techniques they fabricated different set of composites and evaluated the tensile and flexural strength. In their analysis, they found that peroxide treatment of fiber enhances the both the properties of the composites whereas, permanganate treatment results in no effect on the properties of composites. Though in their study, they found that both the treatment enhances the bonding between fiber and matrix. **Muktha, and Gowda [38]** focused their work on water absorption and fire resistance behavior of banana fiber reinforced polyester composites. They prepared specimen of two different thicknesses i.e. of 3 mm and 5 mm with same fiber volume fraction. In their analysis they found that water absorption and fire resistance capacity of 3 mm thick specimen is less than that of the 5 mm thick specimen and concluded that water absorption and fire resistance of composite is a function of thickness of specimen.

Apart from single usage of natural fiber, recent work is in progress for hybrid fiber reinforced composites. In this regard, lot of work is in progress which includes work done by **Xia et al. [39]**, where they incorporate natural fiber in aluminum sheet hybrid composites and developed material to be used in high electromagnetic interference shielding performance. **Manteghi et al. [40]** investigate mechanical properties and failure mode of dual fiber reinforced composites to be used in medical application i.e. for bone fracture fixation plates. Similar mechanical analysis was performed by **Wang et al. [41]** using furan and basalt fiber in combination in epoxy matrix. In their work they reported an increase in mechanical and anticorrosion properties. This shows that hybridization of fiber in polymer composite may result in overall improvement in their properties.

Zuccarello et al. [42] used optimal manufacturing for fabrication of composites and then did mechanical characterization of high performance fabricated composites. With the new technique of manufacturing, they obtain the composite with unidirectional fiber distribution up to volume fraction of 70%. This manufacturing technique helps to improve the properties of the fabricated composites as reported by them. They presented the comparison of their data with recently developed manufacturing technique with the data available in literature and proposed higher mechanical properties. On the basis of their comparative analysis they suggested that the fabrication of composites by present method can advantageously substitute not only materials as steel, aluminum and glass fiber reinforced plastics, but also other bio composites reinforced by more expensive fibers.

2.2 On sisal fiber filler reinforced polymer matrix composites

Among the different types of natural fibers, sisal fibers is a promising reinforcement for use in composites on account of its low cost, low density, high specific strength and low modulus, no health risk, easy availability & renewability. In recent years there is increasing interest in finding new applications for sisal fiber composites that are traditionally used for making ropes, mats, carpets, fancy articles, etc.

Sisal fibers are extracted from agave sislanaperrine leaves. Sisal plants, Agave sisalana, consist of a rosette of sword-shaped leaves about 1.5–2 meters (4.9–6.6 ft) tall. Young leaves may have a few minute teeth along their margins, but lose them as they mature. The sisal plant has a 7–10 year life-span and typically produces 200–250 commercially usable leaves. Each leaf contains an average of around 1000 fibers. The fibers account for only about 3% of the plant by weight. Sisal is considered a plant of the tropics and subtropics, since production benefits from temperatures above 25 degrees Celsius and sunshine. Generally sisal fiber consist of 67-78% cellulose, 10-14 % hemicelluloses, 8-10% lignin, 2% waxes, 1% ash and 1% water. For extraction of sisal fibers ratting is done followed by scraping. After extraction the fibers are washed thoroughly in plenty of water to remove the surplus wastes such as chlorophyll, leaf juices and adhesive solids. The tensile strength, modulus and fracture strain of sisal fiber is not uniform along its length.

Suppakarn and Jarukumjorn [43] presented flame retardancy behavior sisal fiber reinforced polypropylene composites with and without using flame retardant material. In their study, they found that the addition of flame retardants into sisal/PP composites reduced burning rate and increased thermal stability of the composites. They also did study of mechanical properties of both sets of composites and found that there is no synergistic effect was observed when different flame retardant was incorporated in the sisal/PP composites. Their work revels that addition of retardant enhanced flame retardancy of sisal/PP composites without sacrificing their mechanical properties. **Martin et al. [44]** studied thermal analysis of sisal fiber by thermogravimetric analysis and differential scanning calorimetry under air and nitrogen atmospheres. By both the above analysis they show that cellulose and hemi cellulose degraded at lower temperatures than that of the raw sisal fiber, which can be attributed to the removal of lignin.

Zhou et al. [45] works on the development of polymeric composites reinforced with sisal fibers. The main aim of their work is to propose a composite material which will be stronger so that can used in place of timber structures. They present the mechanical characterization of composites under study. The used woven sisal fabric was first undergone through heat treatment process to remove any moisture content present prior to its fabrication. Tensile and cross breaking strength with and without thermal treatment on the fiber is presented in their work. The experimental results show maximum tensile and a cross breaking strength value of 25.0 MPa and 11.0 MPa, respectively among the various set of fabricated composites.

In a more recent work, **Fiore et al. [46]** proposed another method for improving the surface properties of sisal fiber. They utilized eco-friendly and cost effective surface treatment method based on the use of commercial sodium bicarbonate (i.e. baking soda) on properties of sisal fiber and its epoxy composites. They utilized a mathematical model to investigate the relation between the transverse dimension of the fibers and their tensile properties. For experimental study they fabricated epoxy based composites reinforced with short randomly oriented sisal fibers and characterized by means of quasi-static cross breaking tests.

Ramesh et al. [47] fabricated hybrid composites with a combination of synthetic and natural fiber. They used sisal and jute fiber as natural fiber and glass fiber as synthetic fiber in their study. They reinforced the combination of these fibers in polyester resin and fabricated a new class of composites. Later, they experimentally determined the tensile strength, cross breaking strength and impact strength of the developed composites. They reported that the incorporation of sisal–jute fiber with glass fiber improved the various mechanical properties and used as an alternate material for glass fiber reinforced polymer composites.

Orue et al. [50] studied the effect of different chemical treatments on sisal fiber as well as on tensile properties of their composites with poly lactic acid (PLA) as a matrix material. Among the various treatment agent, alkali treated fibers showed the highest tensile strength values. Further the experimental findings were compared with those values obtained using micromechanical models and are found to be in good agreement. More recently, **Dwivedi et al. [49]** fabricated and studied the behavior of hybrid composite with carbon nano tubes and sisal fiber as reinforcement in epoxy resin. They investigated the electrical properties of the fabricated composites. In their study, the composite was fabricated by hand lay-up technique the various electrical properties such as dielectric constant, dielectric dissipation factor and electrical conductivity was measured. All this properties are measured at wide range of temperature and frequencies. They observed that the dielectric constant increases with temperature and decreases with frequency. They concluded that sisal as reinforcement can also be used in material used electronics components.

In a very recent work,**Prasad et al. [50]** studied the impact strength of sisal fiber polyester composites. For this study, they used treated and untreated sisal fiber as reinforcement. They opted for random orientation of fibers within matrix body. Manually operated compression moulding technique is used for fabrication purpose. They found that, treatment of fiber reduces the impact strength of the composites. They reported that untreated sisal polyester composite yielded its peak impact strength of 3.581 N-m at its 30% fiber volume fraction whereas, treated sisal polyester composite has shown highest impact strength of only 1.962 N-m at its 30% fiber volume fraction. Later in their work, they suggested that fabricated class of composites can find their application in Light doom, Mudguards, name and number plates and Engine guard in automobiles; switch gear, panels and insulators in electrical industries.

III. PROBLEM IDENTIFICATION

On the basis of exhaustive literature review, it has been found that there is certain knowledge gap in earlier investigation, and on the basis of that problems are identified as follows:

1. In any of the earlier investigation, sisal fiber has not been used in its short form, rather long sisal fiber were used by many researcher as a reinforcement material.
2. Detailed study of physical behavior i.e. density, void content and water absorption rate of sisal fiber reinforced epoxy composite is missing in earlier investigation.
3. Mechanical behavior of sisal fiber reinforced epoxy composites has not been discussed in detail in earlier investigation.
4. Sliding wear analysis of such fiber matrix combination has not been discussed in past by any researchers.

ISSN : 2455-9679
Impact Factor : 3.805

Generation of sisal fiber is huge in India mainly in the southern part of the country, rather its proper utilization as reinforcement in polymer composites are always remains a less studied area. Though, it was established that reinforcing potential of sisal fiber is good and comparable to many other natural fibers.

IV. Conclusions

This experimental investigation on short sisal fiber reinforced epoxy composites has led to the following specific conclusions:

1. Successful fabrication of epoxy matrix composites reinforced with short sisal fiber is possible by simple hand-lay-up technique.
2. The density of the fabricated composites decreases with increase in weight fraction of the fiber content. The reduction in density is mainly because of low density of fiber.
3. The water absorption rate increases with increase in fiber content and duration of immersion of composite body inside the water.

V. Recommendations for potential applications

Composite materials show excellent performance, these days, starting from manufacturing point of view to sports goods. It is due to their light weight, high stiffness-to-weight and potentially high resistance to environmental degradation, resulting in lower life-cycle costs. The silicon carbide-epoxy composites fabricated and experimented upon in this investigation are found to have adequate potential for a wide variety of applications. Use of these composites may be suggested in applications like engineering structures and low cost building materials. The content of sisal fiber is to be decided judiciously keeping the strength in mind. These composites, in general, may also be recommended for applications like partition boards, door and window frame, false ceilings, wall insulation and floor lamination, pipe lines carrying coal dust, automobile interiors(seat backs, parcel shelves, door trim panels, wheel cover),exhaust fan blades etc.

REFERENCES

1. Harris B (1999). Engineering composite materials, The Institute of Materials, London.

2. Pickering KL, Efendy MGA, Le TM (2016). A review of recent developments in natural fiber composites and their mechanical performance, Composites: Part A 83, 98-112.

3. Wambua P, Ivens J, Verpoest I (2003). Natural fibers: can they replace glass in fiber reinforced plastics? Composites Science and Technology, 63, 1259-1264.

4. Saheb, D. N., & Jog, J. P. (1999). Natural fiber polymer composites: a review. *Advances in Polymer Technology: Journal of the Polymer Processing Institute*, *18*(4), 351-363.

5. Komuraiah, A., Kumar, N. S., & Prasad, B. D. (2014). Chemical composition of natural fibers and its influence on their mechanical properties. *Mechanics of composite materials*, *50*(3), 359-376.

6. Mohammed, L., Ansari, M. N., Pua, G., Jawaid, M., & Islam, M. S. (2015). A review on natural fiber reinforced polymer composite and its applications. *International Journal of Polymer Science*, *2015*.

7. Machado, J. S., &Knapic, S. (2017). Short term and long-term properties of natural fibre composites. In *Advanced High Strength Natural Fibre Composites in Construction* (pp. 447-458). Woodhead Publishing.

8. M. Fan, F. Fu, Introduction: A perspective – natural fiber composites in construction. *Advanced High Strength Natural Fiber Composites in Construction*, 1–20, (2017).

9. Gopinath, A., Kumar, M. S., &Elayaperumal, A. (2014). Experimental investigations on mechanical properties of jute fiber reinforced composites with polyester and epoxy resin matrices. *Procedia Engineering*, *97*, 2052-2063.

10. Pereira, A. C., Monteiro, S. N., de Assis, F. S., Margem, F. M., da Luz, F. S., & de Oliveira Braga, F. (2017). Charpy impact tenacity of epoxy matrix composites reinforced with aligned jute fibers. *Journal of Materials Research and Technology*, *6*(4), 312-316.

ISSN : 2455-9679
Impact Factor : 3.805

11. Mohanty, A. K., Khan, M. A., &Hinrichsen, G. (2000). Surface modification of jute and its influence on performance of biodegradable jute-fabric/Biopol composites. *Composites Science and Technology*, *60*(7), 1115-1124.

12. Sathishkumar, S., Suresh, A. V., Nagamadhu, M., & Krishna, M. (2017). The effect of alkaline treatment on their properties of Jute fiber mat and its vinyl ester composites. *Materials Today: Proceedings*, *4*(2), 3371-3379.

13. Basak, R., Choudhury, P. L., & Pandey, K. M. (2018). Effect of Temperature Variation on Surface Treatment of Short Jute Fiber-Reinforced Epoxy Composites. *Materials Today: Proceedings*, *5*(1), 1271-1277.

14. Dhand, V., Mittal, G., Rhee, K. Y., Park, S. J., & Hui, D. (2015). A short review on basalt fiber reinforced polymer composites. *Composites Part B: Engineering*, *73*, 166-180.

15. Amuthakkannan, P., Manikandan, V., Jappes, J. W., &Uthayakumar, M. (2013). Effect of fibre length and fibre content on mechanical properties of short basalt fibre reinforced polymer matrix composites. *Materials Physics and Mechanics*, *16*, 107-117.

16. Pak, S., Park, S., Song, Y. S., & Lee, D. (2018). Micromechanical and dynamic mechanical analyses for characterizing improved interfacial strength of maleic anhydride compatibilized basalt fiber/polypropylene composites. *Composite Structures*, *193*, 73-79.

17. Bauer, F., Kempf, M., Weiland, F., &Middendorf, P. (2018). Structure-property relationships of basalt fibers for high performance applications. *Composites Part B: Engineering*, *145*, 121-128.

18. Muñoz, E., &García-Manrique, J. A. (2015). Water absorption behaviour and its effect on the mechanical properties of flax fibre reinforced bioepoxy composites. *International Journal of Polymer Science*, *2015*.

19. Huang, K., Rammohan, A. V., Kureemun, U., Teo, W. S., & Lee, H. P. (2016). Shock wave impact behavior of flax fiber reinforced polymer composites. *Composites Part B: Engineering*, *102*, 78-85.

20. Haggui, M., El Mahi, A., Jendli, Z., Akrout, A., &Haddar, M. (2018). Static and fatigue characterization of flax fiber reinforced thermoplastic composites by acoustic emission. *Applied Acoustics*.

21. Campana, C., Leger, R., Sonnier, R., Ferry, L., &Ienny, P. (2017). Effect of post curing temperature on mechanical properties of a flax fiber reinforced epoxy composite. *Composites Part A: Applied Science and Manufacturing*.

22. Perremans, D., Verpoest, I., Dupont-Gillain, C., & Van Vuure, A. W. (2018). Investigation of the tensile behavior of treated flax fibre bio-composites at ambient humidity. *Composites Science and Technology*, *159*, 119-126.

23. Luo, H., Xiong, G., Ma, C., Chang, P., Yao, F., Zhu, Y. & Wan, Y. (2014). Mechanical and thermo-mechanical behaviors of sizing-treated corn fiber/polylactide composites. *Polymer Testing*, *39*, 45-52.

24. Kumar, N. R., Rao, C. R., Srikant, P., & Rao, B. R. (2015). Mechanical properties of corn fiber reinforced polypropylene composites using Taguchi method. *Materials Today: Proceedings*, *2*(4-5), 3084-3092.

25. Youssef, A. M., El-Gendy, A., &Kamel, S. (2015). Evaluation of corn husk fibers reinforced recycled low density polyethylene composites. *Materials Chemistry and Physics*, *152*, 26-33.

26. Luo, Z., Li, P., Cai, D., Chen, Q., Qin, P., Tan, T., & Cao, H. (2017). Comparison of performances of corn fiber plastic composites made from different parts of corn stalk. *Industrial crops and products*, *95*, 521-527.

27. Mechakra, H., Nour, A., Lecheb, S., &Chellil, A. (2015). Mechanical characterizations of composite material with short Alfa fibers reinforcement. *Composite Structures*, 124, 152-162.

28. Du, Y., Wu, T., Yan, N., Kortschot, M. T., & Farnood, R. (2013). Pulp fiber-reinforced thermoset polymer composites: effects of the pulp fibers and polymer. *Composites Part B: Engineering*, *50*, 10-17.

29. Rashid, B., Leman, Z., Jawaid, M., Ghazali, M. J., Ishak, M. R., &Abdelgnei, M. A. (2017). Dry sliding wear behavior of untreated and treated sugar palm fiber filled phenolic composites using factorial technique. *Wear*, *380*, 26-35.

30. Kalapakdee, A., &Amornsakchai, T. (2014). Mechanical properties of preferentially aligned short pineapple leaf fiber reinforced thermoplastic elastomer: Effects of fiber content and matrix orientation. Polymer Testing, 37, 36-44.

31. Sair, S., Oushabi, A., Kammouni, A., Tanane, O., Abboud, Y., & El Bouari, A. (2018). Mechanical and thermal conductivity properties of hemp fiber reinforced polyurethane composites. *Case Studies in Construction Materials*, *8*, 203-212.

32. Sepe, R., Bollino, F., Boccarusso, L., & Caputo, F. (2018). Influence of chemical treatments on mechanical properties of hemp fiber reinforced composites. *Composites Part B: Engineering*, *133*, 210-217.

ISSN : 2455-9679
Impact Factor : 3.805

33. Khan, Z., Yousif, B. F., & Islam, M. (2017). Fracture behaviour of bamboo fiber reinforced epoxy composites. *Composites Part B: Engineering*, *116*, 186-199.

34. Roy, J. K., Akter, N., Zaman, H. U., Ashraf, K. M., Sultana, S., Shahruzzaman& Khan, R. A. (2014). Preparation and properties of coir fiber-reinforced ethylene glycol dimethacrylate-based composite. *Journal of Thermoplastic Composite Materials*, *27*(1), 35-51.

35. Ramesh, M., Atreya, T. S. A., Aswin, U. S., Eashwar, H., & Deepa, C. (2014). Processing and mechanical property evaluation of banana fiber reinforced polymer composites. Procedia Engineering, 97, 563-572.

36. Jordan, W., & Chester, P. (2017). Improving the properties of banana fiber reinforced polymeric composites by treating the fibers. *Procedia engineering*, *200*, 283-289.

37. Muktha, K., & Gowda, B. K. (2017). Investigation of Water Absorption and Fire Resistance of Untreated Banana Fibre Reinforced Polyester Composites. *Materials Today: Proceedings*, *4*(8), 8307-8312.

38. Xia, C., Yu, J., Shi, S. Q., Qiu, Y., Cai, L., Wu, H. F. & Zhang, H. (2017). Natural fiber and aluminum sheet hybrid composites for high electromagnetic interference shielding performance. Composites Part B: Engineering, 114, 121-127.

39. Manteghi, S., Mahboob, Z., Fawaz, Z., &Bougherara, H. (2017). Investigation of the mechanical properties and failure modes of hybrid natural fiber composites for potential bone fracture fixation plates. *Journal of the mechanical behavior of biomedical materials*, *65*, 306-316.

40. Wang, Z., Cao, N., He, J., Du, R., Liu, Y., & Zhao, G. (2017). Mechanical and anticorrosion properties of furan/epoxy-based basalt fiber-reinforced composites. *Journal of Applied Polymer Science*, *134*(19).

41. Zuccarello, B., Marannano, G., &Mancino, A. (2018). Optimal manufacturing and mechanical characterization of high performance biocomposites reinforced by sisal fibers. *Composite Structures*, *194*, 575-583.

42. Suppakarn, N., &Jarukumjorn, K. (2009). Mechanical properties and flammability of sisal/PP composites: effect of flame retardant type and content. *Composites Part B: Engineering*, *40*(7), 613-618.

43. Martin, A. R., Martins, M. A., da Silva, O. R., &Mattoso, L. H. (2010). Studies on the thermal properties of sisal fiber and its constituents. *ThermochimicaActa*, *506*(1-2), 14-19.

44. Zhao, X., Li, R. K., & Bai, S. L. (2014). Mechanical properties of sisal fiber reinforced high density polyethylene composites: Effect of fiber content, interfacial compatibilization, and manufacturing process. *Composites Part A: Applied Science and Manufacturing*, *65*, 169-174.

45. Fiore, V., Scalici, T., Nicoletti, F., Vitale, G., Prestipino, M., &Valenza, A. (2016). A new eco-friendly chemical treatment of natural fibres: Effect of sodium bicarbonate on properties of sisal fibre and its epoxy composites. Composites Part B: Engineering, 85, 150-160.

46. Ramesh, M., Palanikumar, K., & Reddy, K. H. (2013). Mechanical property evaluation of sisal–jute–glass fiber reinforced polyester composites. Composites Part B: Engineering, 50, 1-9.

47. Orue, A., Jauregi, A., Unsuain, U., Labidi, J., Eceiza, A., &Arbelaiz, A. (2016). The effect of alkaline and silane treatments on mechanical properties and breakage of sisal fibers and poly (lactic acid)/sisal fiber composites. *Composites Part A: Applied Science and Manufacturing*, *84*, 186-195.

48. Dwivedi, U. K., Trihotri, M., Gupta, S. C., Khan, F. H., Malik, M. M., & Qureshi, M. S. (2017). Effect of carbon nanotubes implantation on electrical properties of sisal fibre–epoxy composites. *Composite interfaces*, *24*(2), 111-123.

49. Prasad, G. E., Gowda, B. K., &Velmurugan, R. (2017). Comparative study of impact strength characteristics of treated and untreated sisal polyester composites. *Procedia engineering*, *173*, 778-785.

50. Kim, J. T., & Netravali, A. N. (2010). Mercerization of sisal fibers: Effect of tension on mechanical properties of sisal fiber and fiber-reinforced composites. *Composites Part A: Applied science and manufacturing*, *41*(9), 1245-1252.

51. Gupta, M. K., & Srivastava, R. K. (2015). Effect of sisal fibre loading on dynamic mechanical analysis and water absorption behaviour of jute fibre epoxy composite. *Materials Today: Proceedings*, *2*(4-5), 2909-2917.