A STUDY ON MECHANICAL BEHAVIOUR OF HAIR FIBER REINFORCED EPOXY COMPOSITES

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology

In

Mechanical Engineering

BY

AVINASH KUMAR

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DEPARTMENT OF MECHANICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY

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CERTIFICATE

This is to certify that the thesis entitled **"A Study on Mechanical Behaviour of Hair Fiber Reinforce Epoxy Composites"** submitted by **AVINASH KUMAR (Roll No.110ME0295)** in partial fulfillment of the requirements for the award of ***Bachelor of Technology*** in the department of Mechanical Engineering, National Institute of Technology, Rourkela is an authentic work carried out under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to elsewhere for the award of any degree.

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A C K N O W L E D G E M E N T

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ABSTRACT

Fiber reinforced polymer composites is an important class of structural material due to their numerous advantages. Reinforcement in polymer is either engineered or characteristic. Engineered fiber, for example, glass, carbon and so on has high particular quality however their fields of requisition are restricted because of higher expense of creation. As of late there is an increment in enthusiasm toward common composites which are made by reinforcement of characteristic fiber. Human hair has solid malleable property; thus it could be utilized as a fiber reinforcement material. It gives great property at easier expense of generation. It additionally makes ecological issue for its deteriorations because of its non-degradable properties. To this end, an attempt has been made to study the potential utilization of human hair which is economically and effortlessly found in India for making value added products. The objective of present work is to evaluate the mechanical properties of human hair reinforced epoxy composites. The impact of fiber loading and length on mechanical properties like tensile strength, flexural strength, impact strength and hardness of composites is examined. Trials were directed on polymer composites with different contents of human hair fiber i.e. 0%, 10%, 20%, 30% and with shifting length of human hair i.e. 0.5, 1, 1.5 and 2 cm. By testing of composites it has been observed that there is significant influence of human hair reinforcement on the mechanical behaviour of composites.

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CHAPTER 1
INTRODUCTION

1.1 Background and Overview of Composites

Because of the improvement and development of innovation, the need of material having profoundly particular properties is expanding step by step and this test interest can't be satisfy by utilization of polymers, clay and metal composites. Accordingly, as of late composite materials are utilized as elective as a part of a few light weight and high quality applications. Composites are commonly happening or designed materials which are produced from two or more constituents. By and large, composites materials have solid burden convey strengthening material imbedded in weaker framework materials. In composites, the discontinuous phase is called the *reinforcement* which is usually harder and stronger than the *matrix* which is called continuous phase. The matrix material keeps the reinforcements in the desired location and orientation. Reinforcement used to improve overall mechanical properties of matrix and give strength to composites of matrix and give strength to composites. The constituents of composite materials have their property however when they are joined together, they give a mixture of properties that a singular can't have the capacity to give. Composite materials can be classified based on the types of matrix used as

• Ceramic Matrix Composites (CMC)

• Metal Matrix Composites (MMC)

• Polymer Matrix Composites (PMC)

Among various types of composites, PMC is the most commonly used composites, due to its many advantages such as simple manufacturing principle, low cost and high strength. PMCs have two types of polymer that have been used as matrix. These are thermoplastics and thermosetting polymer. Thermoplastic polymer is that polymer which are repeatedly softened and reformed by heating. Some examples of thermoplastics are PVC, LDPE and HDPE.

Thermosetting polymer is the polymer which has hard and stiff cross-linked materials. They are not soften and moldable when they are heated. Epoxy is the most commonly used thermosetting polymer. They have many advantages such as better adhesion to other materials, good mechanical properties, and good electrical insulation. Reinforcements are equally important as matrix materials.

Recently, the natural fibers are gaining interest as reinforcement in polymer composites rapidly. The natural fiber used as reinforcement from very old time as man used grass and straw from beginning of civilization in reinforcing the bricks that are used to make mud wall. There are many advantages of natural fiber over traditional reinforcing material as such as low density, low cost, enhanced energy recovery, good thermal properties, acceptable specific strength and biodegradable [1]. These fibers are easily and abundantly available, biodegradable and these advantages make natural fiber popular over synthetic fiber such as glass fiber, carbon and other man-made fibers. Natural fibers are naturally occurring materials consisting of cellulose fibrils embedded in lignin matrix. The composition of some commonly used natural fibers is shown in Table 1.1. On the basis of the source of origin, natural fibers are characterized into three classifications they are

- Mineral Fibers
- Animal Fibers
- Plant Fibers

Mineral Fibers: Mineral fibers are the commonly happening fiber or marginally adjusted fibers acquire from minerals. It has different classifications they are taking after: Asbestos is the main commonly happening mineral fiber. The Variations in mineral fiber are the anthophyllite, amphiboles and serpentine. The Ceramic fibers are aluminum oxide,glass fibers, boron carbide andsilicon carbide. Metal fibers incorporate aluminumsfibers.

Animal Fibers: Animal fiber for the most part comprises of proteins; illustrations mohair, fleece, silk, alpaca. Animal hairs are the fibers got from animals e.g. horse hair, Sheep's fleece, goat hair, alpaca hair, and so on. Silk fiber is the fibers gathered from dried spit of creepy crawlies throughout the time of readiness of covers. Avian fibers are the fibers from flying creatures. Illustrations silk from silk worms.

Table 1.1 The composition of some commonly used natural fibers [2]

Fiber	Lignin (%Wt.)	Hemi-Cellulose (%Wt.)	Cellulose (%Wt.)	Moisture (%Wt.)	Pectin (%Wt.)	Waxes (%wt.)
Cotton	-	5.7	85-90	7.85-8.5	0-1	0.6
Bamboo	32	0.5	60.8	_	_	_
Flax	2.2	18.6-20.6	71	8-12	2.3	1.7
Kenaf	8-13	21.5	45-47	-	3-5	-
Jute	12-13	13.6-20.4	61-71.5	12.5-14	0.2	0.5
Hemp	3.7-5.7	17.9-20.4	70-74	6.2-12	0.9	0.8
Ramie	0.6-0.7	13.1-16.7	68.6-76	7.5-17	1.9	0.3
Coir	40-45	0.15-0.25	32-43	8	3-4	_
Sisal	10-14	10-14	66-78	10-22	10	2
Banana	5	10	63-64	10-12	-	_

Plant Fibers: Plant fibers are for the most part comprises of cellulose: illustrations cotton, flax, jute, ramie, sisal and hemp. Cellulose fibers are utilized as a part of the manufacture of paper and material. The classification of these fibers is as taking after: Seed fibers are the fibers acquire from the seed case and seed e.g. kapok and cotton. Leaf fibers are the fibers get from the leaves e.g. agave and sisal. Skin fibers are the fibers are get from the skin or bast encompassing the stem of the plant. This fibers having higher elasticity than different fibers. Accordingly, these fibers are utilized as a part of solid yarn, fabric, bundling, and paper. Tree grown foods fibers are the fibers are get from the products of the soil of the plant, e.g. coconut (coir) fiber. Stalk fiber are the fibers that are acquire from the stalks of the plant. Characteristic fiber composites are not new to humanity. Now-a-days, the natural fiber

reinforced polymer composites applications are generally found in automobile industries and building industry and the place where the dimensional stability and load carrying strength under moist and thermal stability conditions is important. For example, flax fiber based polyolefin are widely used in automotive industry. Here, the fiber acts as a reinforcement in non structural interior [3]. Natural fiber reinforced polymer composites used for structural applications, but then usually with synthetic thermoset matrix material which limit the environmental benefits [4, 5]. The natural fiber composites are very cost effective material for given applications:

• For the Furniture: shower, chair, table, etc.

• For the Electrical devices: electricity appliances etc.

• For the daily use: suitcases, lampshades, etc.

• For the transportation: automobile industries and railway coaches, boat etc.

Reinforcement in polymer is either synthetic or natural. Synthetic fibers, for example, glass, carbon are used for polymer composites however their fields of applications are restricted because of high cost. Natural fibers have many advantages over synthetic fibers. The potential utilization of different natural fibers for polymer composites has already been explored. Among various natural fibers, human hair has many advantages. Human hair has solid malleable property; thus it could be utilized as a fiber reinforcement material. It gives great property at easier expense of generation. It additionally makes ecological issue for its deteriorations because of its non-degradable properties. To this end, an attempt has been made to study the potential utilization of human hair which is economically and effortlessly found in India for making value added products. The objective of present work is to evaluate the mechanical properties of human hair reinforced epoxy composites. The impact of fiber loading and length on mechanical properties like tensile strength, flexural strength, impact strength and hardness of composites is examined.

1.2 Thesis Outline

Chapter 2: Includes a survey of proposed work to give an outline on the base of data generally available concerning the issues of interest.

Chapter 3: Includes a description of the materials and methods used. The details test procedure is outlined in this section.

Chapter 4: Presents the mechanical properties of the composites under study.

Chapter 5: Presents specific conclusions drawn from the experimental study and suggests ideas and directions for future research.

CHAPTER 2
LITERATURE SURVEY

This chapter presents the background information on the issues to be considered in the present research work and to focus the significance of the current study.

Hair is a proteinaceous fiber with a strongly hierarchical organization of subunits, from the α-keratin chains, via intermediate filaments to the fiber [6]. The exceptional properties of human hair such as its unique chemical composition, slow degradation rate, high tensile strength, thermal insulation, elastic recovery, scaly surface, and unique interactions with water and oils, has led to many diverse uses. Volkin et al. [7] identified and characterized the processes leading to destruction of cystine residues. They compared proteins from different species, including those of thermophilic bacteria living near the boiling point of water. Thompson [8] manufactured a hair-based composite material by manipulating a plurality of cut lengths of hair to form a web or mat of hair, and combining said web or mat of hair with a structural additive to form said composite material. Jain et al. [9] studied on hair fibre reinforced concrete and concluded that there is tremendous increment in properties of concrete according to the percentages of hairs by weight of in concrete. The addition of human hairs to the concrete improves various properties of concrete like tensile strength, compressive strength, binding properties, micro cracking control and also increases spalling resistance. Therefore human hairs are in relative abundance in nature and are non-degradable provides a new era in field of FRC.

Hu et al. [10] studied on Protein-based composite biomaterials which can be formed into a wide range of biomaterials with tunable properties, including control of cell responses. They provided new biomaterials which is an important need in the field of biomedical science, with

direct relevance to tissue regeneration, nano medicine, and disease treatments. Human hair is considered as a waste material in most parts of the world and it is found in municipal waste streams which cause numerous ecological issues. Gupta [11] studied on Human Hair ‘‘Waste’’ and Its Utilization. Through this it has been concluded that the human hair has a large number of uses in areas ranging from agriculture to medicine to engineering industries. Hernandez et al. [12] studied on keratin which is a fiber which is found in hair and feathers. Keratin fiber has a hierarchical structure with a highly ordered conformation, is by itself a biocomposite, product of a large evolution of animal species. Through this it has been concluded that the keratin fibers from chicken feathers shows a eco-friendly material which can be applied in the development of green composites. Babu et al. [13] studied on bio-based polymers and concluded that it has widely increased the attention due to environmental concerns and the realization that global petroleum resources are finite.

2.2 Objectives of the present research work

Based on the knowledge gap through the existing literature the objectives of the current research work are fixed which are outlined as below:

1. Fabrication of human hair fiber reinforced epoxy composites.
2. Assessment of mechanical properties like tensile strength, flexural strength, impact strength and hardness of composites.
3. To study the effect of fiber length and fiber content on the mechanical behaviour of composites.

CHAPTER 3
MATERIALS AND METHODOLOGY

This chapter represents the materials used and detail fabrication techniques

3.1 Materials

3.1.1 Matrix Material

Around diverse sorts of framework materials, polymer networks are the most generally utilized in view of numerous points of interest, for example, cost viability, simplicity of manufacture with less tooling rate and they likewise have remarkable room temperature properties. Polymer networks could be possibly thermoplastic or thermosetting. The most normally utilized thermosetting gums are epoxy, polyester, vinyl ester, Polyurethanes and phenolics. Around them the epoxy resin is the most commonly used polymer due to numerous points of interest, for example, enormous attachment to wide assortment of filaments, prevalent mechanical and electrical properties furthermore great execution at lifted temperatures. Notwithstanding that they have low shrinkage after curing and great synthetic safety. Because of various points of interest over other thermoset polymers, epoxy is picked as the lattice material for the present examination work. It synthetically fits in with the "epoxide" family and its regular name of epoxy is Bisphenol-A-Diglycidyl- Ether.

3.1.2 Fibre Material

The common fiber human hair is taken out from the local sources. It is a fiber which is easily and cheaply available in India. Fibers are generally utilized as a part of cement for the accompanying reasons:

1. To control breaking because of both plastic shrinkage and drying shrinkage.
2. They additionally decrease the porousness of cement and along these lines diminish draining of water.

3. A few sorts of strands likewise generate more terrific effect, scraped area and smash safety in cement.
4. The fineness of the strands permits them to fortify the mortar division of the cement, postponing split framing and spread. This fineness additionally represses draining in the solid, consequently diminishing porousness and enhancing the surface attributes of the solidified surface.

Hair is utilized as a fiber fortifying material in cement for the accompanying reasons:

1. It has a high elasticity which is equivalent to that of a copper wire with comparable width.
2. Hair, a non-degradable matter is making an ecological issue so its utilization as a fiber fortifying material can minimize the issue.
3. It is additionally accessible in wealth and with ease.
4. It fortifies the mortar and keeps it from spalling.

3.1.3 Composite Fabrication

The human hair fiber is gathered from local sources. Epoxy is taken as matrix material. The low temperature curing epoxy and the corresponding hardener are blended in a degree of 10:1 by weight as prescribed. A mold of size 210×210×40 mm3 is utilized for fabrication of composites. The human hair fibers are blended with epoxy by the basic mechanical mixing. The composites are prepared with three distinctive fiber loading and four distinctive fiber lengths utilizing hand lay-up process. The mixture is put into different molds adjusting to the necessities of different testing conditions and characterization models. The designation and detail composition of composites are presented in Table 3.1. The cast of each composite is safeguarded under a load of around 20 kg for 24 hours. At that point this cast is post cured circulating everywhere for an additional 24 hours in the wake of uprooting out of the mold. Finally, the specimens of suitable dimensions are cut for mechanical tests.

Table 3.1 Designation of Composites

Composites	Compositions
C1	Epoxy (90wt. %)+ Hair fiber (fiber length0. 5mm) (10wt. %)
C2	Epoxy (80wt. %)+ Hair fiber (fiber length0. 5mm) (20wt. %)
C3	Epoxy (70wt. %)+ Hair fiber (fiber length 0.5mm) (30wt. %)
C4	Epoxy (90wt. %)+ Hair fiber (fiber length1mm) (10wt. %)
C5	Epoxy (80wt. %)+ Hair fiber (fiber length1mm) (20wt. %)
C6	Epoxy (70wt. %)+ Hair fiber (fiber length 1mm) (30w.t%)
C7	Epoxy (90wt. %)+ Hair fiber (fiber length1. 5mm) (10wt. %)
C8	Epoxy (80wt. %)+ Hair fiber (fiber length1. 5mm) (20wt. %)
C9	Epoxy (70wt. %)+ Hair fiber (fiber length 1.5mm) (30wt. %)
C10	Epoxy (90wt. %)+ Hair fiber (fiber length2.0mm) (10wt. %)
C11	Epoxy (80wt. %)+ Hair fiber (fiber length2.0mm) (20wt. %)
C12	Epoxy (70wt. %)+ Hair fiber (fiber length 2.0mm) (30wt. %)

Fig: 3.1 Human hair fiber

Fig:3.2 Human fiber reinforced epoxy composite

3.2 Mechanical testing of composites

The mechanical properties of composite are depending on numerous variables like fiber loading and fiber length. According to ASTM D3039-76 test models the tensile test of composites is carried out utilizing Universal Testing Machine Instron 1195. A load was connected to the both sides of composite samples for the testing. The experimental set up and specimen for tensile test is shown in Figure 3.3 and 3.4 respectively.

The flexural test of composites is also carried out utilizing Universal Testing Machine Instron 1195. The findings of flexural strength should be the critical characterization of a composites material. For the testing, the cross head rate is kept as 2 mm per min and a span of 60 mm is kept up. The loading arrangement for flexural test is presented in Figure 3.5. The impact tests are carried out as per ASTM D 256 using an impact tester. The experimental set up for impact test is shown in Figure 3.6.

Fig:3.3 Experimental set up of tensile test

Fig: 3.4 Specimen for tensile test

Fig: 3.5 Loading arrangement for flexural test

Fig: 3.6 Experimental setup of impact test

CHAPTER 4

RESULTS & DISCUSSION

This section associated with the mechanical properties of the hair fibre reinforced epoxy composites. The influence of fiber parameters on the composites is studied in this chapter.

4.1 Mechanical Behaviour of Composites

4.1.1 The influence of fibre parameters on tensile strength of composites

The influence of fiber parameters on tensile strength of composites is shown in Figure 4.1. It is found that for composites with 10% fiber loading, the tensile strength initially increases with increase in fiber length up to 1 cm and after that starts decreasing. And for 20% fiber loading, the tensile strength increases with increase in fiber length upto 1.5 cm and after that starts decreasing. And for 30% fiber loading, the tensile strength increases with the increase in fiber length up to 1.5 cm and then decreases.

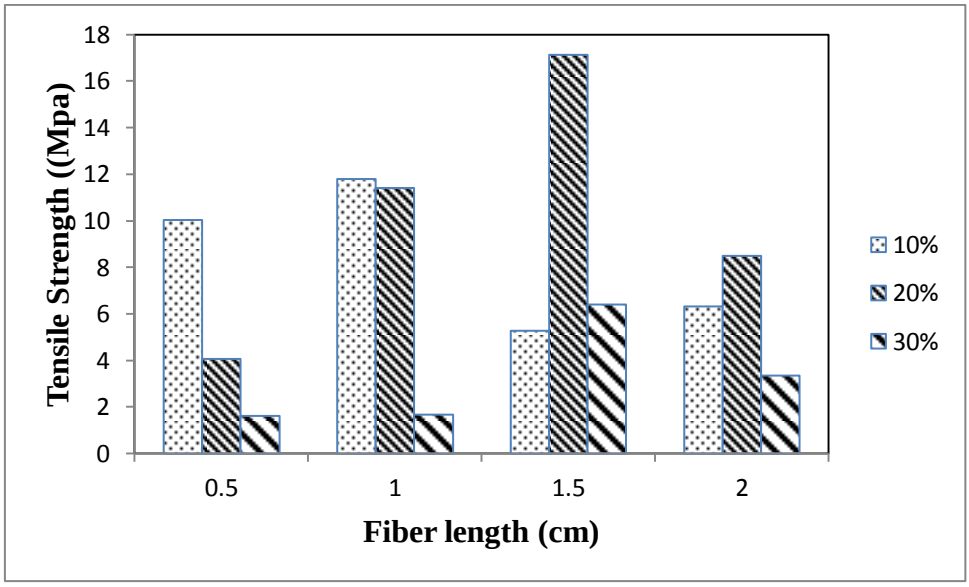

Figure 4.1 Effect of fibre parameters on tensile strength of composites

4.1.2 The influence of fiber parameters on flexural strength of composites

The influence of fiber parameters on flexural strength of composites is shown in Figure 4.2. It is found that for composites with 10% fiber loading, the flexural strength increases up to 1.5

cm of fiber length and after that starts decreasing. And for 20% fiber loading the flexural strength increases up to 1.5 cm of fiber length and after that starts decreasing. And for 30% fiber loading, the flexural strength initially increases up to 1 cm of fiber length and then starts decreasing.

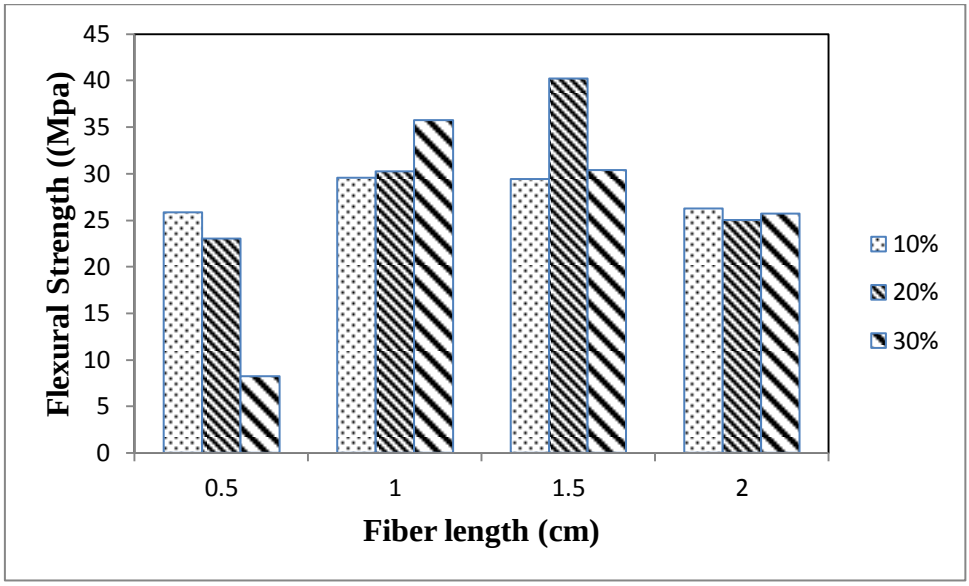

Figure 4.2 Effect of fibre loading and length on flexural strength of composites

4.1.3 The influence of fiber parameters on impact strength of composites

The influence of fiber parameters on impact strength of composites is shown in Figure 4.3.

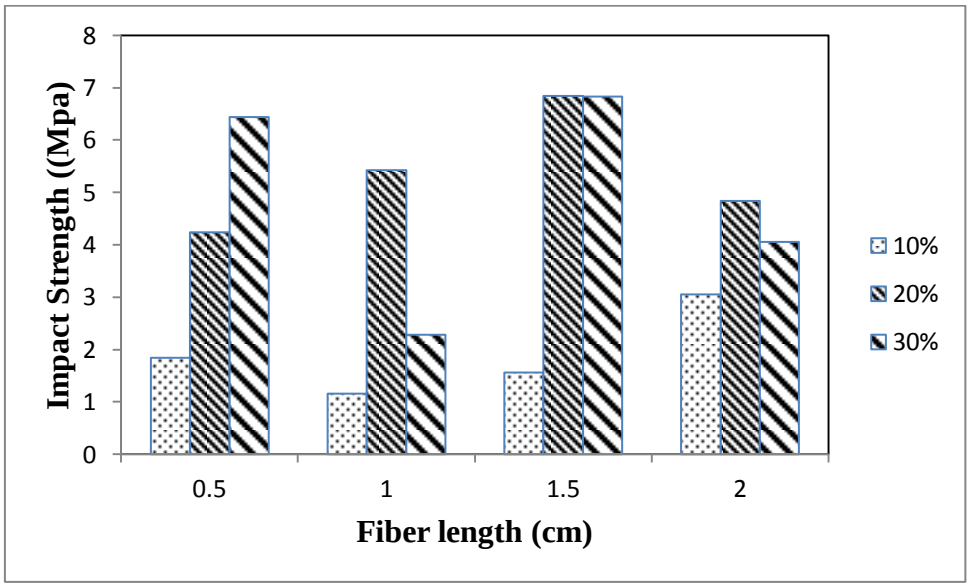

Figure 4.3 The influence of fiber parameters on impact strength of composites

It is found that for composites with 10% fiber loading, the impact strength initially decreases with increase in fiber length up to 1 cm and after that starts increasing. And for 20% fiber loading, the impact strength of composites increases with increase in fiber length up to 1.5 cm and after that starts decreasing. And for 30% fiber loading there is no regular trend is found.

CHAPTER 5
CONCLUSIONS

The experimental investigation on the mechanical behaviour of human hair fibre based epoxy based composites shows the following conclusions:

- In this work the fruitful production hair fiber based epoxy composites with diverse fiber lengths and loading is possible.
- It should be recognized that the fiber parameters such as fiber loading and length has critical impact on the mechanical properties of the composites.
- The mechanical property like flexural strength, tensile strength and impact strength results are found best for composites reinforced with 20wt% fiber loading with 1.5cm fiber length.

5.1. Future Scope in human hair fiber based composites

The utilization of waste human hair as a fiber reinforcement in composites enlarges the entryway for further research in the given field. The research can be further extended to study the influence of hair fiber on other properties of composites such physical, thermal and tribological properties.

REFERENCES

1. Cao Y., Shibata S., Fukumoto I., (2006). Mechanical properties of biodegradable composites reinforced with bagasse fibre before and after alkali treatments, Composites: Part A 37, pp. 423–429.
2. Pervaiz M., Sain M.M., (2003). Carbon storage potential in natural fiber composites, Resource, Conservation and Recycling 39, pp. 139- 325.
3. Satyanarayana K.G., Sukumaran K., Mukherjee P.S., Pavithran C., Pillai S.G.K., (1990). Natural Fiber-Polymer Composites, Cement and Concrete Composites 12 (2), pp. 117-136.
4. Satyanarayana K.G., Sukumaran K., Kulkarni A.G., Pillai S.G.K., Rohatgi P.K., (1986). Fabrication and Properties of Natural Fiber-Reinforced Polyester Composites, Composites 17(4), pp. 329-333.
5. Mansur M.A., Aziz M. A. (1983), Study of Bamboo-Mesh Reinforced Cement Composites, International Journal of Cement Composites and Lightweight Concrete 5(3), pp.165- 171.
6. Popescu C. and Hocker H. (2007). Hair the most sophisticated biological composite material, Chemical Society Reviews 37(8), pp.1282–1291.
7. Volkin D. B. and Klibanov A. M., (1987). Thermal destruction processes in proteins involving cystine residues, The Journal of Biological Chemistry 262(7), pp.2945-2950.
8. Thompson R.M., (2010). Hair based composite, U.S. Patent US 12/304,777.
9. Jain D. and Kothari A. (2012). Hair Fibre Reinforced Concrete, Research Journal of Recent Sciences, Vol. 1, pp.128-133.
10. Hu X., Cebe P., Weiss A.S., Omenetto F., Kaplan D.L., (2012), Protein-based composite materials, Materials Today 15(5), pp. 208–215.

11. Gupta A. (2009), Human Hair “Waste” and Its Utilization: Gaps and Possibilities, International Journal of Refractory Metals & Hard Materials 27, pp. 892–899.
12. Hernandez A.L.M., Santos C.V., (2012). Keratin Fibers from Chicken Feathers: Structure and Advances in Polymer Composites, In: Keratin: Structure, Properties and Applications, Nova Science Publishers, pp.149-211.
13. Babu R.P., Connor K.O. and Seeram R., (2013). Current progress on bio-based polymers and their future trends, Progress in Biomaterials, DOI: 10.1186/2194-0517-2-8.