The Tribological and Mechanical Behaviour of Horsehair Strengthened Composite

Aryan Singh[1] Vipin Devaraj[2]
[1]Maharishi Markandeshwar University, India [2]Cochin University of Science and Technology, Haryana, India

Abstract— This paper assesses the mechanical properties of horse hair strengthened epoxy composites. The impact of fiber stacking and length on mechanical properties like hardness, flexibility, impact strength and wear of composites is investigated. Trials were facilitated on polymer composites with horse hair fiber in different contents i.e. 0%, 5%, 10% and 15% and with moving length of horse hair i.e. 1.5, and 3 cm. By testing of composites, it is clear that there is a basic effect of horse hair reinforcement on the mechanical properties of composites. The test outcomes are shown and conclusions are drawn.

Key words: Tribological, Horsehair Strengthened Composite

I. INTRODUCTION

As science and technology is advancing, the need of materials having significantly specific properties is increasing which cannot be fulfilled by the use of polymers or metal composites. This calls for new types of composite materials. Further, these composite materials are now being extensively used in various fields.

Composites can be defined as a material made from two or more than two parent constituent material with different physical or chemical properties. The characteristic properties of the composite is different from its parent materials. The new material thus produced is preferred due to several reasons like higher strength, lower weight or less expensive than traditional material. Recently, scientists have also started using composites as actuators, sensors and communicators. These are also known as Robotic Materials.

The discontinuous phase of a composite is known as the reinforcement which is usually harder and stronger than the matrix which is called continuous phase. The purpose of the matrix material is to keep the reinforcements as per the required location and orientation. The properties of the constituents and the properties of the material when they are joined (Composite) is totally different.

On the basis of matrix used, composites can be classified as:

- Ceramic Matrix Composites (CMC)
- Metal Matrix Composites (MMC)
- Polymer Matrix Composites (PMC)

As the PMC's simple manufacturing principle, low manufacturing cost and high strength, it is the one which is most widely used. PMCs when used as matrix can be of two types i.e. Thermoplastics and Thermosetting polymer. The polymer which is repeatedly softened and reformed by heating is thermoplastic polymer. For example: HDPE (High-density polyethylene), LDPE (Low-density polyethylene) and PVC (Polyvinyl chloride). The polymers which has hard and stiff cross-linked materials is known as thermosetting polymer. The most commonly used thermosetting polymer is epoxy. Better mechanical properties, electrical insulation and adhesion to other materials are some of the advantages.

The natural fibers nowadays are gaining popularity and are widely being used in polymer composites. This principle is being used from earlier times when our ancestors used grass and straws for reinforcing the bricks used to make walls. Using natural fibers have numerous advantages i.e. low cost, easy availability, low density, good thermal properties and biodegradability.

These fibers are widely being used in the production of:

- Electrical appliances
- Furniture
- Automobile parts.

The natural fibers can be classified into three types based on the source of their origin:

- Mineral Fibers
- Animal Fibers
- Plant Fibers

Mineral fibers are the fibers which are extracted from minerals. Asbestos is one of the most commonly used mineral fiber. Glass fibers, Silicon carbide, Boron carbide are the ceramic fibers. Aluminum fiber is a type of metal fiber. Animal fibers consist largely of specific proteins. E.g.: Silk, hair and fur. Plant fibers comprises commonly of cellulose. Sisal, hemp, jute and cotton are some of the examples. These are widely being used in the manufacture of paper. Plant fibers can further be classified as seed fibers (Cotton), Leaf fibers (Sisal) and skin fibers which are obtained from the stem of the plant.

Reinforcement in a polymer can be of two types, synthetic or natural. Synthetic fibers like carbon fiber are used for polymer composites button a limited way because of its high cost. Whereas naturally occurring fibers are cost effective. Besides, they have other advantages as well. The natural fiber used in this study is horse's hair which has excellent malleable property and thus could be easily utilised as a reinforcement material. The horse hair is economical and easily available and thus can be utilised for commercial use. In this work, the tensile strength, flexibility, wear, impact strength and hardness of composite reinforced with horse hair is examined.

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	-	_

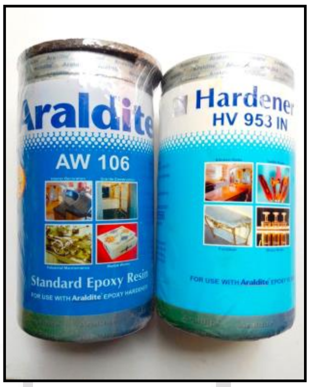
II. LITERATURE SURVEY

Horsehair could be a super-molecule fiber with a powerfully class-conscious organisation of subunits, from the α-albuminoid chains, via intermediate filaments to the fiber [3]. The exceptional properties of horse hair like its distinctive chemical composition, slow degradation rate, high strength, thermal insulation, elastic recovery, scaly surface, and distinctive interactions with water and oils, has junction rectifier to several numerous uses. Volkin et al. [4] known and characterised the processes resulting in the destruction of amino acid residues. They compared proteins from totally different species, together with those of thermophilic microorganism living close to the boiling purpose of water. Thompson [5] factory-made a hair-based material by manipulating a plurality of cut lengths of hair to make an online or mat of hair, and mixing aforesaid internet or mat of hair with a structural additive to make the aforesaid material. Jain et al. [6] studied on hair fiber concrete and over that there's tremendous increment in properties of concrete in keeping with the chances of hairs by weight of in concrete. The addition of horse hairs to the epoxy improves varied properties of epoxy like strength, compressive strength, binding properties, small cracking management and additionally will increase spalling resistance. So horse hairs are in relative abundance in nature and are non-degradable provides a brand new era in the field of FRC. Hu et al. [7] studied on Protein-based composite biomaterials which may be fashioned into a good vary of biomaterials with tuneable properties, together with management of cell responses. They provided new biomaterials that are a crucial want within the field of life science, with a direct connection to tissue regeneration, nano medication, and unwell treatments. Horsehair is taken into account as a material in most elements of the globe and it's found in municipal waste streams that cause various ecological problems. Gupta [8] studied on Horse Hair ''Waste'' and Its Utilisation. Through this, it's been over that the horsehair incorporates a sizeable amount of uses in areas starting from agriculture to medication to engineering industries. Hernandez et al. [9] studied on albuminoid that could be a fiber that is found in hair and feathers. albuminoid fiber incorporates a hierarchical data structure with an extremely ordered conformation, is by itself a bio-composite, product of an oversized evolution of animal species. Through this, it's been over that the albuminoid fibers from chicken feathers show an eco-friendly material which may be applied to the development of inexperienced composites. Babu et al. [10] studied on bio-based polymers and over that it's wide raised the eye attributable to environmental issues and also the realisation that international fossil fuel resources are finite.

III. MATERIALS

The materials used in this composite can be differentiated into matrix phase and dispersed phase. The Purpose of the matrix phase (Epoxy) is to contain and hold the dispersed phase (Horse hair) in position.

Matrix Phase- Since the matrix phase is required to bind the layers of the dispersed phase, we have used the commercial epoxy resin and hardener (Araldite) which is easily available in the market.



Dispersed Phase- The hair of horses are long and coarse growing on their manes and tails. These hair are stiff, fine and flexible. It has been used as a reinforcement material because of its high strength and its capacity to resist stretching. They are widely used for upholstery, brushes, musical instruments, hair clothes etc.

IV. FABRICATION OF COMPOSITE

Hand layup technique has been used for the fabrication of horse hair reinforced composite. The steps involved in the process are enumerated below.

- Step 1: Make a mould of dimension (500mm X 500mm X 50mm). Clean both the inner surfaces of the mould thoroughly.
- Step 2: Now take a 0.2 mm thick transparent sheet of plastic, place it at the lower surface and put some wax on it.
- Step 3: Mix the epoxy, hardener (in the prescribed proportion) along with horse hair with four distinct epoxy weight and two distinct fiber length. The horse hair is blended in the epoxy using basic mechanical mixing.

- Step 4: The mixture is then put in different moulds according to the requirements of different conditions of testing.
- Step 5: Keep the composites under a load of 100kg for 24-36 hours.

The detailed composition of the composites are given below:

Composites	Compositions
C1	Epoxy (95wt. %)+ Hair fiber (fiber length 1.5cm) (5wt. %)
C2	Epoxy (90wt. %)+ Hair fiber (fiber length 1.5cm) (10wt. %)
C3	Epoxy (85wt. %)+ Hair fiber (fiber length 1.5cm) (15wt. %)
C4	Epoxy (95wt. %)+ Hair fiber (fiber length 3.0cm) (5wt. %)
C5	Epoxy (90wt. %)+ Hair fiber (fiber length 3.0cm) (10wt. %)
C6	Epoxy (85wt. %)+ Hair fiber (fiber length 3.0cm) (15w.t%)
C7	Epoxy (100wt. %)

Fig : Seven samples C1, C2, C3, C4, C5, C6 and C7 before testing

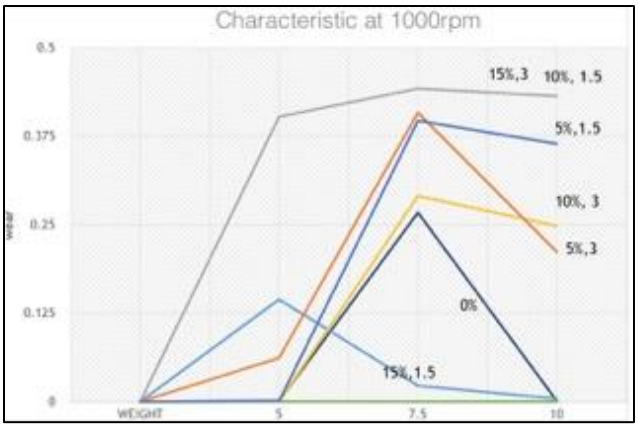
V. MECHANICAL TESTING OF TEST SPECIMENS

A. *Wear test*

The wear test was conducted using a wear test machine with varying weights of 5kgs, 7.5kgs and 10kgs respectively. Three different rotation speeds (1000, 1500 and 2000 rpm) were chosen.

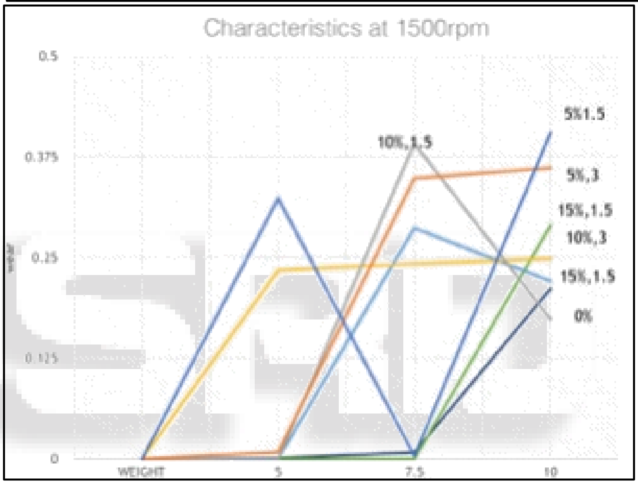
At 1000 RPM

1	WEAR (1000 RPM)						
Weight	5%,1.5 cm	5%, 3 cm	10%, 1.5 cm	10%, 3 cm	15% 1.5cm	15%, 3cm	0%
5	0.0009	0.0618	0.4021	0.0126	0.1444	0.0003	0.0012
7.5	0.3965	0.4079	0.442	0.2905	0.0226	0.0001	0.2668
10	0.3641	0.2113	0.4313	0.248	0.0042	0.0002	0.001



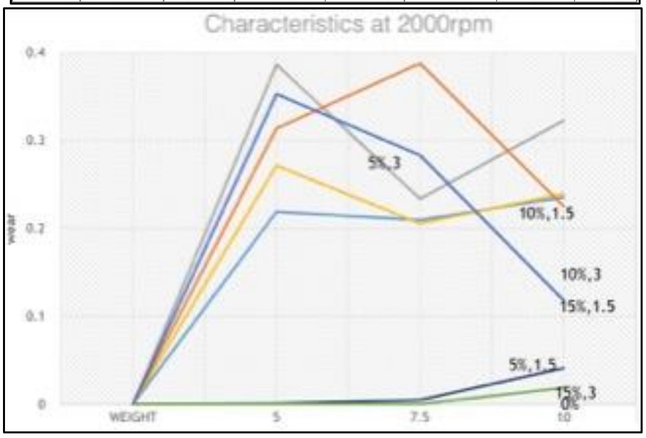
At 1500 RPM

2	WEAR (1500 RPM)						
Weight	5%, 1.5 cm	5%, 3 cm	10%, 1.5 cm	10%, 3 cm	15%, 1.5 cm	15%, 3 cm	0%
5	0.3232	0.0084	0.4021	0.2339	0.0005	0.0001	0.001
7.5	0.0037	0.3482	0.3913	0.2421	0.2864	0	0.0081
10	0.4048	0.3612	0.1729	0.2485	0.2205	0.2897	0.2113



At 2000 RPM

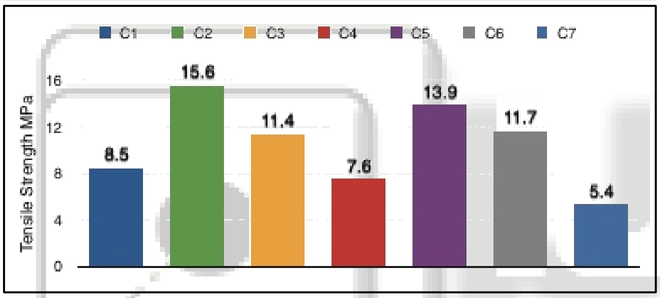
3	WEAR (2000 RPM)						
Weight	5%, 1.5 cm	5%, 3 cm	10%, 1.5 cm	10%, 3 cm	15%, 1.5 cm	15%, 3 cm	0%
5	0.3232	0.0084	0.4021.4244	0.2339	0.0005	0.0001	0.001
7.5	0.0037	0.3482	0.3913	0.2421	0.2864	0	0.0081
10	0.4048	0.3612	0.1729	0.2485	0.2205	0.2897	0.2113



B. *Tensile test*

The tensile test of the composite was carried out using Universal testing machine Instron 1195 in accordance to ASTM D3039-76. The testing was done by applying a load on the both sides of the specimen.

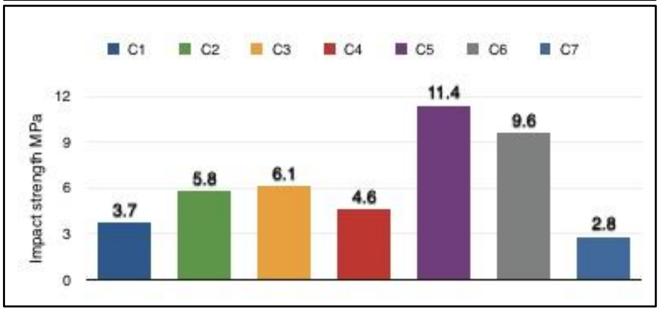
Specimen	Tensile Strength
C1 Epoxy (95wt. %)+ Hair fiber (fiber length 1.5cm) (5wt. %)	8.5
C2 Epoxy (90wt. %)+ Hair fiber (fiber length 1.5cm) (10wt. %)	15.6
C3 Epoxy (85wt. %)+ Hair fiber (fiber length 1.5cm) (15wt. %)	11.4
C4 Epoxy (95wt. %)+ Hair fiber (fiber length 3.0cm) (5wt. %)	7.6
C5 Epoxy (90wt. %)+ Hair fiber (fiber length 3.0cm) (10wt. %)	13.9
C6 Epoxy (80wt. %)+ Hair fiber (fiber length 3.0cm) (10wt. %)	11.7
C7 Epoxy (100wt. %)	5.4



C. Impact test

The impact test of the composite was carried out using an impact tester in accordance to ASTM D 256.

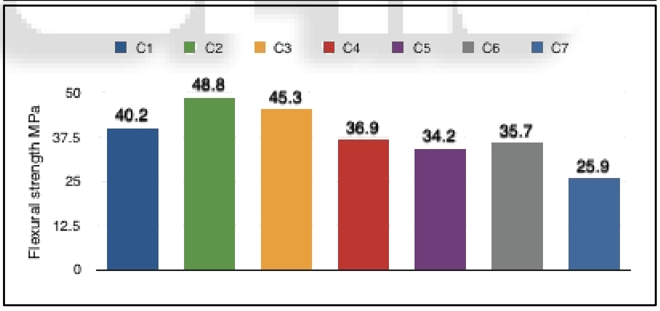
Specimen	Impact Strength
C1 Epoxy (95wt. %)+ Hair fiber (fiber length 1.5cm) (5wt. %)	3.7
C2 Epoxy (90wt. %)+ Hair fiber (fiber length 1.5cm) (10wt. %)	5.8
C3 Epoxy (85wt. %)+ Hair fiber (fiber length 1.5cm) (15wt. %)	6.1
C4 Epoxy (95wt. %)+ Hair fiber (fiber length 3.0cm) (5wt. %)	4.6
C5 Epoxy (90wt. %)+ Hair fiber (fiber length 3.0cm) (10wt. %)	11.4
C6 Epoxy (80wt. %)+ Hair fiber (fiber length 3.0cm) (10wt. %)	9.6
C7 Epoxy (100wt. %)	2.8



D. Flexural Strength

The flexural test of the composite was carried out using Universal testing machine Instron 1195 (Cross head = 2mm/min, span = 60mm).

Specimen	Flexural Strength
C1 Epoxy (95wt. %)+ Hair fiber (fiber length 1.5cm) (5wt. %)	40.2
C2 Epoxy (90wt. %)+ Hair fiber (fiber length 1.5cm) (10wt. %)	48.8
C3 Epoxy (85wt. %)+ Hair fiber (fiber length 1.5cm) (15wt. %)	45.3
C4 Epoxy (95wt. %)+ Hair fiber (fiber length 3.0cm) (5wt. %)	36.9
C5 Epoxy (90wt. %)+ Hair fiber (fiber length 3.0cm) (10wt. %)	34.2
C6 Epoxy (80wt. %)+ Hair fiber (fiber length 3.0cm) (10wt. %)	35.7
C7 Epoxy (100wt. %)	25.9



VI. CONCLUSIONS:

This research work on the mechanical behaviour of Horse hair reinforced epoxy composite shows the following conclusions.

1) The fiber length and fiber weight in a composite has critical impact on its mechanical properties.
2) The composite with Epoxy (90wt. %) and Hair fiber (fiber length 1.5cm) (10wt. %) has the maximum tensile strength.
3) The composite with Epoxy (90wt. %) and Hair fiber (fiber length 3.0cm) (10wt. %) has the maximum impact strength.
4) The composite with Epoxy (90wt. %) and Hair fiber (fiber length 1.5cm) (10wt. %) has the maximum flexural strength.

REFERENCES

[1] Mohini Saxena, Asokan Pappu, Anusha Sharma, Ruhi Haque and Sonal Wankhede, "Composite Materials from Natural Resources: Recent Trends and Future Potentials".

[2] Sanjay Choudhry & Bhawana Pandey, "Mechanical Behaviour of Polypropylene And Human Hair Fibers And Polypropylene Reinforced Polymeric Composites", International Journal of Mechanical and Industrial Engineering (IJMIE), ISSN No. 2231 –6477, Vol-2, Issue-1, 2012.

[3] Popescu C. and Hocker H, "Hair the most sophisticated biological composite material", Chemical Society Reviews 37(8), pp.1282–1291. (2007)

[4] Volkin D. B. and Klibanov A. M., "Thermal destruction processes in proteins involving cystine residues" The Journal of Biological Chemistry 262(7), pp.2945- 2950 (1987).

[5] Thompson R.M., "Hair based composite" U.S. Patent US 12/304,777 (2010).

[6] Jain D. and Kothari A., "Hair Fiber Reinforced Concrete" Research Journal of Recent Sciences, Vol. 1, pp.128-133 (2012).

[7] Hu X., Cebe P., Weiss A.S., Omenetto F., Kaplan D.L., "Protein-based composite materials" Materials Today 15(5), pp. 208–215 (2012).

[8] Gupta A., "Human Hair "Waste" and Its Utilization: Gaps and Possibilities", International Journal of Refractory Metals & Hard Materials 27, pp. 892–899 (2009).

[9] Hernandez A.L.M., Santos C.V., "Keratin Fibers from Chicken Feathers: Structure and Advances in Polymer Composites, In: Keratin: Structure, Properties and Applications", Nova Science Publishers, pp.149-211(2012).

[10] Babu R.P., Connor K.O. and Seeram R., "Current progress on bio-based polymers and their future trends", Progress in Biomaterials, DOI: 10.1186/2194-0517-2-8 (2013).

[11] K Nagi Reddy, V Chanrasekar, K Thirupathi Reddy and Syed Althaf Hussain, "Performance evaluation of EMU feather fiber reinforced polymer composites", International Journal of Mechanical engineering and Robotics Research, ISSN 2278 – 0149 www.ijmerr.com, Vol. 3, No. 1, January 2014.

[12] Isiaka Oluwole Oladele, Jimmy Lolu Olajide, Okikiola Ganiyu Agbabiaka, Olawale Opeyemi Akinwumi, "Tensile Properties and Fractographic Analysis of Low Density Polyethylene Composites Reinforced with Chemically Modified Keratin-Based Bio-fibers", Journal of Minerals and Materials Characterization and Engineering, 2015, 3, 344-352 Published Online July2015 in SciRes. http://www.scirp.org/journal/jmmce http://dx.doi.org/10.4236/jmmce.2015.34037.

[13] Rohit Srivastava "Characterization of Mechanical Properties of Bagasse Fiber/Chicken Feather Reinforced Epoxy Hybrid Composite" Volume 2, Issue 2(March-April 2016), pp.13-17.