Fabrication and Analysis of Human Hair Based Hybrid Epoxy Composite for Mechanical Properties

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Abstract:-Tensile, flexural, impact strengths, hardness and inter laminar distribution of human hair based hybrid epoxy composite were evaluated to assess the possibility of using it as a new material in engineering applications such as automobile and aircraft applications for longer life. Addition of epoxy to the human hair fiber ensures strength. Samples are fabricated by the hand lay-up process (37.5: 62.5 fiber and matrix ratio by weight) and the mechanical properties like tensile, flexural and compressive evaluated using the Universal Testing Machine, Hardness test using Rockwell hardness testing machine, Impact using Izod impact test and Inter De-laminar test using 3 point loading and observation under HD camera. Tensile and flexural strengths for the human hair based hybrid epoxy composite laminates are calculated to be 36.9MPa and 78.6MPa respectively. It is an eco-friendly, long life and cost effective solution for various applications.

KEYWORDS:- Human hair, epoxy, tensile strength, flexural strength, hardness, impact strength, inter de-lamination.

I. INTRODUCTION

A Composite material may be defined as a combination of two or more materials that leads to better properties than those of the individual components used alone. In comparison with metallic alloys, each material retains its separate chemical, physical and mechanical properties. The two main constituents are a fiber and a matrix. The main merits of composite materials are their high stiffness and strength, combined with low density, when compared with bulk materials, allowing a weight reduction in the finished material. The reinforcing phase provides the strength and stiffness. In most cases, the reinforcement is harder, stronger, and stiffer than the matrix. A fiber has a length that is much greater than its diameter. The length-to-diameter (*l*/*d*) ratio is known as the *aspect ratio* and can vary vastly. Continuous fibers have long aspect ratios, while discontinuous fibers have shorter aspect ratios. Continuous-fiber composites normally have regular orientation, while discontinuous fibers generally have a random orientation.

A. Human Hair Based Hybrid Composite

Hair threads form a major part of the external covering of most mammals. In the humans, hair represents a structure which long time ago lost their functional significance during the species evolution.

The hair thread has a cylindrical structure, highly organized, formed by inert cells, most of them keratinized and distributed following a very precise design. Hair forms a very rigid structure in the molecular level, which is able to offer the thread both flexibility and mechanical resistance. Hair is considered as a dead matter and it is only alive when it is inserted in the scalp. When the thread emerges, it becomes dead matter although it appears to be growing since the fiber follows increasing its length by a speed of about 1.0 cm/month.

Human hair has about 65-95% of its weight in proteins, more 32% of water, lipid pigments and other components. Chemically, about 80% of human hair is formed by a protein known as keratin (Kaplin *et al.*, 1982; Wagner, Joekes, 2005).

Threads present significant structural differences, according to the ethnic group, and within the same group.

The factors we have are: resistance, elasticity, diameter, bending, shape of the cross section and color. In spite of depending on threads characteristics and on the morphological components integrity, cosmetic properties are: volume, malleability, shine, combing retention of styling, and ability of flying away.

Hair has a particular genetic nature. We may handle it and applying on it products to mimic differences of the touch sensorial characteristics; these are, however, transient effects (Juez, Gimier, 1983; Dias, 2004).

II. FABRICATION

A. Pre-Requisites

- Mold plates (2 Nos)
- Liquid wax
- Oil
- Gloss paper
- Fixture

- Plain white paper (210*210mm)
- Cardboard strips (200mm long-2Nos ; 220mm long-2Nos)
- Cloth
- Hacksaw blade and Scissors
- Adhesive
- MS roller and Spacers (4mm)

B. Preparation

Two mold plates were taken and a template of 210*210 mm size which is the size of the composite was readied within their boundaries.

The composite was made by collecting hair from various sources and making them into beds of minute thickness by hand rolling in such a way that the follicles are interlocked. Taking approximately 20gms of hair for each bed three such beds were made. After this a bunch of approximately 4inch long hair was taken and small groups of follicles were removed each of approximately same thickness and placed separately in longitudinal fashion. About 50 such strands were formed. The epoxy resin was made with a composition of Araldite LY556 to HY951 hardener in the ratio of (10:1) and mixed well.

Fig: 2(a) Preparation

C. *Fabrication Process*

A portion of the mixed resin was applied on the inner side of the template. Then one of the rolled bed was placed and arranged precisely within the boundaries. This was allowed to dry for about 2 minutes before the second layer of epoxy was poured on top of it and spread evenly by using an MS roller held by a handle. Then they formed strands, about 25of them, were placed longitudinally, uni-directionally on top of the resin at an orientation of 0^0 with respect to the first bed. Then the epoxy resin was poured on top of the second bed and evenly spread by using the MS roller. Then the second bed was used as the third layer and same procedure was followed. Then third bed was used as fourth layer by repeating same procedure. Then the remaining strands were placed on the top as last layer with an orientation at 0^0 with reference to previous layer of strands and all the remaining epoxy was poured on top. Another nicely waxed gloss paper cut to the dimensions of the mold plate was used to cover the top of the material. Then 4mm thick spacers were placed at the vertices of the template in order to ensure non-tapered surface and even thickness throughout. The top mold plate was placed on this preparation for sandwiching it. Then the setup was placed in a fixture and tightened fully until the excess epoxy flowed out and a proper setting was obtained and was left undisturbed for one day. After checking the proper curing of the composite, it was removed from the fixture, separated from the mold plates, the gloss paper was torn and the composite made ready.

After the composite was fabricated it was cut into standard dimensions and the weight was measured.5 similar materials were fabricated for conducting various mechanical tests.

Specimen as per the sample taken (dimensions)	Epoxy Resin (wt. in gms)	Fibre (wt. in gms)
Composite 1 (Human Hair)	125	75

Table 1. Weight of Each Component in Fabricated Material

Fig: 2(b) Fabrication Process

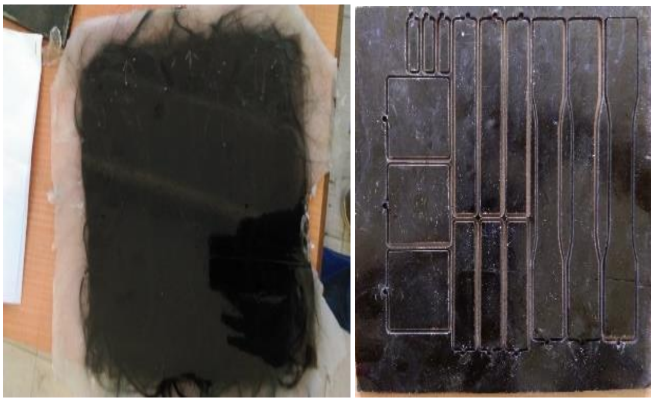

Fig: 2(c) Fabricated Material

III. TESTING

A. *Tensile Test: ASTM D638-03*

Tension testing is a fundamental materials science test in which a specimen is subjected to a controlled tension until failure. Composite specimens are tested for tensile strength as per ASTM D 3039 test standard. The tensile strength and elastic modulus are given in Table 2.

The specimen was loaded in servo assisted hydraulic - Universal testing machine having gauge length of 120mm.The grips were tightened evenly and firmly to prevent any slippage. The speed of testing was set at the proper rate of 1mm/min and the machine was started. As the specimen elongates, the resistance of the specimen increases, and it was detected by a load cell. The vice was fitted firmly and zero reading was observed. Then step by step loading was carried out until the specimen failed at the maximum load. A plotter plots the load vs deflection curve results on the graph sheet. The stress vs strain curve was plotted from the plotter results. The tensile strength was calculated from the test results.

Fig: 3(a) Specimen for Tensile Test in UTM

B. *Flexural Test: ASTM D790*

The flexural properties of the composites were evaluated using the Universal Testing Machine, with a cross head speed of 1mm/min and span length of 50 mm. The flexural strength was measured as per the ASTM D 790.

Fig: 3(b) Specimen for Flexural Test in UTM

The test specimen was positioned horizontally over the two supports of the testing machine as shown in figure 3(b). The upper grip was moved downward, i.e., the load was applied perpendicular to the specimen surface.

The speed of testing was set at the proper rate and the machine was started. A plotter was connected to the testing machine. The deflection of the specimen was continued until a rupture of the specimen was observed. A plotter plots the load vs deflection curve results on the graph sheet. The stress vs strain curve was plotted from the plotter results. The flexural strength was calculated from the test results.

C. *Impact Test: ASTM D256*

Impact testing is done for determining the toughness of a material against sudden force or impact. Izod impact testing is an ASTM standard method of determining the impact resistance of materials. A pivoting arm is raised to a specific height (constant potential energy) and then released. The arm swings down hitting the sample, breaking the specimen. The energy absorbed by the sample is calculated from the height the arm swings to after hitting the sample. A notched sample is generally used to determine impact energy and notch sensitivity.

Fig: 3(c) Specimen for Impact Test in the Izod Impact Testing Machine

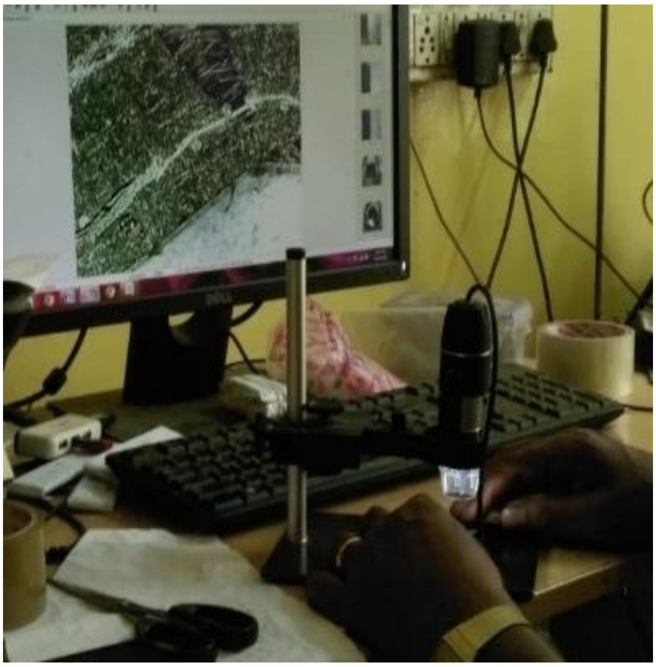

Fig: 3(e) Specimen for inter de-laminar Test under High Definition Camera

D. Inter De-laminar Test: ASTM D2344

Inter de-lamination is the property of a material to show its bending capacity whilst displaying its internal distribution of fibre and resin, in case of polymer. These dimensions are the same as those in the ASTM D-2344 standard. The material was placed on top of a three point loading chuck in form a beam as shown in the figure. Load was applied on this beam at the midpoint until the material fractured. The total fracture is then viewed under a High Definition camera for its inter delimitation images.

Fig: 3(d) Specimen Loaded in UTM for Three Point Bending

E. Hardness Test: ASTM D785

The hardness testing of plastics is most often measured by the Rockwell hardness test. It measures the resistance of the plastic toward indentation, thereby providing an empirical hardness value. The hardness values do not necessarily correlate to other properties or fundamental characteristics. Rockwell hardness is generally chosen for 'harder' plastics such as nylon, polycarbonate, polystyrene, and acetal where the resiliency or creep of the polymer is less likely to affect the results. The figure below, from Quadrant Engineering Plastic Products, shows the Rockwell hardness test geometry.

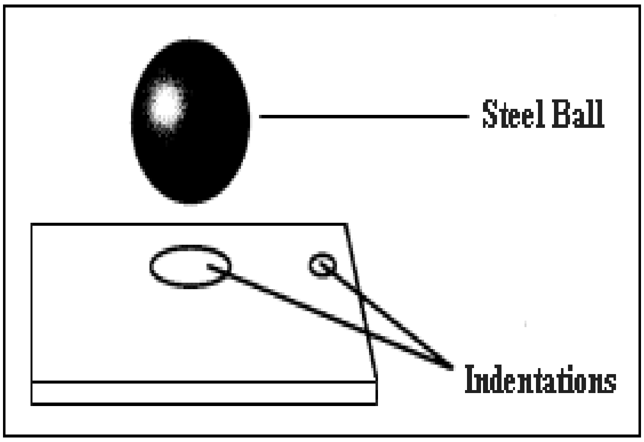

Fig: 3(F) Rockwell Hardness Indentation

A specimen of at least 1/4 inches (6.4 mm) thickness is indented by a steel ball. A small load is applied, the apparatus is zeroed, and then a larger load is applied and removed. After a short time with the preload still applied, the remaining indentation is read from the scale.The results obtained from this test are useful measures of relative resistance to indentation of various grades of plastics. However, the Rockwell hardness test does not serve well as a predictor of other properties such as strength or resistance to scratches, abrasion, or wear, and should not be used alone for product design specifications.

IV. RESULTS AND DISCUSSION

A. Tensile Strength

The experimental values of tensile stress vs strain for composite specimens were plotted and have been shown in Figure 4(a). From the figure it is seen that the tensile strength value is 36.9 MPa for human hair epoxy composite.

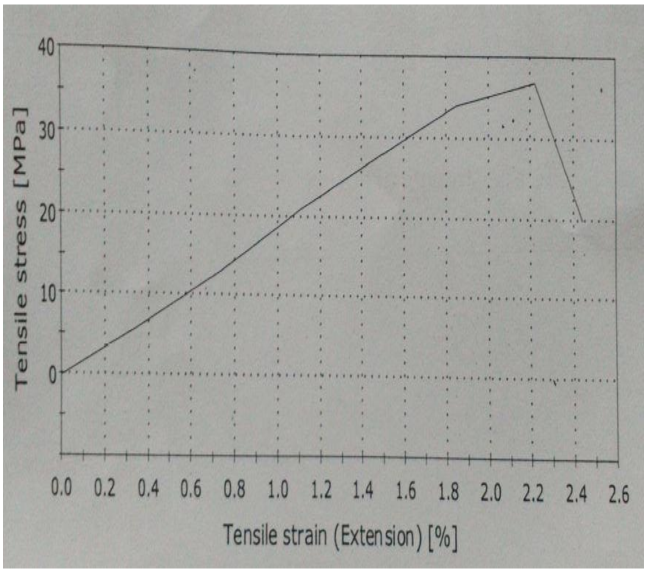

Fig: 4(A) Stress Strain Curve of Human Hair Epoxy Composite

Specimen	Tensile (N/mm^2)	Young's Modulus (GPa)
Composite 1 (Human Hair)	36.9	3.0

Table 1: Tensile Strength

B. Flexural Strength

The experimentally determined values of the flexural stress of the composite specimens were plotted against the flexural strain and have been shown in Figure 4(b). From the figure it is seen that the flexural strength value is 78.6 MPaat approximately 3.7% strain for human hair epoxy composite.

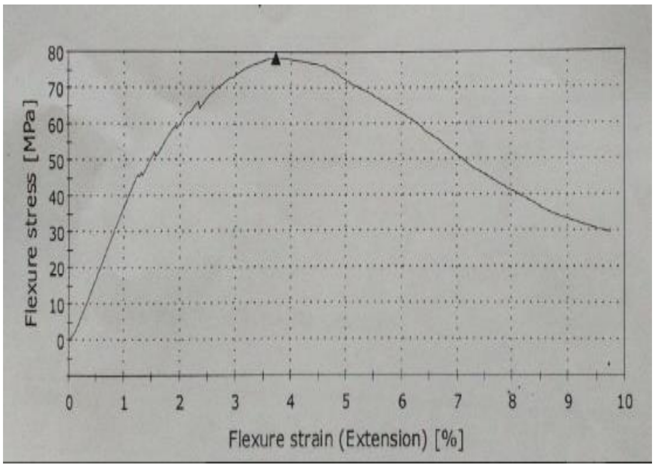

Fig: 4(B) Flexural Stress Strain Curve of Human Hair Epoxy Composite

Specimen	Flexural Strength (N/mm^2)
Composite 1 (Human Hair)	78.6

Table 2: Flexural Strength

The enhanced flexural properties are due to the formation of a thick bonding network structure between the hair strands and the epoxy matrix.

C. Impact Strength

As explained in the previous chapter, the impact test was conducted based on the ASTM D256 and following results were obtained. It was seen that the impact strength value was 6 Joules for human hair epoxy composite.The impact strength values of both the composites are given in Table 4.

Specimen	Impact Strength (Joules)
Composite 1 (Human Hair)	6.0

Table 3: Impact Strength

D. Inter De-lamination

The results that were obtained from the human hair epoxy composite images generated are epoxy distribution is uniform, compaction is good, fibres are distributed evenly, bonding of hair with epoxy is good, Material behaviour is normal.

Fig: 4(C) Inter De-Laminar Test Image of Human Hair Epoxy Composite

E. Hardness

As explained in the previous chapter, the impact test was conducted based on the ASTM D785 and following results were obtained. Rockwell hardness test was done and hardness at 4 different locations were measured and following average value of hardness was obtained.

Material 1.Rockwell hardness (ball indenter): 36.33

V. APPLICATIONS

This composite fabrication was aimed at producing durable bumpers as a primary application using hair fibre,with epoxy resin. The above results prove that this was a good attempt in making the desired composite.

Further, the applications over this material can be extended in other automobile and aircraft applications where there is a need for vibration, noise and dampening. It is also a good water-proofing and fire proof material due to the addition of epoxy.

Future works involve the usage of this composite in combination with other materials such as natural composites and phase changing materials (PCM) for various applications. Few practically possible applications of this materials includes bumpers, aircraft nose, engine covers, fuel tanks etc.

VI. CONCLUSIONS

The tensile strength value of hair fiber epoxy composite is found to be close to 37 MPa which is very good for plastics.

The flexural strength of the composite was found to be 78.6 MPa which is remarkable.

The impact strength was 6 Joules and hardness number in Rockwell scale C was 36.33 which implies that the material is considerably tough and moderately hard. Also, the inter de-lamination images suggest that.

- Epoxy distribution is uniform
- Compaction is good
- Fibres are distributed evenly
- Bonding of hair with epoxy is good
- Material behaviour is normal

Hence, we can conclude that the hair fiber epoxy composite shows better mechanical properties. However, these results may vary depending upon the type of fabrication, fibre: matrix ratio and the number of layers of the individual constituents. It has a good scope of development and wide spread usage and also a good combining abilities. It is an eco-friendly, long life and cost effective solution for various housing problems.

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