Evaluation of mechanical behavior for animal fiber
Reinforced hybrid fiber composite for marine application

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Abstract: When natural fibers are bonded together with synthetic material, they exhibit increased mechanical properties which are environment friendly and of low cost. The application of natural fibers as a substitute for chemical fibers draws great interest due to its less weight, lower raw material price, and ecological benefits of using green resources which are biodegradable and renewable. By combining these natural fibers in different compositions, the above-mentioned properties can be enhanced. In this investigation the natural material of goat woolen fiber, hen feather fiber, human hair fiber and synthetic aramid material of Kevlar 29 (K-29) are reinforced with Epoxy resin by hand layup technique and three samples are prepared at various combination. To distribute uniform pressure on sandwiched layers a method called Compression Molding is followed. Tensile strength, flexural strength is performed as per ASTM standard. In addition to this Water Immersion test is also carried out to determine the amount of water absorbed under specified conditions. Bonding layers and structure characterized by Scanning Electron microscope (SEM). The result proved that composite material is enhanced good mechanical properties and very less water absorption. It is used for light weight and for enormous applications in engineering industries and for lining materials of marine environment.

1. Introduction
Hybrid composite materials can be developed by incorporating various reinforcement of fiber whether they are Natural or synthetic types. The proper selection and ratio of reinforcement can be used generate various application such as marine Application [1]. The hybrid composite materials enhanced good Physical and chemical properties such as light in weight, good corrosion resistance, non-electromagnetic, super structure, high blast resistance, less water absorption, good adhesion strength, high impact resistance optimum tensile and flexural strength[2-5]. Akarsverma et al .Reviewed human hair fiber is non-degradable biological Nano composite and it has fine morphological structure, and it is used in field of advanced engineering materials science [6]. Himanshu kumar Sinha et al fabricated goat hair based composite and tested their mechanical properties, finally bidirectional orientations composite produced good mechanical properties [7], K.srinivas et al reviewed (NFRPC) Natural fiber reinforced polymer composite, comparative evaluation of natural fiber properties lower than synthetic composite, combination of hybrid fiber composite produced malleable mechanical properties. [8]. Sanjay Choudhry et al investigated human hair fibers and polypropylene reinforced polymeric composite, the result shows that better flexural strength, impact strength and produced
lower tensile strength [9]. F.J. Wortmann et al analyzed hair fiber composite in thermal oxidation process effect of affected damage in morphological component. [10]. Guoxia Ran et al investigated adsorption behavior of human hair fiber composite, the result shows that hair surface is suggest to that mono layer or bilayer, the structure of bilayer and top layer interacted electrostatic interaction and lateral hydrophobic interaction [11]. Saafiqh et al investigated hybrid composite for structural application, kevlar,carbon,glass produced higher properties than metallic materials [12]. Basem et al fabricated composite material for production of marine hatch cover with less weight and high strength application [13]. Deepakverma et al investigated by Epoxy resin based composite with carbon nanotube exhibit high performance marine structure[14].The investigation proved that Kevlar and carbon hybrid composite at high strain rate induced failure under novel SHPB-AE coupled test[15] As the reference of previously carried out hair fiber reinforced natural fiber or alone with epoxy resin fabricated by the composites.in any other research not investigated and manufactured by synthetic fiber (Kevlar 29) reinforced with various animal fiber at various compositions, this we are identified in our research work. the main aim of investigation in this research fabricated Kevlar reinforced with Animal fiber (Human hair, hen feather, Goat hair) composite plates in various composition. After formation of composites to be tested Mechanical characteristics and water immersion rate of analyzed or tested by ASTM standard. The composite enhanced mechanical properties and it was utilized various engineering applications.

2. Materials Selection

2.1. Synthetic fiber (Aramid fiber Kevlar 29)

Kevlar is an aramid synthetic fiber very strong compare than other synthetic materials shock resistant, heat resistant. It is having high impact resistance and high energy absorption, high tensile modulus and less weight ratio. It is having high tensile strength and impact resistance. Kevlar used for many applications like a Defense application, Ship building and construction, Automotive engineering, Aerospace, structural engineering. Tensile modulus-70500MPa, less density, high braking tenacity - 2920MPa [16].

![Figure 1. Kevlar29 fabric woven fibre.](image)

Figure 1 shows that kevlar29 woven fiber purchased from vruksha composite Guntur, Andhraprathesh. Polymer chain reaction much perfect and Elasticity of Kevlar 49 almost 30% higher than Kevlar 29. High level properties of Kevlar determined at low and high temperature conditions [17].

2.2. Animal fibers

2.2.1. Human hair. Hair fiber is most important biomaterial formed with protein and notably alpha-keratin. Each strands of hair are made up of medulla, cortex and cuticle. Bundle of hair fiber produced optimum mechanical properties and less reaction in water environment [18-20].
Figure 2. Human hair fibre.

Figure 3. After processed (washed in acetone) hair fibre.

Figure 2 shows that human hair fibre purchased from Chennai hair Factory (India) Pvt.Ltd. Figure 3 shows that Acetone processed hair fiber mate (30cm X 30cm), Thickness 2mm, density 1.32 g/cc, it has a high tensile strength and available in residue at very low cost [21].

2.2.2. Goat fiber. Goat hair fiber also called diamond fiber, it is having excellent insulating properties, good elasticity, Flame resistant, crease resistant, moisture wicking properties and more expensive than human hair fiber. Goat hair [7]. Figure 4 shows that goat hair fiber purchased from protein and meat sales shop in Chennai. Figure 5 shows the goat woolen hair fiber processed with acetone and warm water after dried in sun light. The length of fiber 20 to 30 mm, diameter of 30 to 45 micron, moisture absorption 5.02 %, Elongation in shear 9.054 to 20.05 % [22].

Figure 4. Goat hair fibre.

Figure 5. After processed goat hair fibre.

2.2.3. Hen feather fiber. Chicken feather fiber is livestock waste, it has been used for various application like a textile, crafting and bio composite manufacturing. The feather consists of about 91% keratin, 1.3% fat, 7.9% water. Keratin is a hard protein available in hair fiber and have good thermal stability and high flexural strength [23].
Figure 6. Hen feather fibre. Figure 7. After processed fibre.

Figure 6 and figure 7 shows the before and after processing of hen feather fiber. It was purchased form Namakal Hen farming center, India. HY951 Hardener and LY556 Epoxy Resin has been purchased from Alpha systems & Instruments, Bangalore, India.

2.3. Processing of Animal fiber
All the purchased animal fibers were washed separately at which many times in warm water and these fibers are dried out in sunlight. Acetone (C₂H₄O) is an organic used as a dry cleaning and spot remover. The hair fiber dried out in sunlight after again washed in hot water dried out and manually removes unwanted particles then it is used for making of composite layer by layer arrangement. The figure 8, figure 9 and figure 10 shows after acetone processed animal fibers [24].

3. Research method and Experimental method
The aramid Kevlar fiber density 220gsm, thickness 0.26mm, fabricated bilayer woven mate, weight of 200 g/m² and Epoxy with hardener (viscosity 60-80 MPa at 27° C) used as a Matrix [25-26]. Hand layup method followed by fabricated of composite with mixed proper ratio of binder and resource materials. In our research hand layup method used for manufacturing of composite. In this process the (Hybrid) Composite Samples are fabricated in more than four layers. The samples are prepared in three different layers, Sample 1:(K+GH+HF+K), Sample 2:(K+HHU+HHB+K), Sample 3:(K+GH+HHB+HF+K). K-Kevlar aramid fiber, GH- Goat Hair (1.2 mm thickness, 30mm length), HF- Hen Feather fiber (0.8 mm thickness, 20 to 30 mm length), HHU- Human hair fiber unidirectional mat, HHB- Human hair fiber bidirectional layer. The sample are fabricated by hand layup method and applied constant load for specified time at atmosphere condition. All the samples were fabricated 25cm X 25 cm dimension and 4 mm thickness.

The samples were fabricated layer by layer, the ratio of 25% and 75% taken by natural and synthetic fibers. The base was cleaned, dried and wax coated for better adhesiveness. To increase the strength of the sample, the binder as epoxy resin with hardener is taken in 10:1 ratio in layer by layer arrangement. Figure 8 shows the sample1 layer arrangement, figure 9 shows layer arrangement of sample2 and figure 10 show the sample3 layer arrangement. finally, fabricated samples were tested Tensile strength (ASTM D638), Flexural strength (ASTM D790) and morphological analysis donned by Scanning Electron microscopy (SEM), water resistant measured by water absorption test (ASTM 570).
4. Materials Testing

4.1. Tensile Test

Universal Testing Machine (UTES-60) was used at specified conditions to conduct Tensile Test of the composite. ASTM D638 (Type III and Rectangular Bar Specimen) standards were used to measure the experiment. Each specimen has standard and specified dimensions (full length 165mm, gauge length 50mm, grip section 29mm). Figure 11 and Figure 12 shows the experimental setup before and after tension.
Figure 11 shows the tensile test conducted with animal fiber hybrid composite specimen on UTM. Each samples taken five specimen conducted test and identified mean value of the samples.

4.2. Flexural Test
The bending strength of the materials is measured according to ASTM D790 standard all the specimens had specified dimension before conducting the test. To obtain the average value the Three – Point Load Test was conducted five times with the composition sample.

4.3. Microstructural analysis
The fractured surface of the composite specimen which was treated with acetone binding layer was analyzed using Scanning Electron Microscopy at Department of Manufacturing Engineering, Anna University – Chennai – India.

The SEM specimen was thoroughly cleaned, dried in air and coated with Platinum to provide conductivity which was observed in Scanning Electron Microscopy. The Figure 13 shows the specimen holder and SEM analyser set up.

4.4. Water Immersion Test
As per ASTM 570 Standards the water absorption test was conducted for animal fiber hybrid composite by immersion in water at room temperature. All specimens were dried in oven at 50°C for 24 hours and was stored in a Desiccator. To find out the content of water which was absorbed, the
samples were taken out periodically and water on surface was wiped out and was weighed immediately using a precise balance machine.

\[
\text{Water Immersion (\%)} = \frac{W_2 - W_1}{W_1} \times 100
\]

where, \( W_1 \) - Wet Weight, \( W_2 \) – Dry weight

### 5. Result and Discussion

#### 5.1. Tensile behavior

The tensile test was conducted as per the ASTM standard. The below Table 1 shows that various animal fiber reinforced composite tensile strength and axil pulled load. Figure 14 and Figure 15 shows the specimen before test and broken specimen after testing. The figure 16 shows comparative statics of variable specimen under stressed value and rate of strain. Figure 17 state that Average stress and strain relationship of three samples.

| Name of the specimen | Layer formation | Tensile Modulus (GPa) | Tensile strength (GPa) | Applied Force (KN) | Thickness (mm) |
|----------------------|-----------------|-----------------------|------------------------|-------------------|---------------|
| 1                    | S10 (K+GH+HF+K) | 50                    | 53                     | 6.2               | 4             |
| 2                    | S11 (K+HHU+HHB+K) | 59                    | 65                     | 6.46              | 4             |
| 3                    | S12 (K+GH+HHB+HF+K) | 47                    | 55                     | 6                 | 4             |

**Figure 14.** Specimen at before tensile test.  
**Figure 15.** Specimen at after tensile test.  
**Figure 16.** Tensile strength of animal hybrid composites.
5.2. Flexural Behavior
The flexural test was evaluated the maximum bending strength of the materials. The prepared samples were machined into specimens with size of 80mm X 10mm X 4mm according to ASTM 790 Standard and 3- point flexural technique was Utilized in this experimental investigation [26].

![Figure 18. Flexural specimen before and after testing.](image1)

![Figure 19. Average flexural strength of various samples.](image2)

5.3. Water Absorption Test
Figure 20 shows the percentage of water absorption at various timings for Kevlar Hybrid Natural Composite. Sample 2 (human hair hybrid composite) shows very less water absorption property when more filler of goat hair is added in the composite, which also increased the weight.

5.4. Morphological Evaluation
The figure 21(a) shows the SEM image of Sample 1(K+GH+HF+K) with magnification of 5.00mm. The epoxy resin, hen feather, Goat hair, Kevlar fiber are identified in the Structure. Figure 21 (b) sample 1 shows that in this material undergone brittle failure and fractured surface observed under the magnification of 200μm. the figure 22 (a) sample 2 in the image we can see the surface topography of Kevlar fiber, human hair fiber and epoxy resin at the magnification 500μm. The figure 22 (b) Sample 2 show that of SEM image magnification 5.00mm, in connection that matrix layer and fractured surface are viewed. In figure.23 (a) sample3 the image with magnification of 5.00mm in presence
hybrid fiber (hen feather, goat fiber, human hair fiber, Kevlar fiber, epoxy resin) and able to see surface topography. In figure 23 (b) Sample 3 Shows that hair fiber fractured in side of the sample under magnification of 200µm.

Figure 20. Water Absorption percentage of Kevlar hybrid composites.
Figure 21(a) and figure 21 (b) show that Sample1 (Kevlar and goat, hen composite) micro structure in SEM, Figure 22 (a) and figure 22 (b) show that Sample 2 (Kevlar and hair fiber mat composite) fractured surface, Figure 23 (a) and Figure 23 (b) shows that bonding layer Sample 3(Kevlar, hen feather, goat hair fiber, human hair hybrid composite).

6. Conclusion
The Experimental investigation on animal fiber hybrid composites malleable mechanical properties shows following results:

The sample 1 (K+GH+HF+K) animal fiber hybrid composite elevated the maximum tensile strength 53GPa at 6.2 KN, high flexural strength 65GPa and have very less water absorption, less thickness (4mm). The fabricated composite enhanced good mechanical properties and it is used for automobile part making applications. The sample 2 (K+HHU+HHB+K) human hair hybrid composite enhanced the tensile strength 65GPa at 6.46KN, flexural strength 90GPa. Water absorption very less (0.15%) compare than sample1. The fabricated sample dimension 25 cm X 25 cm rectangular plate have thickness 3.8mm. It has high mechanical properties and less weight compare than other sample. It was suitable for lining materials of shipbuilding construction and also used bulk head construction in marine environment. Fiber length desired the behaviors of in this composite materials. Here the human hair fiber taken 30 cm length and its fabricated bidirectional mate. When the fiber length long and taken ratio fiber loading 20% then its enhanced good mechanical properties and fine micro structural. The sample 3 (K+GH+HHB+HF+K) hybridization of Kevlar and animal fiber reinforced polymer composite have tensile strength 55 GPa at 6 KN, flexural strength – 70GPa. It is having less water absorption than sample 1 and high for sample 2. The matrix of the fiber, weight ratio and length of the fiber desired the various properties of materials. It is used External sheet in automotive constructions. Finally, the investigation concluded this research work the sample 2 (human hair fiber and Kevlar fiber) produced excellence mechanical properties and less water immersion. Reaming samples enhanced mechanical properties. All fabricated composites suitable and using for Automotive Constructions Applications.

7. References

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