Effect of jute fibre treatment on moisture regain and mechanical performance of composite materials

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Abstract. This study was focused to investigate the effect of fluorocarbon, hydrocarbon and hybrid fluorocarbon on the mechanical properties and moisture regain of jute fiber reinforced composites. A significant difference in moisture regain values of treated and untreated reinforcement samples was observed at a concentration of 40 g/l. The composite made from treated reinforcement regained very low moisture content and exhibited improved mechanical properties (tensile and flexural strength). Being dual nature (hydrophilic and hydrophobic groups) of Hybrid fluorocarbon, the treated jute fibers and corresponding composites showed better properties as compared to other two chemicals due to better interface.

1. Introduction
Bio-composites employed for the composite materials having natural reinforcing fibres or biopolymers as embedding matrices [1]. The natural fibers like flax, jute, hemp, kenaf and sisal are the mostly used as reinforcement for the bio-composites [2]. Low cost, easy availability, High specific properties and eco-friendly nature of jute makes it very important degradable natural fiber in composite. The properties of jute fiber in comparison with other natural fibers are given in table 1.

Table 1. Properties of jute fibre in comparison with other fibres [3].

| Fibre | Density (g/cm³) | Tensile strength (MPa) | Young modulus (GPa) | Specific modulus (GPa) | Moisture content (%) |
|-------|----------------|------------------------|---------------------|------------------------|---------------------|
| Cotton | 1.55 | 400-750 | 7-10 | 5-6.5 | 8.5 |
| Flax | 1.45 | 510-910 | 50-70 | 34-48 | 12 |
| Hemp | 1.43 | 350-760 | 30-60 | 20-42 | 12 |
| Jute | 1.34 | 200-460 | 20-55 | 14-40 | 12 |
| Kenaf | 1.30 | 300-1200 | 22-60 | 17-46 | 17 |
| Sisal | 1.45 | 100-800 | 9-22 | 6-15 | 11 |

The jute fiber has gained the attention as reinforcement for composite materials due to its biodegradability, high strength to weight ratio and good thermal insulation properties. However, higher moisture regain of these fibres hinders their use in composites. The moisture absorption may cause the swelling and maceration of the fibres subsequently decreasing its mechanical properties. So, the jute fibers need to be modified either physically or chemically to improve the compatibility between the fiber and the polymer matrix [1]. The surface of natural fibers is generally chemically
modified to minimize the wetting of fibers in addition to improve the interface between the matrix and the reinforcement. Some chemical surface modification techniques include treatment with sodium chlorite [4], methaacrylate [5], isocyanate [6], silane treatment [7], mercerization, acetylation [7], etherification [9], enzymatic treatment [10], peroxide treatments, benzylation [8], dicumyl peroxide treatment [6], plasma treatment [11], ozone treatments [12], and grafting. The oxidation of polyolefins [13], has also been described to improve the incompatibility between the surfaces of natural fiber and polymer matrix. All these treatments are marked to reduce the moisture regain of the natural fibers and their resulting composites.

It is a known fact that lower the surface free energy of a material, lower will be the moisture regain [14]. The surface free energy of hydrocarbons and fluorocarbons is smaller as compared to the majority of the compounds used in the previous researches. Even though having lower surface tension, fluorocarbon and hydrocarbon are not commonly used for the treatment of jute fibers for composite applications. Therefore, the objectives of present study were to reduce the moisture regains of composite materials prepared from jute reinforcement treated with hydrocarbon, fluorocarbons and hybrid fluorocarbons, to study the properties of these composite materials and to check to what extent our assumption regarding hybrid fluorocarbon is valid.

2. Experimental

2.1. Materials
The plain woven jute fabric, having areal density of 190±2 g/m², was used as reinforcement while unsaturated polyester resin (UPE) was the matrix. The three chemicals hybrid fluorocarbons (OLEOPHOBOL CP-R), fluorocarbons (OLEOPHOBOL 7713) and hydrocarbons (PHOBOL RSH) used in this study were procured from HUNTSMAN (pvt) Limited.

2.2. Methods
The first step of the study was the treatment of jute fabric with chemicals, followed by the composite fabrication. Then scouring of the jute fabric was done for 50 min at a temperature of 70-80°C to activate the hydroxyl group of lignin and cellulose and to remove the impurities. The scoured reinforcement was then treated with the solutions of hybrid fluorocarbons, hydrocarbons and fluorocarbons and dried at 100°C for 4 minutes. A total of ten reinforcement samples, represented by RE1 to RE10 were prepared as shown in the table 2. Hybrid fluorocarbons, hydrocarbons and fluorocarbons chemicals are represented by F1, F2 and F3 respectively.

| Sr. # | Reinforcement samples | Chemical Treatment | Concentrations |
|-------|-----------------------|--------------------|----------------|
| 1     | RE 1                  | NO                 |                |
| 2     | RE 2                  | F1                 | 20 g/l         |
| 3     | RE 3                  | F1                 | 30 g/l         |
| 4     | RE 4                  | F1                 | 40 g/l         |
| 5     | RE 5                  | F2                 | 20 g/l         |
| 6     | RE 6                  | F2                 | 30 g/l         |
| 7     | RE 7                  | F2                 | 40 g/l         |
| 8     | RE 8                  | F3                 | 20 g/l         |
| 9     | RE 9                  | F3                 | 30 g/l         |
| 10    | RE 10                 | F3                 | 40 g/l         |
Hand lay-up technique was used to fabricate the composites. Six layers of woven jute fabric (reinforcement) were used; composite plate size was 250×250 mm² and the fibre volume fraction was maintained to 35%. The initial curing took place at room temperature for one hour, followed by post curing at 130°C for 3 hours. Composites were fabricated with untreated jute reinforcement as well as with reinforcements treated with three types of hydrophobic chemicals. Table 3 shows the detail of composite samples produced for the study.

### Table 3. Experimental design for composites samples.

| Sr. # | Samples ID | Reinforcement | Hydrophobic Chemicals | Concentration |
|-------|------------|---------------|-----------------------|---------------|
| 1     | S1         | Jute          | No                    | -             |
| 2     | S2         | Jute          | F1                    | 40 g/l        |
| 3     | S3         | Jute          | F2                    | 40 g/l        |
| 4     | S4         | Jute          | F3                    | 40 g/l        |
| 5     | S5         | Simple resin  | No                    | -             |

2.2.1. **Moisture regain test.** The moisture regains test of jute fabric (untreated and treated with chemicals) was done by using standard test method ASTM D2495, while that of composites and neat resin samples according to ASTM D5229. The composite sample was dried in oven at 60°C, till there was no further change in weight. This initial weight was recorded and sample was immediately placed into environmental system. Change in mass was measured after intervals of time till equilibrium was established. The graph was plotted between the weight gains versus the square root of time.

2.2.2. **Mechanical Characterization.** The ASTM D3039 was used to study in-plane tensile properties of polymer matrix composite. The ultimate tensile strength of the material is observed from the maximum load carried prior to failure. Sample size was 200 mm with 120mm gauge length and width 25 mm with speed of 100 mm/ min. The flexural properties were tested by 3 point bending test using ASTM D7264. The span-to-thickness ratio was 20:1, with standard specimen thickness 5 mm and width 12 mm. The length of specimen was kept 20% longer than the support span. The speed of testing was set to the crosshead movement rate of 1.0 mm/min.

### 3. Results and Discussion

#### 3.1. **Moisture regain of reinforcement**

The moisture regain %age of untreated fabric sample and those samples treated with three different chemicals F1, F2 and F3 (hybrid fluorocarbons, hydrocarbons and fluorocarbons) as function of their concentrations is shown in figure 1. It can be observed that the moisture regain of untreated sample was 12.08 %, whereas moisture regain of treated samples was found in the range 2.81-6.15%. Furthermore, the reinforcement treated with F1 shows the lowest moisture regain value of 2.81% at concentration of 40 g/l. On the other hand F2 and F3 shows moisture regain value 3.11% and 3.05% respectively, at 40 g/l. The difference among the moisture regains of samples treated with F1, F2 and F3 is not very significant because critical surface tension values of all three chemicals are 14-28 mNm⁻¹.
Figure 1. Moisture regain of untreated and treated fabric as function of chemical concentration.

3.2. Moisture regain of composites

Moisture regain %age in equilibrium state of composite samples made from untreated and treated jute reinforcement is shown in Figure 2. The moisture regain % of neat resin sample was found to be 0.30%. Untreated jute composite sample absorbed 4% moisture whereas moisture regain of jute fabric was 12.08%.

It was observed that the moisture regain of composite sample containing reinforcement treated with F1 was the least (0.79%). The moisture regain values of composites samples made by reinforcements treated with F2 and F3 was 2.62% and 1.95% respectively. Hybrid fluorocarbons being soil release are the copolymers which have the fluorocarbon part and hydrophilic part. Fluorocarbon block has the lesser surface tension whereas the hydrophilic part absorbs more amount of resin. Due to both these phenomenon, the ultimate moisture regain of sample is lesser.

Moisture regain plot of the composites and neat resin samples is plotted versus square root of time in figure 3. It was noticed that the moisture uptake was rapid in all the composite samples from beginning to 1000 minutes. This was logical as the test specimen was dried completely. After 1000 minutes, the saturation of specimen commenced and rate of moisture regain became slow. Almost all the samples got saturated after 3000 minutes. Tests were extended to 5800 minutes (4 days) to assure that samples regained maximum amount of moisture and are in equilibrium state.
Figure 2. Moisture regain of resin and composite samples in equilibrium state.

Figure 3. Moisture regain of composite samples.

3.3. Mechanical Characterization
The tensile and flexural properties of composite materials are shown in Table 4. There was significant difference between the values of composite sample made by untreated reinforcement and treated reinforcement (F1, F2 and F3). It was due to the fact that strength of composite mainly depends on the strength of reinforcement. If we compare the tensile strength of composites made from treated reinforcement, it can be seen that F1 treated reinforcement composite has higher tensile strength as compared to F2 and F3 treated reinforcement composites. It is due to hybrid nature of F1 chemical.
It is also clear from the given table that the flexural strength of the treated reinforcement composites is higher than the untreated reinforcement composite sample. This is because the treated reinforcement has the more strength than untreated reinforcement. Sample treated with F1 has the highest deflection, because it provided the good resin-matrix interface.

| Sr. # | Composite samples | Reinforcement                  | Tensile Strength (MPa) | Flexural Strength (MPa) |
|-------|-------------------|--------------------------------|------------------------|-------------------------|
| 1     | S1                | Simple jute reinforcement      | 32.34                  | 38.71                   |
| 2     | S2                | F1 treated reinforcement (40g/l)| 48.72                  | 81.73                   |
| 3     | S3                | F2 treated reinforcement (40g/l)| 42.56                  | 67.11                   |
| 4     | S4                | F3 treated reinforcement (40g/l)| 43.23                  | 56.39                   |

**Table 4. Mechanical properties of composite materials.**

### 4. Results and Discussion

It is concluded from this study that there is a significant difference in the moisture regain of untreated and treated reinforcements. The reinforcement treated with hybrid fluorocarbon shows the lowest moisture regain value 2.81% at 40g/l, as compared to the other two. More moisture is absorbed by reinforcement in the composite, as the moisture regain % of the pure resin sample was only 0.30%. Untreated jute composite sample absorbed 4% moisture, while composites produced by Hybrid Fluorocarbons treated reinforcement has the least (0.79%) moisture regain, validating the moisture regain results of the corresponding reinforcement. There is significant difference between the mechanical properties of composite sample produced from untreated reinforcement and treated reinforcement.

This work was supported by the research project of Student grant competition of Technical University of Liberec no. 21197 granted by Ministry of Education Youth and Sports of Czech Republic.

### References

[1] Campbell F C 2010 *Structural Composite Materials* (Ohio: ASM International)
[2] Gay D, Hoa S V. and Tsai S W 2003 *Composite Materials: Design and Applications* (Florida: CRC Press)
[3] Cristaldi G, Latteri A, Recca G and Cicala G 2010 *Woven Fabric Engineering* 1 317–342(InTech)
[4] Khan G M A and Alam S 2013 *J. Mater. Sci.* 1 39–44
[5] Cantero G, Arbelaiz A, Llano-Ponte R. and Mondragon I 2003 *Compos. Sci. Technol.* 63 1247–1254
[6] Joseph K and Thomast S 1996 *Polymer* 37 5139–49
[7] Alix S, Lebrun L, Morvan C and Marais S 2011 *Compos. Sci. Technol.* 71 893–899
[8] Joseph K, Mattoso L H C, Toledo R D, Thomas S, Carvalho L H de, Pothen L, Kala S and James B 2000 *Nat. Polym. Agrofibers Compos.* 159 159–201
[9] Matsuda H 1996 Chemical Modification of Solid Wood (New York: Marcel Dekker Inc.)
[10] Grönpqvist S, Buchert J, Rantanen K, Viikari L and Suurnäkki A 2003 *Microb. Technol.* 32 439–445
[11] Uhara T and Sakata I 1990 *J. Appl. Polym. Sci.* 41 1695–706
[12] Hon D N-S 1982 *Graft copolymerization of lignocellulosic fibers* (Washington D.C: American Chemical Society)
[13] Gugumus F 1998 *Degrad. Stab.* 62 235–43
[14] Arkles B, Pan Y and Kim Y M 2009 *The Role of Polarity in the Structure of Silanes Employed in Surface Modification Silanes and Other Coupling Agents* 5 51–64