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Fabrication and characterization of cane fiber reinforced unsaturated polyester resin composites

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Abstract

Cane fiber of the generas *Acoruscalamus, Daemonorops Draco, Daemonoropsmollis* climbing palms of tropical Asia, belonging to the family palmae (palm family) and unsaturated polyester resin were used for the preparation of composites. Cane fiber was modified with 5%, 10%, 15% NaOH solution. Various physical and mechanical properties of the composite for different orientations of fiber were measured. The physical properties i.e. water absorption of treated fiber reinforced composites is lower. But the moisture content of cane fiber decreases with higher concentration of alkali solution used for treatment. The ultimate tensile strength (UTS) is higher for treated fiber reinforced composites than the raw fiber reinforced composites for any types of orientations of fibers and the tensile strain of treated fiber reinforced composites is lower than the raw fiber reinforced composites. The UTS value for treated cane fiber composites increases with increasing weight percentage of fiber than the raw fiber reinforced composite.

Keywords: Cane fiber, Composites, NaOH solution, Orientation of fiber, Reinforced, Treated fiber.

Introduction

The term composite means a type of solid material consists of two or more dissimilar separate materials (Richardson, 1987; Mathur 2006). But in modern materials engineering, the term usually refers to a matrix material that is reinforced with fibers. Metals and plastics are not considered composites although they have a lot of fillers and impurities. Only if a significant change in the properties is achieved than the material considered a composite. Composite materials have used vastly in many fields for their better thermo-mechanical properties (Kafi *et al*., 2006; Khan *et al.,* 2010; Hattum *et al*.,2011). Most composites have at least two constituent materials: a binder or matrix and a dispersed phase for reinforcement. The reinforcement is usually much stronger and stiffer than the matrix and gives the composite good properties. Reinforcements basically come in three forms: particulate, discontinuous fiber, and continuous fiber (Callister, 2000). Renewable fibers are often considered for low cost and high production rates compromising low performance. These fibers have many properties that would be an advantage in other fields, such as light weight, high specific strength compared to glass and carbon and low energy requirements for processing. Natural fibers can be substituted for glass and carbon fiber in polymer composites. The art of making composites is restricted mainly to synthetic polymer and synthetic reinforcing fibers like glass, carbon and nylon. The potentiality of natural fiber-based composites using cellulose, wood, jute, kenaf, hemp, sisal, rice husk, wheat, barley, oats, grass, reeds, rye, bamboo, banana fiber, pineapple, cane, coir, etc., as reinforcing fiber in a thermosetting resin matrix has received considerable attention among scientists all over the world for their excellent specific properties (Jawaid, *et al*., 2011; Nayak *et al*., 2009; Joseph and Thomes*,* 2008). Some of them have already been used as industrial products. Composites based on thermoplastic resins are now becoming popular due to their processing advantages (Wiley J and Sons, 1998). Cellulose fibers are used in the manufacture of paper and cloth. Animal fibers generally comprise proteins; examples include silk, wool, angora, mohair, alpaca etc. Cane fiber comes from the category of bast fiber or skin fiber. These fibers have higher tensile strength than other fibers. Therefore, these fibers are used for durable yarn, fabric,

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packaging and paper production. Resin is an important constituent in composites (Akter *et al.*, 2013). Two classes of resins are the thermoplastics and thermo sets. A thermoplastic resin remains a solid at room temperature. It melts when heated and solidifies when cooled. The long chain polymers do not form strong covalent bond. That is why they do not harden permanently and are undesirable for structural application. On the other hand, a thermoset resin will harden permanently by irreversible cross-linking at elevated temperatures. This characteristic makes the thermo set resin composites very desirable for structural applications. The most common resins used in composites are the unsaturated polyesters, epoxies and vinyl esters; the least common ones are the polyurethanes and phenolics. The most important composites are those in which the dispersed phase is in the form of a fiber. Design goals of fiber-reinforced composites often include high strength and /or stiffness on weight basis. These characteristics are expressed in terms of specific strength and specific modulus parameters, which correspond respectively, to the ratios of tensile strength to specific gravity and modulus of elasticity to specific gravity (William, *et al*. 2000). In this study, we investigate the physical and mechanical properties of cane fiber reinforced polyester resin composite. Composites are made with the raw fibers and NaOH treated fibers at different orientation. The physical and mechanical properties of those composites were investigated.

Materials and methods

The raw materials used for preparing the samples were unsaturated polyester resin (UPR), hardener (methyl ethyl ketone peroxide ″MEKP″) and cane fiber. About 500 gm cane fiber are collected from the skin or bust surrounding the stem of the genera calamus, daemonorops and korthasia climbing palms of sylhet (Bangladesh) belonging to the family palmae (palm family). Unsaturated polyester resin and MEKP hardener were collected from the local market.

Raw cane fiber was treated with NaOH solution to extract impurities from cane fibers such as hemi-cellulose, lignin, aromatic acids, ester etc. which might weaken the adhesion between fibers and matrix. Cane fibers were immersed in NaOH solution of volume % of 15% and the treatment time was 24 hours which was the optimum condition among the treated fibers for volume % of 5%, 10% and 15% for 30 min, 1 hour, 24 hours, 48 hours and 96 hours at room temperature. The fibers were washed with distilled water to neutralize the NaOH solution for 3 hours under flowing water. Then they were dried at 80°C for 24 hours in an oven and cut into 6 inch and 8 inch long pieces.

Cane fibers were orientated in different forms for preparations of different types of samples. At first the gap between two fibers was equal to the width of a single fiber, then the gap was equal to the width of two fibers and lastly samples were prepared without any gap between the fibers. The directions of fibers were longitudinal and vertical for a sample.

At first a bottom part of mild steel or stainless steel was taken according to the size of the fiber sheet, a melot paper was placed on dried bottom part. Then a mixture of resin and hardener was spread evenly on the melot paper.

After this one sheet of cane was placed on the open mold and covered with melot paper. Another metal sheet similar to that of the bottom one was placed on the melot paper and the total set up was given on the UTM(Model: FS300 KN, Company: Testometric, Origin: England) to give pressure so that the resin can evenly distributed.

The prepared samples were allowed to cure in this stage under approximate 10 KN/ (25 cm ×25 cm) pressure in UTM at room temperature for 24 hours. After applying the required pressureandallowing particular time, the sample (prepared by the abovementioned method) was collected from the UTM machine.

Results and discussion

The effect of alkali treatment of cane fiber is illustrated in this section, under physical properties of fiber, mechanical properties of fiber andmechanical properties of composite.
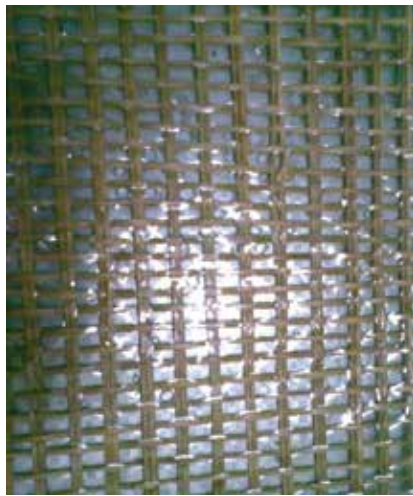
Physical properties of fiber

Water absorption

Figs. 1a-d view that water absorption (g) is lower for single gap oriented raw fiber reinforced composite among the raw fiber reinforced composites. For without gap orientation water absorption is lower for treated fiber reinforced composite. Fig. also show that water absorption increases with the increase of fiber content, as it is a diffusion phenomenon. Water absorption is responsible only for fiber and higher the fiber addition higher will be the water intake. Alkali treatment of fiber are expected toblock the hydroxyl groups of natural fiber thus making the fibers more hydrophobic that's why water absorption of alkali treated fiber reinforced composite is lower than the raw fiber reinforced composite.
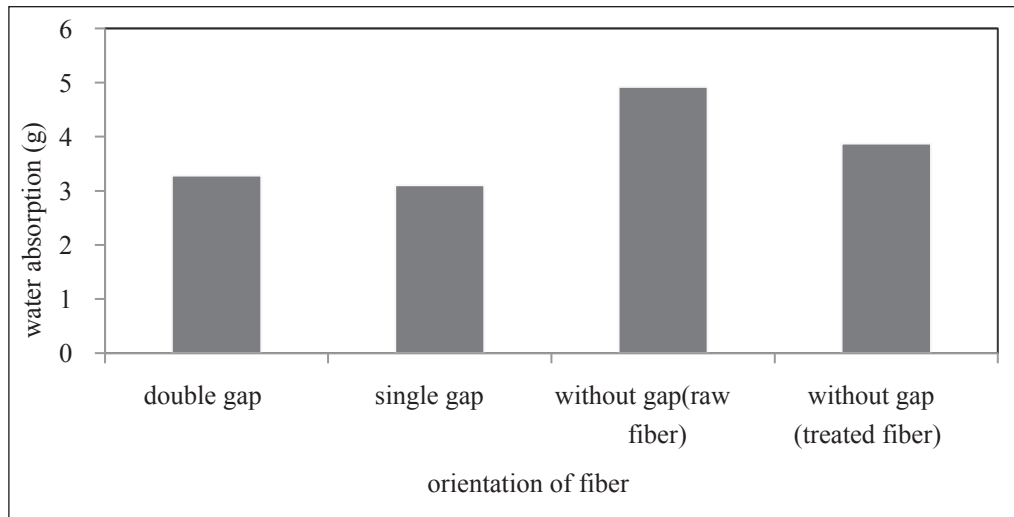
Fig. 1a. Water absorption at different orientations of fiber

Fig. 1b: Single gap orientation of raw fibers, longitudinal and transverse

Fig. 1c:Double gap orientation of raw fibers longitudinal and transverse

Fig. 1d:Without gap orientation of raw fibers longitudinal and transverse

*Mechanical properties of fiber*

Fiber strength

Fig. 2 shows that for 5%, 10% and 15% NaOH treated cane fibers the ultimate tensile strength (UTM) increases linearly up to 24 hours then decreases linearly up to 96 hours. From the above graph we see that the ultimate tensile strength is higher for 24 hours treated fibers.

Alkali treatment can remove natural and artificial impurities and produce a rough surface topography of the fiber. In addition, alkali treatment leads to fiber fragmentation, i.e. breaking down the fiber bundle into smaller fibers. This treatment increases the effective surface area available for wetting. Hence increasing the fiber aspect ratio caused better interfacialpropertiesof fiber as well as increased the mechanical properties.

Fiber strain

Fig. 3 shows that the tensile strain (%) for 5% NaOH treated fiber is lower at 30 minutes and higher for 24 hours, for 10% NaOH treated fiber the tensile strain (%) is lower at 48 hours
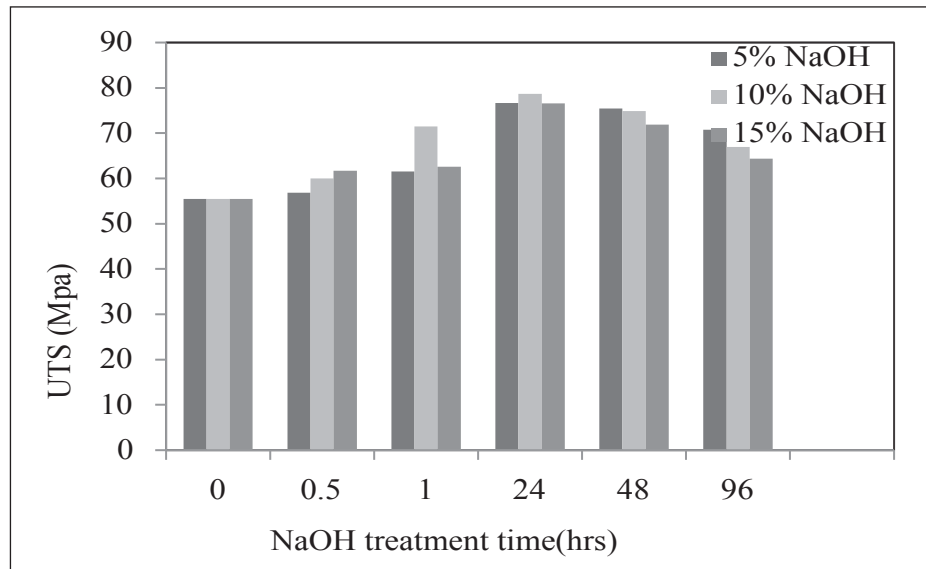
Fig. 2. Ultimate tensile strength (UTM) of NaOH treated cane fiber at different times

and higher at 1 hour and for 15% NaOH treated fiber tensile strain (%) is lower at 48 hours and higher for raw fibers.
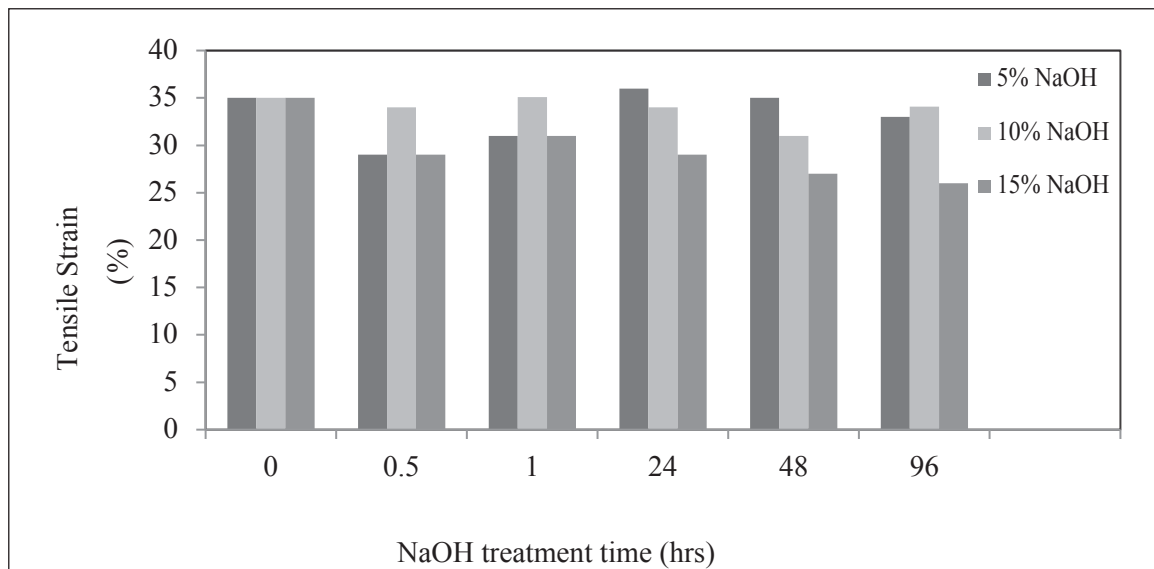
Moisture content of fiber

Fig. 4 shows that moisture content is higher for raw fibers than the treated fibers. For 5%, 10%, 15% NaOH treated fibers moisture content is lower at 48 hours, 30 min. and 48 hours respectively.Raw fiber contains huge amount of materials like lignin, hemicellulose, pectin etc. which have high hydrophilic polar group through which they can easily form hydrogen bond with moisture and hence absorb them. So,the moisture content of fibers is higher. By means of alkali treatment, these polar substances can be dissolved and removed. With enhancement of alkali concentration, the rate of moisture absorption is reduced.

Optimum condition of fiber treatment

From the above discussions, the optimum condition can be found. The ultimate tensile strength is higher at 24 hours for 5%, 10% and 15% NaOH treated fibers but for 5% and 15%

Fig. 3. Tensile strain of 5%, 10%, 15% NaOH treated cane fiber at different times
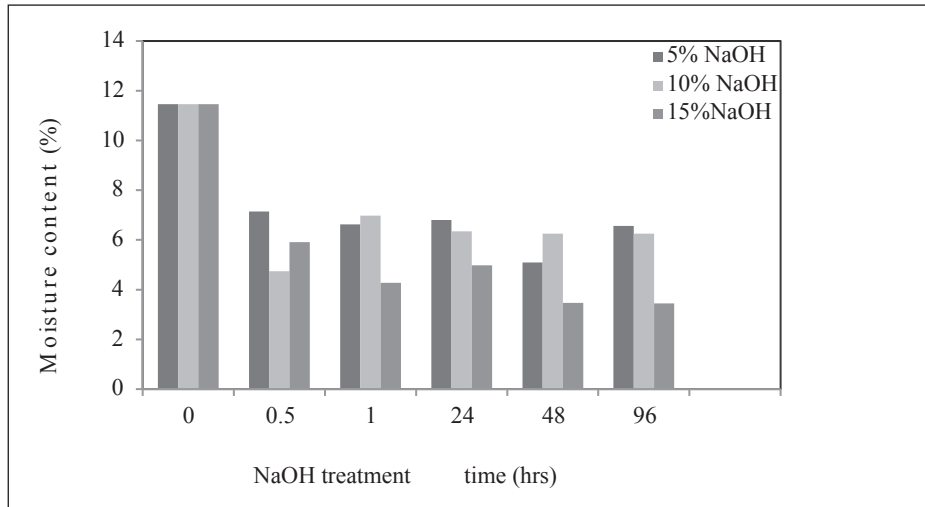
Fig. 4. moisture content (%) for 5%, 10%, 15% NaOH treated cane fibers at different times

treated fiber at 48 hours is lower than 24 hours. The moisture content is lower at 24 hours for 15% treated fibers and at 48 hours for 5% and 15% treated fibers. The tensile strain is also lower for 15% NaOH treated fibers for 24 hours treatment. So, the optimum condition is 15% NaOH treated fiber at 24 hours.

Mechanical properties of composite

Tensile strength

Fig. 5 shows that the ultimate tensile strength is higher for without gap raw fiber orientation of composites (horizontal
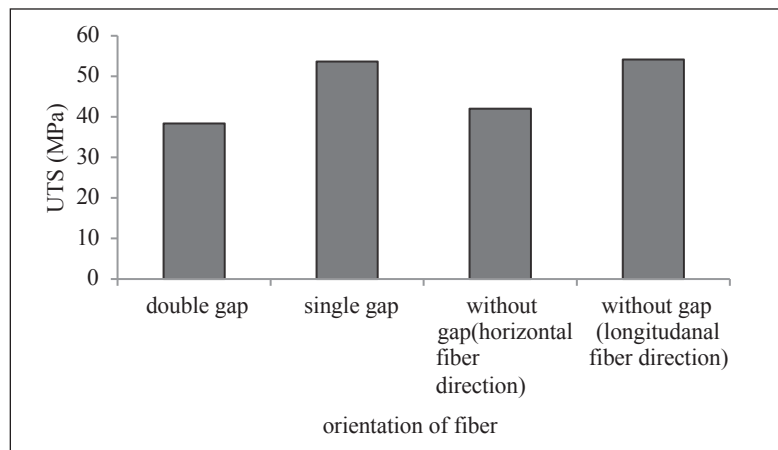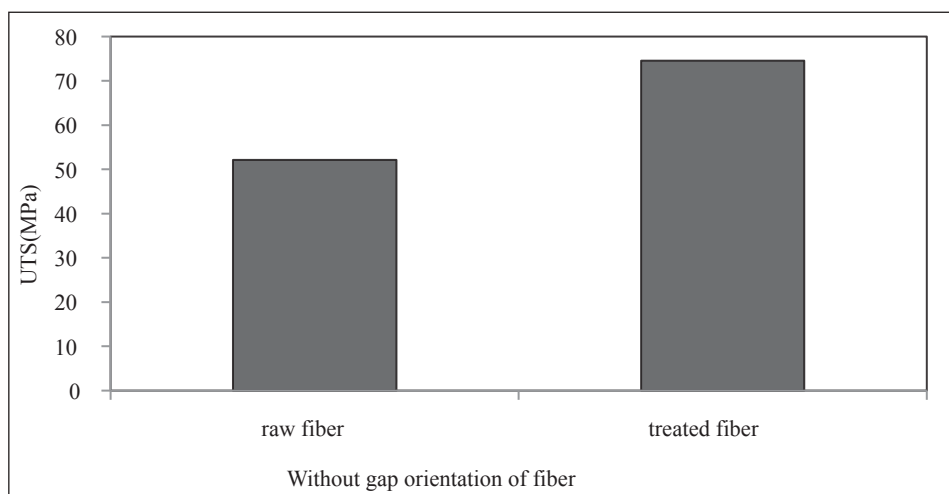

Fig. 5. Ultimate tensile strength of composite for different raw fiber orientation

fiber direction) than the double gap whereas the single gap and without gap raw fiber orientation of composites (transverse fiber direction) are approximately equal with each other.
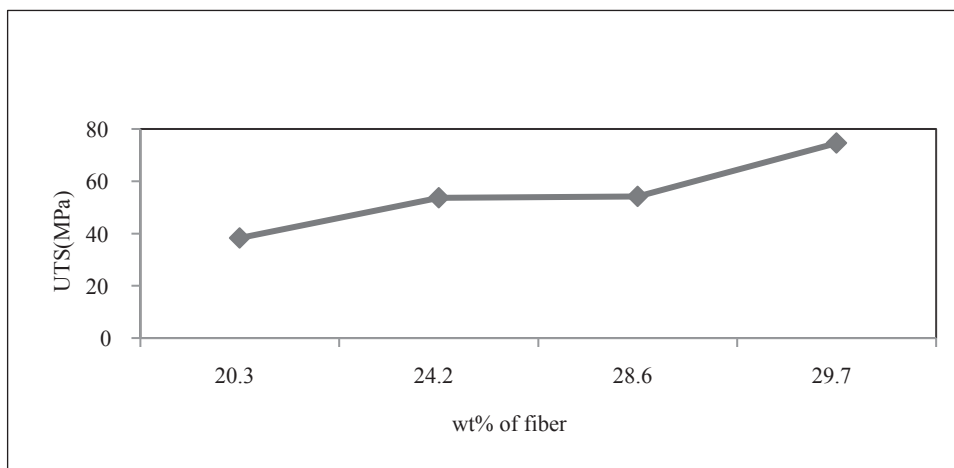
Fig. 6 shows that the ultimate tensile strength of the composite for without gap orientation is higher for 15% NaOH 24 hour treated fiber than the raw fiber.Since raw fiber contains grease and gummy substances interfacial bond of the polymer with the raw fiber is weaker. With alkali treatment the grease and gummy substances are efficiently

removed. Lignin and hemi cellulose get hydrolyzed on alkali treatment and thus removed. The carboxyl group and the size of the pores on the fibers is considerably increased from the alkali treatment, i.e. the swelling capacity of the fiber is increased which helps to give better interfacial bonding between the fiber and the matrix. That is why we get better UTS for treated fiber.

Fig. 7 shows that the ultimate tensile strength of the composite increases with the increase of wt% of fiber from 20.2 (wt% of double gap oriented raw fiber composite) to

Fig. 6. Ultimate tensile strength of composite for without gap orientation of raw and treated fiber

Fig. 7. Ultimate tensile strength of the composite with respect to wt% of fiber

24.2 (wt% of single gap oriented raw fiber composite) and remain apparently constant to 28.6 (wt% of without gap oriented raw fiber composite). But the ultimate tensile strength reaches highest for 29.7 (wt% of without gap oriented treated fiber composite).

Fig. 8 shows that the ultimate tensile strength of only resin is lower than the composites of raw and treated fiber for without gap orientation of fiber. These happen because the fiber increase the strength of the composte.
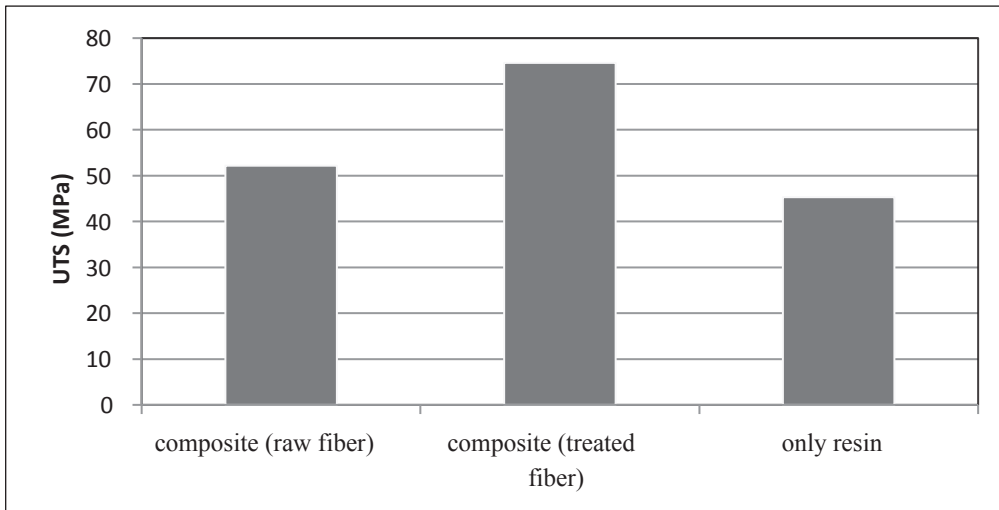
Tensile strain

Fig. 9 shows that tensile strain (%) is lower for double gap oriented raw fiber composite and higher for without gap

oriented raw fiber composite. Because for without gap orientation the fibers support the load better than the composite with double gap orientation of the fiber.

Fig. 10 shows that tensile strain (%) is higher for raw fiber reinforced without gap oriented composite and lower for treated fiber reinforced without gap oriented composite. Because the treated fiber reinforced without gap oriented composites adhere with the matrix resin better than the raw fiber reinforced without gap oriented composite.

Fig. 11 shows that tensile strain (%) for composites increases with the increase of wt% of raw fiber but decreases for the treated fiber reinforced without gap oriented composite.


Fig. 8. Ultimate tensile strength with respect to composites of without gap orientation and only resin
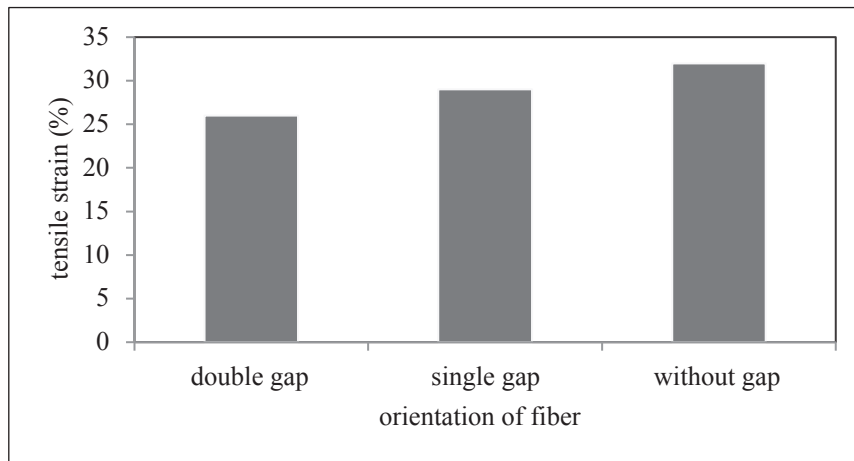

Fig. 9. Tensile strain (%) of composite for different orientations of raw fiber

Fig. 12 shows that the tensile strain is lower for only resin compared to composites of raw and treated fiber reinforced composites of without gap orientation of fibers.

increases with the increase of wt% of fiber.Tensile strain is lower for the treated fiber reinforced composite than the raw fiber reinforced composite. Tensile strain increases with the increase of wt% of raw fiber reinforced
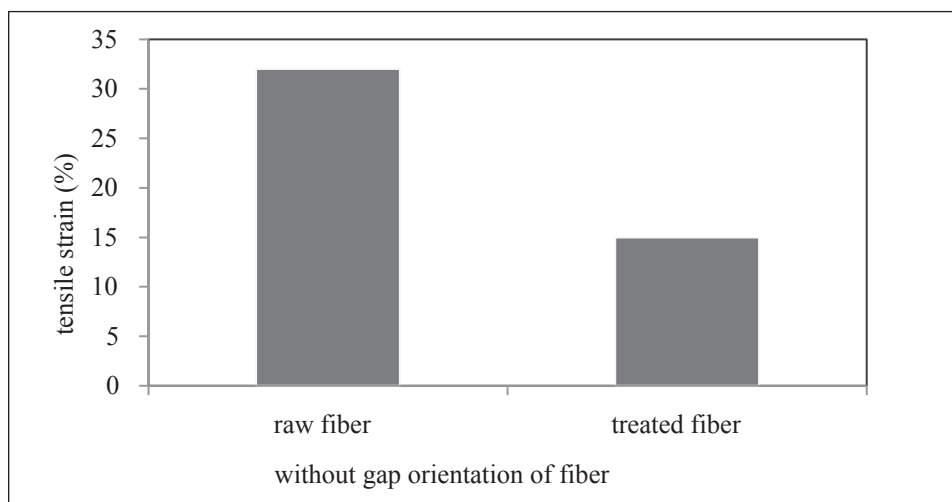
Fig. 10. Tensile strain (%) of composite for without gap orientation of raw and treated fiber
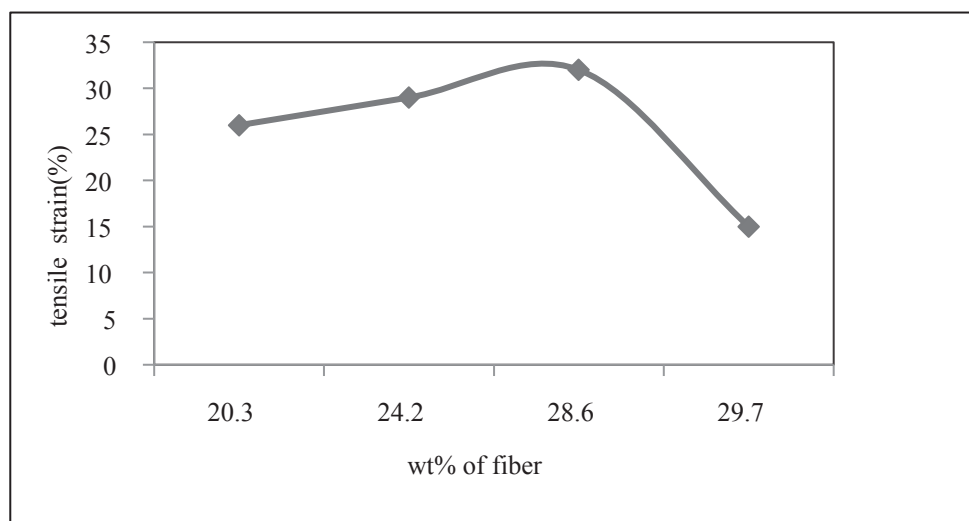

Fig. 11. Tensile strain (%) of composites with respect to wt% of fiber

Conclusion

On the basis of physical and mechanical properties of the composite the optimum condition of fiber treatment was 15% NaOH treated fibers at 24 hours. UTS value, 74.58 MPa was higher for 15% NaOH treated fiber at 24 hours for reinforced composite than the raw fiber reinforced composites.UTS

composite but decreases with the increase of wt% of treated fiber reinforced composite.Moisture content decreses with the increase of NaOH concentration and time.Water absorption is lower for treated fiber reinforced composite than the raw fiber reinfoced composite.
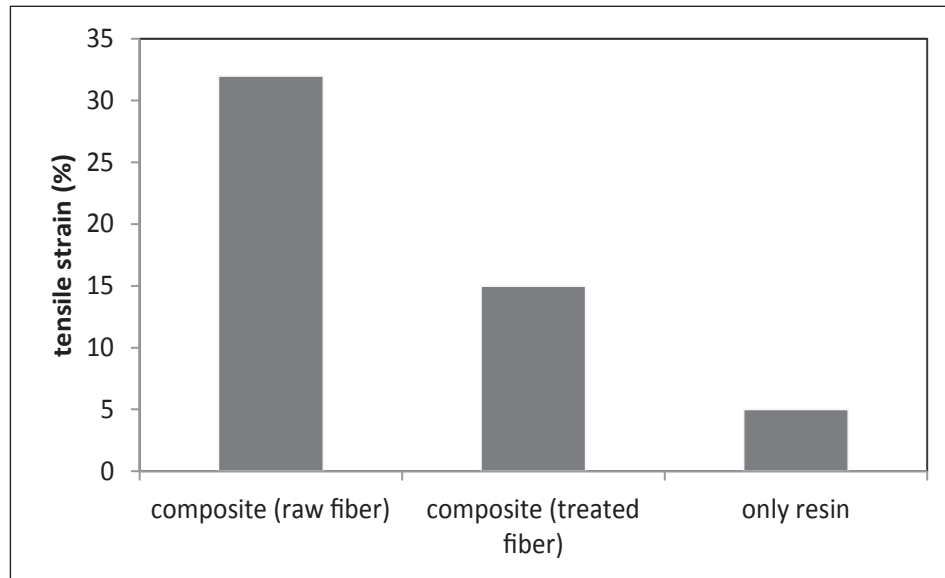
Cane fiber reinforced polyester resin composites

References

Albert F (1972), Hill Economic Botany, TMH Ed., 9th Reprint-1990, pp 18-51.

Akter R, Sultana R, Alam M. Z, Qudir MR, Begum MHA and Gafur MA (2013), Fabrication and Characterization of Woven Natural Fiber Reinforced Unsaturated Polyester Resin Composites 13: 2.

Callister JWD (2000), Materials Science and Engineering -An Introduction John Wiley & Sons, Inc. New York, 473-547.

Hattum FWJ, Regel F and Labordus M (2011), Cost reduction in manufacturing of aerospace composites, *Plast. Rubber Compos.* **40:** 93-99.

Jawaid M, Khalil HPSA, Khanam PN and Bakar A A (2011), Hybrid composites made from oil palm empty fruit bunches/jute fibers: water absorption, thickness swelling and density behavior, *J. Polym. Env.* **19**(1): 106-109.

Joseph S and Thomas S (2008), Electrical properties of banana fiber – reinforced phenol formaldehyde composites, *J. Appl. Sci.* **109**(1): 256-263.

Kafi A, Abedin MZ, Beg M D H, Pickering K L and Khan M A (2006), Study on the mechanical properties of jute/glass fiber-reinforced unsaturated polyester hybrid composites: Effect of surface modification by Ultraviolet radiation, J. Reinforc. *Plast. Compos.* **25:** 575-588.

Khan RA, Khan MA, Sultana S, Khan MN, Shubra QTH and Noor FG (2010), Mechanical, Degradation and interfacial properties of synthetic degradable fiber reinforced polypropylene composites, *J. Reinforce. Plast. Compos*. **29:** 466-476. DOI:org/10. 1177/0731684408100699

Mathur VK (2006), Composite materials from local resources, *Journal of Construction and Building Materials* **20**(7): 470-477.

Nayak SK, Mohanty S and Samal SK (2009), Influence of short bamboo/ glass fiber on the thermal, dynamic mechanical and rheological properties of polypropylene hybrid composites, *Materials Science and Engineering* **523**(1-2): 32-38.

Richardson T (1987), Composite: A design guide, Industrial press.

William D and Callister Jr (2000), Materials Science and Engineering -An Introduction, John Wiley & Sons, Inc. New York, pp 473-547.

Wiley J and Sons (1998), *Journal of Applied Polymer Science* **69:** 329-338.