Performance Improvement of Natural Fibre-Composites using Clay Nanocomposites

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Performance Improvement of Natrural Fibre-Composites Using Clay Nanocomposites

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Abstract

The role of nanoclays on the performance improvement of structural composites made from flax fibers was investigated. The nanoclays were at first dispersed in the polymer matrix before the impregnation the flax fibers. The results obtained for the epoxy based composites demonstrate that specific treatment of the fiber surface can bring up the performance of composites such as the tensile strength, tensile modulus and the interfacial strength of the composites. However, the level of improvement on the properties of the composites is much better in the presence of dispersed nanoclays. In principle, the composite strength and modulus are mainly controlled by the fibers if the fiber-matrix interface is optimized. Thus the observed improvements in composite strength and modulus can be interpreted by the nanoclays role in the improvement of the load transfer from the matrix to the fiber and hence enhancement of the interfacial properties. This study confirmed that nanoclays can be used to upgrade the mechanical performance of natural fiber composite and also can reduce the gas diffusion through the material resulting in the enhancement of the fire resistance.

1 Introduction

With considerable awareness to preserve environment, sincere efforts across the globe look for renewable and bio-degradable sources of material available on the earth. The ultimate aim is to replace products which petrol or high energy demanding and this had pushed the researchers to investigate the potential of natural fibers like flax as reinforcement material for composites.

Flax fibers show very good intrinsic mechanical properties, and low cost, low density (1.4-1.5 g/cm3), low dermal and respiratory irritation and tool wear, this allowed us to compare it with glass fibers. However, natural fiber does not exhibit consistency in properties and it widely depends upon their genotype, agriculture conditions, soil, topographic and climatic condition of the region. Besides that, several inherent properties of the flax fiber including hydrophilic nature, poor fiber/matrix adhesion, low heat stability and processing temperature hamper its long term stability in different engineering application under adverse environmental and designed conditions that limit its scope of utilization [1-4].

In fact, long term stability of fiber and fiber-matrix adhesion causes the limitations of the natural fiber application. Therefore, researchers constantly striving for their best efforts to overcome the limitations associated with the natural fiber composite and to make it a better reinforcement material for the manufacturing of composite for engineering applications [8-11]. This present work was carried to address some of the limitation of natural fibers to enhance the properties of the flax fiber epoxy composite. Different solutions for the improvement of the fiber-matrix interface were investigated.

2 Experimental

The epoxy resin used was the standard DGEBA (diglycidyl ether of bisphenol A) resin EPON™ Resin 828 from Resolution Performance Products (Houston, TX, USA). The epoxy resin was cured with the polyoxypropylene diamine hardener Jeffamine® D-230 from Huntsman LLC (The Woodlands, TX, USA) at a level of 32 phr. The organoclay used was Cloisite® 30B from Southern Clay Products, Inc. (Gonzalez, TX, USA). Satin plain weave flax fabric was supplied by Moss Composites (Belgium). The epoxy-clay nanocomposite was prepared as described elsewhere [12]. Fiber properties can be modified in many ways including physical stretching, thermo-treatment etc. and chemical treatment. But surface properties are considerably changed by chemical treatment. Treatment of the fiber does not only affect the surface properties but it was also reported that micro fibrils rearrange themselves in the fiber [13]. In this work the fibers were treated with 2% solution of NaOH at 80 °C for 2 h. Fibers then were dried at room temperature for at least 6 hrs, then in the oven at temperature of 140 °C for about 2 hours to remove the humidity before use.

Empirical mixture of resin and hardener was prepared in a container and was manually mixed for 5 min. The mixture was subjected to a vacuum oven set at 65°C for 5 min for air removal. The mixture was then used to impregnate the flax fibers. After every two layers of fiber fabric, resin was spread evenly on the fibers and utmost care was taken to prevent any disturbance in the alignment or the straightness of the fibers. Hydraulic press was used to fabricate the composites following specific temperature and pressure profiles (Figure 1). Composite descriptions are shown in Table I. (0.81 cm) space between them. Text must be fully justified.

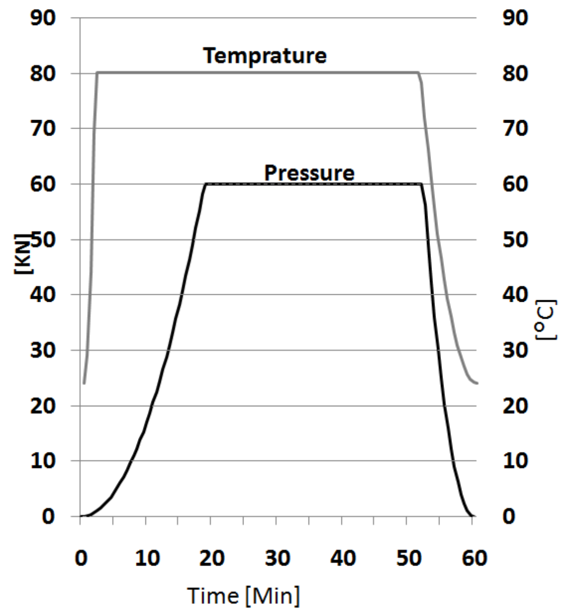


Figure 1. Optimized pressure and temperature profiles

Table 1. Example table

Designation	Description
NT-F+E	Non treated fibers with epoxy
NT-F+NC-E	Non treated fibers with epoxy nanocomposite
T-F+NC-E	Treated fibers-epoxy nanocomposite
T-F+E	Treated fibers-epoxy

The tensile and interlaminate shear strength properties of the epoxy/flax composites were determined at room temperature and 50% relative humidity according to ASTM D638-03 and ASTM D 2344-00 on an Instron 5500R machine, with crosshead speeds of 5.0 mm/min, 1.3 mm/min respectively.

ASTM D3801-06 test for measuring the comparative burning characteristics of solid plastics in vertical position was performed on composite specimens 13 x 125 cm.

3 Results and discussion

SEM images of the flax fibers before and after treatment with 2% solution of NaOH are shown in Figure 2. SEM indicates that the surface of fiber before treatment was not clean and shows many lumps of contaminations on the surface as can be seen on Figure 2a. The result shows that after treatment of the fiber with 2% NaOH solution for 2 hrs at 80°C, the outer surface of the fibers is smooth. In addition, tow opening is also observed on the treated fibers.

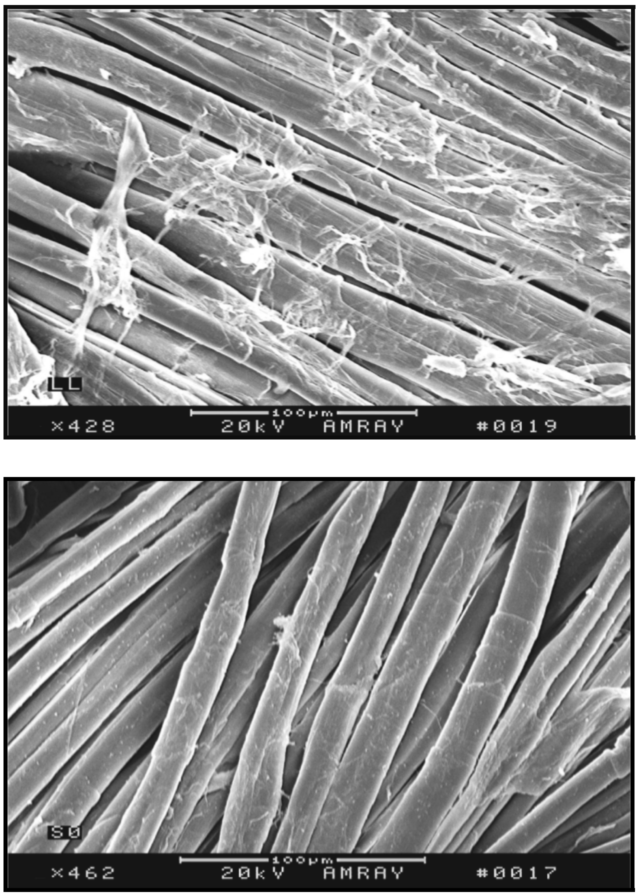
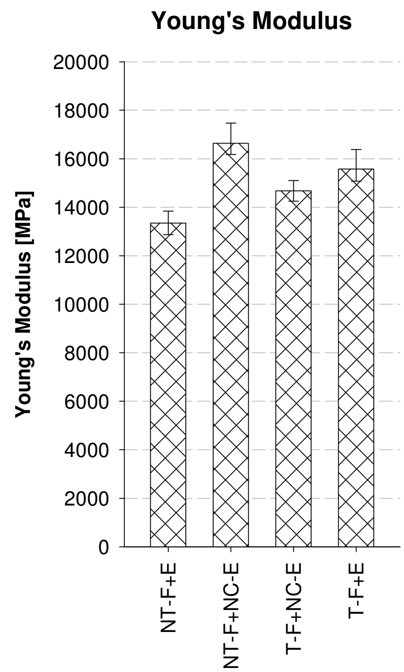
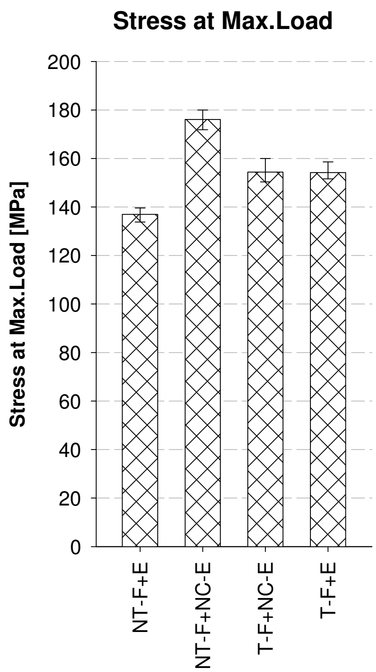


Figure 2. SEM photos for (up) non-treated and (bottom) treated flax fibers.

The tensile Properties of composites are shown in Figure 3. From the tensile property graphs it can be observed that the stress bearing capacity of the composite with the treatment of fibers increases to approximately 15 % and similarly there is an increase in the young's modulus and strain. Moreover, there is also improvement in the mechanical properties when nanoclay is added to the matrix but that improvement diminished in comparison with composite having treated fibers. This is due to the poor level of impregnation and void formation observed in the composites when the viscosity of the matrix increases with the addition of nanoclay particles.

Subsection headings, for example, "2.4 All Headings", are similar except that 10-point boldface is used.





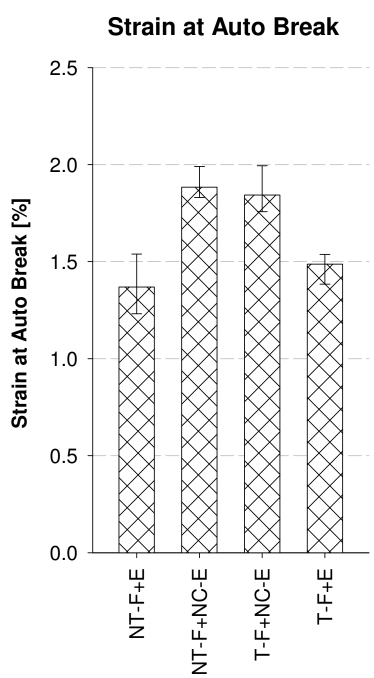


Figure 3. Tensile properties for different epoxy/flax composites

Figure 4 shows the short beam shear strength of the epoxy flax composites. Similar trend of improvement but higher level was observed in the results of short beam shear strength compared the tensile. An improvement of about 60% is observed for treated fibers and treated fibers in the presence of nanoclays. Again better results are found for non treated fibers in epoxy-clay nanocomposite matrix (approximately 85%).

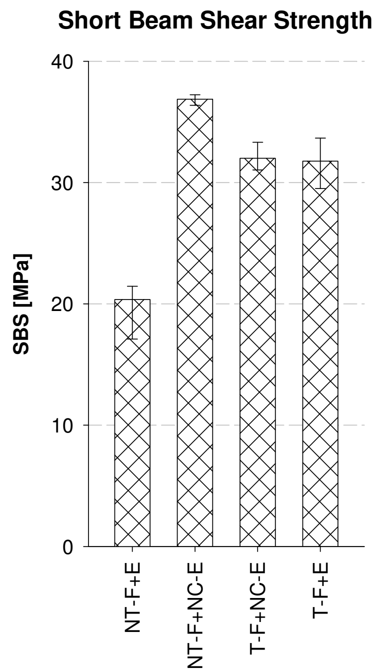
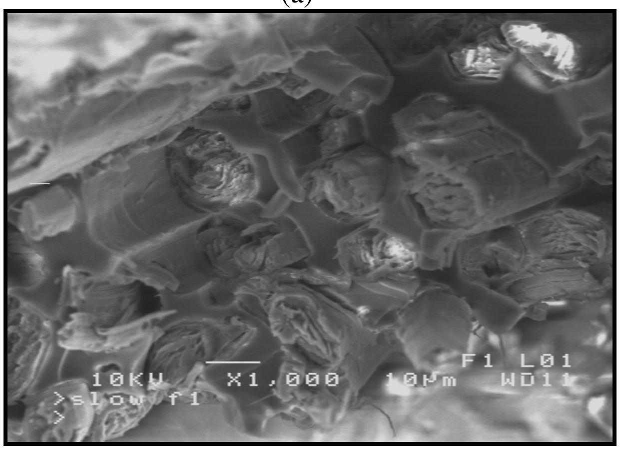


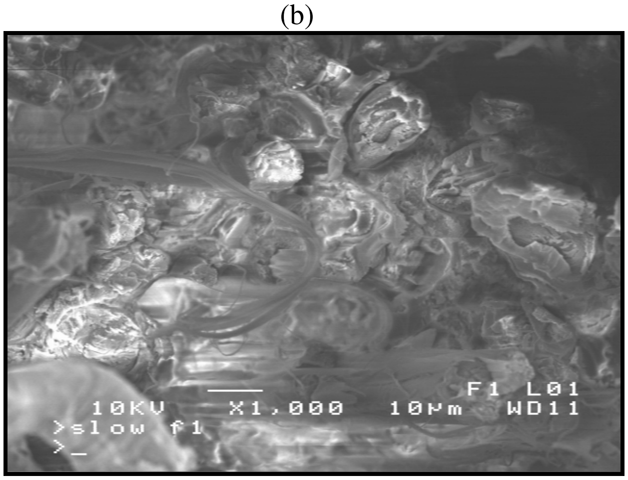
Figure 4. Short beam shear strength for different epoxy-flax composites.

SEM images of the tensile fracture surface of specimen of flax fiber composites are shown in Figure 5. Figure 5a shows that the interfacial adhesion between flax fibers and epoxy matrix of composite is not so strong. The clean fibers were pulled out after test with clean fiber surface and not much adhering epoxy matrix on their surface. The clean and smooth cavities after the pulling of the fibers suggest poor interface. Figures 5b and 5c show that better surface contact is achieved between the fibers and the matrix in case of treated flax fiber epoxy composite. And, this seems much better for the non treated flax fiber epoxy in the presence of nanocclay. This good interfacial adhesion can improve the stress transfer ability from the matrix to the fiber, which results in a better mechanical property.

(a)



(b)



(c)

Figure 5. SEM micrographs for (a) non-treated flax epoxy composite, (b) treated flax epoxy composite; and (c) non-treated flax-epoxy nanocomposite.

The burning characteristics of the composites were shown in Figure 6. The treated fiber composite burned at a slower rate than that of the untreated one. It may be due to the removal of impurities and contaminants on the fiber surface. It is also interesting to observe that the presence of nanoclay in the matrix has improved very significantly the fire resistance of the composites regardless the fiber was treated or not. This can be explained that the nanoclay has more affinity with the fiber than the matrix, the clay layers can migrate to closer the fiber surface thus providing a protection barrier from the diffusion of oxygen from outside into the fiber during the burning process. The results are very much interesting.

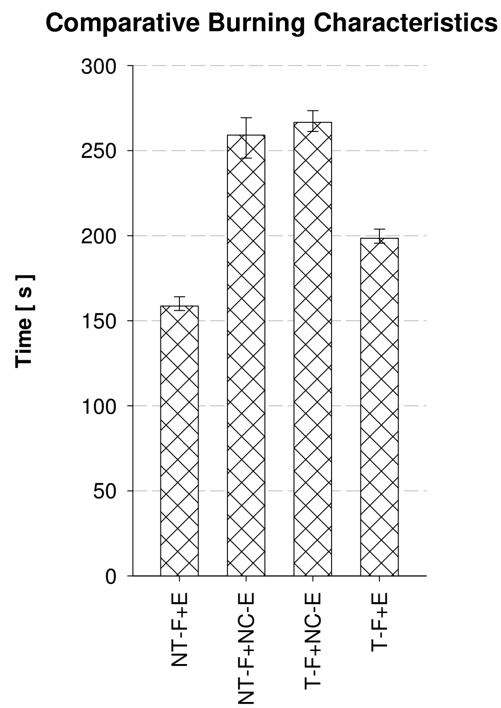


Figure 6: Comparative burning characteristic of the composites

3 Conclusion

Introduction of nanoclay in the epoxy resin significantly improves the mechanical properties of the flax fiber composite. The observed improvements in composite strength, modulus and short beam shear strength can be interpreted by the nanoclays role in the improvement of the load transfer from the matrix to the fibers and hence enhancement of the interfacial properties. This study confirms that nanoclays can be used to upgrade the mechanical performance of natural fiber composites and also can reduce the gas diffusion through the material resulting in the enhancement of the composite strength and fire resistance. Treatment of the flax fibers with 2% alkaline solution for 2 hrs at 80°C has also an impact on the mechanical properties of the composites however the level is not high as the nanoclay. Future work will involved validation of this concept on thermoplastic natural fiber composites.

Acknowledgement

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