DEVELOPMENT OF NATURAL FIBER COMPOSITE CONSTRUCTION WITH IMPROVED TENSILE PROPERTIES

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Keywords: *Natural Fiber, Polypropylene, Tensile Modulus, Tensile Strength, Water Absorption*

Abstract

The use of natural fiber composites is increasing in the automotive industry as well as in many other industries. In this study, we consider combining a natural fiber/polypropylene composite with other polypropylene based composites with the objective of improving their tensile modulus and strength. Compression molded plates were prepared with various combinations of these materials and at different molding temperatures. Tensile properties of the combined materials were determined and are reported in this paper. In addition, water absorption data are also reported.

1 Introduction

Natural fiber composites have great potential in many automotive applications [1, 2] for the following reasons [3]:

(1) Natural fibers are environment-friendly, meaning that they are agricultural products, they are biodegradable, and compared to glass and carbon fibers, the energy consumption to produce them is very small.

(2) The mass density of natural fibers is in the range of 1.2 to 1.5 g/cm^3, which is much lower than both glass and carbon fibers.

(3) The modulus-to-density ratio of many natural fibers is higher than that of glass fibers.

(4) Natural fiber composites can provide higher acoustic damping than glass or carbon fiber composites, and therefore, they are more suitable for noise attenuation.

(5) The price of natural fibers is less than that of glass fibers and much less than that of carbon fibers.

Since natural fibers have many advantages over the conventional fibers, a large number of research has been done to incorporate them in both thermoplastic and thermoset polymers. Several applications of natural fiber composites have also been developed, but most of them are for non-structural applications. One reason for this is that natural fiber composites have relatively low modulus and strength compared to glass and carbon fiber composites. In this paper, we report a preliminary study to develop natural fiber composite sandwich constructions with the goal of achieving higher modulus and higher strength

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2 Experimental

2.1 Materials

The materials used in this study were as follows:

(1)Natural fiber mats containing 50% jute fibers and 50% polypropylene fibers, designated here as NL, NF and NH for low density, low density with an additional coating of polypropylene, and high density, respectively. Both NL and NF mats were 10 mm thick and the NH mat was 2.6 mm thick. All three natural fiber mats were supplied by Flexform, Inc.

(2)Geotextile woven fabrics containing polypropylene filament (Propex 2033, designated here as P and Propex 2044, designated here as Q). The geotextile fabrics were 0.93 mm thick and were supplied by Propex Fabrics, Inc.

(3)Unidirectional carbon fiber reinforced polypropylene prepreg, designated here as C. The prepreg sheet was 0.85 mm thick and was purchased from Baycomp.

2.2 Compression Molding

Compression molding was carried out using a hydraulic press with heated platens. The platens were preheated to the desired temperature. The material was placed between two flat plates separated by steel spacers. The assembled stack was then placed between the preheated platens and the press was quickly closed. The press was held closed for 5 minutes at a pressure of 2.75 MPa. This was followed by cooling at approximately 22°C/min while holding the pressure at 2.75 MPa.

The natural fiber mats and geotextile fabrics were compression molded at various mold temperatures ranging from 170°C to 240°C. Sandwich constructions were prepared using natural fiber mats in the core and either geotextile fabrics or carbon fiber prepregs in the skins. The sandwich structures were compression molded using 200°C as the mold temperature.

2.3 Tensile Testing

Tensile tests were conducted on an Instron tensile testing machine at a cross head speed of 10 mm/min. Dog-bone shaped tensile specimens were prepared using a high speed router. The total length of the specimens was 110 mm. The gage length and width were 50 mm and 12.5 mm, respectively.

3 Results

3.1 Tensile Properties

Table 1 shows the effect of mold temperature on the tensile properties of natural fiber composites and the composites molded from geotextile fabrics. Among the natural fiber composites, the high-density material, designated as NH, had the highest modulus and tensile strength. For all three natural fiber composites, tensile strength decreased with increasing mold temperature, but tensile modulus increased slightly for NL and NH composites and remained relatively unaltered for NF composites. For both geotextile composites, designated as P and Q, tensile modulus was not affected significantly by mold temperature, but tensile strength and elongation were the highest at 170°C mold temperature and decreased significantly as the mold temperature was increased.

It can also be observed from Table 1 that the geotextile composite Q molded at 170°C had a significantly higher tensile strength than the natural fiber composites. At higher mold temperatures, its tensile strength decreased, but it was comparable to that of natural fiber composite NH and still much higher than that of NL and NF composites.

Table 1. Effect of Mold Temperature on Tensile Properties

Specimen Designation	Mold Temp. (deg. C)	Tensile Modulus (GPa)	Tensile Strength (MPa)	Elongation (Gage Length = 50 mm
NL	180	1.01	18.85	2.75
	200	0.99	12.18	1.25
	220	1.22	12.63	1.04
	240	1.26	11.57	1.03
NH	180	1.88	35.61	2.01
	200	1.96	32.87	1.61
	220	2.47	30.03	1.12
NF	180	0.71	11.63	5.87
	200	0.94	13.5	1.72
	220	0.88	11	1.39
	240	0.97	6.1	0.71
P	170	1.11	38.02	25.93
	180	1.39	27.01	2.06
	190	1.14	28.8	9.84
	200	1.17	31.65	106.14
	210	1.73	35.1	8.26
Q	170	0.97	78.35	39.71
	180	1.64	48.93	10.46
	190	1.05	36.45	6.91
	200	0.98	35.53	8.74
	210	1.14	35.29	7.03

Table 2 lists the tensile properties of various sandwich constructions considered in this study. The molding temperature used for all the sandwich constructions was 200°C. Figures 1-3 show comparisons of the tensile properties of natural fiber composites, geotextile composites and sandwich constructions of natural fiber composites and geotextile composites. As can be observed from these figures, both tensile modulus and tensile strength of the sandwich constructions were significantly higher than the tensile modulus and tensile strength of natural fiber composites. The elongation at failure was also improved, but only slightly. As expected, the sandwich composite containing carbon fiber/polypropylene skins had the highest tensile modulus.

Table 2. Tensile Properties of Sandwich Constructions with Natural Fiber Composites in the Core

Specimen Designation	Tensile Modulus (GPa)	Tensile Strength (MPa)	Elongation (Gage Length = 50 mm)
PNLP	2.11	41.25	1.90
QNLQ	2.44	37.78	1.96
PNHP	2.93	49.26	1.81
QNHQ	2.67	39.00	1.30
PNFP	1.58	29.45	2.58
QNFQ	1.84	28.38	2.22
CNHC	10.35	------	------

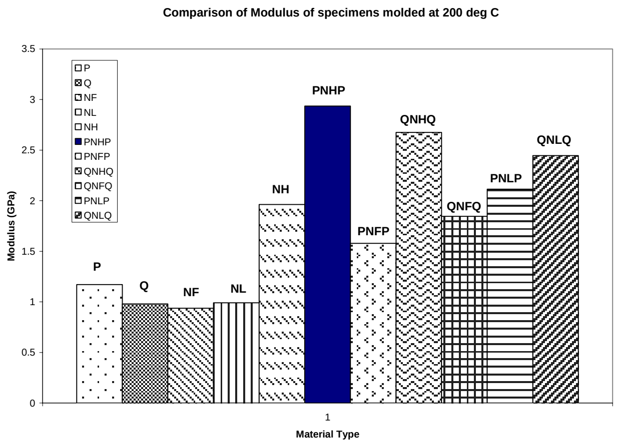

Fig. 1. Comparison of tensile modulus.

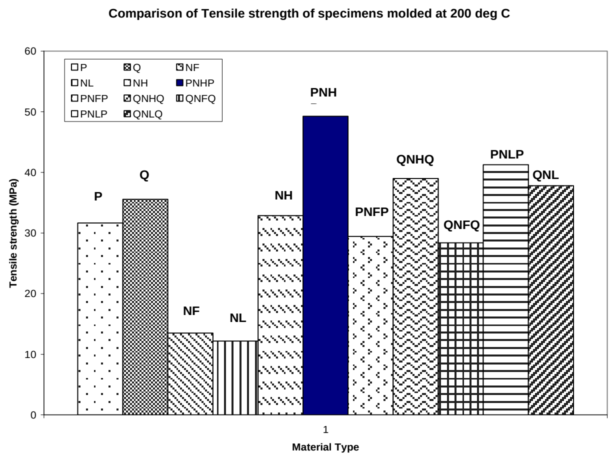

Fig. 2. Comparison of tensile strengths.

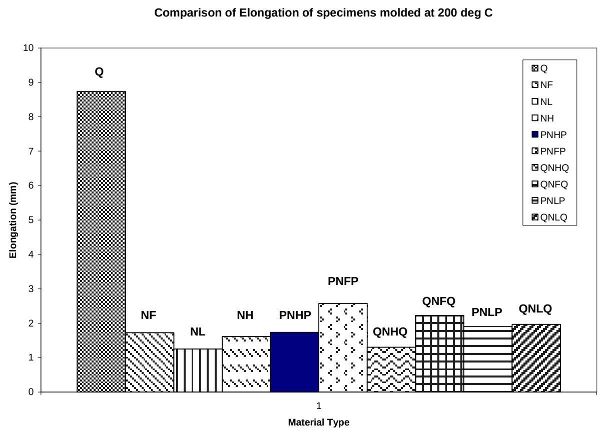

Fig. 3. Comparison of tensile elongation (gage length = 50 mm).

3.2 Water Absorption

Water absorption is one of the major concerns in using natural fiber composites in many applications. In this study, 24-hour water absorption was measured by the weight change method for the natural fiber composites, geotextile composites and their sandwich constructions. The results are shown in Fig. 4. The water absorption in geotextile composites was negligible, but even in 24 hours, all three natural fiber composites absorbed greater than 20% water. The highest water absorption was by the low-density natural fiber composite, designated as NL and the lowest water absorption was by the high-density natural fiber composite, designated as NH. The addition of geotextile composites in the outer skins reduced the water absorption significantly. Similar results were obtained when carbon fiber/polypropylene was used as the skin material.

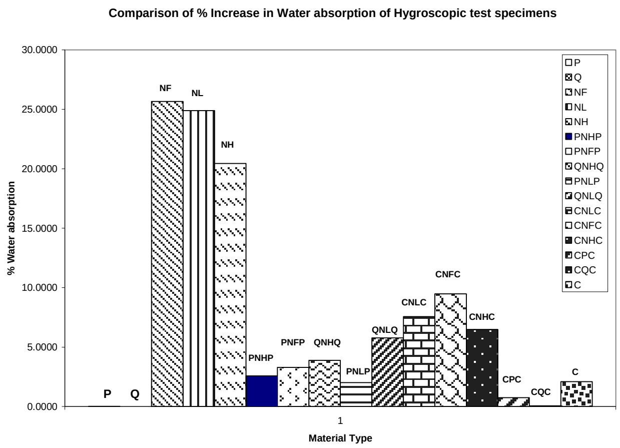

Fig. 4. Comparison of water absorption after 24-hour immersion in distilled water.

In another set of water absorption experiments, dimensional changes were measured in NL, NH, C and CNHC sandwich construction after 24-hour immersion in distilled water. The results are given in Table 3. Both dimensional changes and water absorption were significantly reduced when carbon fiber/polypropylene skins were added to the natural fiber composites.

Table 4. Dimensional changes after 24-hour immersion in distilled water

Material	% Increase in Dimensions			% Change in Weight
	Length	Width	Thickness	
NL	0.544	0.520	0.603	24.88
NH	0.5400	0.915	0.971	20.43
CNHC	0.286	0.122	0.070	6.48
C	0.105	0.101	0.083	2.08

4 Conclusions

It has been shown in this study the tensile properties of natural fiber composites can be significantly improved by combining them with either geotextile composites or carbon fiber composites in a sandwich construction. Significant reduction in water absorption of natural fiber composites is also obtained with the sandwich construction.

References

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