HIGH PERFORMANCE NATURAL FIBRE REINFORCED SHEET MOLDING COMPOUND FOR AUTOMOTIVE APPLICATIONS

Merry Lo, Suhara Panthapulakkal and Mohini Sain[a],

Centre for Biocomposites and Biomaterials Processing, University of Toronto, Canada

Abstract

This research work aims to replace glass fibres in sheet molding compounds (SMC) by renewable natural fibres. These eco-efficient and cost effective SMC with natural fibres are gaining much attention in the automotive industry because of their specific properties. The specific objective of the work was to develop a high performance natural fibre hybrid SMC to meet the specifications required for automotive parts such as front fenders, body panels etc. Hemp fibres with and without a combination of a small amount of glass fibres were used to reinforce vinyl ester resin for making SMC. Different combinations of layers of hemp and glass fibres were made to prepare SMC. Mechanical properties, such as tensile and flexural properties and impact strength of the SMC prepared were found to be highly promising. The current OEM specifications for automotive parts, for example, rare lift gate and front fenders, recommend the composite should have tensile strength of 62 MPa and tensile modulus of 2 GPa (Source of Automotive Engineers Car Technology yearbook 2000" USA 2000, Body panels Properties). SMC prepared by the combination of 45% of hemp fibres and 5% of glass fibres showed tensile strength and modulus were more or less same or better than that of the requirements for car body parts such as rare lift gate and front fenders (Tensile strength greater than 62 MPa and tensile modulus of 2 GPa).Use of this SMC with natural fibre is an economically viable alternative to SMC with glass fibres and at the same time it helps reducing the green house gas emission, as there is lesser amount of synthetic resins and plastics.

Introduction

At present, automobile industry is one of the most prominent consumer sections of the biobased composites and the major motivation being weight reduction (about 10 – 30%), day-to-day fuel efficiency and the CO_2 emission reduction. Researchers have developed natural fibre reinforced thermoset composites for interior as well as exterior structural applications mainly because of the added advantages of natural fibres such as high strength to weight ratio, low cost, ease of processing, environmental benefits (biodegradable, combustible and CO_2 neutral) and world wide availability [1-3]. More over, unlike glass fibres these fibres will cause no harm during handling and cause less wear to the processing equipments. Researchers are trying to explore the technical applications of various natural fibres such as hemp, flax and jute in the automotive industry [4,5] and they include door and instrument panels, body panels, under body panels, roof tops and front end fenders. Natural fibre reinforced automotive components are currently being used by vehicle manufacturers like Ford, Opel, GM, Daimler Chrysler, Saturn, BMW, Fiat, Audi, Peugeot, Renault, Mercedes Benz and Volvo and are experimenting to explore the full potential of the green fibres in structural applications [6]. Even though natural

---

[a] Corresponding author: Centre for Biocomposites and Biomaterials Processing, Faculty of Forestry, 33 Willcocks Street, University of Toronto, Toronto, Canada M5S 3B3

fibre filled composites can attain stiffness of that of glass fibre filled composites, low impact strength and poor dimensional stability are the bottlenecks associated with these fibres [7].

SMC is a compression molded short fibre reinforced thermoset composites by a two-step production process and the products are gaining much attention in the automobile industry because of their specific properties [8]. The first step is the preparation of pre-preg which is a stiff sheet consisting of thermoset resin, reinforcing fibres (natural or glass fibres), inorganic fillers and other additives such as catalyst, release agent and thickening agent. Second step is the compression molding. This project aims to develop sheet molding compound (SMC) using natural fibres and epoxy vinyl ester resin targeting to develop composites that can meet the requirements for the automotive structural components such as rare lift gate and front fenders.

Experimental Procedure

The primary raw materials used for this study were

Resin: Epoxy vinyl ester resin, with a density of 1.046 g/cm^3; curing temperature of the resin is 140-150^{o}C

Fillers: Hemp fibre, obtained from Hempline, with a density of 1.48 g/cm^3 cut into 2.5 cm length
Glass fibres available locally with a density of 2.5 g/cm^3
Initiator : Peroxide type with a density of 1.33 g/cm^3

Processing and Testing of Composites

Cut hemp fibres were impregnated with the thoroughly mixed composition of vinyl ester resin and initiator. The wetted fibre is then divided in to different layers (3-6) and excess resin is removed from the mat. The prepared pre-pregs were then compression molded at 145^{o}C for 2 minutes under a pressure of 40-80 tons. The cured sample was then placed in an oven for at least 3 hrs for post curing. The composites prepared for this study were given in Table I. The details of mechanical properties tested from the SMC test specimens were given in Table II.

Results and Discussion

Effect of Natural fibre loading

Figures 1-3 shows the variation of tensile, flexural and impact properties of different SMCs containing 30-50 % of natural fibre composites. The results (figure 1) indicate that increase in natural fibre content of SMC significantly improved the tensile strength of the composite; about 55% of increment in tensile strength is observed from increasing the fibre content from 30 to 50 wt%. However, flexural strength showed only a marginal increase by increasing the fibre content with a maximum strength value at 50% of fibre content. Both the results indicate the reinforcing efficiency of natural fibres in the composite. Modulus (tensile and flexural) of the composites is not much altered by the increase in the fibre content of the composites (figure 2).

Impact strength of the composites (figure 3) show that notched impact strength decreased marginally with increasing fibre content with a minimum at 50% fibre content where as un-notched impact strength increased with fibre loading with a maximum at 50% fibre content. This indicates the poor notched impact resistance of the natural fibre composites, which is the bottleneck of the natural fibre composites in many structural applications.

Effect of glass fibre addition

In order to improve impact strength of SMC, a small fraction of natural fibres (5-15%) were replaced by glass fibres in the composite containing 50% natural fibres and the mechanical properties of the resulted SMCs are summarized in Table III. Replacement of even 5% of glass fibres (Composite A3 vs B1) showed significant improvement in the notched as well as un-notched impact strength properties. However, tensile and flexural strength of the composites did not show any improvement and could be due to the incompatibility between the glass fibre and natural fibres in the composite. Composites B1 and B2 contain the same combination of natural fibres and glass fibres but differ in the placement of the glass fibres. In B1, glass fibres were placed as a central layer, where as in B2 glass fibres were placed as two layers at the top and bottom of the natural fibre layers. It was observed that impact strength of the composites improved by 25% by placing the glass fibres as the top and bottom layers compared to the composite with one layer of glass fibres at the centre. Compared to 50% of natural fibre composites, composite B2 showed an improvement of 163 and 100 % respectively in the notched and un-notched impact strength. Though tensile properties of composites B1 and B2 remain more or less same, flexural properties of these composites improved by placing the glass fibres as two layers at the top and bottom. This may be attributed to the effective bending resistance offered by the glass fibres at the top and bottom compared to the glass fibres placed at the central part (B1), where natural fibres are experiencing the bending force. As expected replacement of 15% natural fibre by galss fibres (composite C) as a top and bottom layers increased tensile (53%), flexural (99%) and impact strength of (300%) the composites significantly.

Comparison of the Properties with the Current OEM Requirements

Comparison of the properties of the composites with that of the OEM requirements of the automotive tailgate, front fenders and body panel roof is provided in Table IV. As can be seen from the table that natural fibre and / or hybrid composites can satisfy the requirements of structural components such as tailgate and front fenders; tensile modulus and impact strength of the composites has to be improved in order to use for body panel roof structures. The use of these composites reduce the use of synthetic resin in automobile applications compared to engineering plastics as well as glass fibre reinforced plastic composites that may lead to a reduction in the green house gas emission.

Conclusions

Natural fibre reinforced SMC composites were developed to replace glass fibres for structural applications in transportation sector. Mechanical properties, except impact strength, of SMCs with different natural fibre loading showed a maximum improvement at 50% fibre loadings. Combiantion of 5% glass fibre along with natural fibre showed remarkable improvement in the flexural and impact properties compared to the SMC with 50% fibre content. Composites with 35% natural fibre and 15% glass fibre showed the highest mechanical properties. The study revealed that natural fibre and or hybrid SMC can meet the requirements of structural materials such as front fenders and tailgate. Impact strength of the composites has to be modified further to achieve the requirements needed for body panel roof. The developed SMC composites can partially replace glass fibre and can reduce the synthetic resin content in the composite.

Acknowledgement

Authors would like to acknowledge NSERC, Canada for providing the financial assistance of this project and all industrial partners for their in-kind contribution.

References

1. Bledzki A. K. and Gassan J., Prog. Polym.Sci., 24, 221-274, (1999).
2. Sain M. M. and Balatinecz J. J., Proceedings of IUPAC conference, July 1997, Prague.
3. M. Pervaiz and Sain M. M., Resources, Conservation and Recycling, 16, 1-6, (2003).
4. Ienica summary report for European Union – Fibre crops, Aug.2000., www.ienica.net/reports/BIGFIBRES.pdf
5. Karus M., Kaup M. and Ortmann S., Use of natural fibre composites in the German and Austrian automotive industry, Survey 2002: Status, Analysis and Trends., nova-Institute GmbH, Hurth., www.as-koeh.de/pdf/03-03_Market_NF_Composite.pdf
6. Composites for the automotive industry, www.nntcc.co.uk/products/fibre/cftai.etm
7. Panthapulakkal S., Sain M. and Law S., SAE Paper 2004-01-0014, (2004)
8. van Voorn B., Smit H. H. G., Sinke R. J. And de Klerk B., Composites Part A., 32, 1271-1279 (2001).

Table I. Abbreviation and formulation of SMC studied

Composite	**Filler used**	**Filler : Resin ratio**
A1	Hemp	30: 70
A2	Hemp	35:65
A3	Hemp	50:50
B1	Hemp+ Glass	45:5:50 (Glass fibre layer in the middle)
B2	Hemp + Glass	45:5:50 (Glass fibres on the top and bottom)
C	Hemp + Glass	35:15:50(Glass fibres on the top and bottom)

Table II. Mechanical properties, ASTM standards and specimen dimensions

Property	Standard	Sample Dimension, mm
Tensile Properties	ASTM D 638	165 X 13 X 3
Flexural Properties	ASTM D 790	128 X 13 X 3
Impact Strength	ASTM D 256	64 X 13 X 3

Table III. Mechanical properties of natural fibre composite (A3) and natural fibre - glass fibre hybrid composites (B1, B2 and C)

Composite No.	Tensile Strength, MPa	Tensile Modulus, MPa	Flexural Strength, MPa	Flexural Modulus, GPa	Notched Impact Stength, J/m	Un-notched Impact strength, J/m
A3 (50%hemp)	82.5 ±5.51	1.7 ±0.36	107.2 ±4.6	7.7 ±0.41	83 ±5	120 ±19
B1(45% hemp + 5% glass)	81.2 ±6.1	1.9 ±0.23	104.2 ±4.75	7.0 ±0.45	163 ±18	193 ±23
B2(45% hemp + 5% glass)	80.3 ±4.1	2.3 ±0.46	173.1 ±4.1	10.4 ±0.43	219 ±17	239 ±18
C(35% hemp + 15% glass)	126.7 ±6.5	1.8 ±0.07	213.1 ±5.3	12.5 ±0.54	357 ±19	493 ±51

Table IV. Comparison of properties with the OEM requirements of automobile structural parts

Property	Tailgate[b] (NorylGTX)	Liftgate front fenders[c]	Body panel roof[c]	Composite with 50% hemp	Composite with 45% hemp+ 5% glass fibre +50% resin	Composite with 35% hemp+ 15% glass fibre + 50% resin
Tensile Strength, MPa	45	62	90	82.5	80.3	126.7
Tensile Modulus, GPa	2	2.42	8.3	1.7	2.3	1.8
Flexural Modulus, MPa	1.8	-	5.5	7.7	10.4	12.5
Noched Izod Impact strength, J/m	-	-	690	83	219	357

---

[b] Source: www.matweb.com

[c] Source: SAE Car Technology Year Book 2000, USA 2000

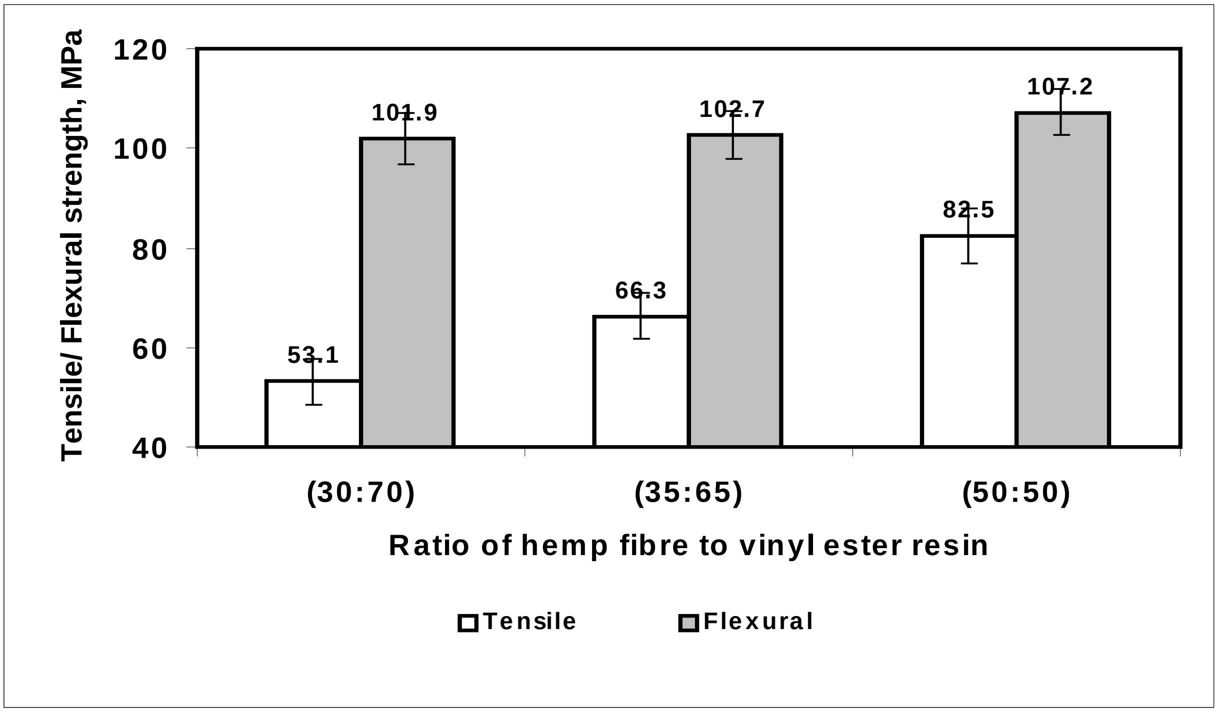

Figure 1. Variation of tensile and flexural strength of SMC with natural fibre loading

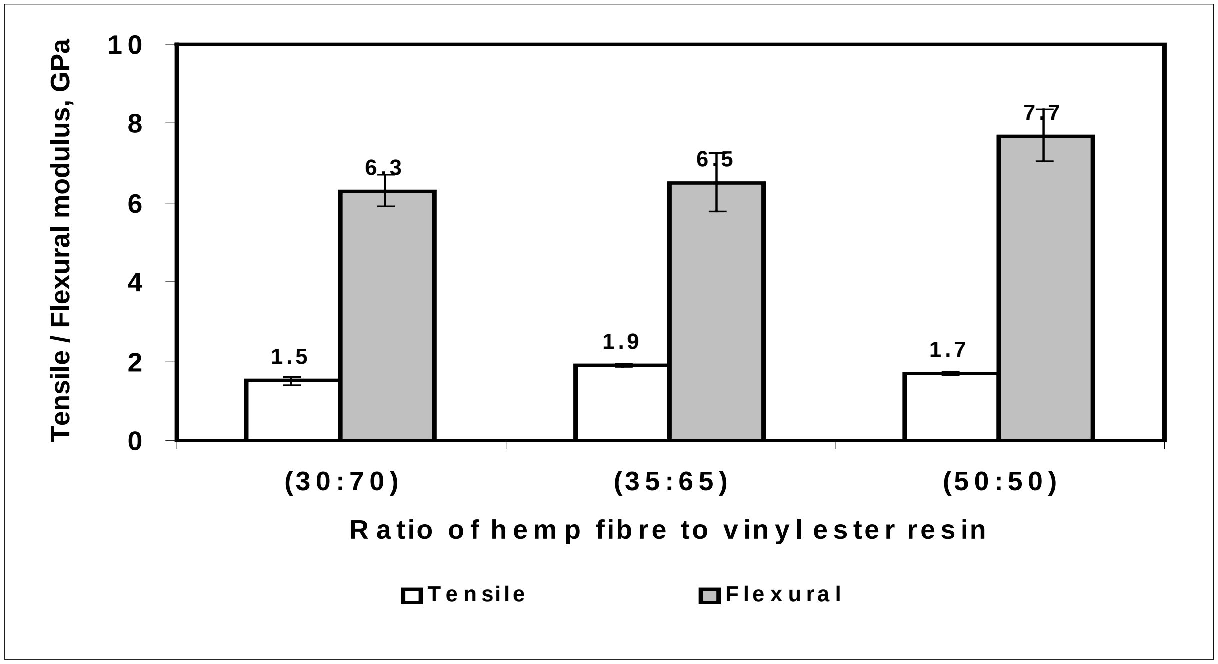

Figure 2. Variation of tensile and flexural modulus of SMC with natural fibre loading

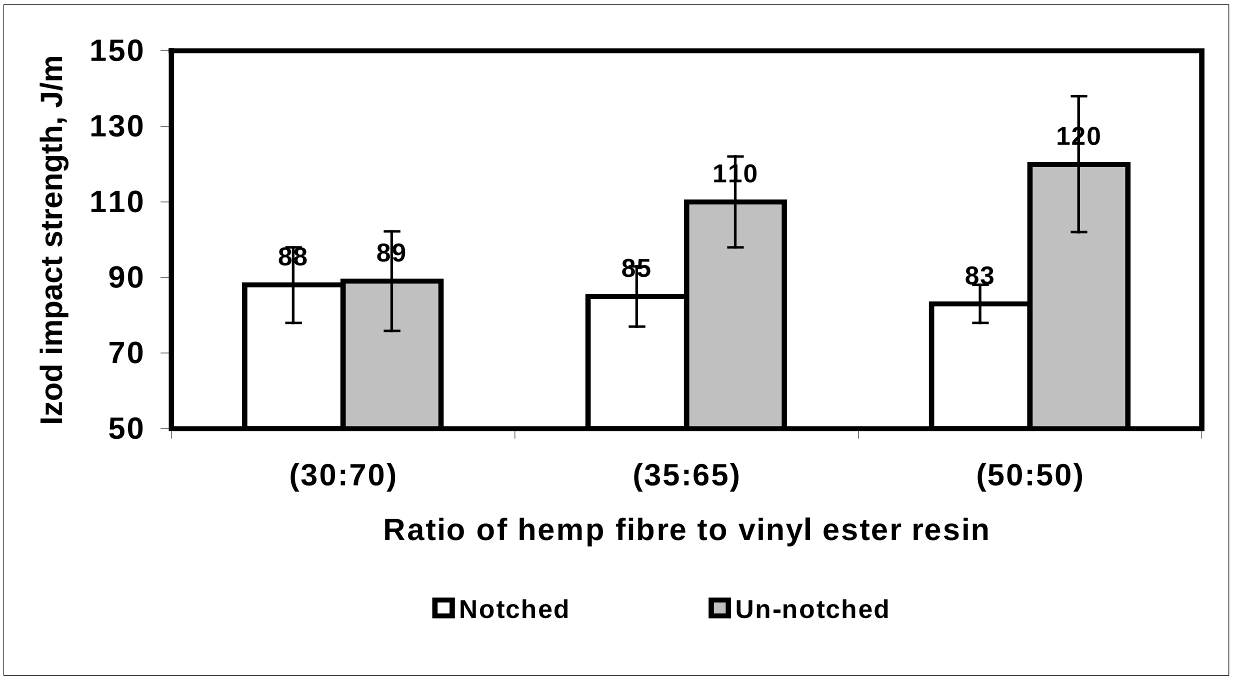

Figure 3. Variation of Izod impact strength of SMC with natural fibre loading