Report No. 07-020-03-R04

PROJECT REPORT

DEVELOPMENT OF AN AGRICULTURAL FIBRE MAT FOR REINFORCING COMPOSITE PANELS

Prepared by:

Zhi-Cheng Yu
Engineer, Composite Applications EIT
Composites Innovation Centre Manitoba Inc.

Approved by:

Sean McKay
Executive Director
Composites Innovation Centre Manitoba Inc.

Project Sponsors:

Department of Agriculture and Agri-Food Canada
United States Department of Agriculture, Cotton Quality Research Station
Schweitzer-Mauduit Canada Inc.

Rev 1.0
15 July, 2008

EXECUTIVE SUMMARY

This report encompasses the assessment results of biofibre mat from the project 07-020-03, Development of an Agricultural Fibre Mat for Reinforcing Composite Panels. The project aimed to develop an engineered biofibre mat as an alternative of E-glass chopped strand mat (CSM) for use in resin infusion processes to produce parts for the ground transportation industry.

In the third phase of the project, hemp, flax and synthetic fibres were used to produce 61 different mats at Philadelphia University (Philadelphia, PA) and North Carolina State University (Raleigh, NC) using 6 different mat forming and binding technologies. Among them, 45 mats were recommended for preliminary testing. Permeability was measured in the preliminary tests. 11 mats, representing three mat forming technologies and five binding methods, were selected based on their performance in the preliminary testing.

Table 1: Selected Biofibre Mats

Mat Number	Composition			Mat Weight per Unit Area, g/cm^2	Manufacturing Method
	Flax %	Hemp %	Copoly %		
2A	50.0	50.0	0.0	0.085	Scan Feed, Needle Punch
2B	47.5	47.5	5.0	0.051	Scan Feed, Needle Punch
2C	95.0	0.0	5.0	0.049	Scan Feed, Needle Punch, Calendar
2D	0.0	90.0	10.0	0.0067	Wetlay, Dry
2E	47.5	47.5	5.0	0.0092	Wetlay, Dry
2F	0.0	95.0	5.0	0.014	Wetlay, Dry
2G	100.0	0.0	0.0	0.020	Airlay, Latex Bonded
2H	90.0	0.0	10.0	0.024	Airlay, Need Punch
2I	0.0	90.0	10.0	0.014	Airlay, Thermal bonded
2J	100.0	0.0	0.0	0.025	Airlay, Needle Punch
2K	0.0	100.0	0.0	0.025	Airlay, Needle Punch

Note: Copoly is a polyester fibre which could be melted at low temperature

Composite panels were manufactured with the selected mats by infusing Hydropel R037-YDF-40 vinyl ester resin catalyzed by 2% of DDM-9 into the cavity of a specially made rigid mould under assistance of vacuum. It was found that infusion time was comparatively shorter on wet lay-up mats, indicating these mats were more permeable. The composites' properties were assessed through tensile, flexural, short beam shear (SBS) and Izod Impact tests following ASTM standards.

Table 2: Top Five Tension and Flexure Results for Composite Mats

Rank	Tension		Flexure	
	Strength, MPa	Modulus, GPa	Strength, MPa	Modulus, GPa
Design Expectation[10]	82.74	7.58	142.03	5.17
E-Glass csm [3]	138.00	10.30	221.50	8.50
1	48.27 (2K)	5.04 (2K)	80.04 (2K)	6.13 (2K)
2	39.43 (2I)	4.54 (2I)	70.10 (2F)	5.71 (2F)
3	37.97 (2D)	4.47 (2F)	65.90 (2J)	5.45 (2D)
4	37.72 (2F)	4.40 (2A-Parallel)	65.34 (2D)	5.20 (2A-Parallel)
5	34.02 (2E)	4.36 (2D)	64.41 (2I)	5.15 (2I)

Note: mat numbers included after numerical properties

Table 3: Top Five Short Beam Shear and Impact Results for Composites Mats

Rank	Short Beam Shear	Izod Impact
	SBS Strength, MPa	Impact Strength, KJ/m^2
E-Glass csm [3]	-	66.6[3]
1	12.12 (2F)	6.5 (2C-Parallel)
2	11.18 (2K)	5.71 (2K)
3	11.12 (2D)	5.5 (2B-Parallel)
4	10.74 (2C)	4.9 (2F)
5	10.41(2I)	4.8 (2C-perpendicular) /4.8 (2E)

Scan feed mat composites showed anisotropy and prominent mechanical properties. However, the properties were not consistent due to the discontinuity in fibre distribution and texture, especially for the 100% flax mat. Scan feed mats' anisotropic features may not be desirable in some applications. The dense and thick mats also have other shortcomings: preforming and permeability. The thick mat may reduce labour time by needing only one layer for preforming, except the lack of layering reduces the ability for inconsistencies in the fibre distribution to be averaged over several layers. The dense and thick mats are generally stiff and may not properly conform to the tooling surface. In this assessment, the mats needed more time for resin infiltration indicating a poor permeability as compared to the other mats in the study. To take the advantages that scan feed mat may offer, the mat should be formed thinner and looser than currently assessed mats. Further work is required in improving the mat continuity and uniformity.

The wet lay mat in its current flimsy and fragile form lacks processability as a composite mat. To achieve good quality, many layers of the mats needed to be laid up to form a preform. This requirement increases the time and labour cost in manufacturing. Despite these drawbacks, the wet lay composites resulted in high quality composite panels which presented good mechanical performances in almost all the testing. This may be attributed to their tissue like texture, large number of preforming layers, high compaction ratio and good permeability. Reducing the layering requirements and fragility would improve this mat into a more commercial form.

Air lay mats are very promising candidates for ideal engineered mats. In general, they are more continuous and uniform in comparison to the other mats. The mats of randomly oriented fibres are soft and easy to conform to tooling surface. 3 or 4 layers are normally required for preforming, offering good quality as well as efficiency and productivity. Air laid hemp mats produced comparatively high tensile and flexural strengths and moduli regardless of the binding method used: needle punch or thermal bond. The flexural moduli surpass the design requirements for the bus components (Table 2). However, the loft makes air lay mats hard to achieve a high compaction ratio in current VARTM and RTM light processes. It is found a high compaction ratio could effectively reduce the void content and improve shear and impact strength. A lower loft air lay mat, produced without reducing the other beneficial qualities found in this study may thus serve to be a good biofibre mat for composite use.

Latex was the least compatible to Hydropel R037-YDF-40 vinyl ester resin. The latex bonded, air laid mat composites had the highest void content and lowest mechanical performance.

Fibre agglomeration appeared to be a major problem in mats containing flax fibres. The agglomeration caused inconsistencies in the mats which may have caused voids and fibre deficient areas. Shives and other contaminants were often at the nuclei of the clustered fibres and a relationship between the agglomeration and the contaminants may be present. Hemp mats illustrated the best strength and moduli in tension and flexure regardless of forming (wet lay or air lay) and binding method (needle punch or thermal bond). This was not surprising because the hemp mats were very uniform, continuous, soft and clean. Comparatively, the flax mats resulted in composites with relatively low mechanical behaviours. This implies that fibre forms, such as diameter, length, space orientation, and easiness of commingling, are possibly the other factors interfering the mat physical appearance and performance. Further investigations are necessary in the future work.