Near Ready, Real Potential

The Feasibility of Using Natural Fibres for Reinforcing Thermoset Composite Parts for Ground Transportation Applications
Biofibres Development Approach

- Use existing plant varieties initially
- Review current harvesting techniques, develop & implement alternates
- Develop new decortication technologies to provide a natural fibre source
- Define composite part & engineered mat req's
- Identify & implement a holistic fibre grading approach
- Develop a material preparation and mat making capability
- Investigate and develop suitable fibre surface treatments
- Identify and select suitable resins
- Identify/develop additional test methods
- Perform panel and part manufacturing trials
- Evaluate composite panel properties
- Produce and test in-service composite parts
Market Size (E-glass Composites)

- The demand for E-glass fibre in North America in 2004 was estimated to be around 1.4 billion lbs, or over 632,000 tonnes
- Available in a variety of forms, of which chopped strand and chopped strand mat are initially the most favourable forms for biofibres

Oilseed Flax Fibre Availability (Canada)

**Flax Volume**

- Low Estimate: 36,562 m³
- High Estimate: 138,571 m³

**Favourable Glass Forms Volume**

- Canada: 4,213 m³
- North America: 42,130 m³
### Scenarios Investigated

<table>
<thead>
<tr>
<th>Scenario Abbre.</th>
<th>Raw Fibre Input</th>
<th>Primary Processing</th>
<th>Secondary Processing</th>
<th>Glass End Market Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>SH</td>
<td>Salvaged Oilseed</td>
<td>Hammer Mill + Screening</td>
<td></td>
<td>Loose Fibre, Low Quality</td>
</tr>
<tr>
<td>SHNW</td>
<td>Salvaged</td>
<td>Hammer Mill + Nonwoven Mat</td>
<td>Chopped Strand Mat, Low Quality</td>
<td></td>
</tr>
<tr>
<td>SHNP</td>
<td>Salvaged Oilseed</td>
<td>Hammer Mill + Nonwoven + Needle Punch</td>
<td>Chopped Strand Mat, Low Quality</td>
<td></td>
</tr>
<tr>
<td>SHNWx2</td>
<td>Salvaged Oilseed</td>
<td>Hammer Mill + 2 lines Nonwoven Mat</td>
<td>Chopped Strand Mat, Lowest Quality</td>
<td></td>
</tr>
<tr>
<td>SHNPx2</td>
<td>Salvaged Oilseed</td>
<td>Hammer Mill + 2 lines Nonwoven + Needle</td>
<td>Chopped Strand Mat, Low Quality</td>
<td></td>
</tr>
<tr>
<td>MR</td>
<td>Managed Oilseed</td>
<td>Roller / Shaker</td>
<td></td>
<td>Loose Fibre, High Quality</td>
</tr>
<tr>
<td>MRNW</td>
<td>Managed Oilseed</td>
<td>Roller / Shaker</td>
<td>Nonwoven Mat</td>
<td>Chopped Strand Mat, Low Quality</td>
</tr>
<tr>
<td>MRNP</td>
<td>Managed Oilseed</td>
<td>Roller / Shaker</td>
<td>Nonwoven + Needle Punch</td>
<td>Chopped Strand Mat, Mid Quality</td>
</tr>
</tbody>
</table>
## Calculated COGS, G&A and Gross Profit As % Of Revenue

<table>
<thead>
<tr>
<th>Scenario</th>
<th>COGS % of Revenue</th>
<th>G&amp;A % of Revenue</th>
<th>Profit % of Revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>SH</td>
<td>77%</td>
<td>22%</td>
<td>25%</td>
</tr>
<tr>
<td>SHNW</td>
<td>66%</td>
<td>21%</td>
<td>26%</td>
</tr>
<tr>
<td>SHNP</td>
<td>56%</td>
<td>43%</td>
<td>32%</td>
</tr>
<tr>
<td>SHNWx2</td>
<td>54%</td>
<td>16%</td>
<td>47%</td>
</tr>
<tr>
<td>SHNPx2</td>
<td>43%</td>
<td>19%</td>
<td>15%</td>
</tr>
<tr>
<td>MR</td>
<td>68%</td>
<td>49%</td>
<td>25%</td>
</tr>
<tr>
<td>MRNW</td>
<td>49%</td>
<td>38%</td>
<td>10%</td>
</tr>
<tr>
<td>MRNP</td>
<td>47%</td>
<td>15%</td>
<td>0%</td>
</tr>
</tbody>
</table>

### Scenarios
- SH
- SHNW
- SHNP
- SHNWx2
- SHNPx2
- MR
- MRNW
- MRNP

### Percent of Revenue

- 110%
- 100%
- 90%
- 80%
- 70%
- 60%
- 50%
- 40%
- 30%
- 20%
- 10%
- 0%
- -10%

### COGS % of Revenue

- 30%
- 25%
- 22%
- 21%
- 16%
- 26%
- 32%
- 49%
- 38%
- 21%
- 19%
- 15%

### G&A % of Revenue

- 9%
- 22%
- 25%
- 43%
- 6%
- 32%
- 43%
- 68%
- 25%
- 25%
- 19%
- 15%

### Profit % of Revenue

- -7%
- 9%
- 22%
- 43%
- 6%
- 32%
- 47%
- 25%
- 25%
- 47%
Scenarios incorporating a biofibre mat line(s) suggested sizable profits could be gained.

The production of loose fibres from oilseed flax was the only form that was not considered commercially viable.

Hemp also has some potential to be more economical than flax due to increased biomass per hectare.

Full Marketing Report available for download at:
http://www.compositesinnovation.ca/FTP/website/biofibre.php

Fibre Processing Scenario Comparison Tool (Excel) available with Marketing Report to produce custom scenario analysis.
Baseline Technical Ability

Objectives

- Establish a method to manufacture composite panels from flax fibre mat using existing industry practices
- Determine baseline properties through physical and mechanical testing and compare results to E-glass panels of similar fibre volume content
- NOT optimized – a starting point from which optimization can occur
- Process selected was resin infusion using a polyester thermoset resin matrix
## Properties

<table>
<thead>
<tr>
<th>Properties</th>
<th>Comparative Results for Flax Panel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acoustic Transmission Loss</td>
<td>• Better sound damping capabilities than glass</td>
</tr>
<tr>
<td>Water Absorption</td>
<td>• Small increase in water absorption over glass in 2 hr submersion</td>
</tr>
<tr>
<td></td>
<td>• Large increase in water absorption over glass in 24 hr submersion</td>
</tr>
<tr>
<td></td>
<td>• No measurable swelling</td>
</tr>
<tr>
<td>Surface Flammability</td>
<td>• Reduced flammability resistance compared to glass</td>
</tr>
<tr>
<td>Heat Distortion</td>
<td>• Reduced performance at high temperatures compared to glass</td>
</tr>
<tr>
<td></td>
<td>• Improved performance over neat resin</td>
</tr>
<tr>
<td>Charpy Impact</td>
<td>• Significantly reduced performance compared to glass</td>
</tr>
<tr>
<td></td>
<td>• Reduced performance compared to neat resin</td>
</tr>
</tbody>
</table>
### Properties Continued

<table>
<thead>
<tr>
<th>Properties</th>
<th>Comparative Results for Flax Panel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrosion Resistance</td>
<td>• Properties similar to glass</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>• No visual degradation</td>
</tr>
<tr>
<td></td>
<td>• Properties similar to glass</td>
</tr>
<tr>
<td>Flexural Strength</td>
<td>• Significantly reduced performance compared to glass</td>
</tr>
<tr>
<td></td>
<td>• Reduced performance compared to neat resin</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>• Significantly reduced performance at high temperatures compared to glass</td>
</tr>
<tr>
<td></td>
<td>• Reduced performance compared to neat resin</td>
</tr>
<tr>
<td>Flexural Modulus</td>
<td>• Reduced stiffness compared to glass</td>
</tr>
<tr>
<td></td>
<td>• Improved stiffness over neat resin</td>
</tr>
<tr>
<td>Tensile Modulus</td>
<td>• Reduced stiffness compared to glass</td>
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</table>
Areas for Optimization

- Fibre Matrix Bond
- Reducing impurity content in flax
- Fibre consistency
- Engineered mat structure

Current Applications

- Non-structural, dry environments where weight savings with comparable acoustic damping needed
  - Ducts
  - Headliners
Compatibility of the Matrix/Fibre Bond

Objective
- Identify a commercially available thermosetting resin which exhibits strong bonding capability with natural fibres
- Assess the strength of an interface bond and fibre/resin compatibility using multiple test methods

Constraints
- Several thermosetting polymeric resins to be investigated
- Resin selection will be based on typical industry practices and material prices
- Oilseed flax fibre currently grown in Canada
- Vacuum assisted resin infusion processing
 Compatibility of the Matrix/Fibre Bond

Multiple evaluation techniques in consideration, minimum of three to be used

- Atomic Force Microscopy
- Single Fibre Pull-Out
- Confocal Laser Scanning Microscopy
 Compatibility of the Matrix/Fibre Bond

This slide will contain data on the results we have collected as of September

Scheduled end of project for Beginning of October
Developing Engineered Mats

Objective

- Develop an engineered mat from natural fibres to replace E-glass chopped strand mat (CSM) in fibre reinforced thermoset components
- Targeted end-use is in resin infusion processes to produce parts for the ground transportation industry
- Primary fibres are flax and hemp varieties currently cultivated in Canada, although other materials may be added to meet performance specifications
Developing Engineered Mats

- Specifications are finalized for a mat product: purity, consistency, physical and mechanical properties and compatibility with thermoset resins and processes.
- Four potential sources are identified capable of mat manufacture and/or development of pre-commercial equipment to produce the mat.
- Existing flax and/or hemp mats are obtained from other sources, panels fabricated, tested and compared with E-glass.
- Mat process method(s) is/are selected for upgrade to pre-commercial pilot plant scale.
- Economic processing data is generated sufficient to prepare a business case that supports economic viability of the processes selected.
Developing Engineered Mats

- This Slide will contain information on the current status of the project by September
- Project has just started (June 11th)
- Project scheduled to be completed March 2008
Fibre Testing Protocol

Objectives

- Identify relations between fibre properties and affect on composite performance
- Establish test methods to quantify fibre properties which affect performance and document the procedures
- Perform multiple fibre tests and create composite samples from fibre forms to build statistical data on fibre properties vs composite performance
- If possible, identify acceptable ranges of variation in fibre properties which do not adversely affect the composite end product for use in quality control
Fibre Testing Protocol

Proposed Fibre Tests may include, but are not limited to:

- Degree of Ret
- Fineness
- Straightness
- Impurity Content
- Strength
- Density
- Fibre Constituents (wax, cuticle, lignin and or pectin content)
- Hydrophobicity
Fibre Testing Protocol

Proposed Composite Tests may include, but are not limited to:

- Microstructure analysis
- Resin/matrix interface properties
- Density
- Water Absorption
- Flexural Strength
- Tensile Strength
- Impact Resistance
- Fibre Content
Fibre Testing Protocol

- This slide will discuss any progress achieved or test results collected before September
- Project scheduled to start Mid July
- Project schedule for completion March 2008
Near Ready, Real Potential

- Producing fibre for the composites industry has potential to make money for farmers, processors and composite manufacturers.
- Current baseline flax material harvested in Canada and processed using known technology is able to manufacture non-structural composite parts and show a weight saving.
- Resins will be selected to optimize matrix/fibre bonds.
- Engineered mats to be produced to introduce natural fibres to structural applications.
- Fibre assessment system to be developed to quantify fibres with their composite performance and ultimately lead to standardized testing and grading systems.