PRELIMINARY STUDY USING HEAT TREATED WOOD IN ENGINEERING THERMOPLASTIC COMPOSITES

Esra Erbas Kiziltas, Deniz Aydemir
Alper Kiziltas, Douglas Gardner and Gokhan Gunduz

SPE ACCE Conference-Sustainable Composites
September 10, 2014
OUTLINE

➢ Background-Thermowood
➢ Objectives
➢ Materials and Methods
➢ Results
➢ Conclusions
➢ Acknowledgements
FINISH INNOVATION- THERMOWOOD

- Improves woods dimensional stability and durability against decay and gives it a pleasant deep-brown colour.

- ThermoWood is a heat-treatment technology for wood developed and patented by VTT. Today the industrial scale of wood heat treatment process, under trade name ThermoWood®, has licensed to the members of the Finnish Thermowood Association.
THERMOWOOD PROCESS

Wang and Cooper 2010, Ala-Viikari 2008

Fresh Wood

Wood Drying
T:100°C, then 130°C
Time:0-48 hrs

Heat Treatment
T:150-240°C
Time:4 hrs
Media: Steam

Cooling and Conditioning
T:70°C
Time:24 hrs

Esra Erbas Kiziltas, Ph.D
Advanced Structures and Composites Center
Email: esra.erbas@umaine.edu
composites.umaine.edu
THERMOWOOD SALES PRODUCTION

http://www.thermowood.fi/
LIFE CYCLE ASSESSMENT (LCA)

- LCA study of ThermoWood was carried out by Imperial college London.

- Conclusion:
  "ThermoWood has a potential of being a 'green' building material if consideration is made to the production as well as the use and disposal at the end of its life cycle using best available technologies"
HEAT TREATMENT-WPC

- Presumably, using HTW as filler should not enhance the properties of WPCs to the same extent as untreated wood does.

- The changes imposed by HT could reduce polarity of wood and make the wood a more compatible material with non-polar thermoplastic matrix.

- Adding HTWF should also lead to an improvement in the thermal stability of the composites.
<table>
<thead>
<tr>
<th>Polymer</th>
<th>Type of Wood</th>
<th>Heat Treatment (°C)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE</td>
<td>Bamboo</td>
<td>160, 175, 190, 205, 220</td>
<td>Fang et al. 2013</td>
</tr>
<tr>
<td></td>
<td>Maple</td>
<td>175, 190, 205</td>
<td>Kaboorani and Faezipour 2009</td>
</tr>
<tr>
<td></td>
<td>Maple</td>
<td>175, 190, 205</td>
<td>Kaboorani et al. 2008</td>
</tr>
<tr>
<td></td>
<td>Spruce and NF</td>
<td>230</td>
<td>Robin and Breton 2001</td>
</tr>
<tr>
<td></td>
<td>Norway Spruce</td>
<td>200</td>
<td>Sgerholm 2007</td>
</tr>
<tr>
<td></td>
<td>Birch and Spruce</td>
<td></td>
<td>Butylina et al. 2011</td>
</tr>
<tr>
<td></td>
<td>Poplar</td>
<td>180, 200</td>
<td>Kaboorani 2009</td>
</tr>
<tr>
<td></td>
<td>Poplar</td>
<td>200</td>
<td>Luo et al. 2014</td>
</tr>
<tr>
<td></td>
<td>Eucalyptus</td>
<td>120, 150, 180</td>
<td>Ayrilmis et al. 2011</td>
</tr>
<tr>
<td>CAB</td>
<td>Norway Spruce</td>
<td>200</td>
<td>Segerholm 2007</td>
</tr>
</tbody>
</table>

Aydemir et al. 2014
OBJECTIVES

➢ To explore the use of PA 6 and HTWF for low-cost and high volume applications especially ‘under-the-hood’ applications in the automobile industry.

➢ Produce and evaluate the material properties of natural fiber filled-engineering thermoplastic composite materials developed on the bench scale.

The upper air intake manifold for the Ford Windstar’s 3.8-liter V-6 engine is injection molded from Zytel® nylon 66 resin

Manifold used by Dodge and Plymouth Neon small cars uses Zytel® nylon
MATERIALS-FORMULATIONS

- Wood flour of pine and maple, greater than 100 mesh and nylon 6 with the trade name Entec NL 2000 (density: 1.23 g/cm³) were used.

- The lubricant (TPW113) used as an additive to improve processing conditions, was supplied by Struktol Co.

<table>
<thead>
<tr>
<th>Sample Code</th>
<th>Nylon 6</th>
<th>WF</th>
<th>HTWF</th>
<th>Lubricant</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA+L</td>
<td>97</td>
<td>-</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>P-5</td>
<td>92</td>
<td>5</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>P-10</td>
<td>87</td>
<td>10</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>P-20</td>
<td>77</td>
<td>20</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>P-30</td>
<td>67</td>
<td>30</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>TP-5</td>
<td>92</td>
<td>5</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>TP-10</td>
<td>87</td>
<td>10</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>TP-20</td>
<td>77</td>
<td>20</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>TP-30</td>
<td>67</td>
<td>30</td>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>

Esra Erbas Kiziltas, Ph.D
Advanced Structures and Composites Center
Email: esra.erbas@umaine.edu
composites.umaine.edu
COMPOSITES PRODUCTION - BOWL MIXER

PA 6
WF/HTWF
Lubricant → High Speed Mixer → Melt Blend Brabender → Dry Grinded Mixture → Injection Molding → ASTM Test Samples
EXPERIMENTAL APPROACHES

- Tensile and Flexural Strength
- Tensile and Flexural MOE
- Elongation at Break
- Notched Izod Impact Strength
- Crystallinity

- Thermal Stability
- DTGA Temperature
- Residual Mass

- Viscosity
- Elastic Modulus
- Tan Delta
Thermal stability increased with the heat treatment.

Aydemir et al. 2014
The XRD curves indicated that the crystallinity index of wood was increased by heat treatment.

Aydemir et al. 2014   Ou et al. 2014
TENSIILE PROPERTIES OF THE COMP.

➢ TMOE and TMOR increased with the addition of HTWF. The increase in TMOE is only to the reinforcement effect of dispersed HTWF.  

Aydemir et al. 2014
FLEXURAL PROPERTIES OF THE COMP.

FMOE and FMOR increased with the addition of HTWF. The increase in FMOE is only to the reinforcement effect of dispersed HTWF.  

Aydemir et al. 2014
IMPACT STRENGTH OF THE COMPOSITES

➢ Increased HTWF loading has a negative effect on impact strength. Aydemir et al. 2014
<table>
<thead>
<tr>
<th>Polymer</th>
<th>Type of Wood</th>
<th>Characterization Method</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE</td>
<td>Bamboo</td>
<td>Hygroscopicity and Dimension Stability, FTIR and TGA</td>
<td>Fang et al. 2013</td>
</tr>
<tr>
<td></td>
<td>Maple</td>
<td>TGA</td>
<td>Kaboorani and Faezipour 2009</td>
</tr>
<tr>
<td></td>
<td>Maple</td>
<td>Mechanical Tests and SEM</td>
<td>Kaboorani et al. 2008</td>
</tr>
<tr>
<td></td>
<td>Spruce and NF</td>
<td>Mechanical Tests, TGA and SEM</td>
<td>Robin and Breton 2001</td>
</tr>
<tr>
<td></td>
<td>Norway Spruce</td>
<td>Water sorption, UV laser technique, ,Biological Durability and LV-SEM</td>
<td>Segerholm 2007</td>
</tr>
<tr>
<td></td>
<td>Birch and Spruce</td>
<td>SEM Hygroscopicity, thickness swelling and Mechanical Tests</td>
<td>Butylina et al. 2011</td>
</tr>
<tr>
<td></td>
<td>Poplar</td>
<td>TGA, DSC</td>
<td>Kaboorani 2009</td>
</tr>
<tr>
<td></td>
<td>Poplar</td>
<td>XPS, Hygroscopicity, DMA, Mechanical Tests, Thickness Swelling and SEM</td>
<td>Luo et al. 2014</td>
</tr>
<tr>
<td></td>
<td>Eucalyptus</td>
<td>Hygroscopicity, thickness swelling and Mechanical Tests</td>
<td>Ayrilmis et al. 2011</td>
</tr>
<tr>
<td>CAB</td>
<td>Norway Spruce</td>
<td>Water sorption, UV laser technique, ,Biological Durability and LV-SEM</td>
<td>Segerholm 2007</td>
</tr>
</tbody>
</table>

Aydemir et al. 2014
The decrease in the slopes of elastic modulus for the composites compared to nylon 6 can be explained by the microstructural changes of the polymer matrix because of the incorporation of HTWF. 

Aydemir et al. 2014
The higher the HTWF content of the composite, the higher the shear viscosity.

Aydemir et al. 2014
MELT VISCOSITY COMPARISON

Aydemir et al. 2014

Ou et al. 2014

Esra Erbas Kiziltas, Ph.D
Advanced Structures and Composites Center
Email: esra.erbas@umaine.edu
composites.umaine.edu
Conclusions

- The tensile strength increased and reached an optimum value at 20 wt. % of HTWF loading level.

- The TMOE and FMOE increased with the addition of HTWF.

- Increased HTWF loading level has a negative effect on impact strength.

- The thermal stability and crystallinity increased with heat treatment.

- The incorporation of HTWF in a nylon 6 matrix results in higher storage modulus and shear viscosities compared to those of neat nylon 6. The results of TMOE and FMOE are in accordance with the rheological data.

- This study laid groundwork for future research on the role of heat modification in WPC processing.

Aydemir et al. 2014
Acknowledgements

- My advisor Dr. Douglas J. Gardner.
- The republic of Turkey, TUBITAK for the scholarship. ERDC and USDA cellulose research projects for support.
- Chris West and Alex Nash.
- University of Bartin.
THANKS FOR YOUR ATTENTION!