BIOBASED HEADLAMP HOUSING FOR AUTOMOTIVE LIGHTING
Ayse Ademuwagun, Varroc Lighting Systems
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1. Company Overview
1.1 Varroc Group - Business Overview

- Fiscal year 2015 global revenue of $1.3 billion
  - 28.5% CAGR since FY ‘07
- 62% revenues from passenger car market
- 36% revenues from India
- 64% is from International business
- Lighting represents 58% of global business
1.2 Tech Centers & Manufacturing Sites

- Monterey, MEXICO: 32 Engineers & Technicians
- Cologne, GERMANY: 23 Engineers & Technicians
- Nový Jičín, CZECH REPUBLIC (2): 340 Engineers & Technicians
- Rychvald, CZECH REPUBLIC: 23 Engineers & Technicians
- Plymouth, USA: 60 Engineers & Technicians
- Pune, INDIA: 31 Engineers & Technicians
- Changzhou, CHINA (2): 89 Engineers & Technicians
- Chongqing, CHINA: 89 Engineers & Technicians

- 575+ Engineers Globally
- 100% of Manufacturing Sites in Cost Competitive Footprint
- 89% PD Cost Competitive Footprint
- Global Technology Support Structure in Place
1.3 Varroc Lighting Product Portfolio – Headlamp
1.4 Varroc Lighting Product Portfolio – Rear lamp
2. Background
2.1 Project Scope

- **Scope**: To develop and evaluate thermoplastic biocomposite materials for use in headlamp housing
  - Current Headlamp Housing materials:
    - 30-40% Talc filled PP

- **Goal**: 20% weight of selected parts using biocomposites
2.2 Headlamp Part Requirements

- Enough stiffness to carry sub-parts such as reflector, light guides, brackets, wires
- Good bonding adhesion to lens material with hot-melt adhesives
- Good heat aging, heat cycle & vibration resistance
- No fogging or outgassing
- Good dimensional stability
2.3 Biofiller Selection

Why Miscanthus Fiber?
- Non-invasive grass that thrives with minimal care & water
- Utilizes land unsuitable for food crops like corn or soy beans
- Potential to bring 30 million acres of farmland into production and support farmers

Why Coffee Chaff Fiber?
- Globally scalable as it is available in all parts of the world where coffee is roasted
- Excellent mechanical properties.

Why Carbonized?
- More compatible with thermoplastic resin
- Less water absorption and better mechanical properties
2.4 How is bio-PP Headlamp Housing made?

**Carbonization** = conversion of organic substance into carbon or a carbon-containing residue

**Step 1:** Heat fiber at very elevated temps under inert conditions

**Step 2:** Foliation of fiber via chemical treatment

**Step 3:** Reduce particle size of carbonized fiber and format

**Step 4:** Dry carbonized fiber at 80°C for 4 hours

**Step 5:** Mix the dried formatted fiber with base PP

**Step 6:** Using twin screw extruder, compound the material.

**Step 7:** Using injection molding machine, make headlamp parts
3. Results
### 3.1 Mechanical Properties

<table>
<thead>
<tr>
<th>Test</th>
<th>Unit</th>
<th>30% Bio-Carbon PP</th>
<th>40% Talc PP</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melt Index</td>
<td>g/10min</td>
<td>14</td>
<td>12</td>
<td>ASTM D1238</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>230° C Load 21.2N</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>g/mL</td>
<td>1.03</td>
<td>1.23</td>
<td>ASTM D256</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>MPa</td>
<td>42</td>
<td>30</td>
<td>ASTM D638</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Test Speed: 5mm/min</td>
</tr>
<tr>
<td>Elongation</td>
<td>%</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Flexural Strength</td>
<td>MPa</td>
<td>47</td>
<td>42</td>
<td>ASTM D790</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Test Speed: 14mm/min</td>
</tr>
<tr>
<td>Flexural Modulus</td>
<td>GPa</td>
<td>3.5</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>Notched Izod Impact</td>
<td>J/m</td>
<td>29</td>
<td>23</td>
<td>ASTM D256 (23° C)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Hammer: 2.94J</td>
</tr>
<tr>
<td>UN-Notched Izod Imp.</td>
<td>J/m</td>
<td>362</td>
<td>275</td>
<td></td>
</tr>
<tr>
<td>HDT</td>
<td>° C</td>
<td>140</td>
<td>132</td>
<td>ASTM D648</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Stress Loading: 0.45 Mpa</td>
</tr>
<tr>
<td>Mold Shrinkage</td>
<td>cm/cm</td>
<td>0.014-0.016</td>
<td>0.015-0.018</td>
<td>ASTM D 955</td>
</tr>
</tbody>
</table>

**Bio-Carbon-filled PP vs. Talc-filled PP**
- Comparable mechanical properties
- Lower density (17% ↓)
- Higher HDT & impact resistance compared to talc PP
3.2 Adhesive Testing per WSS-M11P28-D

- Lap shear (1”x4”) samples with a 1” bond line.
- PC lens material and Bio-PP material were bonded and cured for 7 days prior to testing via Instron.
Results showed that bio-carbon PP bonded well to PC lens material and meet minimum requirements per WSS-M11P28-D spec.

<table>
<thead>
<tr>
<th>Adhesive testing with PC material</th>
<th>Ford Adhesive Requirement, Mpa</th>
<th>Bio PP Shear Strenght, Mpa</th>
<th>Talc PP Shear Strenght, Mpa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Lap Shear at 22°C</td>
<td>600</td>
<td>2215</td>
<td>1806</td>
</tr>
<tr>
<td>Initial Lap Shear at 107°C</td>
<td>450</td>
<td>599</td>
<td>579</td>
</tr>
<tr>
<td>Initial Lap Shear at -30°C</td>
<td>900</td>
<td>1618</td>
<td>1976</td>
</tr>
<tr>
<td>Heat Aged: 14 days at 107°C</td>
<td>700</td>
<td>2093</td>
<td>1955</td>
</tr>
<tr>
<td>Water Immersion: 14 days</td>
<td>500</td>
<td>2216</td>
<td>1937</td>
</tr>
<tr>
<td>Humidity</td>
<td>500</td>
<td>1980</td>
<td>2076</td>
</tr>
</tbody>
</table>
3.3 Fogging Test per SAE J1756

- The photometric fogging test per SAE J1756 at 100°C heating temperature
  - The resin was pre-dried in an oven at 80°C for 2 hours prior to testing.
  - 10g of bio-carbon resin was put in beaker was covered with a glass plate.
  - The beakers were heated in a Hart Fog Test Chamber for 3 hours at 100°C heating temperature and 21°C cooling temperature.
  - The gloss of the glass plates was measured before and 16 h after testing.
  - The fogging number was determined (Fogging number = Rf / Ro × 100)

- Bio-carbon material meet fogging requirements per SAE J1756.

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>R0</th>
<th>Rf</th>
<th>Fog #</th>
<th>Examination of Fog residue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specimen 1</td>
<td>152</td>
<td>151</td>
<td>99.3</td>
<td>No droplets, crystals or clear film</td>
</tr>
<tr>
<td>Specimen 2</td>
<td>152</td>
<td>150</td>
<td>98.7</td>
<td></td>
</tr>
<tr>
<td>Specimen 3</td>
<td>152</td>
<td>151</td>
<td>99.3</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>152</td>
<td>151</td>
<td>99.1</td>
<td></td>
</tr>
</tbody>
</table>
3.4 ASTM G21, Determining Resistance of Synthetic Polymeric Materials to Fungi

The samples are placed on (non-nutrient) mineral salts and inoculated with a mixed fungal spore suspension of:

- Aspergillus Niger ATCC 9642
- Penicillium Funiculosum ATCC 9644
- Chaetomium Globosum ATCC 6205
- Aureobasidium Pollulans ATCC 9348
- Trichoderma Sp. ATCC 9645

After 28 days of incubation at 28°C, antifungal is evaluated by visually rating the degree of fungal growth on the samples.

<table>
<thead>
<tr>
<th>ASTM Rating</th>
<th>Surface Fungal Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Growth</td>
</tr>
<tr>
<td>1</td>
<td>0-10% Growth</td>
</tr>
<tr>
<td>2</td>
<td>10-30% Growth</td>
</tr>
<tr>
<td>3</td>
<td>30-60% Growth</td>
</tr>
<tr>
<td>4</td>
<td>60-100% Growth</td>
</tr>
</tbody>
</table>
3.4 ASTM G21, Determining Resistance of Synthetic Polymeric Materials to Fungi

- Bio PP had growth rating of 0 (No fungi growth on the test specimens)

<table>
<thead>
<tr>
<th>Test Results:</th>
<th>WPP-PPH4TF4 (Talc PP)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>Growth Rating:</th>
</tr>
</thead>
<tbody>
<tr>
<td>CGTech-BCR-HMS 40 (Bio PP)</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

Bio PP after incubation

Positive Control Sample
3.5 ASTM G22 – Determining Resistance of Plastics to Bacteria

- The samples were placed on a mineral salts medium and inoculated with the following bacteria: Pseudomonas sp, Pseudomonas aeruginosa, Staphylococcus aureus, Flavobacterium sp, Slaphylococcus pyogenes, Serratia marsescens, Legionella pneumophilla.
- These samples were then incubated 21 days at 35°C and 85 percent relative humidity.
- Bio PP had no bacterial growth on the test specimens.

<table>
<thead>
<tr>
<th>Report Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organism Species:</td>
</tr>
<tr>
<td>Pseudomonas aeruginosa</td>
</tr>
<tr>
<td>Incubation Period:</td>
</tr>
<tr>
<td>4/26/2016 at 10:00 to 5/17/2016 at 10:00</td>
</tr>
<tr>
<td>Test Results:</td>
</tr>
<tr>
<td>WPP-PPH4TF4 (Talc PP)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>CGTech-BCR-HMS 40 (Bio PP)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
3.6 FLTM BZ 157-01 Headspace Gas Chromatography

- VOC = total volatile organic compounds where determined per Ford request

- Gas chromatography analysis and detection with a flame ionization detector (GC/FID) or mass selective detector (GC/MS) is used as a measure of the total emission of a material.

- Total carbon emission was low and meets Ford’s requirements
4.1 Molding Trials

- Fifty sets of Ford headlamp housings were molded
- Bio-carbon reinforced PP were molded at 420F compared to 500F (power savings of 80F = 27C).
- Faster cycle compare to talc PP composites (4 sec)
- Parts made with Bio-carbon filled PP were 17% lighter than talc PP
- There were no odor with the parts with bio-carbon PP
4.2 Dimensions of Bio PP vs. Talc PP housing

Bio PP dimensions on CAD

Talc PP dimensions on CAD
4.3 Why Heat Stabilizers Required?

- Housing part were put on fixture and aged at 80°C for 1 week
- Warpage of the part due to lack of heat stabilizer in the Bio-carbon PP formula

Pre-Heat Aging

Post-Heat Aging
4.4 Heat Aging Resistance per VW 44045 Spec

- Parts were put on fixture and aged at 150 °C for 700hrs.
  - **Requirements**: No brittleness, no change in shape or surface that would impair performance

- Talc PP failed this test, but Bio-Carbon PP showed no brittleness- passed

![Bio PP PASS](image1.png) ![Talc PP FAIL](image2.png)
4.5 Light Weighting

- The weight of an Exterior Headlamp Housing was evaluated for bio-filled PP versus the current talc filled PP.
- The calculation was done by actual molded parts.
- By using 30% bio-carbon, the similar mechanical properties with 17\% light weighting is possible.

<table>
<thead>
<tr>
<th>Material</th>
<th>Density (g/mL)</th>
<th>Headlamp Housing Weight (grams)</th>
<th>Weight Savings (Compare to 40% Talc filled PP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40% Talc-PP</td>
<td>1.23</td>
<td>1980</td>
<td>0%</td>
</tr>
<tr>
<td>30% Bio-carbon PP</td>
<td>1.03</td>
<td>1651</td>
<td>17%</td>
</tr>
</tbody>
</table>
5. Conclusion

- By using 30% bio-carbon, similar mechanical properties with 17% light weighting is possible.
- Bio-carbon has higher HDT and impact compared to talc PP
- Positive photometric fogging results indicates that this resin is suitable for automotive lighting
- Bio PP had no fungi or bacterial growth on the test specimens per ASTM G21 and ASTM G22 respectfully
- Outgassing per FLTM BZ 157-01 method meets Ford requirements
- Bio-carbon PP bonded well to PC lens material and meet minimum requirements per WSS-M11P28-D spec
- The molding trials were successful as energy savings achievable with faster cycle time.
- Bio-carbon PP performed better than talc PP at heat aging test per VW spec
- Based on these results and successful molding trials makes this bio-composite resin promising for headlamp application
The material tests:

- Heat Aging for tensile and impact bars (140°C for 1000 hours) per WSS-M4D643-B1
- Vent patch adhesion test

The part validation tests:

- SAE J575E Vibration test
- Varroc Dunk Test
- Condensation Test per SAE J575
- FMVSS Temperature Cycle and Internal Heat
- Adhesive testing per WSS-M11P28-D
References


Acknowledgments

Special thanks to

- Alper Kiziltas from Ford
- Competitive Green Technologies
- University of Guelph, Bio-products Discovery and Development Centre

Together for a better future
Questions?