BIOMATERIAL

[Bio-composite]

Nur Istianah, ST.,MT.,M.Eng
Specific biomaterial

Bidirectional layers. 45 fiberglass. Provide torsional stiffness.

Unidirectional layers. 0 (and some 90°) fiberglass. Provide longitudinal stiffness.

Core wrap. Bidirectional layer of fiberglass. Acts as a torsion box and bonds outer layers to core.

Bidirectional layer. 45 fiberglass. Provides torsional stiffness.

Edge. Hardened steel. Facilitates turning by “cutting” into the snow.


Damping layer. Polyurethane. Improves chatter resistance.

Unidirectional layers. 0 (and some 90°) fiberglass. Provide longitudinal stiffness.

Side. ABS plastic having a low glass transition temperature. Containment and cosmetic purposes.

Core. Polyurethane plastic. Acts as a filler.

Top. ABS plastic having a low glass transition temperature. Used for containment and cosmetic purposes.
Figure 16.1 Schematic representations of the various geometrical and spatial characteristics of particles of the dispersed phase that may influence the properties of composites: (a) concentration, (b) size, (c) shape, (d) distribution, and (e) orientation. (From Richard A. Flinn and Paul K. Trojan, *Engineering Materials and Their Applications*, 4th edition. Copyright © 1990 by John Wiley & Sons, Inc. Adapted by permission of John Wiley & Sons, Inc.)
Figure 16.4 Photomicrograph of a WC–Co cemented carbide. Light areas are the cobalt matrix; dark regions, the particles of tungsten carbide. 100×. (Courtesy of Carboloy Systems Department, General Electric Company.)

Figure 16.5 Electron micrograph showing the spherical reinforcing carbon black particles in a synthetic rubber tire tread compound. The areas resembling water marks are tiny air pockets in the rubber. 80,000×. (Courtesy of Goodyear Tire & Rubber Company.)
### Properties of Unreinforced and Reinforced Polycarbonates with Randomly Oriented Glass Fibers

<table>
<thead>
<tr>
<th>Property</th>
<th>Unreinforced</th>
<th>20</th>
<th>30</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific gravity</td>
<td>1.19–1.22</td>
<td>1.35</td>
<td>1.43</td>
<td>1.52</td>
</tr>
<tr>
<td>Tensile strength [MPa (ksi)]</td>
<td>59–62 (8.5–9.0)</td>
<td>110</td>
<td>131</td>
<td>159</td>
</tr>
<tr>
<td>Modulus of elasticity [GPa (10^6 psi)]</td>
<td>2.24–2.345 (0.325–0.340)</td>
<td>5.93</td>
<td>8.62</td>
<td>11.6</td>
</tr>
<tr>
<td>Elongation (%)</td>
<td>90–115</td>
<td>4–6</td>
<td>3–5</td>
<td>3–5</td>
</tr>
<tr>
<td>Impact strength, notched Izod (lb/in.)</td>
<td>12–16</td>
<td>2.0</td>
<td>2.0</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Source: Adapted from Materials Engineering’s *Materials Selector*, copyright © Penton/IPC.
<table>
<thead>
<tr>
<th>Material</th>
<th>Specific Gravity</th>
<th>Tensile Strength [GPa (10^6 psi)]</th>
<th>Specific Strength (GPa)</th>
<th>Modulus of Elasticity [GPa (10^6 psi)]</th>
<th>Specific Modulus (GPa)</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Whiskers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Graphite</td>
<td>2.2</td>
<td>20 (3)</td>
<td>9.1 (1)</td>
<td>700 (100)</td>
<td>318</td>
</tr>
<tr>
<td>Silicon nitride</td>
<td>3.2</td>
<td>5–7 (0.75–1.0)</td>
<td>1.56–2.2 (0.25–0.55)</td>
<td>350–380 (50–55)</td>
<td>109–118</td>
</tr>
<tr>
<td>Aluminum oxide</td>
<td>4.0</td>
<td>10–20 (1–3)</td>
<td>2.5–5.0 (2–4)</td>
<td>700–1500 (100–220)</td>
<td>175–375</td>
</tr>
<tr>
<td>Silicon carbide</td>
<td>3.2</td>
<td>20 (3)</td>
<td>6.25 (3)</td>
<td>480 (70)</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fibers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminum oxide</td>
<td>3.95</td>
<td>1.38 (0.2)</td>
<td>0.35 (0.05)</td>
<td>379 (99)</td>
<td>96</td>
</tr>
<tr>
<td>Aramid (Kevlar 49™)</td>
<td>1.44</td>
<td>3.6–4.1 (0.525–0.600)</td>
<td>2.5–2.85 (0.19)</td>
<td>131 (19)</td>
<td>91</td>
</tr>
<tr>
<td>Carbon</td>
<td>1.78–2.15</td>
<td>1.5–4.8 (0.22–0.70)</td>
<td>0.70–2.70 (0.05–0.25)</td>
<td>228–724 (32–100)</td>
<td>106–407</td>
</tr>
<tr>
<td>E-glass</td>
<td>2.58</td>
<td>3.45 (0.5)</td>
<td>1.34 (0.15)</td>
<td>72.5 (10.5)</td>
<td>28.1</td>
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<tr>
<td>Boron</td>
<td>2.57</td>
<td>3.6 (0.52)</td>
<td>1.40 (0.15)</td>
<td>400 (60)</td>
<td>156</td>
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<tr>
<td>Silicon carbide</td>
<td>3.0</td>
<td>3.9 (0.57)</td>
<td>1.30 (0.05)</td>
<td>400 (10)</td>
<td>133</td>
</tr>
<tr>
<td>UHMWPE (Spectra 900™)</td>
<td>0.97</td>
<td>2.6 (0.38)</td>
<td>2.68 (0.17)</td>
<td>117 (17)</td>
<td>121</td>
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<tr>
<td></td>
<td></td>
<td>Metallic Wires</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High-strength steel</td>
<td>7.9</td>
<td>2.39 (0.35)</td>
<td>0.30 (0.05)</td>
<td>210 (30)</td>
<td>26.6</td>
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<tr>
<td>Molybdenum</td>
<td>10.2</td>
<td>2.2 (0.32)</td>
<td>0.22 (0.04)</td>
<td>324 (47)</td>
<td>31.8</td>
</tr>
<tr>
<td>Tungsten</td>
<td>19.3</td>
<td>2.89 (0.42)</td>
<td>0.15 (0.02)</td>
<td>407 (59)</td>
<td>21.1</td>
</tr>
</tbody>
</table>
Development and Characterization of Compression Molded Flax-Reinforced Biocomposites

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Saskatoon, Saskatchewan, Canada.
Flax fiber

• Flax, is an annual crop used both for fiber and its edible seed.

• CANADA is the largest seed flax growing jurisdiction in the world with acreage regularly exceeding a million acres.

• Advantages of flax fiber:
  low density, low cost, and recyclables.
  - potential reinforce materials
Flax fiber as reinforcement

<table>
<thead>
<tr>
<th></th>
<th>Flax fiber I</th>
<th>Flax fiber II</th>
<th>Flax fiber III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiber content  (% wt.)</td>
<td>98-99</td>
<td>85</td>
<td>42</td>
</tr>
<tr>
<td>Shive content  (% wt.)</td>
<td>1-2</td>
<td>15</td>
<td>58</td>
</tr>
</tbody>
</table>
## Compositions of Bio-fiber

<table>
<thead>
<tr>
<th>Fiber</th>
<th>Cellulose</th>
<th>Hemi-cellulose</th>
<th>Pectin / Lignin</th>
<th>Wax</th>
<th>Water soluble</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flax</td>
<td>64.1</td>
<td>13.7</td>
<td>3.8</td>
<td>1.5</td>
<td>3.9</td>
</tr>
<tr>
<td>Hemp</td>
<td>67.0</td>
<td>16.1</td>
<td>4.1</td>
<td>0.7</td>
<td>4.1</td>
</tr>
<tr>
<td>Jute</td>
<td>64.4</td>
<td>12.0</td>
<td>12.0</td>
<td>0.5</td>
<td>1.1</td>
</tr>
<tr>
<td>Sisal</td>
<td>65.8</td>
<td>12.0</td>
<td>10.7</td>
<td>0.3</td>
<td>10.7</td>
</tr>
</tbody>
</table>
Biocomposite

- Biocomposite consist of a polymer as matrix material and fiber as reinforcing element

- The interest of using natural fiber as a reinforced component was increased recently.

- Some of the potential applications in this field are: door and instrument panels
Biocomposite
Biocomposite

Environmental Advantages:
• Renewable raw material base
• Biodegradable
• Reduced fossil fuel and resource consumption
• Lower greenhouse gas emissions
• Lower overall emissions and environmental impacts

Properties Advantages:
• Low density
• High mechanical properties
Objectives

a). To investigate the effect of flax fiber loading on compression molded HDPE biocomposites

b). To investigate the effect of processing parameters (temperature and pressure) on different physical and mechanical properties of compression molded HDPE biocomposites
Materials and methods

• High Density Polyethylene (HDPE)
• Silane Treated Flax Fiber (as reinforcement)

**Flax Fiber Loading:**
10%, 20%, 30% Flax Fiber (by wt%) control sample (0% Fiber)

• **Molding temperatures**
  - HDPE (150°C, 170°C)

• **Molding Pressure**
  - 6.89 MPa, 10.34 MPa
Biocomposite processing

Fiber

Pre-treatment

Drying

Size Reduction

Mixing

Extrusion

Pelletizing

Size Reduction

HDPE

Compression Molding
Pressure: 6.89/ 10.34 MPa
Temp: 150/ 170 ºC (HDPE)
Residence time: 10 min
Cooling/Curing: Cold Water

Biocomposite Board
Biocomposite processing (compounding system)
Biocomposite processing (Compounding Process)

- Fiber moisture 8-12%
- Polymer fed Melt or solid

Fiber
(Pellets or powder)

Polymer
Water

Additives
Vacuum

Gear Pump

ZSK Twin Screw

Single Screw

Compounding
Venting
Gear pump of
Characterization

Physical properties –

Density test
Color analysis
Water absorption Test

Mechanical properties –

Tensile Test
Flexural Test
Hardness Test
Processing conditions for HDPE biocomposites

<table>
<thead>
<tr>
<th>Condition</th>
<th>Temperature (°C)</th>
<th>Pressure (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-I</td>
<td>150</td>
<td>6.89</td>
</tr>
<tr>
<td>C-II</td>
<td>150</td>
<td>10.34</td>
</tr>
<tr>
<td>C-III</td>
<td>170</td>
<td>6.89</td>
</tr>
<tr>
<td>C-IV</td>
<td>170</td>
<td>10.34</td>
</tr>
</tbody>
</table>
Extruded flax fiber reinforced HDPE samples

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Flax Fiber Content (wt %)</th>
<th>HDPE (wt %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FC10</td>
<td>10</td>
<td>90</td>
</tr>
<tr>
<td>FC20</td>
<td>20</td>
<td>80</td>
</tr>
<tr>
<td>FC30</td>
<td>30</td>
<td>70</td>
</tr>
<tr>
<td>HDPE (Control)</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>
Results – Biocomposite - Color

- higher fiber content = higher ΔE
- higher molding temperature = higher ΔE
- higher molding pressure = higher ΔE
- higher fiber content increases density
- flax fiber density > HDPE
Results - Water Absorption Test

- higher fiber loading increases water absorption
- higher fiber loading (20%) increases tensile strength
- Low temperature = higher tensile strength
- Young’s modulus (YM) increases with higher fiber loading
- Flax reinforcement resulted in 142% increase in YM
- Low temperature = higher YM
- Higher fiber loading (20%) increases flexural strength
- Low temperature = higher flexural strength
Conclusions

- Flax fiber served as reinforcement.
- Increase in fiber loading increases the composite color, density, and water absorption.
- Tensile and bending strength increased with increase in fiber loading, but decreased after 20% fiber loading.
- Young’s modulus showed a continuous and significant increase with increase in fiber loading.
- HDPE biocomposites have better mechanical properties for lower molding temperature.
THANK YOU