SUSTAINABLE COMPOSITES BASED ON POLYAMIDES AND CELLULOSE FIBERS

Alper Kiziltas and Ellen C. Lee

Materials Research and Advanced Engineering, Ford Motor Company, Dearborn, Michigan 48121, USA

SPE Automotive Composites Conference & Exhibition (ACCE) - September 9-11, 2014
Ford’s Sustainable Materials Strategy

- **Vision**
  - Ford Motor Company will ensure that our products are engineered to enable sustainable materials leadership without compromise to Product Quality, Durability, Performance or Economics.

- **Key Positions**
  - Recycled and renewable materials must be selected whenever technically and economically feasible.
  - When we use recycled and renewable materials, there will be no compromise to Product Quality, Durability & Performance or Economics.
  - We will enhance technologies, tools and enablers to help validate, select and track the use of these materials in our products.
  - The use of recycled and renewable content is increased year by year, model by model where possible.
Sustainable Materials at Ford Today

“Henry Ford (the founder of Ford) was first to introduce bio-based materials (soy-bean products) to automobiles in 1940. Continuing the legacy, Ford has been actively involved in conducting active renewable materials research and development program.”

“The average Ford vehicle now uses between 20 to 40 pounds of renewable materials.”

“Ford use more than 50 million pounds of post-consumer recycled materials on the exterior of Ford vehicles made in NA, which translates to more than 17.8 pounds per vehicle on average across our NA fleet.”

“We're making changes to reduce our environmental footprint. In addition to reducing our greenhouse gas emissions, supporting conservation efforts and making more fuel-efficient vehicles, we're also improving the materials we use to build our vehicles.”

Alper Kiziltas, Ph.D. Research Scientist
Ford Research and Innovation Center
Plastic Research Group
Email: akizilt1@ford.com
Project Overview

➢ Background
  ✓ Promising cellulose-polymer concept from cellulose and bio-based nylon.
  ✓ Fully or partially bio-based
  ✓ Good mechanical properties
  ✓ Perceived naturalness

➢ Challenges
  ✓ Lack of viable industrial production methods to make end consumer products
  ✓ Degradation and odor

➢ Objective
  ✓ Development of a processing technology that allows to make injection molded parts out of cellulose and nylon but keeping material bio identity.
Background-Bio-Based Polymer

- Limited fossil resources, increased cost of fossil resources and public concern about climate change are significant drivers.

- The bio-based polymer business is 0.4% of the total polymer.

- Bio-based polymers not only replace existing polymers in a number of applications, but also provide new combinations of properties for new applications.

Endres, Hans-Josef and Siebert-Raths, Andrea 2011
What is Bio-Based Nylon?

- High bio content,
- Significant reduction of CO2 emissions,
- Polymers with strong properties,
- True alternatives to crude oil based Engineering Plastics,
- Fully recyclable polymers,
- Non-biodegradable and durable polymers.

http://www.biyoplastik.net/
Why Nylon 1010?

- Very high bio content up to 99% (Grilamid 1S PA1010),
- Properties similar to PA12,
- Very low moisture absorption,
- Strong UV and chemical resistance,
- For injection molding and extrusion,
- Low melting temperature compared to other bio-based nylons.
### Formulations

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Compounding</th>
<th>PA1010</th>
<th>PA610</th>
<th>PA6</th>
<th>Cellulose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TSE</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>TSE</td>
<td>-</td>
<td>100</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>TSE</td>
<td>-</td>
<td>-</td>
<td>100</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>TSE</td>
<td>50</td>
<td>50</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>TSE</td>
<td>50</td>
<td>-</td>
<td>50</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>TSE+MB</td>
<td>90</td>
<td>-</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td>7</td>
<td>TSE+MB</td>
<td>80</td>
<td>-</td>
<td>-</td>
<td>20</td>
</tr>
<tr>
<td>8</td>
<td>TSE+MB</td>
<td>70</td>
<td>-</td>
<td>-</td>
<td>30</td>
</tr>
<tr>
<td>9</td>
<td>TSE+MB</td>
<td>-</td>
<td>90</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>TSE+MB</td>
<td>-</td>
<td>80</td>
<td>-</td>
<td>20</td>
</tr>
<tr>
<td>11</td>
<td>TSE+MB</td>
<td>-</td>
<td>70</td>
<td>-</td>
<td>30</td>
</tr>
<tr>
<td>12</td>
<td>TSE+MB</td>
<td>40</td>
<td>40</td>
<td>-</td>
<td>20</td>
</tr>
<tr>
<td>13</td>
<td>TSE+MB</td>
<td>40</td>
<td>-</td>
<td>40</td>
<td>20</td>
</tr>
</tbody>
</table>
Production – TSE and IM

Cellulose
PA6/PA610/PA1010

Melt Blend
TSE

Dry Ground
Mixture

Injection
Molding

ASTM Test
Samples
## Temperatures Profiles for Composites (°C)

<table>
<thead>
<tr>
<th></th>
<th>TSE</th>
<th>IM</th>
<th></th>
<th>TSE</th>
<th>IM</th>
<th></th>
<th>TSE</th>
<th>IM</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA1010</td>
<td>195</td>
<td>235</td>
<td>195</td>
<td>240</td>
<td>200</td>
<td>245</td>
<td>200</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>250</td>
<td>205</td>
<td>250</td>
<td>205</td>
<td>250</td>
<td>210</td>
<td></td>
</tr>
<tr>
<td>PA610</td>
<td>215</td>
<td>240</td>
<td>215</td>
<td>245</td>
<td>220</td>
<td>250</td>
<td>220</td>
<td>255</td>
</tr>
<tr>
<td></td>
<td>225</td>
<td>260</td>
<td>225</td>
<td></td>
<td>225</td>
<td></td>
<td>230</td>
<td></td>
</tr>
<tr>
<td>PA6</td>
<td>215</td>
<td>235</td>
<td>215</td>
<td>240</td>
<td>220</td>
<td>245</td>
<td>220</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>225</td>
<td>250</td>
<td>225</td>
<td></td>
<td>225</td>
<td></td>
<td>230</td>
<td></td>
</tr>
</tbody>
</table>

**TSE Screw Speed:** 200rpm
Impact Strength of Composites

Increased cellulose loading has a negative effect on impact strength.
Impact Strength of Blends and Composites

Impact Strength (J/m)

- PA1010
- PA610
- PA6
- PA1010+PA6
- PA1010+PA610
- PA1010+PA6+20%CELL
- PA1010+PA610+20%CELL
Tensile Strength of Composites

Increased cellulose loading has a positive effect on tensile strength.
Tensile Strength of Blends and Composites

![Bar chart showing tensile strength of different polymer blends and composites.]

- PA1010
- PA610
- PA6
- PA1010+PA6
- PA1010+PA610
- PA1010+PA6+20%CELL
- PA1010+PA610+20%CELL

Tensile Strength (MPa)

30 40 50 60 70
Strain at the Max. Load of Composites

- The elongation at break of composites was shorter than neat composites.
Strain at the Max. Load of Blends and Composites

Strain at the Maximum Load (%)

- PA1010
- PA610
- PA6
- PA1010+PA6
- PA1010+PA610
- PA1010+PA6+20%CELL
- PA1010+PA610+20%CELL
Young Modulus of Composites

- MOE increased with the addition of cellulose. The increase in MOE is only to the reinforcement effect of dispersed cellulose.
Young Modulus of Blends and ETPCs

![Bar chart showing the Young Modulus (GPa) for different blends and ETPCs.]

- Young Modulus (GPa):
  - 1.5
  - 2.0
  - 2.5
  - 3.0
  - 3.5
  - 4.0

Blends and ETPCs:
- PA1010
- PA610
- PA6
- PA1010+PA6
- PA1010+PA6+20%CELL
- PA1010+PA610
- PA1010+PA610+20%CELL
Flexural Strength of Composites

![Graph showing flexural strength of composites with different filler loadings.](image-url)
Flexural Strength of Blends and Composites

![Bar chart showing flexural strength (MPa) for different blends and composites.]

- PA1010
- PA610
- PA6
- PA1010+PA6
- PA1010+PA610
- PA1010+PA6+20%CELL
- PA1010+PA610+20%CELL
MOE increased with the addition of cellulose. The increase in MOE is only to the reinforcement effect of dispersed cellulose.
FMOE of Blends and Composites

Flexural Modulus of Elasticity (MPa)

- PA1010
- PA610
- PA6
- PA1010+PA6
- PA1010+PA610
- PA1010+PA6+20%CELL
- PA1010+PA610+20%CELL
Expected Impact and Target Groups

Novel cellulose reinforced composite

- 100% bio-based composite (PA 1010 & cellulose)
- Injection molding

Significantly increasing of using cellulose reinforced biopolymers

- Open up the market of consumer products
- High efficient processing technology (IM)
- High-quality products
- Light-weight, natural perception
- Good eco-balance

Potential Applications in Automotive Industry

- Air Cleaner Housing, Air duct, Air inlet manifold
- Air ventilation, Air Resonator, Air Injector
Ongoing Studies

- SEM for dispersion properties.
- Viscoelastic properties of composites using DMTA.
- Rotational rheometer for rheology study.
- Heat ageing studies.
Acknowledgements

- Ellen Lee
- Debbie Mielewski
- Giuseppe Lacaria
- Till Skoerde
THANKS FOR YOUR ATTENTION!