Products from Post-Consumer Carpet

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Outline

• Georgia Tech and Georgia Composites
• Glass Fiber Composites
• Wood Fiber Composites
• Bracket Demonstration Product
• Additional Products
• Conclusions

• Catalytic pyrolysis/depolymerization
Georgia Tech’s Role

• CCACTI project:
  – Products from Post-consumer carpet
    • Focus on reinforced composites
    • Determine properties and processing routes
    • Identify and assess applications
  – Use processing and testing facilities in the Center for Polymer Processing
Georgia Composite’s Role

• CARE Project:
  – Molded Products containing Post-Consumer Carpet
    • Screen applications
    • Demonstrate molding of viable candidates
    • Commercialize molded products
Georgia Composites Background

• Georgia Tech start-up
  – Initial technology from Muzzy in 1997
• Eleison Composites, Inc has majority stake
  – As of April, 2006
• Primary product is GcompR
  – Mostly glass mat reinforced recycled polypropylene
SUV Load Floor

Decorative Carpet (PP)
Top Reinforcing Skin (Gcomp)
Internal Core Layer (PP)
Bottom Reinforcing Skin (Gcomp)

Molded by Cadence-USA
(previously Venture Industries)
SUV Load Floor
Load Floor in SUV
Jeep Grand Cherokee
## Why Reinforce PCC?

Fibers dominate properties (99 %) (GPa)

<table>
<thead>
<tr>
<th></th>
<th>Thermoplastic</th>
<th>Glass Fiber</th>
<th>Composite 60 vol %, unidirectional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile Strength</td>
<td>0.05</td>
<td>3.5</td>
<td>2</td>
</tr>
<tr>
<td>Modulus</td>
<td>2</td>
<td>70</td>
<td>40</td>
</tr>
</tbody>
</table>
Why Long Fiber?

- Impact Strength increases with fiber length
- Avoid fiber breakage
  - Requires use of low shear extruders

![Graph showing the impact strength increases with fiber length from 1 to 100 mm.](image.png)
Approach: Do only easy separation

- Sort carpet by face fiber
  => process entire carpet
  => pellets with mixed polymers
  - Suitable for low cost, high volume processing
  - Low properties due to incompatibility between nylon & PP?
  - May improve properties by using compatibilizers AND/OR fiber reinforcement
Glass Fiber Reinforced PCC status

- Glass mat reinforced PCC has good mechanical properties
- Evaluating extrusion compounding
- Demonstrating coupling extrusion compounding with compression molding
Wood Fiber vs Glass Fiber Composites

• Advantages
  – Cheaper
  – Renewable
  – Lower density
  – Less abrasive
  – More durable

• Disadvantages
  – Lower strength
  – Lower modulus
  – Hard to disperse
  – Low aspect ratio
  – Degradation
Wood Pulp Composite Status/Plans

- PP and N6 composites promising
- N66 needs work (less time at high temp.)
- Couple extrusion and molding (less time at high temp.)
- Find feeders for pulps and shredded carpets
Integrated Process Scheme

PC Carpet → Sort → Shred → Compact

Melt → Devolutilize → Compound → Extrude

Adsorb → Waste

Compression Mold → Molded Products

Dirt and CaCO₃ → Additives and Reinforcements

Extruded Products
Lab Demonstration

Cross-section of twin screw

25 mm rod die

NFM Welding Engineers
30 mm twin screw design

Hopper
Vent
Glass Feed Vent
Glass Feeding
Chopper Feed

Glass Roving

Chopper Gun (motorized)

Hopper
Extruded Charge (RPET)
Molding Z Base Bracket

Hot Log from Extruder
Brackets from PCC / Chopped Glass

PP PCC + 20 wt % 1/2” GF

N6 PCC + 20 wt % 1” GF
Bracket Outside, RPET/Wood Flour
Bracket Economics

- Raw materials: $0.30/lb or $0.50/bracket set
- Need 4 presses and molds for one 30 mm extruder
- Make 450,000 bracket sets/yr (760,000 lb/yr)
- Break-even selling price $2.10 / bracket set
- Assessment:
  - Feasible
  - Try wood fibers instead of glass fibers
  - Look for bigger products
    - Better for larger extruders and larger parts
Composite applications

• Brackets (just covered)
Everything that follows is > than 10 lbs/part
• Truck accessories
  – Tool boxes
• Manhole covers
• Car components
  – Bumpers
• Shipping
  – Pallets
  – Containers
• Building Elements
  – Structural lumber
  – Ramps
Conclusions

• PP, N6 and N66 PCC successfully reprocessed and tested
  – Shredded carpet repelletized
  – Pellets injection molded with good properties
  – Glass mat composites compression molded with commercially attractive properties

• Wood fiber reinforcement feasible for PP and N6 PCC
  – Need better equipment to gain benefits of fiber length, improve dispersion and to process N66 PCC
Conclusions

• Integrated extrusion-molding demonstrated with Z base garment rack bracket
• High volume applications identified
  – Pallets, structural lumber, bumpers, truck accessories
  – Large parts preferable for integrated process
• Commercialization feasible
Work in progress

• Further demonstration of bracket molding
  – Field testing of brackets
• Integrated extrusion-compression molding of test plaques
  – Wood and glass fibers
  – Fiber lengths and distributions
  – Properties
• Candidate Products
• Exploring Commercialization
Catalytic Pyrolysis of PCC

Objectives

• Recover monomers from carpet
  – first: caprolactam from nylon 6
  – Catalytic depolymerization

• Recover liquid mixtures for refining and fuel use
  – first: low molecular weight hydrocarbons from polypropylene
  – Catalytic pyrolysis
**Approach**

- Catalytic depolymerization/pyrolysis
  - Faster reactions
  - More selective
  - Lower temperature operation

- Extruder/Reactor
  - Multi-purpose
    - Compounding → Composite products from post consumer carpet
    - Compounding (plus catalyst, co-reactant) → Monomers and chemicals
Approach (cont.)

- Extruder/Reactor
  - Potentially low cost
    - High volume extrusion compounding around 10 cents per pound
  - Suitable for low or high volumes
    - Operate close to recycled carpet sources
    - Ship crude products to refiners
    - Minimize transportation costs
  - Well suited for intended application
Extruder Design for Depolymerization/Pyrolysis

- Volatiles are the desired products
- Recover volatiles quickly to avoid further degradation
- Volatiles also recovered from extrudate stream
Nylon 6 summary

• Caprolactam yields not known
  – Expect > 90%
• KOH and K₂CO₃ catalysts are effective at 1 %
  – Don’t need catalyst recovery system
• Can operate below 400 °C
• Can depolymerize in < 10 minutes
• Process looks economically attractive
• Pilot extrusion runs this summer
Polyolefin summary

- Waste zeolite catalysts from petroleum refining work well for PE and PP
  - Very inexpensive catalysts
- Post-consumer carpet appears to be inherently catalyzed for pyrolysis
- Polyolefins still require temperatures above 400 C for fast pyrolysis
- Expected products are gas and liquid hydrocarbons suitable for a refinery
- May not be profitable (whereas nylon 6 to caprolactam looks profitable)
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