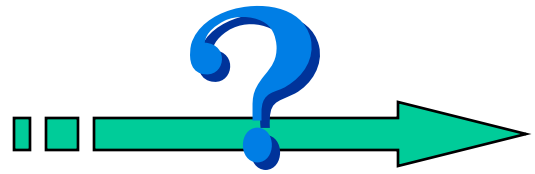
Products from Post-Consumer Carpet

John Muzzy, Georgia Tech
Richard Simmons, Georgia Composites & Eleison Composites

CARE Conference
May 2, 2006
Callaway Gardens



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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

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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

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Georgia Composite's Role

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

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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 Gcomp^{R}
  - Mostly glass mat reinforced recycled polypropylene

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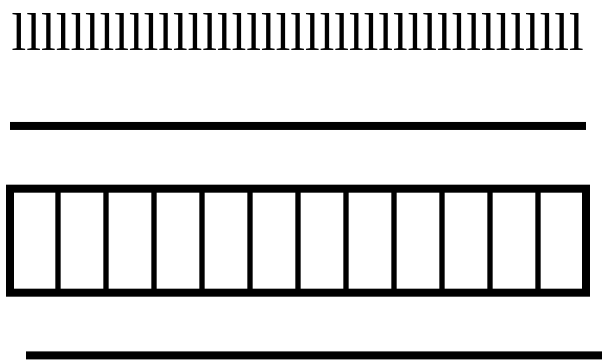
SUV Load Floor

Decorative Carpet (PP)

Top Reinforcing Skin (Gcomp)

Internal Core Layer (PP)

Bottom Reinforcing Skin (Gcomp)



Molded by Cadence-USA
(previously Venture Industries)

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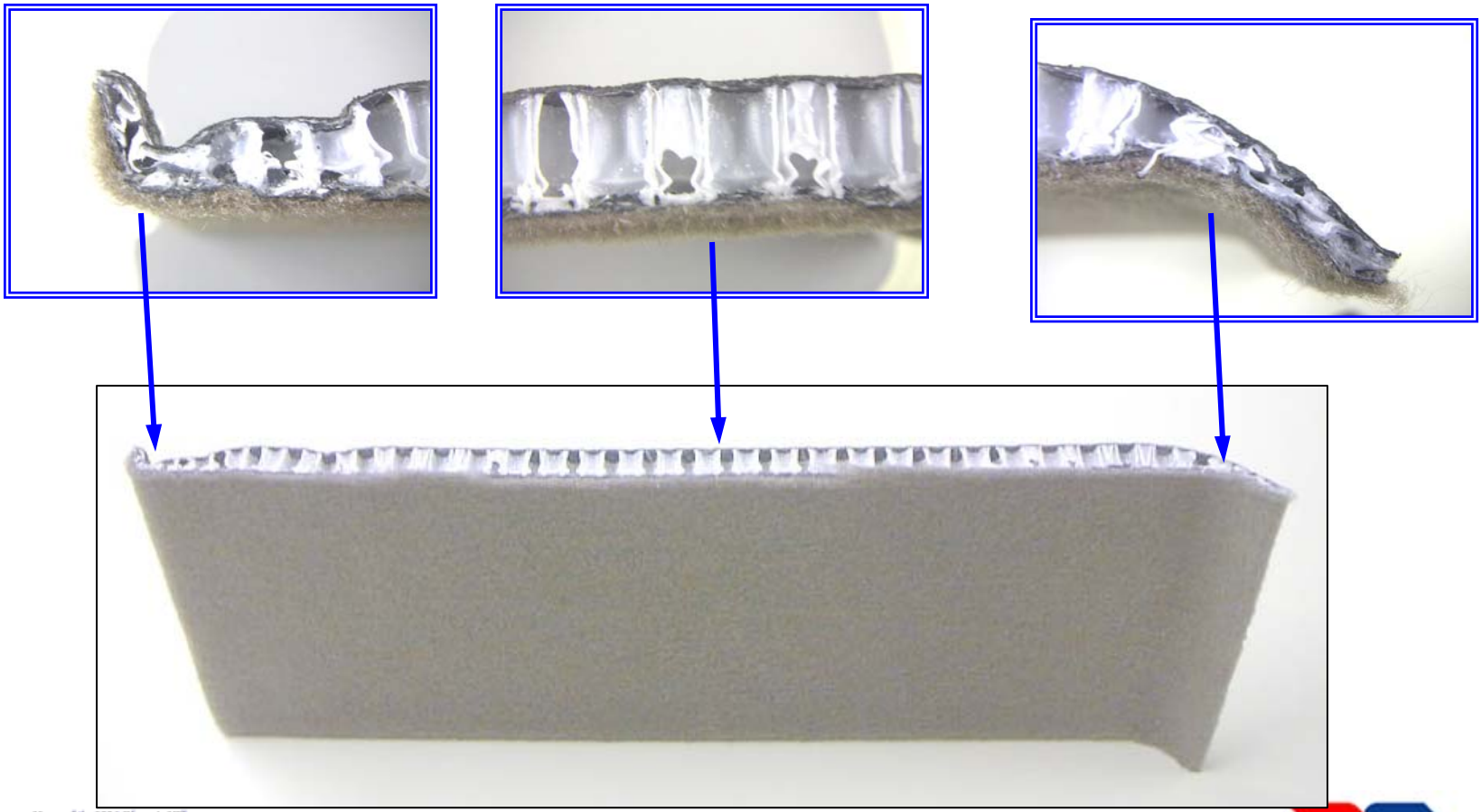

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Load Floor in SUV
Jeep Grand Cherokee

Why Reinforce PCC?

Fibers dominate properties (99 %) (GPa)

	Thermoplastic	Glass Fiber	Composite 60 vol %, unidirectional
Tensile Strength	0.05	3.5	2
Modulus	2	70	40

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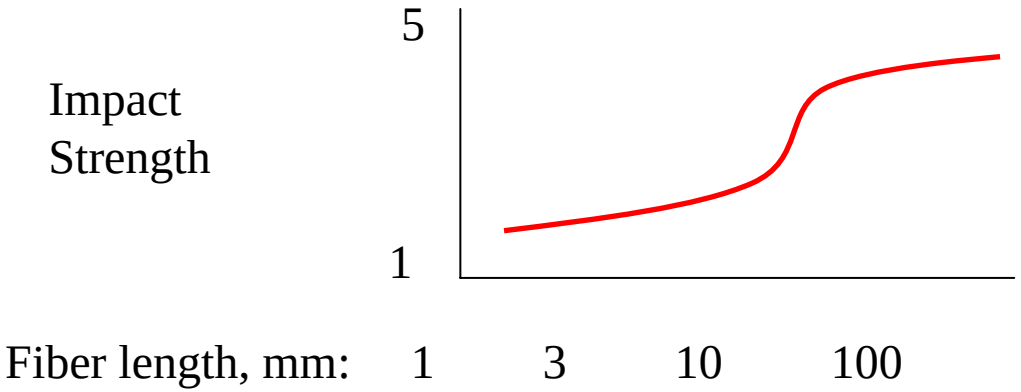
Why Long Fiber?

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



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

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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

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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

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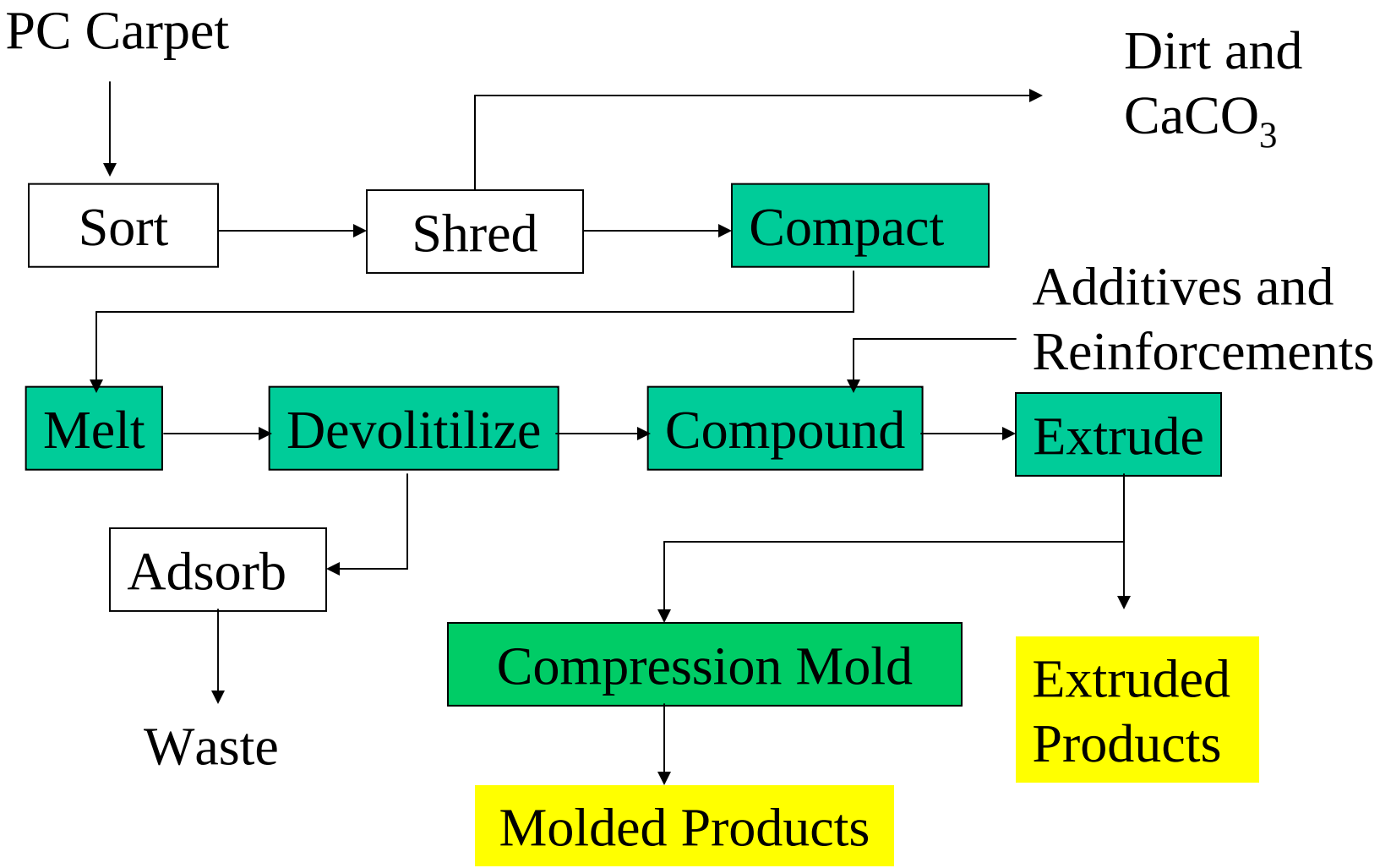
Integrated Process Scheme



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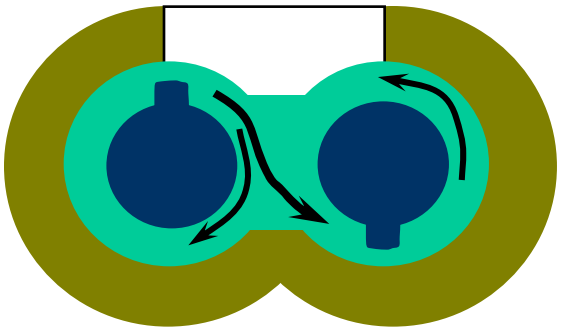
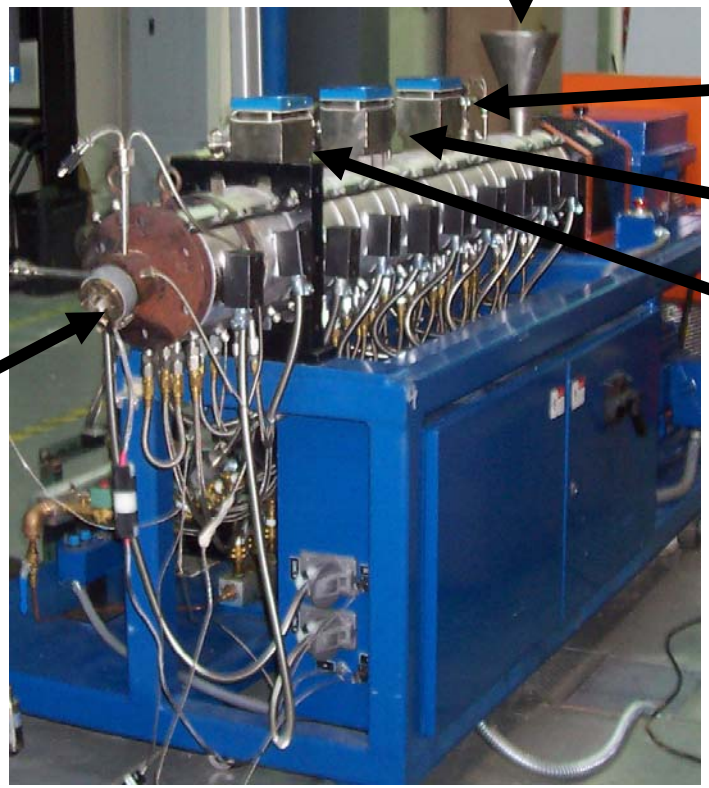
Lab Demonstration

Cross - section
of twin screw



25 mm rod die



NFM Welding Engineers
30 mm twin screw design

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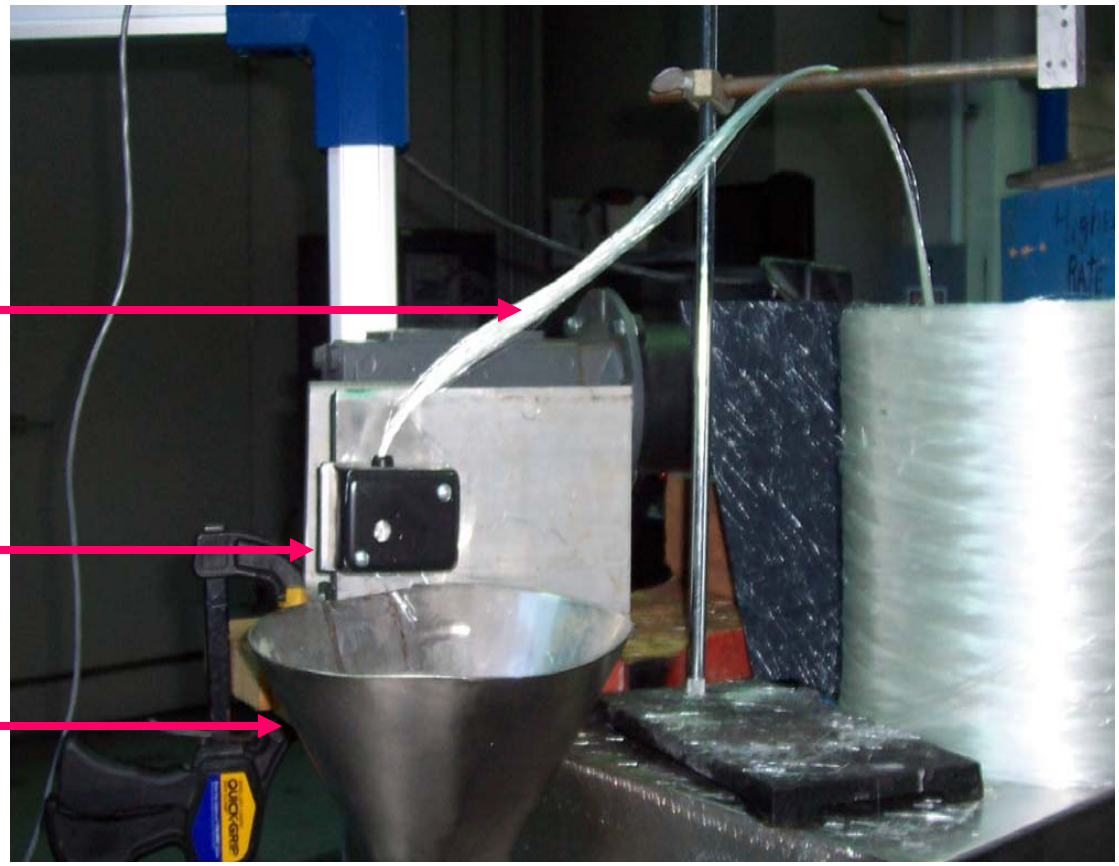
Glass Feeding

Chopper Feed

Glass Roving

Chopper Gun
(motorized)

Hopper



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Extruded Charge (RPET)

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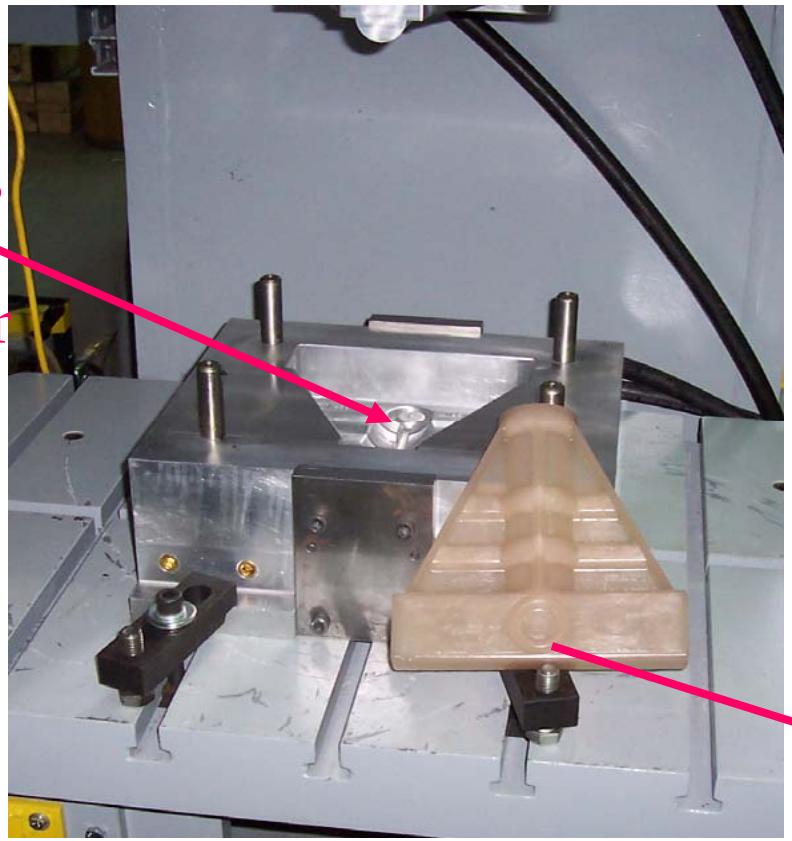
Molding Z Base Bracket

Hot Log from Extruder



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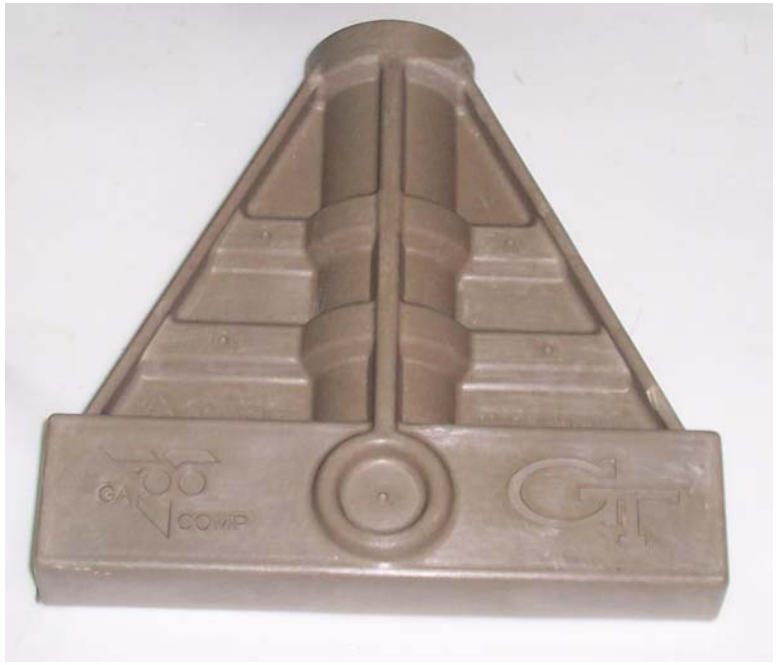
Brackets from PCC / Chopped Glass



PP PCC + 20 wt % 1/2” GF

N6 PCC + 20 wt % 1” GF

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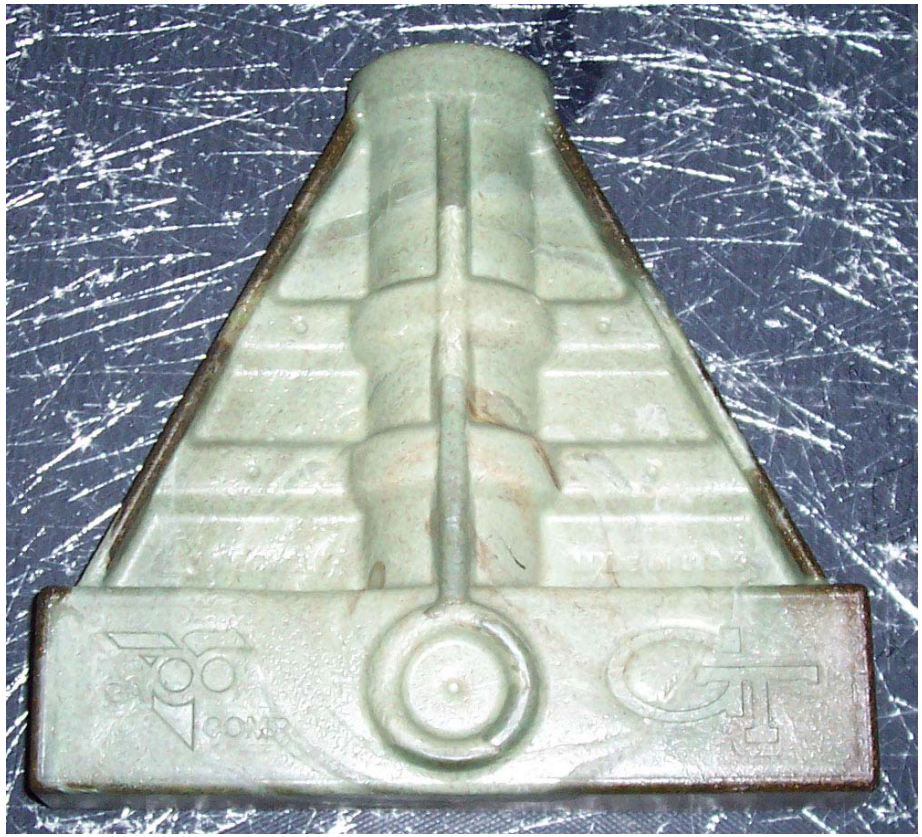
Bracket Outside, RPET/Wood Flour



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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

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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

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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

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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

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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

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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

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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

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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

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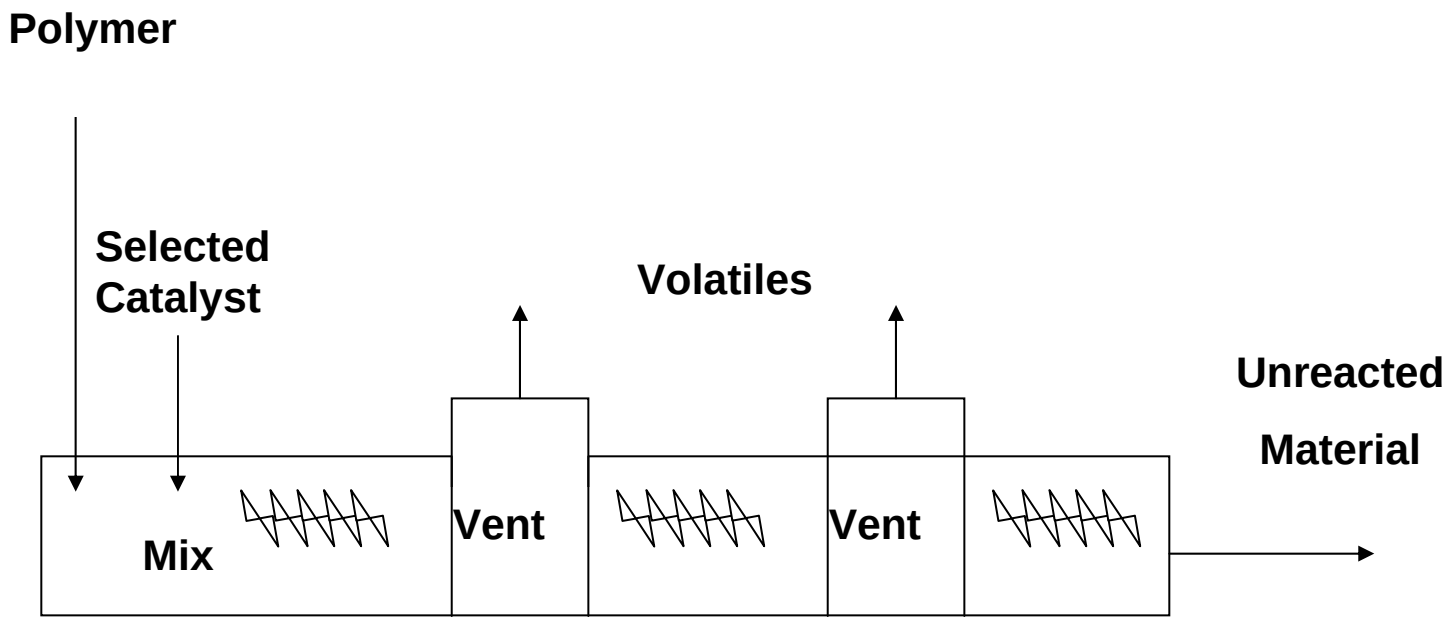
Extruder Design for Depolymerization/Pyrolysis



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

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Nylon 6 summary

- Caprolactam yields not known
  - Expect > 90 %
- KOH and K_2CO_3 catalysts are effective at 1 %
  - Don't need catalyst recovery system
- Can operate below 400 ^oC
- Can depolymerize in < 10 minutes
- Process looks economically attractive
- Pilot extrusion runs this summer

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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)

Acknowledgements

- Project support
  - Funding from Georgia TIP - CCACTI program and GT IPST Exploratory Grant
  - Wellman, Inc (Shredded PCC carpet, pellets)
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  - Invista

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