

Composite Products from Post-Consumer Carpet

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CARE Conference

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Callaway Gardens



Outline

- Georgia Tech and Georgia Composites
- Glass Fiber Composites
- Wood Fiber Composites
- Bracket Demonstration Product
- Additional Products
- Conclusions
- Future work

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

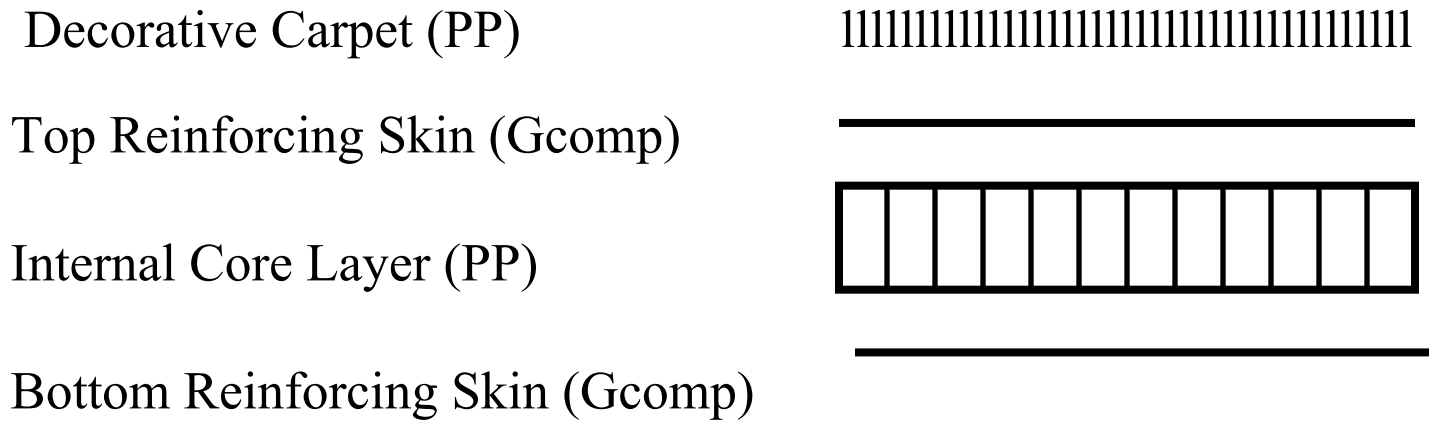
Georgia Composite's Role

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

Georgia Composites Background

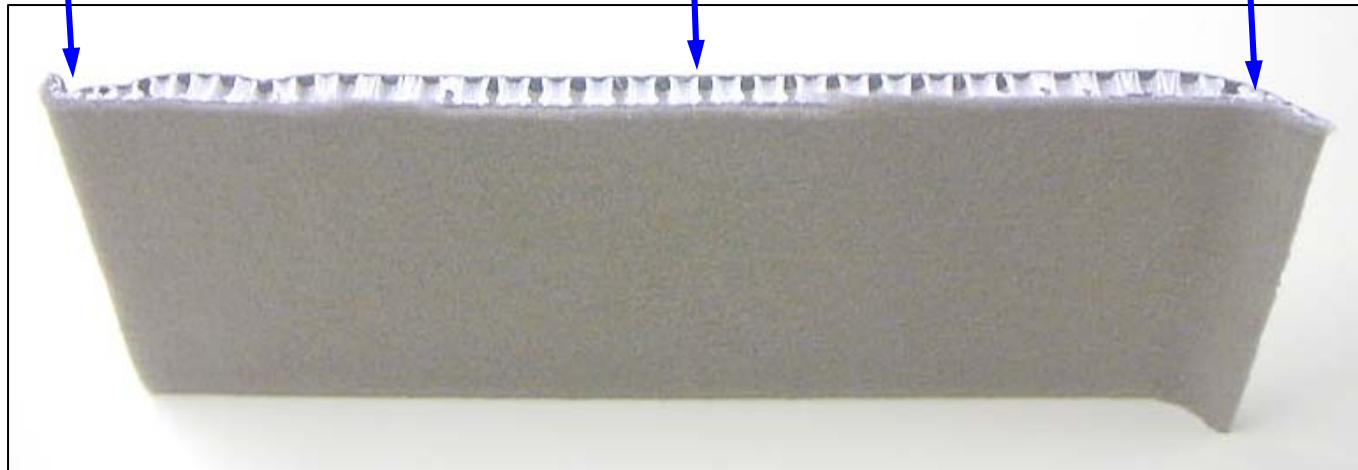
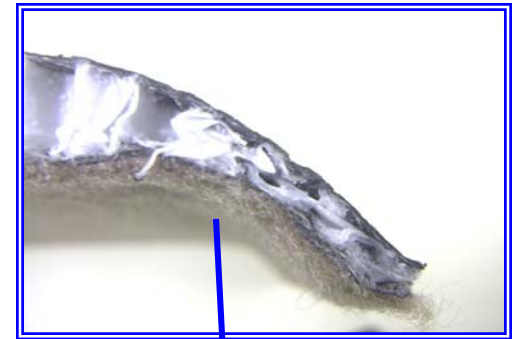
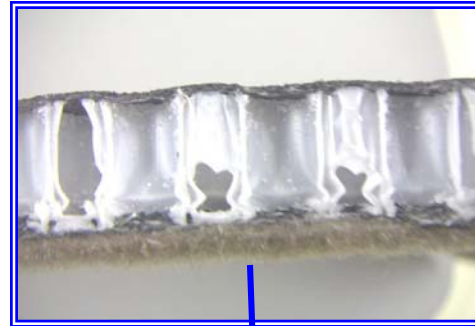
- Georgia Tech start-up
 - Initial technology from Muzzy in 1997
- Eleison Composites, LLC has majority stake
 - As of April, 2005
- Primary product is Gcomp^R
 - Mostly glass mat reinforced recycled polypropylene

SUV Load Floor



Molded by Venture Industries

SUV Load Floor



Load Floor in SUV Jeep Grand Cherokee



Challenges & opportunities

- 4 billion lbs per year of carpet waste is landfilled
- Industry initiative, CARE, set a goal to divert 40%, or recycle 1.5 billion lbs per year in 7 years (2012)
- What's needed
 - Diversified technologies, products & commercial activities
 - Large volume, cost-effective applications

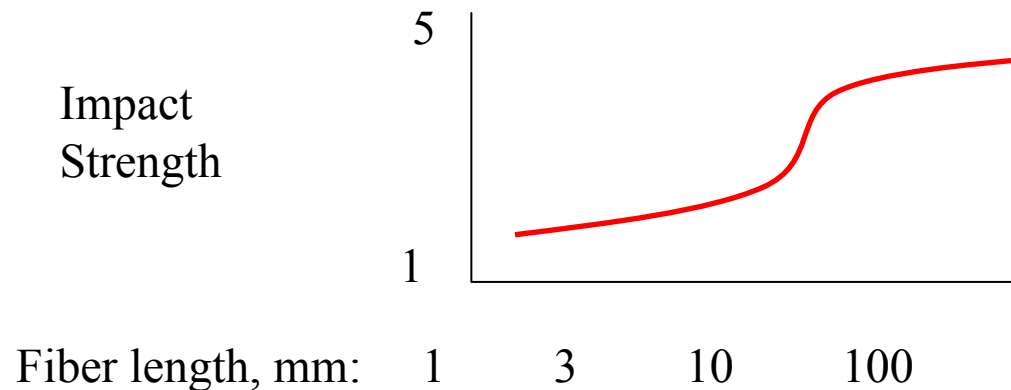
Why Reinforce PCC?

Fibers dominate properties (99 %) (GPa)

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

Why Long Fiber?

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

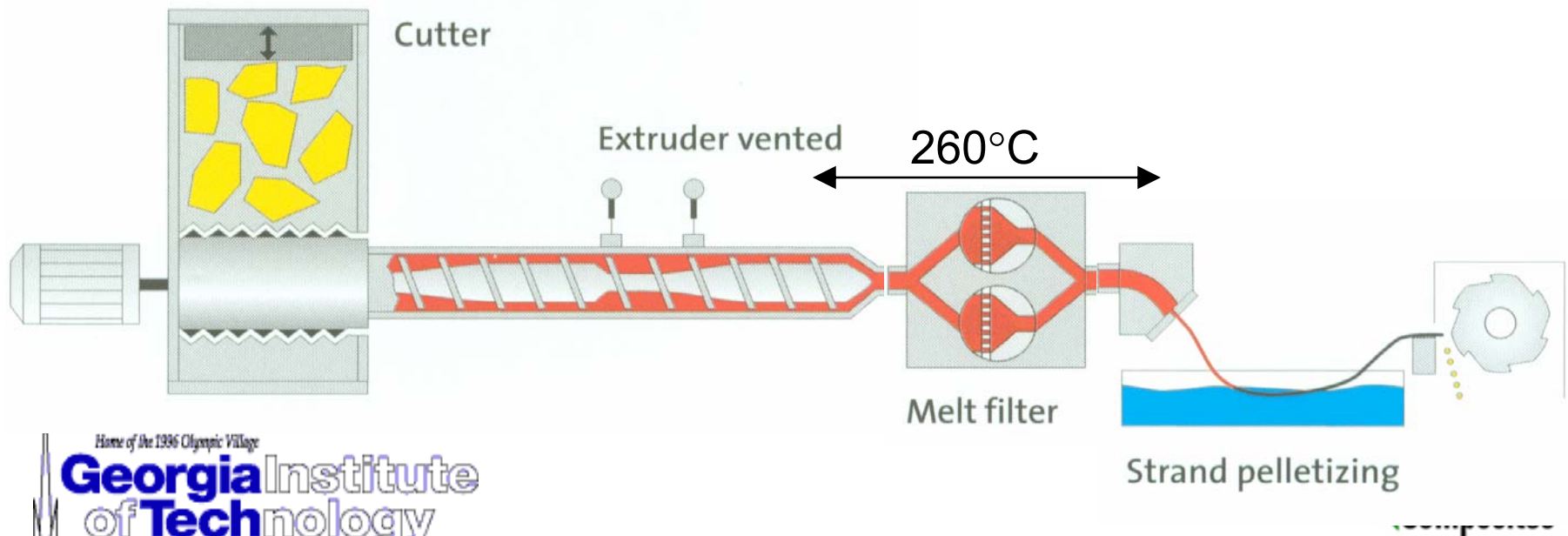


Approach: Do only easy separation

- 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

Pelletizing Shredded Carpet

- Shredded carpet (separated by face fiber)
 - Courtesy of Wellman, Inc.
- Pelletized using NGR A-Class Type 55 Repelletizing System
 - Some provided by Wellman, Inc.



High Face Fiber Contents in NGR pellets from shredded PCC

Weight % via DSC

	PP	N6	N66	Remainder
PP PCC	84	9	0	7
N6 PCC	11	77	0	12
N66 PCC	8	0	81	11

- Significant loss of SBR, calcium carbonate and dirt in shredded PCC
- N6 in PP PCC is an artifact from changeover
- DSC analytical technique quick and effective

Properties of Compression Molded Pellets of PCC Close to Neat Resins

PCC	Flexural Strength (MPa)	CV (%)	Flexural Modulus (GPa)	CV (%)	Drop Impact Strength (J@4.0 mm th)	CV (%)
PP	42	6.2	2.3	16.9	4	29.6
N6	70	16.2	2.7	3.7	4.9	39.7
N66	63	2.7	2.0	14.5	1.7	6.6

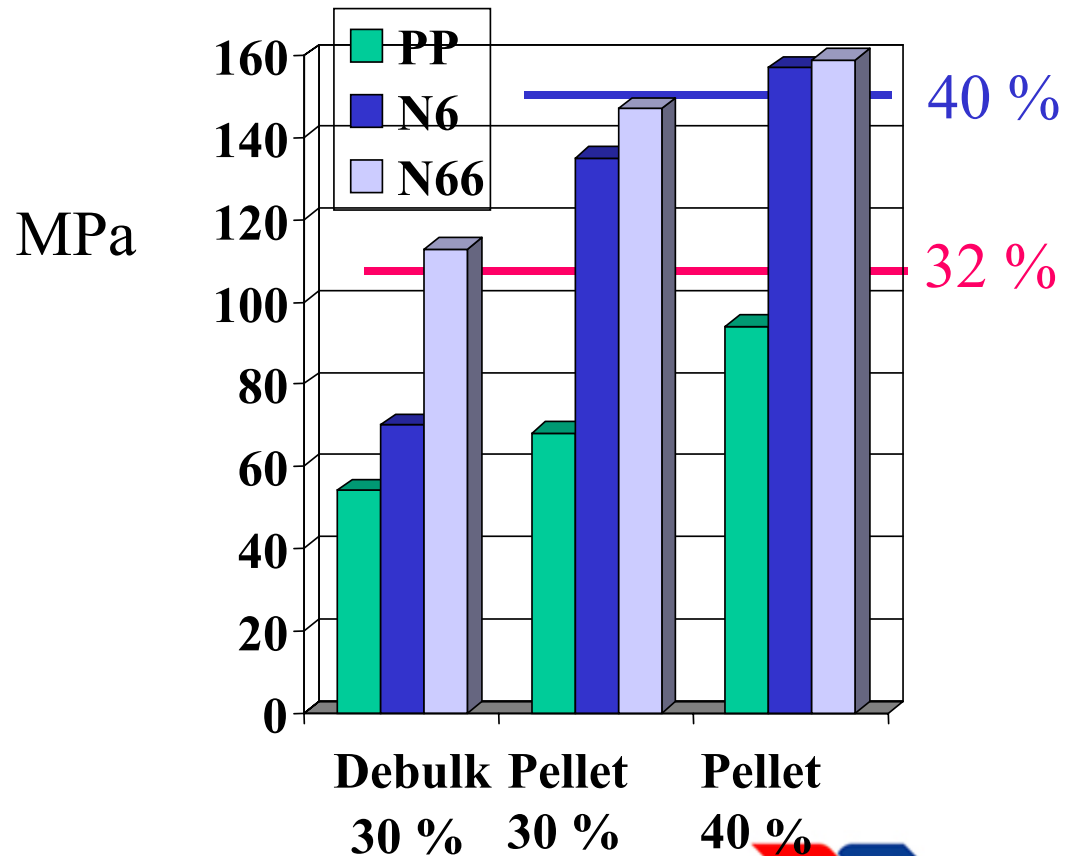
- Impact strengths low
- Note: 1 MPa = 145 psi, 1 GPa = 145,000 psi

Glass Fiber Mat Composite Preparation

- E-Glass mat from Eleison Composites, Brighton, MI
 - Weight=115 g/m², with about 10 wt% TP binder
- Shredded PCC debulked into thin mats
- PCC Pellets ground to coarse powder, **OR**
- Powder or debulked mats interleaved with mats in 30 x 30 cm mold
- Mold heated above PCC melt temperature at 0.1 MPa
- Pressure increased to 1.5 MPa during cooling

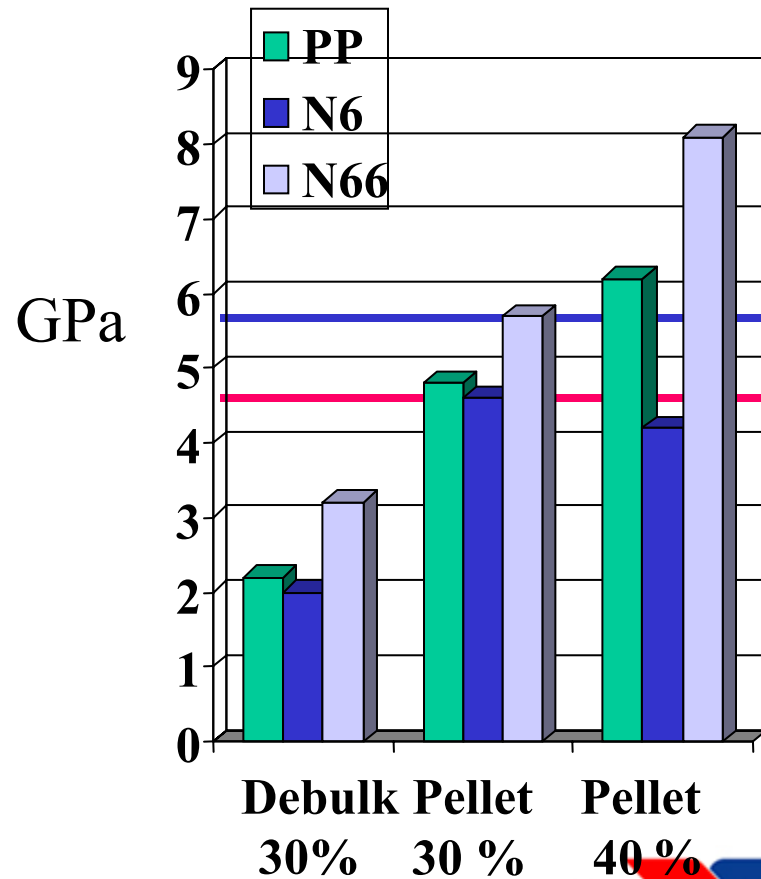
Flex Strength of Glass Mat PCC Composites Close to Commercial GMT

- Commercial GMT:
 - Azdel
 - 32 % : 104 MPa
 - 40 % : 146 MPa
- Nylon PCC better
- PP PCC probably needs an adhesion promoter
- Pellets better than Debulked



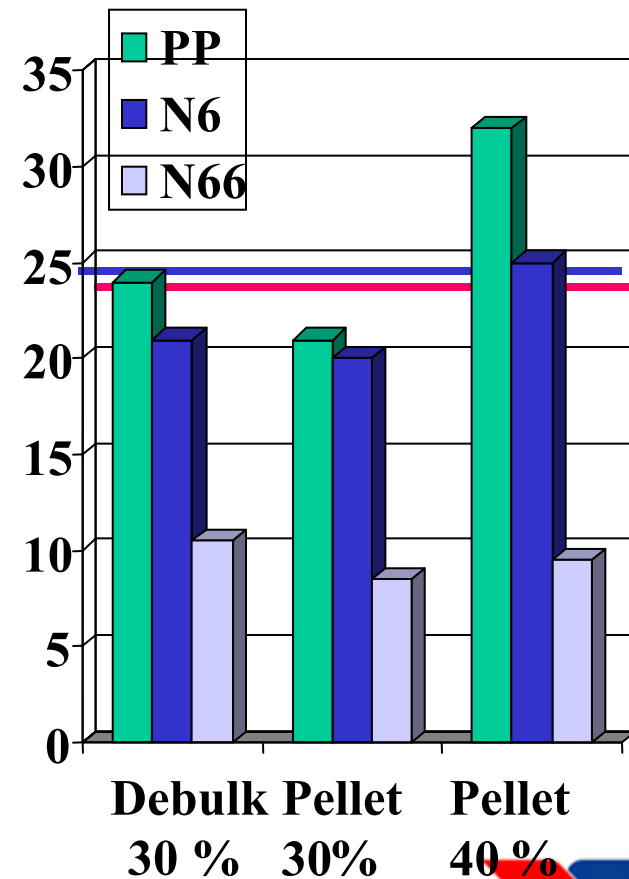
Flex Modulus of GMT from PCC similar to Commercial GMT

- Commercial GMT:
 - Azdel
 - 32 % : 4.6 GPa
 - 40 % : 5.5 GPa
- Nylon 66 PCC better
- Other PCC comparable
- Pellets > Debulk



Drop Impact Strength of GMT from PCC similar to Commercial GMT, J @ 4 mm thickness

- Commercial GMT:
 - Azdel
 - 32 % : 22.7 J @ 4 mm
 - 40 % : 23.7 J @ 4 mm
- PP and Nylon 6 PCC comparable
- N66 low (degradation)
- Debulking close to pellets



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 Fiber Processing

- Heat treatment of wood fibers
 - 1 hour, above matrix melt temp, N₂ purge
- Sizing of fibers
 - Polyurethane emulsion from Hydrosize Technologies
- Dry fibers and matrix
- Compounding and molding
 1. Batch mixer and compression mold
 2. Double injection mold
 - Dry blend, injection mold, grind, mold again
 - Less time at high temperature than # 1

PCC / Wood Flour Properties

(60 / 40 wt %)

Face Fiber	Heat treat	Sizing*	Flex Str.	Flex Mod.	Ten. Str.	Ten. Mod.
		%	MPa	GPa	MPa	GPa
PP/neat	-	-	31	0.9	22	2.0
PP/flour	Yes	No	20	3.2	18	2.4
PP/flour	Yes	3	29	3.4	23	2.6
N6/neat	-	-	40	1.0	36	2.0
N6/flour	Yes	No	78	2.4	40	2.7
N6/flour	Yes	3	66	1.5	44	3.2

* Polyurethane emulsion

Nylon 6 PCC/Pulp Properties

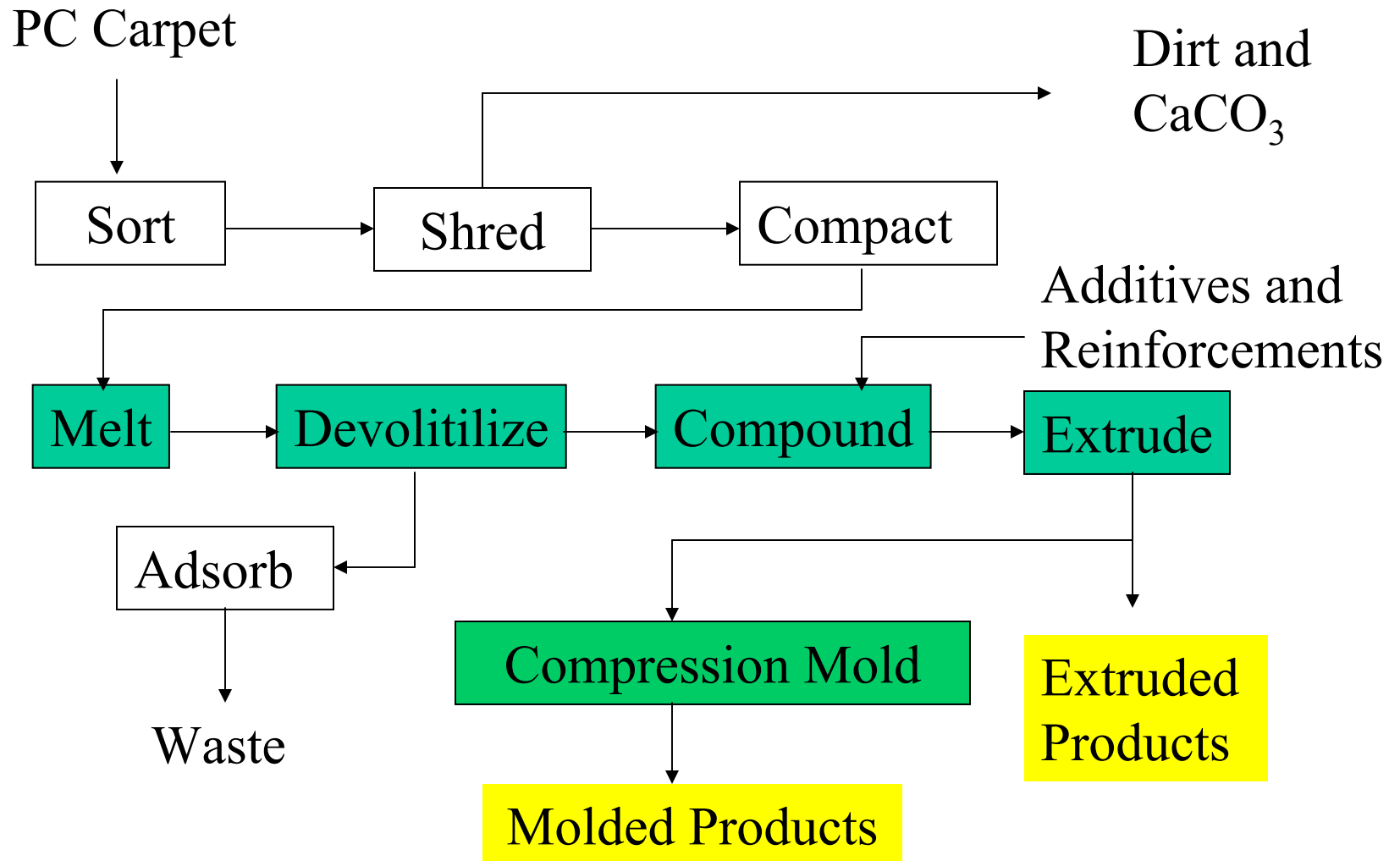
Pulp	Heat Treat	Sizing*	Flex Str.	Flex Mod.	Ten. Str.	Ten. Mod.
40 wt %		%	MPa	GPa	MPa	GPa
None	-	-	40	1.0	36	2.0
Flour	Yes	3	66	1.5	44	3.2
TMP	No	-	62	3.8	39	3.2
TMP	No	3	53	4.7	30	2.9
TMP	Yes	3	50	4.3	31	3.0
Kraft	No	3	46	3.5	40	2.9
Kraft	Yes	3	49	4.3	38	3.2
Newsprint	No	3	54	2.9	32	3.1

* Polyurethane emulsion

Wood Pulp Composite Status/Plans

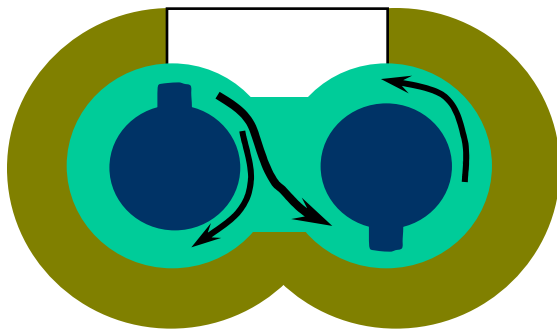
- PP and N6 composites promising
- N66 needs work (less time at high temp.)
- Scale up to 30 mm twin screw
- Couple extrusion and molding (less time at high temp.)
- Find feeders for pulps and shredded carpets

Integrated Process Scheme



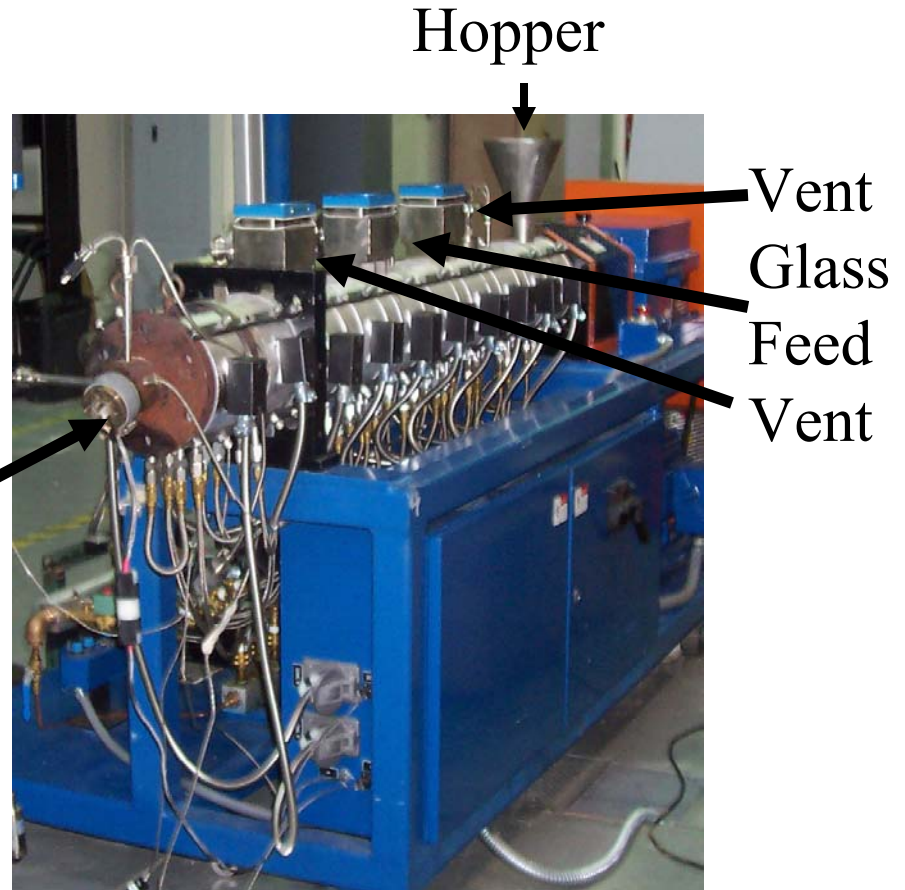
Lab Demonstration

Cross - section
of twin screw



25 mm rod die

NFM Welding Engineers
30 mm twin screw design



Glass Feeding

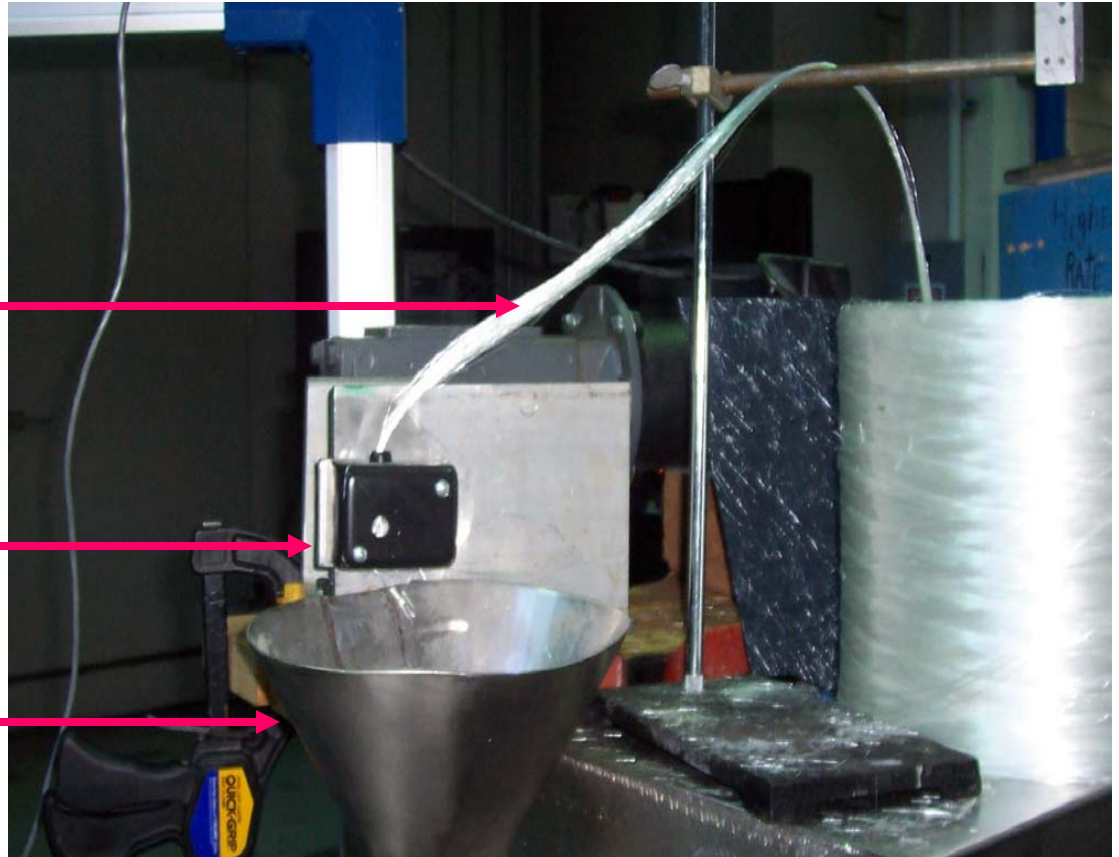


Chopper Feed

Glass Roving

Chopper Gun
(motorized)

Hopper

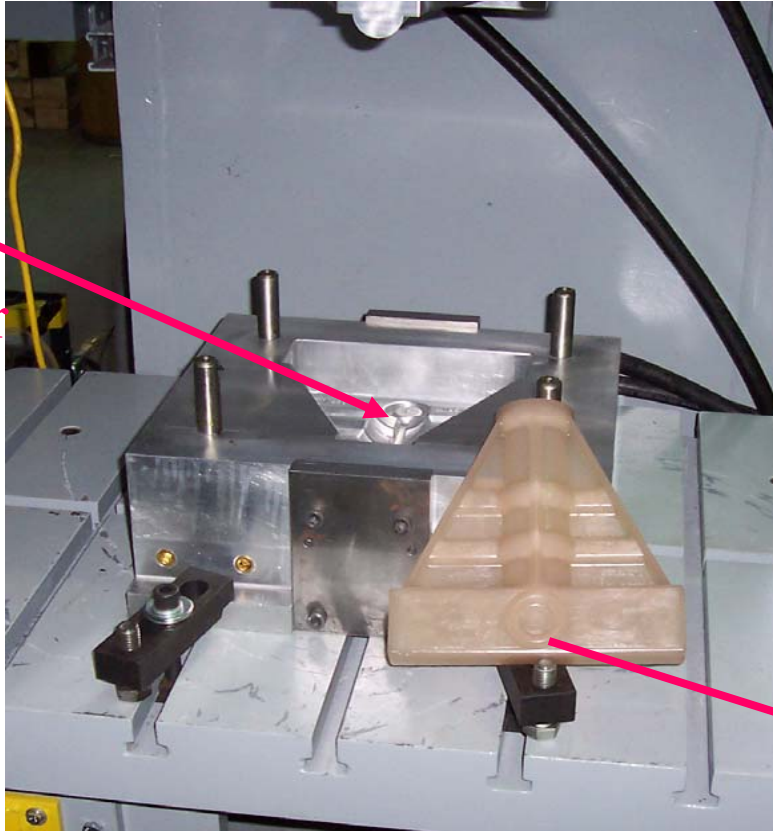


Extruded Charge



Molding Z Base Bracket

Hot Log
from
Extruder



Brackets from PCC / Chopped Glass

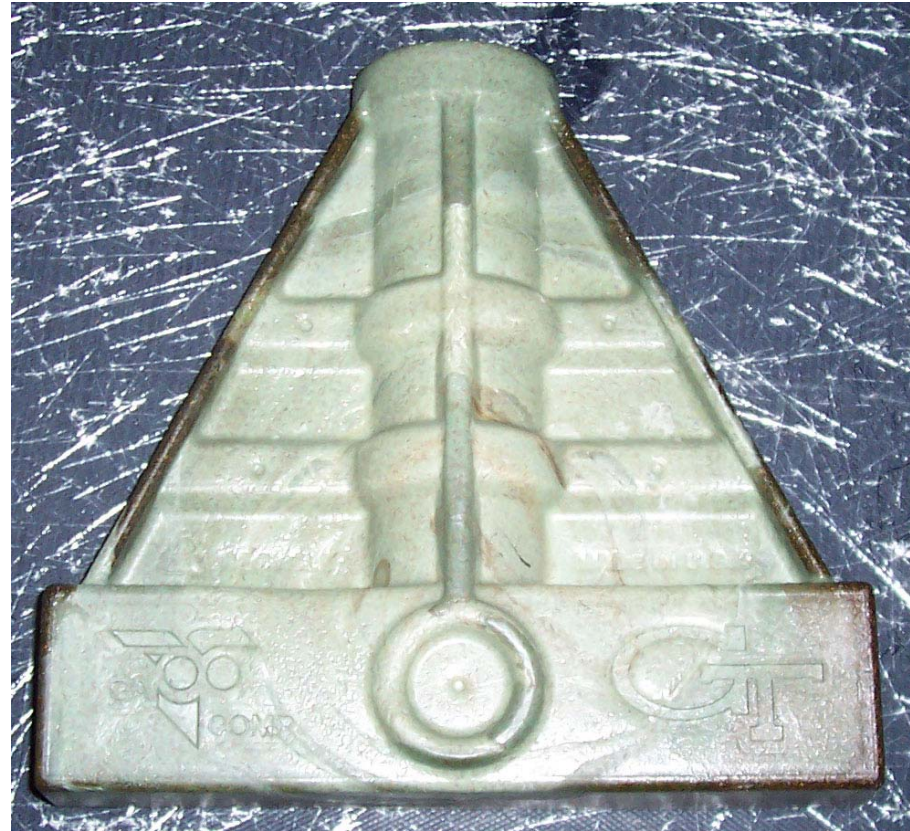


PP PCC + 20 wt % 1/2" GF



N6 PCC + 20 wt % 1" GF

Bracket Outside, PET/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

Acknowledgements

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 - Funding from Georgia TIP - CCACTI program and GT IPST Exploratory Grant
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