

# Combining Thermoplastics with Reinforcing Fibers

ver 1

## Outline

- Issues
- Approaches
  - Short Fibers
  - Long Fibers
  - Continuous Fibers
- Conclusions

## Issues

- Controlling fiber orientation
- Obtaining high fiber content
- Achieving good fiber wetting
- Preserving fiber length
- Avoiding polymer degradation

## Short Fiber Processes

- Extrusion Compounding Dominates
  - Benefits:
    - Low cost (< \$ 0.20 per kg)
    - High volume (> 100 kg/hour)
      - > 1 Billion kg/year
    - Available as “standard” pellets (3 mm length)

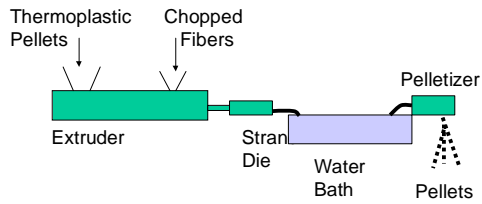
## Short Fiber Processes

- Extrusion Compounding Dominates
  - Limitations
    - Low fiber volume (< 30 vol % typically)
    - Random fiber orientation
    - Significant fiber breakage
      - Input: 3 mm fibers
      - Output: < 1mm fibers (but L/D still > 40)

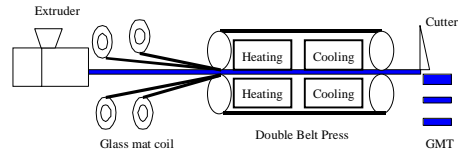
## Short Fiber Processes

- Extrusion Compounding Dominates
  - Typical results:
    - Modulus > 1.5 - 3 X
    - Tensile Strength > 1.5 - 3 X
    - Impact Strength often decreases
    - Heat Distortion Temperature
      - crystalline polymers much higher
      - amorphous polymers slightly higher
  - Many injection molded products

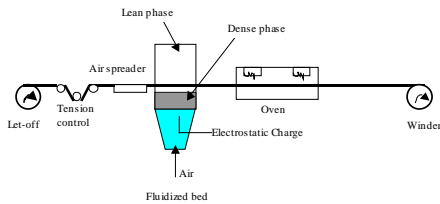
## Short Fiber Processes



## GMT Process



## Electrostatic Fluidized Bed Powder Coater



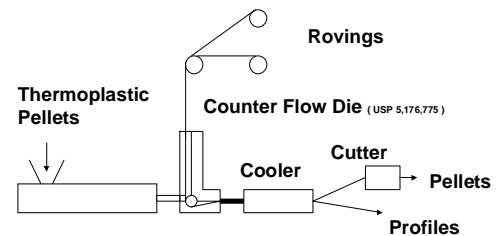
## Flexible Powder Coated Tow Development

- |      |                                                                                                                                                                                                                                                                         |
|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1985 | <ul style="list-style-type: none"> <li>Complaints about APC (boardy, expensive)</li> <li>FIT process developed (flexible, expensive)</li> <li>GT process developed (flexible, cheap?)</li> <li>Military interest in TPC fades</li> </ul>                                |
| 1990 | <ul style="list-style-type: none"> <li>Prince Vortex racquet commercialized</li> <li>Custom Composites (CCMI) started                             <ul style="list-style-type: none"> <li>GT process, focus on sports</li> <li>GT process dropped</li> </ul> </li> </ul> |
| 1995 | <ul style="list-style-type: none"> <li>Applied Fiber Systems acquires CCMI                             <ul style="list-style-type: none"> <li>Fast, reliable production achieved</li> <li>K2 mountain bike successful</li> </ul> </li> </ul>                            |
| 2000 | <ul style="list-style-type: none"> <li>Industrial applications multiplying</li> </ul>                                                                                                                                                                                   |

## Long/Continuous Fiber Processes

- Extrusion coating dominates
  - Higher conversion cost (> \$ 1.00/kg)
  - Low volume (< 100 kg/hr) (< 1 billion kg/yr)
- 6 and 12 mm pellets common
  - Designed for injection molding
  - Longer pellets harder to mold and little benefit
- Other shapes:
  - Ribbon, Tape, BMC, Profiles

## Long Fiber Extrusion Coating



## Long Fiber Extrusion Coating

- Coating Limitations
  - Intermediate fiber volume (20 to 50 %)
  - Low viscosity thermoplastic
  - Need fiber spreading
  - Time to permeate fiber bundles
- Injection Molding Limitations
  - Significant fiber breakage
  - input: 12 mm fibers
  - output: 0.5 – 3 mm fibers

## Long Fiber Extrusion Coating

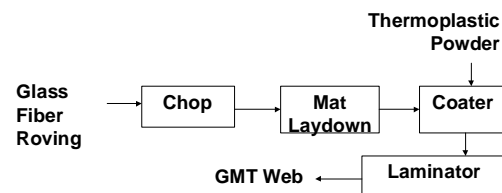
- Typical results\*:
  - Modulus > 3 – 6X
  - Tensile strength > 2 – 5X
  - Impact Strength > 2 – 10X
  - Heat Distortion Temperature > 10 – 100°C
    - (amorphous – crystalline)

\* Based on injection molding

## Alternative Long Fiber Processes

- Lamination Approaches
  - Extrusion
  - Wet laid
  - Dry laid
- Flexible Fiber Bundle Approaches
  - Commingling of fibers
  - Powder coating

## Dry GMT Process



## Laminated Panel Products

- Truck trailer liners (tough)
- Bus panels (tough)
- Doors (tough, insulating)
- Floating piers (light, water resistant)
- Form boards (light, chemical resistance)

## Compression molded products

- Mostly automotive, e.g.:
  - bumper beams (good impact)
  - battery trays (chemical resistance)
  - seat structures (impact, fatigue)
  - sound insulation (damping)
  - instrument panels (complex shape)

## Thermoformed Products

- Shipping containers (light, tough)
- Luggage racks (tough, stiff)
- Pallets (tough, stiff, moisture resistant)
- Flooring (tough, resistant)
- Boats (moisture resistant, tough, stiff)
- Concrete form boards (moisture resistant, tough, stiff)

## Effect of Glass Content on the Mechanical Properties of GMRT

Shear Lint + Wt % glass	Tensile strength, MPa (ksi)	Tensile modulus, GPa (msi)	Flexural strength, MPa (ksi)	Impact strength, J (ft-lb)
0	25.5 (3.7)	1.72 (0.25)	39.3 (5.7)	6.8 (5.0)
20	40.7 (5.9)	2.12 (0.31)	42.1 (6.1)	15.6 (14.1)
30	55.2 (8.0)	2.76 (0.40)	44.2 (6.4)	18.3 (13.5)
40	84.1 (12.2)	5.9 (0.86)	53.1 (7.7)	21.7 (16.0)

	"SANDWICH" OF TWINTEX* AROUND CORE OF GMRT	"SANDWICH" OF U.D. TAPE AROUND CORE OF GMT (Kao)	"SANDWICH" OF TWINTEX AROUND CORE OF GMT (Osten)
Glass Content, wt. %	50	42	50
Flexural Strength, MPa (ksi)	170 (25)	210 (31)	280 (41)
Flexural Modulus, GPa (ksi)	10.7 (1550)	-	11.4 (1640)
Tensile Strength, MPa (ksi)	210 (31)	250 (36)	185 (27)
Tensile Modulus, GPa (ksi)	9.4 (1360)	-	9.0 (1300)

\* Vetrotex Certainteed

GMRT PANEL	40% E-glass Virgin Polypropylene	40% E-glass on Surface and 20% in Core Virgin Polypropylene
Panel Density, grams/cc	1.22	1.16
Panel Thickness, mm	3.8	4.3
Flexural Strength, MPa (ksi)	92 (13)	97 (14)
Flexural Modulus, GPa (ksi)	4.8 (700)	4.5 (650)

## Concluding Remarks

- Towflex® finally successful
  - Limited by cost
- Gcomp® success starting
  - Low cost sells well
  - Established GMT technology helps
- GMRT science and technology needs exporation

What mixtures? How dirty?  
 What additives? Using natural fibers  
 Predicting properties

## Dynatup Impact Tester

