Natural Fiber – Polyolefin Composites

ver 1

Outline

- Motivation
- Current trends
  - Why the rapid growth?
- Research Issues
  - Compatibility, Strength, Modulus, Creep, Moisture, Cost, Durability, Recycling
- Needs

Motivation

- Composites – Forest Products Joint Session
- Natural Fiber's appeal:
  - Renewable - Lightweight
  - Cost - Biodegradable
  - Moderate strength and modulus
  - High aspect ratio
- Drawbacks: see issues

Current Trends

- Rapid growth
  - 13 % compounded last 10 years
  - Currently 400 million lbs annually
  - Growth projections to 2005:
    - Building products 60 % per year
    - Automotive products 50 % per year
- What's growing?
  - Ref.: Eckert, Kline & Co.

Building Products

- Current
  - 75 % of market
  - **Decking**, Trim, Fencing, Window/door profiles
- Soon
  - Shutters, siding, shingles
- Most applications have modest structural requirements

Decking

- Composition
  - 50 + % wood flour
  - 50 - % polyolefin
    - LDPE
    - HDPE
    - PP
    - Often recyclate
- Options
  - Foam, Hollow cores
- Appeal
  - Warp resistance
  - Insect resistance
  - Asthetics
  - Longevity

“Synthetic Hardwood”

SHW Technologies Inc, Guelph, Ontario

- Process:
  - 70 % PP/30 % Wood Flour → Ram Extrusion → Cold Drawing →
  - Oriented PP and High Void Content (40 %)

Properties	Flex Str, psi	Flex Mod, psi
– PP	7,000	270,000
– Wood	14,000	1,300,000
– “SH”	20,000	1,100,000

Automotive Applications

- Less developed (about 8 % of market)
- Primary
  - Trim panels - Spare tire covers - Seat backs
- Secondary
  - Instrument panels - Glove boxes
  - Headliners - Sun visors
- Exceed 100 million lbs of fibers in 2005

Research Issues

- Compatability is poor
  - Add maleated polyolefin
    - 10 % “best”
    - 1% affordable (> $ 1/lb for mPO)
  - Improves strength, creep resistance
  - Lowers moisture absorption
  - Benefits are incremental @ 1 %

Strength and Modulus Low

Fiber	Length, mm	Strength, MPa	Modulus, GPa
Glass	Infinite	2,400	70
Wood	0.1 – 50	200	25 – 30
Flax	25 – 60	600	50
Sisal	600 +	500	17

Comparative Mechanical/Physical Properties of Bast and Wood Materials (WoodHandbook, 1996):

FIBROUS	DENSITY(g/cm^3 FIBER)		LENGTH	DIAMETER		LENGTH/ DIAMETER		TENSILE (psi)
MATERIAL	FIBER	BUNDLE	RANGE (mm)	AVG (μ m)	RANGE	AVG	RATIO	STRENGTHS
FLAX	1.51	1.2	10 - 65	32	10 - 25	18	1,778	51,000
KENAF (bast)	-	1.2	1.4 - 5	2.6	14 - 23	21	124	58,000
KENAF (core)	.31	-	0.4 - 1.1	0.6	18 - 37	30	20	-
HEMP	1.48	1.2	7 - 55	25	13 - 30	18	1,087	118,000
S. Y. PINE	.51	-	2.7 - 4.6	3.7	32 - 43	38	97	11,600
D. FIR	.48	-	2.7 - 4.6	3.7	32 - 43	38	97	15,600
ASPEN	.39	-	0.7 - 1.6	1.2	20 - 30	25	48	7,400

Fully-Coupled, Polypropylene(1) / Natural Fiber Composites

Fiber	Fiber(2) Loading (%)	Tensile Strength (MPa)	Tensile Modulus (GPa)	Flexural Strength (MPa)	Flexural Modulus (GPa)	Izod - notched (J/m)	Izod - unnotched (J/m)
Jute	50	73	8.5	100	7.5	40	210
Sisal	50	60	6.0	85	5.1	55	190
Wood(3)	50	39	5.5	68	5.3	23	90
none	0	32	1.7	41	1.4	24	620

(1) Solvay Fortilene 1602, MI=12
(2) property values (except impact) are proportional to fiber loading
(3) 30 mesh pine
Source: Global Resource Technologies, Madison, WI

Lower Costs Sought

Fiber	Price, cents/lb	Specific Gravity	Price, \$/ m^3
Glass	85	2.6	4,850
Wood	12	1.6	420
Flax	18	1.5	600
PP matrix	33	0.9	650

High Moisture Adsorption (> 10%)
(2-3 % after compounded)

- Must dry to compound
  - Can use vacuum venting in extrusion
  - Increases cost
- Interferes with fiber/matrix coupling
- Causes swelling
- Lowers strength and modulus
- Increases creep

Short Fibers Dominate

- Advantages
  - Lower cost
  - Easier processing
    - Extrusion compounding with intensive mixing
    - Extruded products
    - Conventional injection molding
    - Complex shapes
- Disadvantages
  - Lower properties, particularly
    - Strength
    - Impact
  - Hard to orient

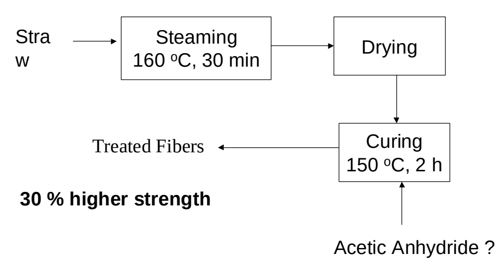
Long Fiber Systems

- Harder to make prepreg
- Mat composites not better than injection molded composites in tensile strength
  - Flax/PP comparison by Peijs at Eindhoven
- Long fiber pellets slightly better that short fiber pellets
  - Impact strength benefits most (> 200%)
- Why don't long fibers perform better?

Thermal Degradation

- Lignin starts degrading above 70 ^{o}C
- Hemicelluloses next
- Cellulose quite stable?
  - Survives neutral pulping at 280 ^{o}C
- General guide: process below 200 ^{o}C
- How to stabilize?
  - Pulping?
  - Thermal treatment?
  - Other?

Flax Fiber – Duralin^{TM} Process



Research Needs

- Fibers
  - Longer, stiffer, stronger
  - Better thermal stability
  - Lower moisture sensitivity
- Interface
  - Better adhesion and lower cost coupling agents
- Matrix
  - Lower cost

Forest Products Questions

- Is grinding and milling the only way?
- Can any pulping process be justified?
  - Just thermal? - What is gained?
  - Thermomechanical?
  - Chemical?
- Would paper sizes help?