Natural Fibers in Extrusion Process for Profiles Production

A.L. Leão, J.C. Caraschi, S.M. Sartor, V.L. P. Salazar

Department of Natural Resources - UNESP
Caixa Postal 237, Botucatu, SP 18603-970, BRAZIL

e-mail: alcidesleao@fca.unesp.br
Searching

- Key words: Natural Fiber; Polymer composite; Plastics Composite
- 2000-2005
- Language: english
Where are the Technologies in FPC
Fiber Plastics Composites

- USA: 16
- Germany: 5
- India: 5
- Japan: 5
- Canada: 5
- Netherlands: 5
- Italy: 7
- Others: 10
- SciFinder
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<td>Utrecht University, Netherlands</td>
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<td>Doshisha University, Japan</td>
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<td>Others</td>
<td>50</td>
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Scientific and Technological Research?

- Patents: 50
- Papers: 35
- Meetings: 15
Which Natural Fibers are Used in Composites?

<table>
<thead>
<tr>
<th>Natural Fibers</th>
<th>No. Of Papers</th>
</tr>
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<tbody>
<tr>
<td>Bamboo</td>
<td>8</td>
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<tr>
<td>Banana</td>
<td>6</td>
</tr>
<tr>
<td>Hemp</td>
<td>38</td>
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<td>Coir</td>
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<td>Flax</td>
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<td>Jute</td>
<td>37</td>
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<td>Kenaf</td>
<td>28</td>
</tr>
<tr>
<td>Sisal</td>
<td>30</td>
</tr>
<tr>
<td>Pinneapple</td>
<td>4</td>
</tr>
<tr>
<td>Curauá</td>
<td>4</td>
</tr>
</tbody>
</table>
Processes Utilized in Composites at UNESP - Botucatu

- Extrusion (profiles and pellets)
- Injection molding
- Thermoforming
- BMC (partnership with private companies)
- SMC (partnership with private companies)
- RTM (partnership with private companies)
- LFRT – Long Fiber Reinforced Thermoplastics – profiles and railroad crossties)
Fox Models: parts made of curauá

FOX Sliding Roof
FOX Trunk Lid
FOX Moulded Headliner
Carrier: 50/50 Curauá Fiber + Polymeric Resin

Developed in partnership with UNESP
Use natural resources based on an ecological intuition of non-linear biological processes - SUSTAINABILITY

Extrativism – low pressure of natural resources
Economics – high pressure; making money at any cost

Resulting Processes Of Low Environmental Impacts
Engineering Materials
(Repetitive, Homogenous, Predictable)

- Engineering Materials
  - Classics
    - Wood
    - Ceramics
    - Glass
    - Metals
  - Non-classics
    - Man-made Polymers

Natural Fibers Composites or FPC (Fiber Plastics Composites)

MANO, 2000
Vegetable Fibre Classification

- **Vegetable Fibres**
  - **Cellulosic fibres**
  - **Bast Fibres**
    - Flax
    - Hemp
    - Kenaf
    - Abaca
    - Banana
    - Bamboo
    - Jute
    - Totora
  - **Leaf Fibres**
    - Sisal
    - Curaua
    - Fique
    - Phormium
    - Palm trees
    - Caroa
    - Kurowa
    - Pineapple
  - **Seed Fibres**
    - Cotton
    - Capok
  - **Fruit Fibres**
    - Coir
    - African palm
  - **Wood Fibres**
    - Pinewood
    - Hardwood
    - Eucaliptos
Natural Fibers in South America
Brazil is the biggest producer and consumer

- Abaca – Ecuador
- Fique – Colombia, Ecuador
- Totora – Ecuador, Peru and Bolivia
- Flax – Argentina (?)
- Embira – Brazil
- Caroá – Brazil
- Bamboo - Brazil
- Phormium (imbira, New Zealand Flax) - Brazil
- Curauá – Brazil, Venezuela
- Kurowa (curaua) - Guiana
- Sugar cane bagasse – Brazil, Cuba and Colombia,
- Sisal – Brazil, Cuba, Haiti México
- Buriti, Carnauba, Buriti, and Tucum – NE of Brazil (native palm trees)
- Malva & Jute – Brazil
- Coir – Brazil
- Banana – Brazil
- Hemp – Chile
- Taboa (Typha) - Brazil
- Piteira – Brazil and Ecuador
- Tagua – Ecuador
- Jarina – Brazil (Vegetable ivory)
- Piaçava – Bahia, Brazil
Curauá Plantation (High Density Stand)
Application of Natural Fibers Composites

- Marine: 12%
- Construction: 26%
- Automotive: 31%
- Miscellaneous: 4%
- Aerospace: 1%
- Consumer products: 8%
- Appliances: 8%
- Electronic components: 10%

Racz, 2005
High performance (expensive)

Polymer

FPC

Fibers

Cheaper plastic
## FPC Properties

<table>
<thead>
<tr>
<th>Material</th>
<th>Plastics</th>
<th>Wood</th>
<th>FPC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical</td>
<td>++</td>
<td>++</td>
<td>?</td>
</tr>
<tr>
<td>Properties</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Absorption</td>
<td>+++</td>
<td>-</td>
<td>?</td>
</tr>
<tr>
<td>Fungi Resistance</td>
<td>++</td>
<td>-</td>
<td>?</td>
</tr>
<tr>
<td>Facing Quality</td>
<td>+</td>
<td>++</td>
<td>?</td>
</tr>
<tr>
<td>Quality</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Most Used Fibers

- Wood (hardwood residues; *Eucalyptus* and pine)
- Rice husks
- Palm Tree fibers …
- Sugar cane bagasse
- Sisal
- Curauá
- Coir
Target Sectors in Brazil for FPC

- Automotive Industry – 40,000 tons/year (23 kg/car in Europe and 13 kg/car in Brazil) – the Brazilian demand is about 8,000 tons/year
- Railroad crossties – replacement of solid wood and concrete crossties
- Civil Engineering – door frames, doors, window frames, fences, decks
- Geotextile – 100 millions m² – 500,000 km roads & 50,000 km of railroads
- Furniture Industry – cabinets, back seats, etc.
- Electro/Electronics – injection molded parts (computer monitors, mobile phones
- Packaging Industry – fruit box
- Toys industry- injection molding of several articles
- Pens, pencil, etc…
Soap and lipstick container using Injection Molding Technique
Advantages of FPC

- Environmentalist pressure over more utilisation of Natural Renewable Resources
- Better efficiency in converting raw-materials in products compared to other man-made fibers
- Products based on Life Cycle Analysis (ISO 14.000)
- National strategy to create rural jobs in economically deprived areas
- Good mechanical properties relations: Weight versus Resistance
- Composites/Ecomenes
- Recyclability
- Greenhouse Effect
- Marketing – Lignocelullosics Composites = Low Tecnology
Advantages of FPC

- Excellent specific strength and high modulus. High flexural and tensile modulus - up to $5 \times$ base resin, high notched impact strength - up to $2 \times$ base resin
- Reduced density of products.
- Biodegradable (?!)
- Renewable source of raw-material.
- Lower price of polymer composites reinforced with natural fibres than those reinforced with glass fibre.
- Reduced tool wear.
- Safe manufacturing processes, no airborne glass particles, relief from occupational hazards. Reduced dermal and respiratory irritation. No emission of toxic fumes when subjected to heat and incineration.
- Most thermoplastic composites are recyclable. Possibility of recycling the cuttings and manufacturing wastages.
- Energetically recyclable.

Racz, 2005
Limitations of FPC

- Concerns over fibre consistency/quality
- Low impact strength (high concentration of fibre defects)
- Problem of storing raw material for extended time
  - Possibility of degradation, biological attack of fungi and mildew
  - Foul odor development
- Fibres are hydrophilic
- UV resistance – similar to plastics
- Low surface hardness – *Quinch-kinch*
- Issues of bonding with polymers
- Previous 2 issues largely overcome by development of effective fibre surface treatments – MAPP
- Emission issues – fogging and odor
- Processing Temps – natural sugars caramelize between 150-205°C must keep below this level. Limits the number of applicable matrix polymers
Natural fibres & high impact?

Sonntag & Barthel, 2002)
“The most environmentally friendly thing that you can do for a car that burns gasoline is to make lighter bodies”

Henry Ford
Economical Aspects

Development for prices of crude oil, standard thermoplastics & natural fibres from Europe since 2003

Renewable Energy: many alternatives: available

Future trend: Fibres and Polymers based on renewable resources

(Karus, Ortmann, Otremba, Scheurer & Müssig 2006 - adapted presentation)
The increasing demand for natural and wood fibres

Source: UN 2006, AEO 2006, nova-Institut 2006

Production Quantities

<table>
<thead>
<tr>
<th>Year</th>
<th>Wood</th>
<th>Jute Fibres</th>
<th>Other Natural Fibres</th>
<th>Wood</th>
<th>Jute Fibres</th>
<th>Other Natural Fibres</th>
<th>Wood</th>
<th>Jute Fibres</th>
<th>Other Natural Fibres</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Scenario "Low" | "Referenz" | "High"
How FPC is Viewed

- ++ durable
- ++ innovative
- ++ comfortable
- + natural
- + “warm”
- +/- elegant/exclusive
- - expensive
Market Profiles

• Exterior (decks, fences, siding) – natural competitiveness
• Interior (door frames, skirting, etc...)
Composite Families

- **Composite Families**
  - Fibre Reinforced
    - Short fibre reinforced
      - Synthetic
        - aramide
        - glass
        - carbon
        etc.
    - Vegetable
      - hemp
      - curaua
      etc.
    - Animal
      - wool
      - mohair
      etc.
    - Mineral
      - basalt
      etc.
  - Long fibre reinforced (LFRT)
    - Synthetic
      - aramide
      glass
      carbon
      etc.
    - Vegetable
      - hemp
      flax
      etc.
    - Animal
      - wool
      mohair
      etc.
    - Mineral
      - basalt
      etc.
  - Particle reinforced /filled
    - Manmade
      - nanotubes
      etc.
    - Mineral
      - metal particl.
      etc.
    - Vegetable
      - talc
      chalk
      etc.
      wood flour
      etc.

*Racz, 2005*
## Volume of WPC in the EU 25 (+ Norway and Switzerland)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>1000 tonnes</td>
<td>% p.a.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td>0.2’</td>
<td>3.5</td>
<td>16</td>
<td>160%</td>
<td>46%</td>
</tr>
<tr>
<td>Building exteriors</td>
<td>11.4</td>
<td>32</td>
<td>95</td>
<td>41%</td>
<td>31%</td>
</tr>
<tr>
<td>Building interiors</td>
<td>4</td>
<td>11</td>
<td>32</td>
<td>40%</td>
<td>31%</td>
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<tr>
<td>Miscellaneous</td>
<td>4.1</td>
<td>6</td>
<td>13</td>
<td>14%</td>
<td>21%</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>19.7</strong></td>
<td><strong>52.5</strong></td>
<td><strong>156</strong></td>
<td><strong>39%</strong></td>
<td><strong>31%</strong></td>
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</tbody>
</table>

*Source: AMI Consulting*
Materials for FPC
Melting Point

- ABS 105°C
- PE 125°C
- PP 160°C
- Polystyrene 240°C
- Nylon-6 220°C
- SAN 115°C
- PET and PVC (personal restrictions)
Types of Twin Screw Extruders

- Co-Rotating
  - Parallel Screw Shafts
  - Fully Intermeshing
- Counter-Rotating
  - Parallel Screw Shafts
  - Fully Intermeshing
- Counter-Rotating
  - Conical Screw Shafts
  - Fully Intermeshing
Twin Screw Extruder

Excellent melting capability – pellets, flake, recycled resins ok
- Lower raw material cost
- Able to recycle scrap

Flexible feeding options
- Melt resin separately from fiber
- Introduce fiber downstream for optimal heat balance
- High feed capacity for low density materials (natural fibers)
Twin Screw Extruder

Excellent mixing capability and modular design
- Screw design can be optimized for highest possible rate for a given extruder D and formulation
- Maintenance cost reduced by modularity

Excellent devolatilization
- Remove residual moisture

Excellent devolatilization
- Remove residual moisture
- Vacuum can be designed for very high reliability, less scrap
Twin Screw Extruder

Flexible processing possibilities
- Direct profile extrusion
- Pellets

Pumping capability is limited; low pumping efficiency (~10%) generates excess heat
- Melt pump or single-screw needed for most applications, even simple deck profiles
- Melt viscosity is very high –well suited for melt pump
Characterization of different Plasticizing Systems

<table>
<thead>
<tr>
<th>Conveying mechanism</th>
<th>Single Screw Extruder</th>
<th>CounterRotating Twin Screw Extruder</th>
<th>Co-Rotoating Twin Screw Extruder</th>
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</thead>
<tbody>
<tr>
<td>Drag flow</td>
<td>60-250 rpm</td>
<td>25-80 rpm</td>
<td>drag flow (Forced flow)</td>
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<tr>
<td>Screw Speed range</td>
<td>small</td>
<td>large</td>
<td>large</td>
</tr>
<tr>
<td>Viscosity range</td>
<td>large</td>
<td>small</td>
<td>small</td>
</tr>
<tr>
<td>Resistance time range</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Mass and heat exchange</td>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Mixing</td>
<td>+</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>• Dispersing</td>
<td>+</td>
<td>+</td>
<td>+++</td>
</tr>
<tr>
<td>• Mixing</td>
<td>+</td>
<td>+</td>
<td>+++</td>
</tr>
<tr>
<td>Self cleaning</td>
<td>+</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Degassing</td>
<td>+</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Pressure built up</td>
<td>++</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Flexibility</td>
<td>+</td>
<td>+</td>
<td>++</td>
</tr>
</tbody>
</table>

+++ very good      ++ good      + satisfying  Source: Der Doppelschneckenextruder,KVD
39
7aS. Jornadas de plasticos en automocion
Profile Process Configuration

Undried Fiber
(Pellets or powder)

Polymer
Additives

Conical or parallel Twin Screw

Water

Vacuum

Calibrator/
Cooler/Puller

Melt-Mixing = Max Torque Load

Coperion
### Processing Conditions

<table>
<thead>
<tr>
<th>Component</th>
<th>Target [°C]</th>
<th>Actual [°C]</th>
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<tbody>
<tr>
<td>Extruder Zone 1</td>
<td>230</td>
<td>228.4</td>
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<tr>
<td>Zone 2</td>
<td>210</td>
<td>209.8</td>
</tr>
<tr>
<td>Zone 3</td>
<td>190</td>
<td>189.9</td>
</tr>
<tr>
<td>Zone 4</td>
<td>180</td>
<td>180.1</td>
</tr>
<tr>
<td>Adapter</td>
<td>180</td>
<td>180.1</td>
</tr>
<tr>
<td>S1</td>
<td>130</td>
<td>128.8</td>
</tr>
<tr>
<td>Die Zone 1</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td>Zone 2</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td>Zone 3</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td>Zone 4</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td>Zone 5</td>
<td>180</td>
<td></td>
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</tbody>
</table>
Economic Model

- Raw material costs dominate expenses (68%). Resin represents 60% of total raw material cost.
- Labor is the 2’nd largest component of expense, but decreases in importance as extruder D increases.
- Profitability depends on formula cost and efficient operation (high utilization, low scrap rate).
- Higher D (higher capacity) extruder is more economical because of reduced labor.
- Expense per unit of product produced. Capital cost per unit of production is also somewhat lower for higher D.
To Composite Lumber Products
Profiles in Pallets

Song, 2007
Marine Applications
Profile made of Sisal, Wood and Polypropylene
Profiles made of WPC (wood, rice husk, coir, etc...
Door Frames Profile
ADVANTAGES

- Pre-drying is not required to reach high rates for pellet process
- Some residual moisture is tolerable in pellet process
- Some decomposition of fiber is tolerable in pellet process
- Fiber mixing is less critical than with direct profile extrusion (2'nd melt history)
Direct Profile Extrusion: Solids, Hollows, Sheet

ADVANTAGES

♦ Lower capital cost
♦ Lower operating costs (1 heat history, less labor)
♦ Separates primary feeding/melting/drying/mixing process from profile formation
♦ Less inventory of raw materials
Direct Profile Extrusion: Solids, Hollows, Sheet

DISADVANTAGES

- Fiber drying for highest rate – capital/operating costs offset equipment savings
- Minimal fiber decomposition is tolerable, especially for solid profiles
- Complicated process – melting, drying, mixing and profile formation (less throughput)
Green energy innovations

Pellet Extrusion vs. Profile Extrusion

DISADVANTAGES

- Higher capital cost for pellet and profile equipment vs. direct profile
- Higher operating costs (labor, maintenance, energy, etc.)
- Pellets must have low initial moisture and cannot be allowed to absorb moisture from the environment
- More inventory in the event of quality problem in raw materials or pellets
Natural Fiber Compounding

Polymer

Wood or Natural Fiber

Water

Pelletizer

ZSK Twin Screw

To Pellet Cooling
## Typical Formulations

<table>
<thead>
<tr>
<th>Material</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Fibers</td>
<td>(48+%) 40-80 wt %</td>
</tr>
<tr>
<td>(moisture &lt;7%)</td>
<td></td>
</tr>
<tr>
<td>Polymer</td>
<td>Powder or pellets 20-55%</td>
</tr>
<tr>
<td>Stabilizers and Additives</td>
<td>1-2%</td>
</tr>
<tr>
<td>(secret)</td>
<td></td>
</tr>
<tr>
<td>Colorants</td>
<td>1-2%</td>
</tr>
<tr>
<td>Foaming Agents</td>
<td>?</td>
</tr>
</tbody>
</table>
Additives Developments

- Tailor-made lubricants
- Non stearate & compatibilizer package
- Special HALS (FRT)
- Antimicrobials (Smelling and Odor)
- Blowing agents (Foamng)
- Anti smelling agents/treatments
- Surface hardness and impact resistance
- Lubricants

Rangaprasad, 2003, modified
FPC Composition (UNESP)

- Output – 70 kg/h
- Wood Fiber. 65 and 80%
- PP: 33 and 28%
- Coupling agent
- UV Stabiliser
- Lubricants
- Fire Retardants
- Processing Agents
Hardwood Residues Profiles Properties

- Tensile – ISO 527-2: 1993
- Flexural – ISO 178:2005
## Mechanical Properties Summary

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charpy</td>
<td>kJ/m²</td>
<td>2.09 – 4.56</td>
</tr>
<tr>
<td>Flexural Ef</td>
<td>MPa</td>
<td>2943 – 4168</td>
</tr>
<tr>
<td>Flexural Strength</td>
<td>MPa</td>
<td>18.23 – 46.31</td>
</tr>
<tr>
<td>Tensile Et</td>
<td>MPa</td>
<td>2030 – 3819</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>MPa</td>
<td>6.28 – 21.80</td>
</tr>
<tr>
<td>Shore D</td>
<td></td>
<td>72 – 78</td>
</tr>
<tr>
<td>Density</td>
<td>g/cm³</td>
<td>0.906 – 1.020</td>
</tr>
</tbody>
</table>
LFRT – Long Fiber Reinforced Thermoplastics

MEGAcompounder ZSK 58

Polymer
Gravimetric feeder
Devolatilization

Sisal Rovings

Polishing roll stack with roller conveyer
Belt-type take-off

Backing film
The Future in Brazil
Partnership between

Suzano Petroquímica

FIBERTECH™ 50, 60 and 70

FLEXWOOD™

Fiber Plastics Composites

diretoria@plastitech.com.br
(xx14) 3814 5200
Caixa Postal 69 – Botucatu, SP
Plastitech

- Compounder company (Coperion machinery)
- FPC as masterbatch
- Natural fibers as reinforcement agents
- Matrix: PP, HDPE, PS and ABS
- Additives: Fire retardant; compatibilizers, UV filters
Important Reminders

- Operational excellence is a necessity because of raw material costs and inelasticity of product price
- Find low-cost formulations that work well before tightening building codes make changes difficult and expensive
- Determine what the consumers want and sell it
- Wood competition in Brazil is very hard
- Investment in machinery (twin screw vs single screw)
The Future

The future of the materials based on FPC depend on many factors, such as:
1. Identification of new products;
2. Quality of the products;
3. Consumers perception;
4. Performance of the products; and
5. Identification with innovation
“There is no Substitute for Quality”

Our Principles
Life is pretty simple: You do some stuff. Most Fails. Some Works. You do more what works. If it works big, others quickly copy it. Then you do something else. The trick is the doing something else.

Leonardo da Vinci
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