Extrusion of Wood Polymer Composites (WPC)

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Content

• Introduction of Wood K plus
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• Aspects in the course of time
• Why WPC?

• Components
• Processes

• Applications
• Recycling
Wood K plus

- Non profit **R&D Institute** for **Wood Composites & Wood Chemistry**
- **Founded 2001** by the Austrian Government
- **4 Areas** on 4 locations + 1 cross-section market research field
- **110 scientific employees**
- **50 projects**
- **Budget: 8.5 million € p.a.**

**Market Analysis and Innovation Research**
- **LENZING** Wood and Pulp Chemistry
- **TULLN** Solid Wood and Wood Composites
- **ST. VEIT** Surface technology and logistics
- **LINZ** Wood Polymer Composites
R&D services – Division WPC

• Consulting

• Raw material characterization
  ➢ Wood and fiber analytics
  ➢ Polymer analytics

• Material characterization
  ➢ Compound analytics
  ➢ Material testing
  ➢ Component testing

• Extrusion trials - Pilot plant

• Injection molding

• Material and process development
**FprEN 15534-1:2013**

**wood-polymer composite**
**WPC**
**or**
**natural fibre composite**
**NFC**

Material or product made thereof being the result of the combination of one or several cellulose-based material(s) with one or several thermoplastics, intended to be or being processed through plastic processing techniques

Polyethylene (PE).

**Sta**

WPC materials can be processed by different techniques, as extrusion for profiles, calendering for films and sheets, injection moulding or compression moulding. The contents of natural fibres and polymers depend on the application and the processing techniques.

**Nat**

WPC materials may be considered neither as filled plastics nor as a special kind of wood. They should be considered as different materials having their own characteristics.

For the moment, the main applications of WPC products are decking, cladding, panelling and fencing and furniture.
Aspects in the course of time - Europe

- Cognition of WPC
  - Development of products
    - Improving of performance
    - Marketing
  
  - Durability
  - Searching for new applications

- Recycling
  - ........
## Why WPC?

- **mechanical properties**
  - increase of stiffness and heat deflection temperature

- **ecological aspects**
  - use of renewable instead of fossil-based raw materials
  - improvement of the carbon footprint → long transport routes of tropical wood

- **reduction of abrasive wear in plastics processing machines**
  - WPC-melts are less abrasive than e.g. glass fiber-filled melts

- **reduction of weight**
  - reduction of density through the use of cellulose-based instead of mineral-based fillers
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Raw materials for WPC

- **Wood / natural fiber**
  - wood and natural fibers, wood flour, wood waste, sugar cane, rice hulls, paper waste, industrial fibers …

- **Polymers**
  - PE, PP, PVC, bio-polymers (e.g. PLA), thermosets

- **Additives**
  - lubricants, coupling agents, mineral fillers (e.g. talcum), pigments, UV-stabilizer, fungicides, algaecides …
Wood quality

**influences**

- dosing and feeding
- **extrusion process** (melt pressure, temperature, etc.)
- **material properties** (strength, stiffness, etc.)
- **equipment lifetime** (extractives, wear)
# WPC Characteristics

<table>
<thead>
<tr>
<th>Polymer</th>
<th>Wood Content</th>
<th>Strength</th>
<th>Stiffness</th>
<th>Impact</th>
<th>Expansion (water)</th>
<th>Expansion (thermal)</th>
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<tbody>
<tr>
<td>PP*</td>
<td>high</td>
<td>+++</td>
<td>+++</td>
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<td>medium</td>
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<td>PE*</td>
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<td>PVC</td>
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<td>+++</td>
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<td>-</td>
<td>+++</td>
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</tr>
</tbody>
</table>

*Coupling agents are used*
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WPC-Formulations

Extrusion

- **wood / PP or PE**
  - 50 - 80 w-% wood (medium - high)
  - coupling agents, lubricants
  - inorganic filler

- **wood / PVC**
  - 30 - 60 w-% wood (low - medium)
  - stabilizer, lubricants
  - inorganic filler

- **Injection molding**
  - 5 - 60 w-% wood (low-medium)
  - coupling agents, lubricants
  - inorganic filler

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**Polymer-Type**

- **PE**
  - 39%

- **PP**
  - 50%

- **PVC**
  - 11%

own benchmark 2008 & 2011
Processes

Components (wood, polymers, additives)

2-step

Compounding
- counter-rotating conical TSE
- parallel, co-rotating TSE
- hot-/cool batch mixer

WPC-Granules

Injection moulding

Extrusion
- counter-rotating conical TSE
- single-screw extruder

3D-parts

1-step

Direct extrusion
- counter-rotating conical TSE

Profiles

1-step

3D-parts
Pelletizing systems

- **hot die face pelletizing system**
  - melt is pressed through a nozzle plate → rotating knives
  - airflow transports and cools the granules
  - cyclone/filter separates granules from the airflow
  - inevitable dust content

- **under water pelletizing system**
  - similar system as hot die face pelletizing system
  - process water instead of airflow
  - centrifuge separates granules from the water flow
  - less dust and noise
  - more spherical particles

- **strand pelletizing system**
  - melt is pressed through a nozzle plate or a die
  - strands are cooled in a water-bath
  - solid strand is cut to granules
Compounding / Direct extrusion

- counter-rotating conical TSE
  - Compact design, short retention time, low rotational speed → low thermal stress
  - Insufficient mixing behavior
  - Forced transport of the melt → spindle-nut principle

- Compounding or direct extrusion
- Force feeding unit
Compounding - I

- parallel, co-rotating TSE
  - Plasticizing, mixing, homogenizing, granulating
  - Mixing of fillers and additives (flame retardants, plasticizer)
  - Good mixing behavior
  - Self-cleaning of the screw-elements

- Twin-screw side-feeder → wood is dosed in the polymer melt
- (atmospheric) venting

- Direct extrusion → melt pump is necessary to provide the required pressure
Compounding - II

- **hot-/cooling batch mixer**
  - mainly used for polyvinylchloride (PVC) dryblends
  - hot-mixer: mixing of the polymer, wood and additives for 5 to 10 minutes at 110°C to 130°C → polymer agglomerates with wood and additives
  - cooling-mixer: cooling of the mixture (to 40°C) to avoid caking
  - get agglomerates
Profile-Extrusion

• counter-rotating conical TSE
  ➢ Production of semi-finished products (e.g. profiles, pipes)
  ➢ Most important production process for WPC (deckings, sidings, railings)
  ➢ Procedure
    o Plasticizing of the WPC-compound
    o Shaping in an extrusion-die (die with gradual change in cross-section)
    o Calibration
      ▪ dry calibration → rigid shell (inherent stability)
      ▪ vacuum calibration tanks → support panels with profile contour
    o Standard down-stream equipment
      ▪ haul-off and cutting unit
Co-Extrusion

• Co-Extrusion
  ➢ All main polymeric components of wood, such as cellulose, hemicellulose, lignin and extractives, suffer from photo degradation
  ➢ Produce a multilayered product with different properties at outer and inner layers
  ➢ Encapsulation of WPCs with polymer-rich cap layer → reduction of water absorption
  ➢ Clear cap layer for retarding of discoloration
  ➢ Saving costs and raw materials → use of recycled materials for inner layers
  ➢ For example: Trex Transcend® Decking
    - is made from reclaimed plastic and wood - materials that would otherwise go unused in landfills

Foaming

- **Foaming**
  - Reduction of material costs (components density reduction, thinner design, material substitution)
  - Reduction of operating costs (cycle time reduction, reduced scrap and reject rates, lower energy consumption)

- Foaming agents
  - **physical foaming agents**
    - compounds that liberate gases as a result of physical processes (evaporation, desorption) at elevated temperatures or reduced pressures
    - include water, argon, nitrogen and carbon dioxide
  - **chemical foaming agents**
    - substances that decompose at processing temperatures thus liberate gases like CO₂ and/or nitrogen
    - solid organic and inorganic substances (such as azodicarbonamide and sodium bicarbonate)
    - division in exothermic (release energy) and endothermic (absorb energy) foaming agents
Challenges in extrusion of WPC

- **Wood moisture**
  - pre-drying is essential for direct extrusion
  - moisture content should max. 10% - 12% for compounding
  - demands high standard to degassing systems (atmospheric, vacuum)
  - special screw design → back venting

- **Temperature**
  - thermal degradation of wood and natural fibers ≥ 200°C melt temperature
  - thermal degradation causes an embarrassing and typical odor
  - thermal stress influences the color of the compound and in further consequence the appearance as well as the performance of the final product
  - adaption of the screw design for special formulations/materials → to reduce shear stress, thermal stress
  - adjustment of the process window (retention time, rotational speed, output)

- **Homogeneity**
  - compounding parameters + feeding position
  - degassing
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WPC in exterior applications_1

Structura from Werzalit, 2014
www.werzalit.com

Kovalex from Kosche, 2014
www.kosche.de

Twinson® Face, Winlife, 2014
www.winlife.com.au
WPC in exterior applications_2

WPC noise barrier,
NATURinFORM, 2014
www.naturinform.com

WPC privacy shield,
NATURinFORM, 2014
www.naturinform.com

Relazzo from Rehau, 2014
www.rehau.com
Simple housing

- **WPC-blockhouse** from Deltawood
- **easy and fast to establish**
- e.g. use as emergency shelter
Niche applications

**extrusion:** pencils, furniture, technical profiles

Staedtler, 2009

Hiendl, 2009

**injection moulding:** speaker boxes, gun stocks, furniture, palettes, urns, musical instruments, meeples, ...

Tecnaro, 2008
European trends

• Trend into **decking as a main product**, all big producers produce decking, but although new applications are permanent coming up

• **Exterior siding** is also produced by all big producers

• **Trend to injection molded products**, e.g. furniture and furniture parts, **automotive**

• Trend to **consumer goods and music instruments**

• Mainly virgin materials are used, but trend to **use of recycled material ongoing**
Advantages of WPC ...

... for the customers ("end user") – no ranking

do not splinter
  do not warp
    low maintenance
      high dimensional stability
        good weather resistance
          good UV-resistance
            free design
              simple to clean
                ...........

made from wood
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Recycling of WPC - I

• Re-use of waste, minor products or post consumer products of the consumer goods industry as raw materials for the production of new products

• Different objectives
  ➢ reduction of the raw material consumption
  ➢ decrease of the amounts of waste to be disposed
  ➢ (cost savings)

• Utilization possibilities
  ➢ material utilization (classical recycling)
  ➢ separation in low-molecular fractions - monomers / synthesis gas for subsequent processing (feedstock recycling)
  ➢ Combustion and energy recovery (thermal utilization)
Recycling of WPC - II

some benefits

• **Cost advantage** (oil price, less virgin material)
• **Reduction / minimization of waste** (post production -, classical recycling)
• **Protection of environment / resources**
• **Improvement of image**

some drawbacks

• **Inconstant quality** (composition, contamination, unknown history)
• **Unsteady quantities**
• **Additional stabilization needed** (at least 2 times thermal stress)
• **Downgrading of performance**
Recycling of WPC - III

• many WPC-producers advertise with phrases like
  “100 % recyclable and climatefriendly”
  “Future-oriented ecological”
  “Entire recyclable”
  “Recyclable”

• but they do not go into details

• some WPC-producers take back the used products from the market
  ➢ use recovered grist for the production of new production

• if the WPC-products contains more than 50 w-% wood, it can be declare as wood waste (class A II respectively A III) → Waste Wood Ordinance
  ➢ disposal in recycling center or with bulky waste
  ➢ small amounts (cut-offs) can be disposed of with domestic waste

• Take note:
  ➢ WPC-products for outdoor applications (deckings, sidings, railings, fencings) are continually exposed to weather (sun → UV radiation, rain, show, temperature)
  ➢ impairment and degradation of the matrix-polymer and natural fillers
  ➢ re-use can led to loss in quality
Post production recycling

- simulation of **in-house recycling** (10 cycles) → injection molding
- 2 different WPC-formulations, PP-homo
- no coherent trends regarding Flexural Modulus, Flexural Strength and HDT for PP-homo and WPC
- the **maximum change of mechanical properties** is < 20 % (for WPC, PP)
- **distinct change in the wood particle size distribution**
- recycling led to a **reduction of water absorption** and **swelling in thickness**
- distinct colour differences caused by thermal stress

⇒ The re-use of small amounts of production wastes does not significantly diminish NFC/WPC product quality
Thank you for your attention!