Applications and Opportunities with European Wood Modification

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Own research background

• 1987 – 2000: TNO/ SHR
  Timber Research, The Netherlands
  – Heat treatment technology (PLATO)
  – Acetylation technology (Accoya)

• 2000 – today: University Göttingen
  – Belmadur
  – Silicones/ Silanes
  – Furfurylation (Kebony)
  – Waxes/ oils
  – Melamines/ phenols
Content of presentation

Wood modification

- Why?
- How (principles)
- Processes and material
- Products and markets
- Challenges

Wood: material of the future

- Ecological
- Sustainable
- Renewable
- Esthetical
- Traditional and modern
Wood: material of the future

- Energy efficient
- End-of-life: energy

Wood: material of the future?

**Weak points:**
- Moisture sensitive
- UV-stability
- Dimensional movements
- Resistance against fungi
- Soft surface
Wood: material of the future?

Maintenance problems due to dimensional instability and UV instability!

Solutions/ Alternatives?

- Use wood with high natural quality (as many tropical hardwoods)
  - Availability (mid term, long term)
  - Sustainability

- Use of wood preservatives
  - Toxicity issues
  - New biocides with low impact
  - Only durability item solved

- Use of new technologies for wood treatment
  - Wood modification!
What is „wood modification“?

What is wood modification?
Wood modification technology

- Heat treatment
- Acetylation (Accoya)
- DMDHEU (Belmadur)
- Furfurylation (Kebony)
- Silicone/Silane
- Oil / Wax/ Parafins

On the market production capacity

- Melamine resin

Production capacity built

- Chitosan/
  - Extractives etc.

??

Challenges: “from idea to commercial applications”
(PhD defense Stig Lande 2008/ ECWM 2009 Militz, Lande)

Technology development

- Raw materials
- Chemical reactions
- Process parameters

Product development

- Material interactions
- Quality control
- Market requirements

Business development

- Market
- Economy
- Intellectual property
Thermo treatment (TMT, Thermowood)
- no chemicals
- temperature 180° C to 220° C
- many wood species used
- difference between producers:
  - technology used

Status quo of production (2010): EUWID
(Europäischer Wirtschaftsdienst)

- Production in Finland, Germany, France, Croatia,
  Austria, Switzerland, Netherlands, Turkey, Sweden,
  Estonia
- Total capacity approx. 200,000 m³/year
- Finland approx. 100,000 m³/year
- Largest plants: 30,000 m³/year
- Smallest plants: 1,000 m³/year
- New plants planned/ under construction
Use class 3 (EN 335)
(Photos by Thermowood Association, Finland)

Use class 3 (EN 335)
(Photos by Mitteramskogler/ Austria)
Use class 1-2 (EN 335)
(Photos by Mitteramskogler/ Austria)
Modification technology based on liquids

- **Belmadur Technology**
  - (DMDHEU)
- **Kebony Technology**
  - (Furfurylation)
- **Accoya Titanwood**
  - (Acetylation)
- **Silanes/ Silicones**

Modification based on liquids

- liquid, catalyst
- vacuum-pressure impregnation
- drying and reaction
- drying temp: above 100 °C
Materials and methods

- NMM-BS impregnation of beech
- High temperature curing

Belmadur® Technology

Originally:
- textile modification
- (Easy Care Cotton)

DMDHEU
(1,3-dimethylol-4,5-dihydroxyethylene urea)
Cross-linking cellulose molecules

Process development of the recent years

- Solid wood
- Veneers
- Wood composites
  - Particles
  - Fibres
- WPC
Main focus last years: upscaling processes

Wood Treatment Curing Belmadur® Wood
Belmadur® Solution
Room temperature Temperature > 100° C

© = patent and registered trademark of BASF
Superheated steam process

Development of construction

<table>
<thead>
<tr>
<th>massive wood</th>
<th>wooden lamella</th>
<th>sandwich</th>
<th>functional layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>frames made from solid wood blocks</td>
<td>all lamella consist of same wood</td>
<td>Lamella consist of different wood</td>
<td>Choice of material regards the function</td>
</tr>
</tbody>
</table>

- Solltemp Luft [°C]
- Temperatur Luft [°C]
- Temperatur Holz [°C]
- Sollfeuchte Luft [%]
- Feuchte Luft [%]
- Feuchte Holz [%]
New product...new process...

BECKER belmadur®

DMDHEU particle boards
**Kebony® Technology**

![Chemical structure](image)

**Basic materials**
- Hydration from Furfural
- Furfural by distillation from waste of bagasse, corn, rice, peanut..

**Kebony® production**

Autoclave: 13 m length, 3.25 m diameter (0.1 - 13 bar)
Kebony® products

www.kebony.com

Kebony® Products
Kebony® products

Process:
- impregnation with acetic anhydride
- reaction at elevated temperatures
- post treatment (acetic acid)

Photos: SHR (NL)

Accoya® Titanwood

Photos: SHR (NL)
Production plant, Arnhem, NL

Accoya® products

Bridge in Sneek (NL)
Lorry bridge (60t lorries, 40 m length)
silicon based compounds

Hydrophilic and potentially reactive

Protection of masonry

Clothes (dyeing agents fixation)

Coupling agents (electrical circuit)

Hydrophobic

Hydrophobation of glass

Silanes, silicones

“water shade effects”
types of silanes

\[ Y = \text{“Organo-functional groups”} \]
\[ OX = \text{“Silicone-functional group OCH}_3, \text{ OC}_2H_5 \text{ etc.} \]

Material properties
TMT: new material, new properties

- Consistent colour through the piece
- Reduced equilibrium moisture content
- Improved durability against decay
- Reduced thermal conductivity
- Resin removed
- Reduced splitting strength
- Improved stability
- Slightly reduced bending strength

Capillary water uptake

- Water absorption coefficient shows the water uptake in relation to time [kg/m²/√h]
Outside weathering - results

- significant lower m.c. than untreated material
- uncoated furfurylated is lower than untreated/coated

Moisture content [%] of SYP samples over a period of 21 month
Surface appearance

Beech control 30% NMM-BS yellow modified beech 30% NMM-BS brown modified beech

30% NMM-BS yellow modified beech 30% NMM-BS brown modified beech
Sorption properties
(Tjeerdsma, Boonstra 1990’s)

Scotch pine
- Heat-treated adsorption
- Heat-treated desorption
- Non-treated adsorption
- Non-treated desorption

Equilibrium Moisture Content (%)

Relative Humidity (%)

Swelling and shrinking of wood species

Relative swelling of wood species from 0% moisture content to fibre saturation point

Swelling [%]

Treatment
- Interface
- teak
- pine heartwood
- pine sapwood
- oak
- beech

Radiale swelling
Tangentielle swelling
Brinell hardness (parket flooring)

- *Pinus sylvestris*
- *Tectona grandis*
- *Fagus sylvatica*

**Hardness [N/mm²]**

- Untreated
- 10% concentration of DMDHEU
- 30% concentration of DMDHEU
- 50% concentration of DMDHEU
- 80% concentration of DMDHEU

**MOE in bending mode (DMDHEU)**

(Bollmus 2010)
Impact bending strength
(Bollmus 2010)

Degradation of beech wood after 32 weeks in soil contact (ENV 807)
Main material properties gained with NMM

- Durability improvement

![Graph showing material properties gained with NMM]

Pine modified with 10% NMM after 16 weeks EN 113; DBU-Report, Az: 26869 (2009)

Fungal resistance as function of process conditions
(Tjeerdsma, Militz 2002)

*Pinus silvestris*

- Soil block test
- Weight loss after 54 weeks

![Graph showing fungal resistance as function of process conditions]

EN 113; DBU-Report, Az: 26869 (2009)
Termite resistance: test fields Australia, Portugal, lab tests Spain

Results *Coptotermes acinaciformis*

<table>
<thead>
<tr>
<th>Specimens</th>
<th>Mass loss [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scots pine Feeder</td>
<td>DMDHEU 1.3 M</td>
</tr>
<tr>
<td>Scots pine DMDHEU</td>
<td>2.1 M</td>
</tr>
<tr>
<td>Scots pine DMDHEU</td>
<td>1.3 M</td>
</tr>
<tr>
<td>Slash pine DMDHEU</td>
<td>2.1 M</td>
</tr>
<tr>
<td>Slash pine DMDHEU</td>
<td>1.3 M</td>
</tr>
<tr>
<td>Beech DMDHEU</td>
<td>2.1 M</td>
</tr>
<tr>
<td>Beech DMDHEU</td>
<td>1.3 M</td>
</tr>
</tbody>
</table>
Wood - Treatability / Permeability

No obvious effect for thermowood

Wood - Treatability / Permeability

Obvious effect for impregnation technology
Basis materials for wood modification

- Easy „treatable“
- Large quantities
  - Pines
  - Poplars
  - Beech?
  - Eucalypts?
  - Ash? Alder?
  - Other fast growing wood species!

Challenge:
processing, costs and markets
Other factors of concern to clients...

- Environmental concerns
  - Emissions to air
  - Emissions to water
  - Human tox
  - Eco tox
  - Working environment

- Machinability and further processing
  - Tools
  - Material homogenity
  - Glueability/ paintability
  - End product performance

- Disposal/ recycling
  - Reuse of fibres?
  - Energy – burning?
  - Land fill

Potential markets for modified wood

**Outdoor**
- Decking
- Roofing
- Utility poles
- Rail ties
- Fences
- Garden furniture
- Bridges
- Marine applications
- And more...

**Indoor**
- Flooring
- Windows
- Doors
- Furniture
- Mouldings
- And more...

- Furniture, Thermowood
- Decking, Accoya
- Roofing, Kebony
- Floor, Kebony
- Bridge, Accoya
- Decking, Belmadur
- Chair, Belmadur
Challenge: markets

- Biocide treated wood
  - Costs!!
  - Special products

- Markets of tropical hardwoods
  - use classes 1-5
  - „high quality”

- Special products with diverse functions

ECWM European Conferences on Wood Modification

- ECWM 6: Sept. 2012 in Ljubljana, Slovenia
- ECWM 2014: Lisbon/ Portugal
- ECWM 2016: Helsinki/ Finland

(Proceedings ECWM 1-6: contact me!)
Thank you for your attention!

10 % NMM, 20 x magnification, ash