To what extent is UF resin really cured in medium density fiberboard?

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Outline

• Background

• Panel properties

• Water Extractables
  – resin component extraction

• Chemical Analysis
  – panel extractables

• Summary
Background

• UF resin is susceptible to moisture
  – studies focus on hydrolysis and panel emissions

• MDF : differences → surface and core layers
  – resin & temperature effects
  – EMC, contact angle, panel bonding & swell, extractables
  – high nitrogen contents removed
    ▪ 60% !!! (urea?)

• Suggest resin cure differences within panels
  ⇒ may confer differences in panel properties
  - emissions, water soak, fibre

Consider this?
Methodology

UF resin + Fibre → Hot-press Fibre → Water Soak 20°C, 24 h → Analyze Residues %N loss, chemistry

Acid Cure Resin 100°C → Panel Properties
Nitrogen Mass Balance ⇒ Resin Loss

E0 Panel (13.3% resin loading)

- MDF Panel: 1.0 g
- grind up
- water
- Residue: 88.2% mass
- oven dried
- Extract: 4.2% mass
- freeze dried

\[ \text{MDF Panel} \quad \text{grind up} \quad \text{water} \quad \text{Residue} \quad \text{Extract} \]

\[ \begin{align*}
\text{MDF Panel} & \rightarrow 1.0 \text{ g} \\
\text{5.41 \% N} & \rightarrow 54.1 \text{ mg N} \\
\text{51 \% N} & \rightarrow 27.2 \text{ mg N} \\
\text{2.68 \% N} & \rightarrow 23.6 \text{ mg N} \\
\end{align*} \]

Finding

- Account for 93-98\% of panel nitrogen

Panel Properties

- Laboratory and commercial MDF panels
  - Mechanical- & blowline-blending

<table>
<thead>
<tr>
<th>Panel</th>
<th>Resin (%)</th>
<th>IB (MPa)</th>
<th>Formaldehyde Emissions (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lab 8mm MDF</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control E0</td>
<td>9.1</td>
<td>0.53</td>
<td>-</td>
</tr>
<tr>
<td>Control E1</td>
<td>8.5</td>
<td>0.72</td>
<td>0.70</td>
</tr>
<tr>
<td><strong>Commercial E0 3mm MDF</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comm 5</td>
<td>4.8</td>
<td>1.29</td>
<td>0.27</td>
</tr>
<tr>
<td>Comm 12</td>
<td>12.9</td>
<td>2.04</td>
<td>0.13</td>
</tr>
<tr>
<td>Comm 14</td>
<td>13.3</td>
<td>2.12</td>
<td>0.12</td>
</tr>
</tbody>
</table>
Cured UF Resin Extraction

• Cure E1 resin with acid
  – acetic or hydrochloric acids
⇒ <2% mass loss
  – 106% N% → enrichment of nitrogen

• E1 resin, 100°C, 30 mins (without acid)
⇒ 48% mass loss
  – 107% N%

⇒ Curing UF resin distinguishes mass loss
MDF Panel Water Extractions

• Some 50-70% nitrogen removed on soaking

![Bar chart showing extracted nitrogen (%) for Comm 5, Comm 12, and Comm 14 with Resin Loading.](chart.png)
Water Extractives v Emissions

- Resin loading influences emissions
  - Extracted %N correlates with formaldehyde emissions

![Bar chart showing extracted nitrogen and formaldehyde emissions for Comm5, Comm12, and Comm14.]
Q. Is the %N removed dependent on extraction time?

⇒ Extraction at 2, 6 & 24 h → similar values

Finding

Resin components readily solubilised from fibre

⇒ Resin hydrolysis not cause of high %N losses
Type of Resin Cure

- Uncured fibre v oven curing v hot-pressing
  - similar %N removed

⇒ No differences in %N extracted due to cure

![Bar chart showing extracted nitrogen (%) for Uncured Fibre, Cured Fibre, and Panel. The chart indicates that there are no significant differences in %N extracted among the three treatments.](image)

10% E0 resin loading
Chemical Characterisation – is it just urea?

- GPC used to get MW profile of panel extractables

Water Extraction
20°C, 24 h

Analyze Residues
%N loss, chemistry

Extractable material
Fibre only
E1 resin

Elution Time (sec)
Chemical Characterisation – is it just urea?

- MW profile of extractables

Chemical Characterisation – is it just urea?

- MW profile of extractables
  - minor differences across extracts
Chemical Characterisation

• NMR confirmed chemistry of extracts
  – -NH, -NH₂ and N-CH₂-N/O consistent with small oligomers
Chemical Characterisation – UF oligomers?

- Extractables → UF resin components & fibre extractives
Discussion

• Rapid loss of labile UF resin species
  – unlikely due to UF resin degradation and hydrolysis

• Extractables are UF oligomers

• Quantity of Extractables?
  – no difference once applied to fibre
  – relationships with resin loading, formaldehyde emissions
Hypothesize?

• Apply resin → components separate within fibre matrix
  – a chromatography effect

• Components available only to partially couple → oligomers
  – cannot fully crosslink
  – more resin greater opportunity to couple → crosslink

Outcome
⇒ Incomplete cure compared to pure UF resin

Does it matter?
• Panel properties are fine, more resin better performance
• UF oligomers responsible for panel emissions?
Summary

• MDF panels contain labile resin components
  – High proportions, readily extractable into water

• Chemistry → low MW UF oligomers
  – GPC, NMR confirm methylene-urea components

• UF resin may not achieve full cure within MDF/panelboards

• UF oligomers → contribute to emissions?
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