Adhesives from biomass pyrolysis

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Adhesives from Biomass Pyrolysis

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Outline

- Introduction

- Preparation of pyrolysis bio-oils
  - Fractional condensation
  - Autothermal operation

- Bio-phenol resins for wood adhesives

- Conclusions
Introduction

➢ Bio-phenol resins for wood adhesives:
  • Biomass fast pyrolysis can produce phenolic chemicals in the form of “Bio-Oil”
  • PF resins are widely used for wood adhesives
  • Prior studies with whole bio-oil or a solvent-extracted oil fraction provide 20-50% phenol substitution

➢ Research objective
  • Develop an inexpensive pyrolysis process to produce better bio-oil for phenol substitution in PF resins
Preparation of Pyrolysis Bio-oils

Problem: Bio-oil contains ~35% water, and volatile acids

Solution: Fractional Condensation of Pyrolytic Vapors

Results:
- Two fractions: dry bio-oil (<1%), aqueous condensate
- Dry bio-oil HHV: 20 → 30+ MJ/kg (ethanol: 29.7)
- Recovery of organic chemicals: > 90%
- Recovery of total bio-oil energy: > 90%
Preparation of Pyrolysis Bio-oils

Problem: External heating required (endothermic process)

Solution: Autothermal Operation from partial oxidation

Results:
• No need for external heating → simplified reactor design, less expensive process
• Better dry bio-oil quality:
  - reduced acidity
  - reduced amount of heavy sugars and pyrolytic lignin
  - enriched concentration of simple phenolics
Dry Bio-oil for Bio-Phenol Applications

- Dry bio-oil yield (%)
  - Birch Wood
  - Birch Bark
  - Hydrolysis Lignin
  - Kraft Lignin

- Total phenolics concentration (g GAE/g dry bio-oil)
  - Birch Wood
  - Birch Bark
  - Hydrolysis Lignin
  - Kraft Lignin

25%
70%
40%
Problem: High-value application for dry bio-oil?

Preparation of Bio-phenol Resins for Wood Adhesives
Adhesive Characterization

- Tests → Bio-phenol resins can be made in existing plants with no reduction in production capacity

- Regulatory requirements for plywood panels are met:
  - Mechanical shear strength
    (dry test, and boil test – 28 h cycle)
  - Formaldehyde emissions
Meeting ISO/JIS Specifications: Mechanical Strength

Biomass Type / Autothermal (?) / Mechanical Test

Phenol substitution ratio (%)

- 80
- 65
- 50
- 40
- 30
- 20
- 10
- 0

Mechanical shear strength

- 2.5 MPa (CSA, dry test)
- 1.0 MPa (ISO/JIS)
- 0 MPa

Results:

- Not binding
- Fail

Dry No Birch wood
Dry Autothermal
Boil No Birch bark
Boil Autothermal
Dry No Hydrolysis lignin
Dry Autothermal Kraft lignin

Values:

- 1.3
- 1.7
- 1.4
- 1.3
- 1.2
- 1.3
- 1.8
- 1.6
- 1.4
- 1.6
- 1.9
- 2.0
- 1.5
- 1.6
- 1.5
- 1.4
- 1.7
- 1.5
- 1.9
- 1.4
- 1.7
- 1.7
- 1.9
- 1.8
- 2.0
- 2.5
Meeting ISO/JIS Specifications: Formaldehyde Emission

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<th>65</th>
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<td>Autothermal</td>
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Formaldehyde emission

- 0.0 mg/L (E0, indoor use)
- 0.5 mg/L (E1, indoor use)
- 1.5 mg/L
Low-Cost Waste Biomass: Digestate?

- Digestate → Low cost, high lignin content, and high ash
- Dry bio-oil (500 °C): Two types of digestates
  - Total phenolics: > birch bark
  - Viscosity (MW): > birch bark
  - Phenol substitution: 50%, < birch bark (65%)
- Future work:
  - For better bio-oil quality and phenol substitution ratio:
    - Higher pyrolysis temperature
    - Longer vapor residence time
Conclusions

High bio-phenol substitution ratio was achieved:
• 50 wt. % - 80 wt. % phenol substituted by pyrolysis bio-oil
• Fractional condensation and autothermal operation are beneficial

Bio-PF wood adhesive is attractive:
• Cost savings: expensive, fossil-sourced phenol
  → inexpensive, sustainable bio-oil
  (cost < 50% of phenol from benzene)
Acknowledgements

- ICFAR colleagues
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