Drying and Devolatilization of Black Liquor

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Objective

• Review current knowledge and modeling capabilities

• Define experimental and modeling needs
Why Important?

- Controls location of drying and release of combustibles
  - Impact on local energy release and gas composition
- Determines char carbon yield
  - Impacts combustor or gasifier residence time
- Impacts tar yield and possibly tar species distribution
- Controls sulfur and nitrogen gas species formation
- Influences fine particle production

Hupa’s Stages of Droplet Burning

Photos courtesy of M. Hupa
Measuring Drying and Devolatilization

- Two options:
  - Large droplets or particles
  - Small droplets or particles

Tradeoffs with Large Droplets

- Observe “actual” phenomena as they occur
- Stages can overlap considerably, making it difficult to extract basic rate data
Tradeoffs with Small Particles

- Particles react uniformly and isothermally throughout
- No overlap of stages
- May not observe important interactions (e.g. autogasification)

We Need Both

- Observe phenomena
- Measure kinetics
- Detailed model of behavior
- Validate Results
Devolatilization is Fast
(Sricharoenchaikul, 2001)

Time Scale for Tar Reactions is Longer
(Sricharoenchaikul, 2001)
Models for Swelling

- Frederick, 1991
  - Empirical, dimensionless description of Hupa’s curve
  - Extent of swelling depends upon extent of drying
  - $S V_{\text{max}}$ is the single liquor dependent parameter
- Frederick et al., 1995
  - No plateau during drying; continuous swelling to $S V_{\text{max}}$
- Verrill & Wessel, 1995
  - Adapted the 1991 swelling model to a 1-D, multi-layer droplet

Swelling During Drying

<table>
<thead>
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<th>Time, s</th>
<th>Diameter, mm</th>
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- Frederick et al., 1995
- $T > 800^\circ\text{C}$
- Frederick et al., 1991
- Drying
- Devol
- Char burn
- 800°C in air
Models for Swelling

- Verrill & Wessel, 1995
  - Adapted the 1991 swelling model to a 1-D, multi-layer droplet
- Jarvinen et al., 2002
  - Adapted the 1991 swelling model to a 1-D, multi-layer droplet

→ No model predicts the maximum swelling in terms of liquor composition, properties, or reactor environment

Research Needs

- Better devolatilization rate data
- A better swelling model
- A better understanding of tar formation and transformation
- Computational capability to scale up basic data to process level