Drying and Devolatilization of Black Liquor

Jim Frederick
Chalmers University of Technology
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

0.1 mm
Tradeoffs with Large Droplets

• Observe “actual” phenomena as they occur
• Stages can overlap considerably, making it difficult to extract basic rate data

2-3 mm
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)

![Graph showing devolatilization and char reactions between Liquor A and Liquor B. The x-axis represents particle residence time in seconds, while the y-axis shows the percentage of carbon volatilized, expressed as a percentage of carbon in BLS.]
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
  – $SV_{\text{max}}$ is the single liquor dependent parameter

• Frederick et al., 1995
  – No plateau during drying; continuous swelling to $SV_{\text{max}}$

• Verrill & Wessel, 1995
  – Adapted the 1991 swelling model to a 1-D, multi-layer droplet
Swelling During Drying

Frederick et al., 1995

Frederick et al., 1991

Drying
Devol
Char burn

Time, s

Diameter mm

T > 800°C

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