Challenges and Possibilities in Char Bed Control

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Kari Saviharju, Jarmo Kaila
Impact of Char Bed Management

- Boiler operability
- Maximum capacity
- Reduction rate
- Smelt flows
- Green liquor suspended solids
- Emissions
- Fouling
- Corrosion
Recover Boiler Operability

- After pyrolysis approximately half of the combustible material in black liquor has been converted to char
  - This should combust in the lower furnace below the liquor gun level
  - Small droplets can escape with vertical flows but with proper air system and set-up will rapidly combust in flight
- Large portion of the char combusts in flight
  - Large droplets can have aerodynamic properties that allow them to impact the furnace walls
- In the hot lower furnace reduction reactions won’t need long residence time
  - Need is for good char coverage, not for large bed volume
- Bed must be stable and not allowed to climb up the walls. Liquor spraying on the walls must also be avoided
  - Sticks to walls and occasionally collapses down
  - Uneven smelt flow, even smelt rushes or explosions
Recover Boiler Operability

Impact of Liquor Properties

- Variation in various liquor properties has impact on liquor spraying and lower furnace operations and thus impacts bed behavior

- Variation should be minimized or at least identified/anticipated:
  - Cook
  - Dry solids
  - Soap
  - Viscosity
  - Ash mixing and variations in it – evaporator wash etc
  - Make-up chemical feed

- The different departments of the mill have to work together and share information for better char bed control
The Key Factors for Char Bed Control

- Liquor spraying, swelling and other physical properties
  - Liquor Gun locations and elevations
  - Spray geometry, velocities (pressure) and direction
  - Average droplet size and size distribution
  - Mass flows with the directional distribution and coverage
- Liquor combustion properties
  - Liquor dry solids
  - Inorganics in liquor (ash mixing)
  - Swelling
  - Time needed for drying, pyrolysis and combustion
- Air Feeds into the Lower Furnace and induced flow fields
  - Temperature Distributions in the Lower Furnace
Liquor Droplet Swelling (Åbo Akademi)
Combustion in Flight (Figure from Mika Järvinen’s thesis)

**Roughly:**

- Relative velocity \( w = w_0 \cdot \exp[-L \cdot \frac{SW^{2/3}}{D}] \)
  - \( L \)=Flight distance
  - \( SW \)=Swelling index = droplet volume/original volume

**Example:**

- 1 mm droplet, which \( SW=30 \) looses its velocity in 2 m
- 6 mm droplet, with \( SW=12 \) (typical for high D.s.), looses 1/3 of the velocity in 5 m, and 10 m is needed to reduce velocity by 60 %. In practice furnace flows and liquor gun positions are needed in steering the flight

- ● 95 % dried
- ○ 95 % pyrolysed
- □ Complete char combustion

Flight trajectories for 0.5, 1, 2 and 4 mm droplets, \( w_0 =13 \) m/s, 5° tilt, 27-fold swelling, \( w_{up} =6 \) m/s

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Challenges and Possibilities in Char Bed Control
Flow Fields in the Furnace

Flow fields in the furnace are complex, and gradients can be strong
- Flow Fields have a strong effect on droplet’s flight
- Droplet should be dry, pyrolysed and char combusted when entering strong flows close to the walls
  - Wet droplets do not follow the gas flows, but can fly straight to the walls
  - This is often difficult to completely prevent in small furnaces
  - Too heavy, although swollen, droplets impact the wall in strong rotational firing concepts

Positioning and type of the liquor guns is important
- Liquor gun positions in relation to lower furnace gas flow fields
- Liquor gun type and operational parameters
Velocity vectors and particle concentrations, Vertical Air™ System in a 3000 t D.S./d boiler

Black liquor concentration and velocity vectors in the secondary air levels

Lowest secondary air level          Second secondary air level          Highest secondary air level

Concentration = 0 kg/m³ (blue) - 0.1 kg/m³ (red).
Velocity has been shown between 0 m/s - 80 m/s.
Reduction

- Smelt temperature is typically approximately 830-870 °C, lower furnace temperature is higher at 1000-1200 °C
  - Temperature quickly drops a couple of hundred °C inside the bed
- Good reduction requires:
  - Good char coverage
  - Sufficiently high temperature
- With modern high dry solids and reasonable liquor heating values large bed volume is not needed for good reduction
  - The increase in temperature from 850 °C to 1000-1100 °C makes reduction kinetics with carbon 20 fold higher
  - With long contact time high reduction can also be achieved with lower solids
- Smelt pools in contact with air jets must be eliminated
Example of Bed Management by Boiler Tuning

In the next example there are four photos of a rapidly changing bed.

Starting case:

- Bed is “normal”, low and elongated in shape.
- Bed reaches half way between primary and secondary air ports.
- Low char covered region surrounds the bed on all four walls.
- Just slight spraying into one corner, otherwise corners are “clean”.

Challenges and Possibilities in Char Bed Control
Altitude Contours of a Char Bed
Bed at 2000 t/d BLS Load

Picture from the Front Wall
Bed at 2000 t/d BLS Load
Picture from the Side Wall
Example of Bed Management by Boiler Tuning

- Change in liquor quality

- Sudden bed growth on the front wall next to gun opening
  - Forms rapidly a massive ridge when liquor spray hits the top of bed and doesn’t fly over it
  - Growing material is very light, swollen liquor
  - This growth can become compacted into dense inorganic material if allowed to remain
  - Slight adjustment on the gun angle and liquor temperature brought the bed rapidly back to normal
Spraying Straight into the Bed
Rapid Changes in Bed Height
Example of Bed Management by Boiler Tuning

- Lessons learned
  - Good bed cameras in proper locations are important
  - Important to monitor lower furnace temperatures
  - Pro-active attitude to char bed management is needed, changes can happen quickly
  - Slight fouling of spray guns can alter their characteristics
    - Keep them clean
Smelt Flows
A Case Before Boiler Trimming

RELATIVE SMELT FLOWS AND SMELT TEMPERATURE AT THE SPOUTS

30% 40% 100% 120% 100%

811 °C 835 °C 849 °C 868 °C 815 °C
Summary

- Char bed (and lower furnace) operation has major impact on recovery boiler operations
  - Operatability, capacity
  - Reduction rate, smelt flows, green liquor suspended solids
  - Emissions, fouling, corrosion

- Char Bed Behavior and control is a function of multiple inter-related parameters
  - Liquor properties
  - Liquor spraying parameters
  - Lower furnace flow fields

- Boiler operators need good tools and training to adjust boiler for changing operating conditions
  - Good bed cameras in proper locations essential
  - Willingness and knowledge to change operating parameters