Fouling Evaluation of A PC-fired Boiler using SmartBurn® AshProSM – A Comprehensive CFD Ash Prediction Tool

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Introduction to AshPro℠

• AshPro℠ - a comprehensive CFD ash prediction tool for coal-fired boilers, developed utilizing:
  – The University of North Dakota Energy & Environmental Research Center (EERC) coal ash behavior expertise
  – RMT - SmartBurn®’s expertise in combustion, CFD modeling and boiler operation

Key Inputs
- Fuel properties
- Power plant design
- Operating conditions

Key Outputs
- Localized ash deposition
- Heat transfer in specific areas
- Deposit growth & strength over time
- Ash management options & strategies
AshPro\textsuperscript{SM} Sub-Models

- Ash Slagging Model
  - Capability:
    - Furnace wall slagging evaluation
    - Predict furnace wall deposit formation, deposit growth, strength development, deposit removal through gravity shedding and sootblowing, and heat transfer properties
  - Input information includes
    - Ash particle size and chemical composition from CCSEM and XRF analysis
    - Initial furnace wall thermal properties, ash impaction on furnace wall and flue gas properties from CFD simulation
AshPro℠ Sub-Models

• Fouler Model
  – Capability:
    • Convective pass fouling evaluation
    • Predict tube bank high- and low-temperature fouling deposit formation and growth, strength development, deposit removal through gravity shedding, load drop shedding and sootblowing, and heat transfer properties
  – Input information includes
    • Fly ash particle size and chemical composition from CCSEM and XRF analysis
    • Fly ash loading, flue gas species concentration, temperature and velocity from CFD simulation
Fouling Deposits in Convective Pass

Upstream Deposits (US):
Formed by inertial impaction of ash > 10 micron

Downstream Deposits (DS):
Formed by eddy impaction of ash < 10 micron

Source: EERC, University of North Dakota
Flue Gas Temperature (°F) in Tube Banks of a 512 MW T-fired Boiler

SH Platen
1,550 < T < 2,530 °F

RH Front Pendant
990 < T < 2,250 °F

Final SH Pendant
1,005 < T < 1,860 °F

RH Rear Pendant
1,000 < T < 1,675 °F

SH Division Panels
1,690 < T < 2,950 °F

Slagging:
T > 2,400 °F

High Temperature Fouling:
1,800 °F < T < 2,400 °F

Low Temperature Fouling:
T < 1,800 °F
Ash Chemical Composition and Size Distribution Input for Fouler

- Overall 7 chemical categories and 6 size bins
- Size bins:
  - < 1 μm; 1~ 5 μm;
  - 5 ~ 10 μm; 10 ~ 20 μm; 20 ~ 30 μm; 30 ~ 200 μm
- < 5 μm ash contributes to inner layer of deposit
- < 10 μm ash contributes to downstream deposit
- > 10 μm ash contributes to upstream deposit
RH Inlet Fouling Deposit Pattern

Eagle Butte, t = 200 h
US Thickness (in)

Black Thunder, t = 200 h
US Thickness (in)

Buckskin, t = 200 h
US Thickness (in)

Eagle Butte, t = 200 h
DS Thickness (in)

Black Thunder, t = 200 h
DS Thickness (in)

Buckskin, t = 200 h
DS Thickness (in)
RH Inlet Fouling Deposit Pattern (Continued)

• Three different coals were investigated
• No sootblowing (SB) during the 200 hour run time
• Mainly high temperature fouling and overall deposit pattern is similar for the three types of coal
• Upstream: Eagle Butte coal caused the thickest upstream deposit, followed by Black Thunder and Buckskin (the relatively clean one)
• Downstream: Buckskin coal caused the thickest downstream deposit, followed by Black Thunder and Eagle Butte (the relatively clean one)
Final SH Inlet Fouling Deposit Pattern

Eagle Butte, t = 200 h
US Thickness (in)

Black Thunder, t = 200 h
US Thickness (in)

Buckskin, t = 200 h
US Thickness (in)

Eagle Butte, t = 200 h
DS Thickness (in)

Black Thunder, t = 200 h
DS Thickness (in)

Buckskin, t = 200 h
DS Thickness (in)
• Three different coals were investigated
• No sootblowing (SB) during the 200 hours run time
• Mainly low temperature fouling and overall deposit pattern is similar for the three types of coal
• Upstream: Eagle Butte coal caused the thickest upstream deposit, followed by Black Thunder and Buckskin (the relatively clean one)
• Downstream: Buckskin coal caused the thickest downstream deposit, followed by Black Thunder and Eagle Butte (the relatively clean one)
High Temp Fouling Deposit Growth and Removal for Different Coals

- RH front pendant
  - Local flue gas temperature is ~2000 °F
  - Sootblowing frequency: every 6 hours
- Upstream deposit
  - Eagle Butte has the greatest remaining ash deposit although Black Thunder has similar deposit growth
  - Buckskin and Black Thunder are easy to clean with sootblowing
- Downstream deposit
  - Buckskin has the greatest deposit growth
  - Sootblowing is very effective for all three coals
Low Temp Fouling Deposit Growth and Removal for Different Coals

- **Final SH pendant**
  - Local flue gas temperature is ~ 1500 °F
  - Sootblowing frequency: every 6 hours

- **Upstream deposit**
  - Deposit growth: Eagle Butte > Black Thunder > Buckskin
  - Buckskin and Black Thunder are easier to clean with sootblowing

- **Downstream deposit**
  - Deposit growth: Buckskin > Black Thunder > Eagle Butte
  - Deposit is hard to clean with sootblowing for all three coals
Ash Chemical Composition in Different Size Bins

- **Particle < 10 μm**
  - Mainly contributes to downstream deposit
  - Alkali wt%:
    - Buckskin > Black Thunder > Eagle Butte

- **Particle > 10 μm**
  - Mainly contributes to upstream deposit
  - Alkali wt%:
    - Eagle Butte > Black Thunder > Buckskin
Ash Size Distribution and Deposit Strength

- Ash weight percent in different size bins plays important role in upstream or downstream deposit growth
  - > 10 μm – upstream deposit:
    - Eagle Butte > Black Thunder > Buckskin
  - < 10 μm – downstream deposit:
    - Buckskin > Black Thunder > Eagle Butte
- Sulfate strength factor calculated from chemical compositions is critical to deposit removal at low temperature
  - > 10 μm – upstream deposit:
    - All smaller and Eagle Butte > Black Thunder > Buckskin
  - < 10 μm – downstream deposit:
    - All greater and Eagle Butte > Black Thunder ≈ Buckskin
Sootblowing Frequency Impact on Pendant Cleanness

US deposit, no Sootblowing

US deposit, Sootblowing = 6h

US deposit, Sootblowing = 18h

DS deposit, no Sootblowing

DS deposit, Sootblowing = 6h

DS deposit, Sootblowing = 18h
Sootblowing Frequency Impact on Pendant Cleanness (Continued)

- Analysis of Eagle Butte coal
- Sootblowing pressure: 250 psi
- Sootblowing angle: 90°
- For both upstream and downstream deposits, sootblowing effectiveness decreases as sootblowing frequency is reduced from 6 to 18 hours, which indicates deposits are difficult to clean
- With sootblowing every 18 hours, 51% of deposit is removed; With sootblowing every 6 hours, 74% of deposit is removed
Sootblowing Pressure and Nozzle Impact on Pendant Cleanness

US deposit, Angle = 90°, P = 250 psi

US deposit, Angle = ±10°, P = 250 psi

US deposit, Angle = ±10°, P = 175 psi

DS deposit, Angle = 90°, P = 250 psi

DS deposit, Angle = ±10°, P = 250 psi

DS deposit, Angle = ±10°, P = 175 psi
Sootblowing Pressure and Nozzle Impact on Pendant Cleanness (Cont’d)

• Analysis of Eagle Butte coal
• Sootblowing frequency is every 6 hours
• For both upstream and downstream deposits, sootblowing with 10° lag angle enhances the cleaning effectiveness
• Sootblowing with 10° lag angle with lower steam pressure has similar cleaning effectiveness as 90° lag angle with higher steam pressure
• An updated sootblower nozzle can improve sootblowing system performance and reduce O&M costs
Summary

• Different coal types consist of different ash chemical compositions and particle size distributions, which are critical for fouling deposit formation, growth and removal

• The fouler model can be used to evaluate fouling in the convective pass for fuel switching and provide support in fuel selection

• The fouler model can also be used to evaluate and optimize sootblowing system performance such as sootblower nozzles, sootblowing pressure and frequency