Comparisons of a Coal Ash Deposition Model with Deposition Measurements of a Tube in Cross Flow

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Background

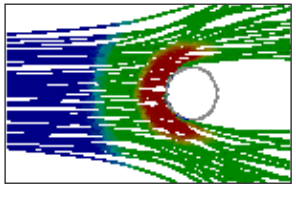
Emerging coal-derived energy technologies promise increased efficiency and potential environmental benefits. To realize these benefits however, better tools are needed to predict the growth rates and physical properties of ash deposits. Deposition behavior is understood to be dependent on ash-particle size, composition, temperature, and other properties. Various models have been combined together into a CFD-based user-define function (UDF) for predicting ash deposition behavior on a heat transfer surface.

Objectives

1. Develop a model of coal ash deposition using User-Defined Functions (UDF) in a commercial CFD code.
2. Measure coal ash deposition on a simulated boiler tube in cross flow and compare measured and predicted deposition rates.

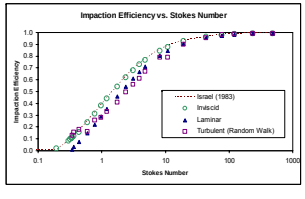
Models

Particle Tracking/Impaction



CFD-simulated particle tracks using a random-walk model.

Actual particles impacting on a cooled tube in crossflow.



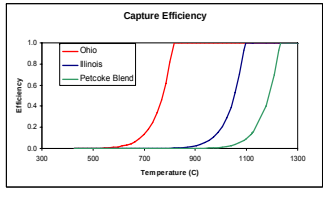
Impaction efficiency as a function of Stokes Number.

Particle Capture

$$\log\left(\frac{\mu}{T-T_S}\right)=\frac{14788}{T-T_S}-10.391$$

$$Capture\,Efficiency=\frac{m_{deposited}}{m_{particle}}=\min\left[\frac{\mu_{critical}}{\mu},1\right]$$

Relationship between effective ash viscosity and temperature. Note T_S is a function of ash composition.

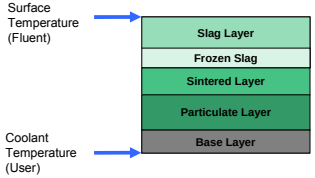


Capture efficiency as a function of temperature for three fuels.

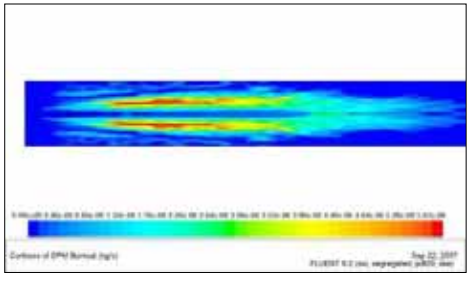
Thermal Properties of Deposit

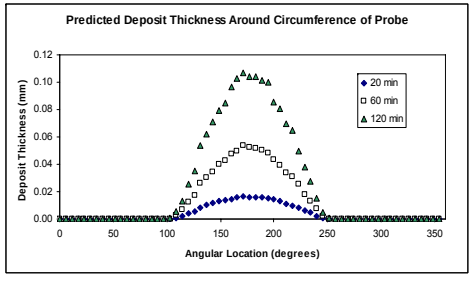
Captured mass from incoming particles are added to a deposit layer according to the current surface temperature of the deposit. Heat flux through the accumulated ash layers, calculated using the equation shown, is returned to the CFD solver as the thermal boundary condition.

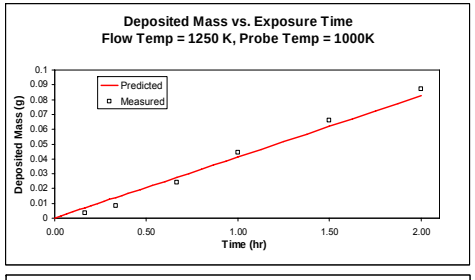
$$q'' = \frac{T_{Surface} - T_{Cool}}{R_{Sinter} + R_{Particulate} + R_{Frozen} + R_{Slag} + R_{Base}}$$

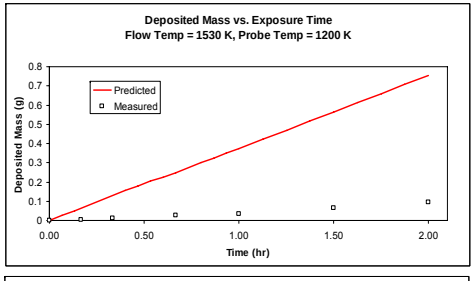


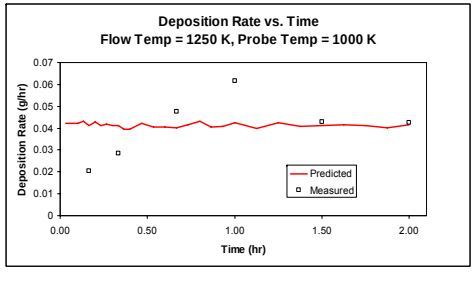
Results

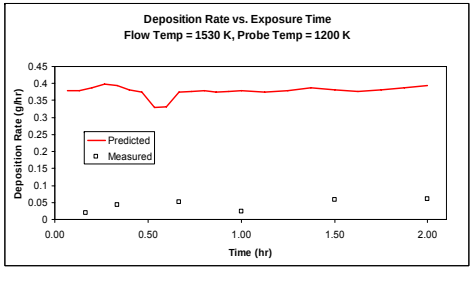












Conclusions

1. Model parameters (primarily μ_C) can be tuned to match measured data
2. Predicted increase in deposition rate with increased temperature not reflected in experimental data. Relatively large increase in temperature does not show significant increase in deposition rate.
3. Formation of "initial" deposit layer is not captured with the current particle capture model.

Future Work

1. Implement fragmentation/agglomeration models to eliminate need for separate combustion and deposition models.
2. Develop/Find new deposition model that captures important aspects of particle capture besides particle temperature.