Deposit Formation Fundamentals: Experiments Reconciled with Models

Shrinivas Lokare, Brent Poole, Bob Chan, Dale Tree, Larry Baxter, Brigham Young University, Provo, UT 84602
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Background

- Fossil fuel and biomass combustion is a major source for power generation in the US
- Combustion behavior is significantly varying with fuel composition, ash content and ash composition
- Ash content and composition governs boiler designs and operation

Deposit formation mechanisms

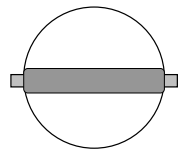
$$\frac{dm}{dt} = I \cdot G + T + C + R + E$$

I = Impaction, T = Thermophoresis, C = Condensation, R = Chemical Reaction, E = Eddy Impaction

Impaction - the most significant from the standpoint of total deposit mass
Condensation - the most important with respect to corrosion and other surface reactions

Impaction Model

$$m_{ashflow} = \frac{m_{fuel} \cdot x_{ash} \cdot A_{projected}}{A_{reactor}}$$



$$m_{impaction} = m_{ashflow} \cdot \eta$$

$$m_{capture} = m_{impaction} \cdot G$$

$$\zeta = \eta G$$

η= Particle Impaction efficiency

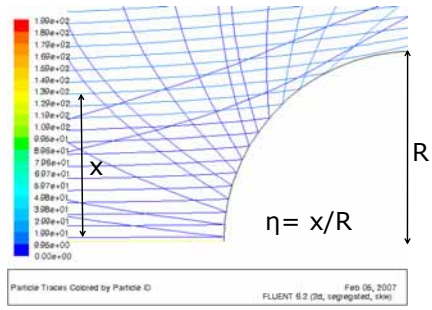
G= Particle Capture efficiency

ζ= Particle Collection efficiency

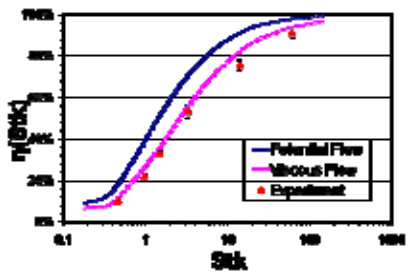
Fluent Impaction Model

$$\eta(Stk\ ) \cong \left[1 + b(Stk\ - a)^{-1} - c(Stk\ - a)^{-2} + d(Stk\ - a)^{-3}\right]^{-1}$$

- Solver – 2D, segregated
- Grid – Quadrangular, Paved
- Cells – 12308
- Viscous model – Standard k-w (2 equation)

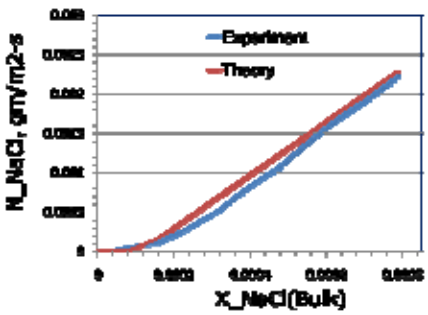


Calculation of Impaction Efficiency



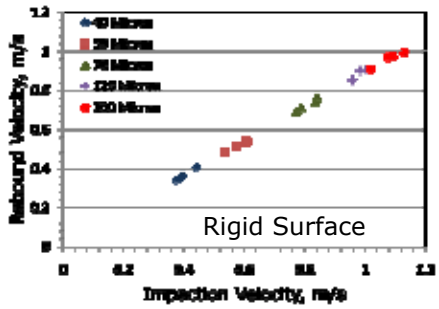
	a	b	c	d
Potential Flow	0.1238	1.34	-0.034	0.0289
Viscous Flow	0.0868	1.9495	-0.457877	-0.047

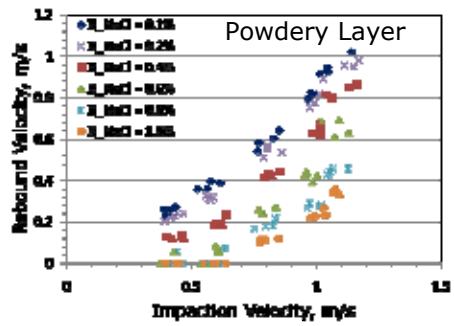
Chloride Condensation Rate



Condensation of alkali chlorides is a strong function of mole fraction of chlorides in gas phase and deposit surface temperature.

Particle Rebound/Capture





Particle impaction on rigid surface results in rebound with a coefficient of restitution ~ 0.9, which decreases even further when the surface is coated with fine particulates (or condensed with alkali chlorides). Some cases of higher chloride condensation yield capture of small-to-intermediate size particles.

Summary and Conclusions – The improvement of previous representations resulted in up to 40% decrease in impaction efficiency. Condensation theory and experimental results also provide mechanistic and accurate deposit descriptions. Particle capture mechanisms on different surfaces (e.g. rigid metal wall, fine particulate layer) provide quantitative capture efficiencies, rates and structures that compare well with experimental data.

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