Investigation of Impaction and Capture Efficiency During Coal Ash Deposition

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Outline

- Motivation
- Objectives
- Theory
- Approach
- Results and Discussions
- Conclusions

Motivation

- **Size and species distributions of inorganic part of fuel govern the involvement of various mechanisms of ash deposition**
- **Prior knowledge of participation of such mechanisms and their degree of involvement facilitates the cobustor and/or gasifier operation through improved design and operating parameters**

Objective

- **Develop experimental and predictive representations inertial impaction**

Theory - Ash deposition

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

(I) Inertial impaction

(E) Eddy impaction

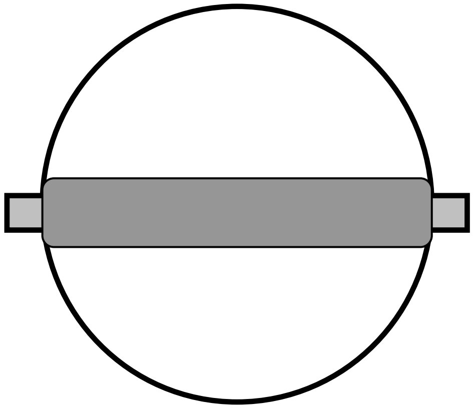
(T) Thermophoresis

(C) Condensation

(R) Chemical Reaction

Capture Efficiency (G) is the fraction of particles that stay on the surface after impaction.

Inertial Impaction



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

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

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

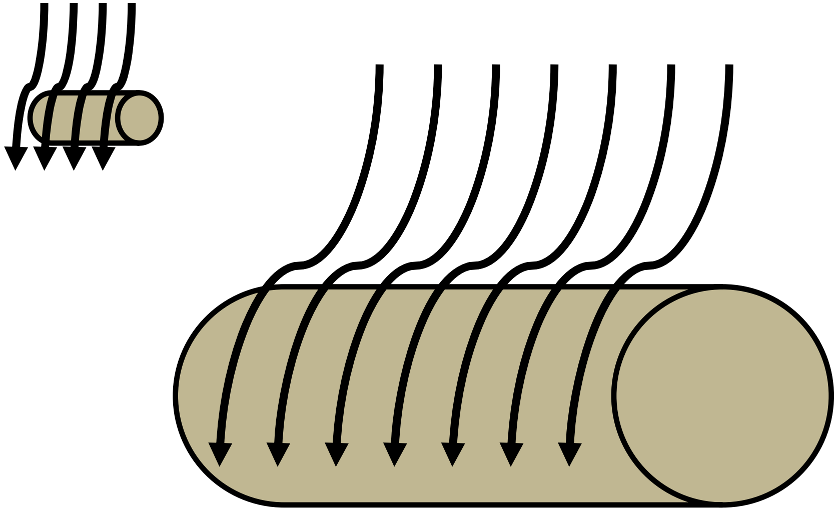
η = Impaction efficiency

G = Capture efficiency

ζ = Collection efficiency

$$\zeta = \eta\, G$$

Impaction Efficiency model



Stokes Number

(Modified Reynolds Number)

$$Stk = \frac{\rho_p d_p^2 V_p}{9 \mu_g d_c} \psi$$

Ψ = Non-Stokesian Drag Correction

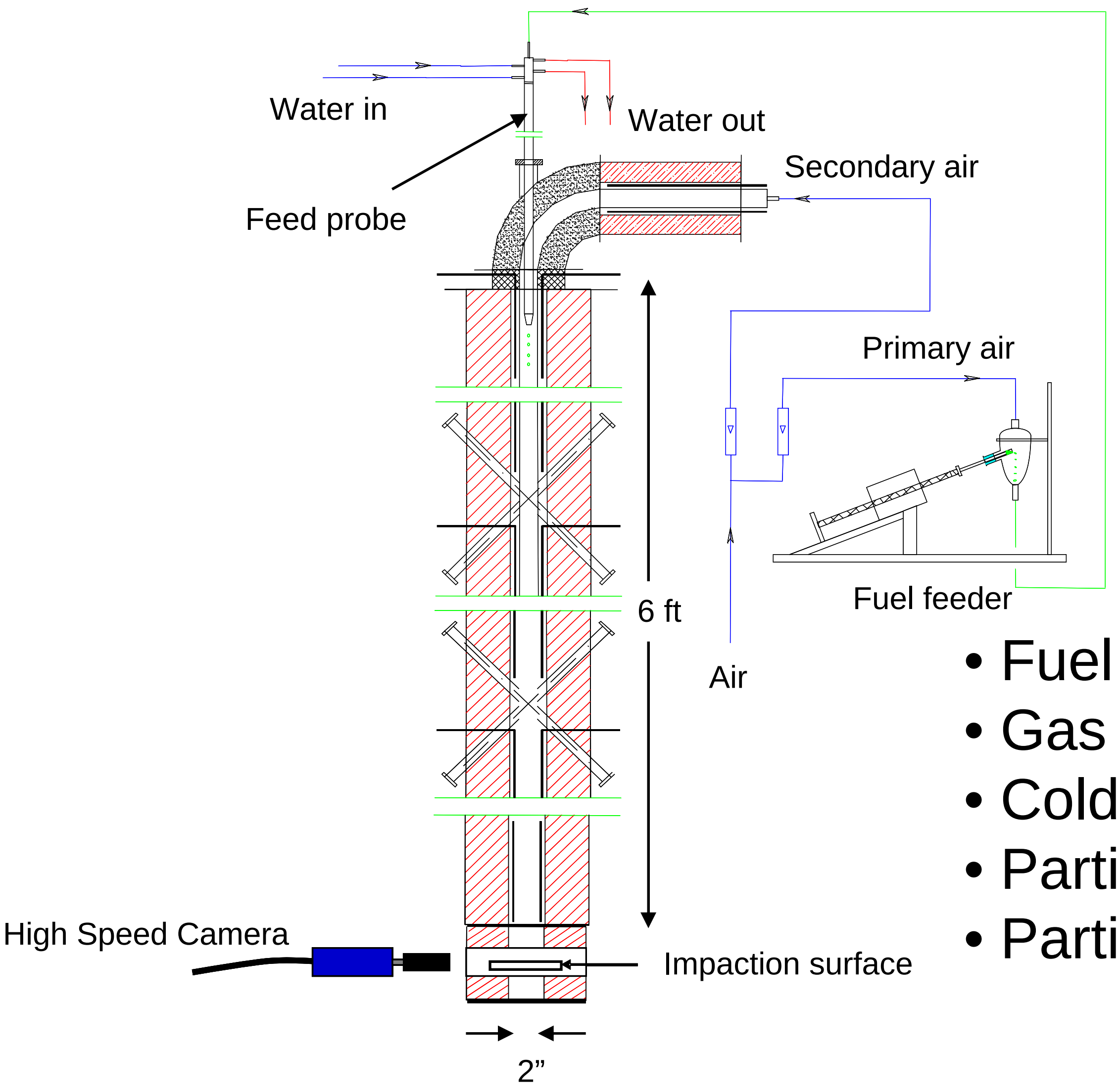
Impaction efficiency: The fraction of particles that impact on a deposition surface.

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

Where a, b, c and d are empirically-derived parameters.

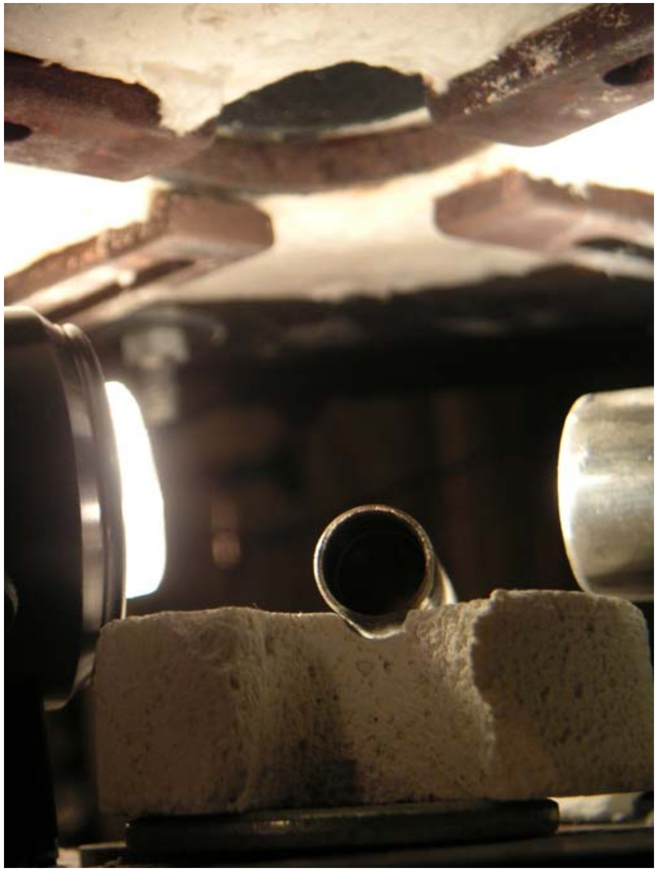
Reference - Report on “Ash deposition and corrosion mechanisms”, by Dr. Larry Baxter, Sandia National Lab.

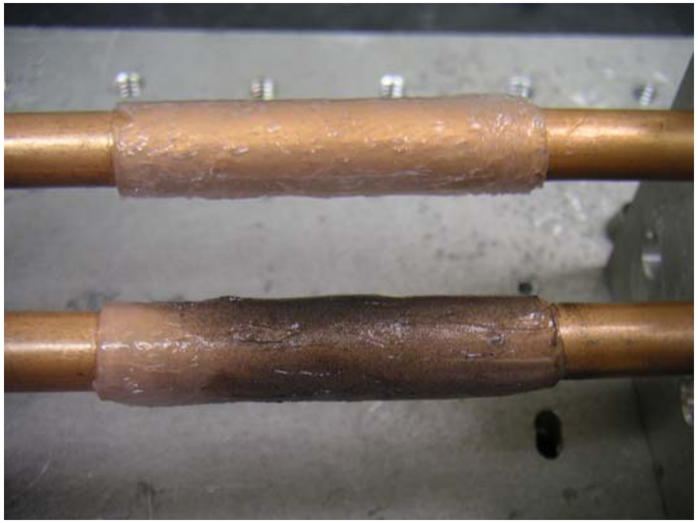
Experimental facility



- Fuel – Pittsburgh#8
- Gas velocity – 0.5-2 m/s
- Cold Flow environment
- Particle Size – 20-300 microns
- Particle feed rate – 4-5 gms/hr

Particle Capture Arrangement



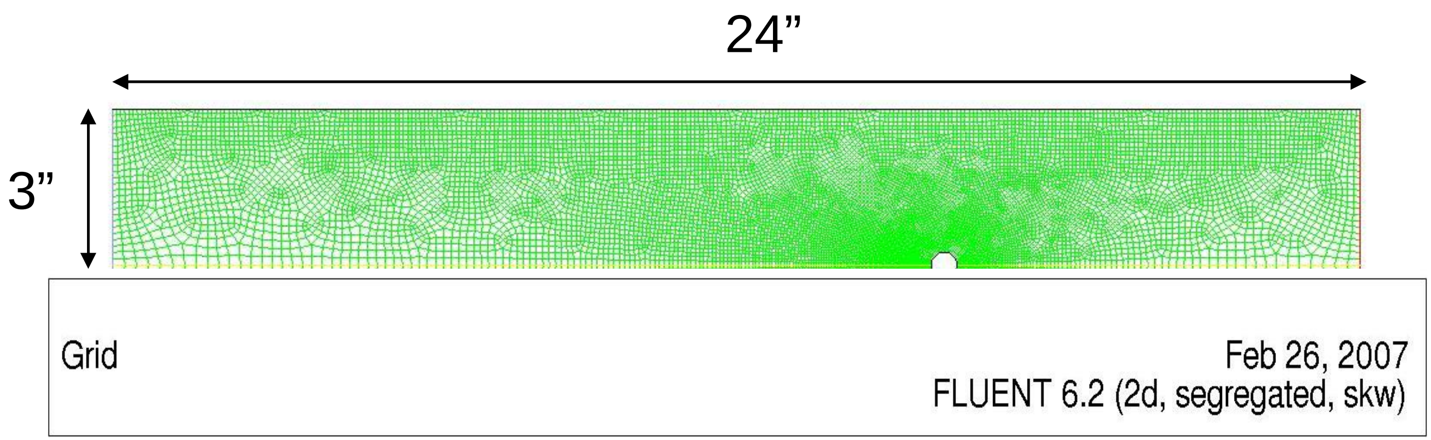


High temperature vacuum grease provides 100% particle capture system.

Rotating probe arrangement (not shown) provides uniform particle capture.

Fluent Simulation

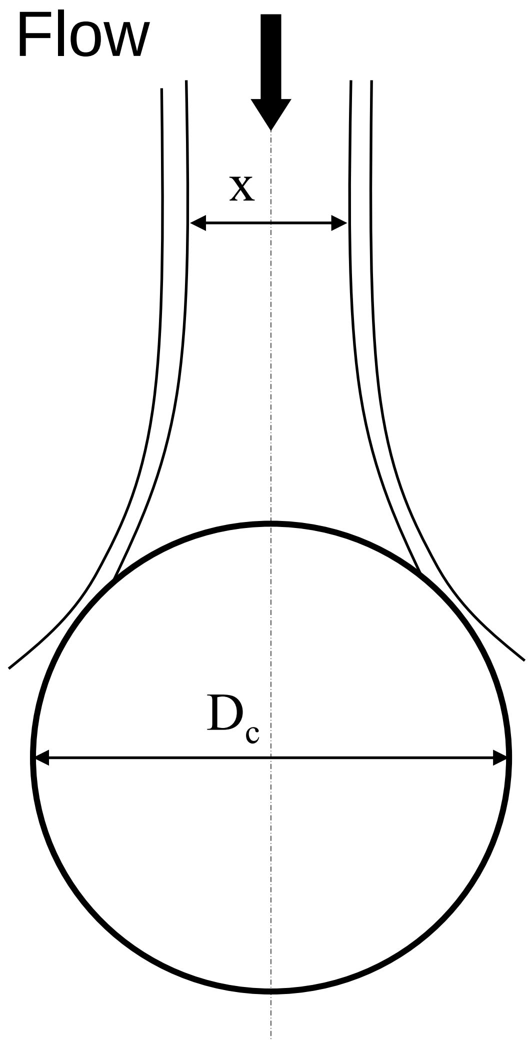
- **Model – 2D, segregated**
- **Grid – Quadrangular, Paved**
- **Cells – 12308**
- **Viscous model – Standard k-w (2 equation)**
- **Working fluid – Air**



Fluent Simulation

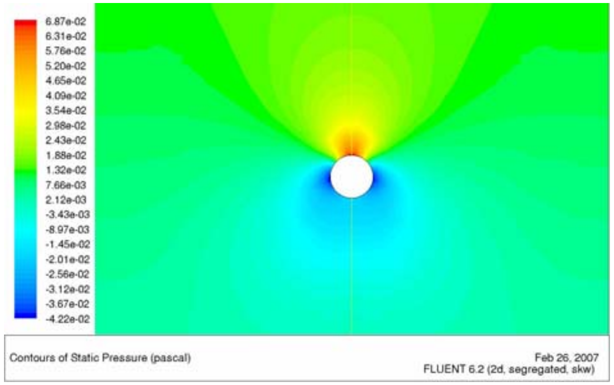
- Operating Parameters
  - Particle Velocity : 0.5 – 100 m/s
  - Particle diameter : 5 – 2000 microns
  - Gas Velocity : 95% of Particle Velocity
  - Gas Temperature : 1300 K
  - Particle Temperature : 1400 K
  - Probe Surface Temperature : 800 K
- Combination of particle velocity and particle diameter selected for Stokes number range: 0.01 – 150.

Fluent Simulation

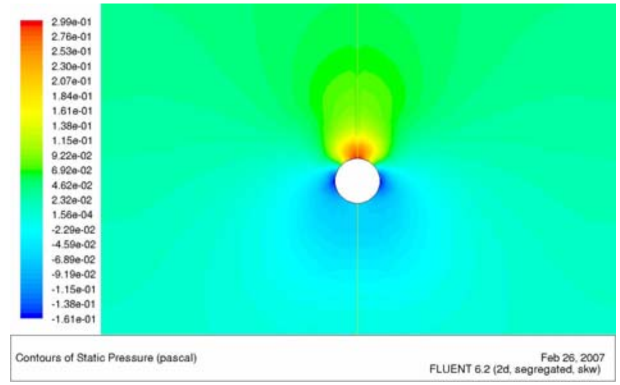


$$\eta = x/D_c$$

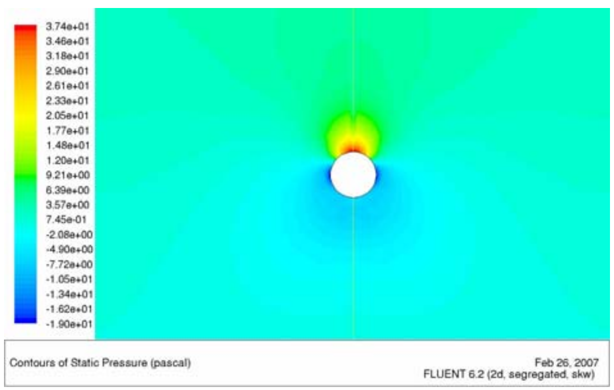
Results – P-Distribution



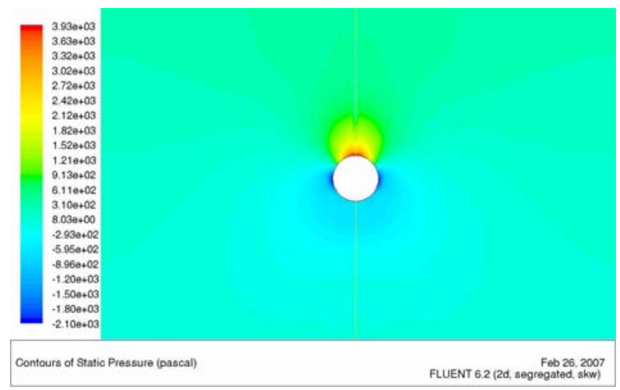
Vp = 0.5 m/s



Vp = 1 m/s



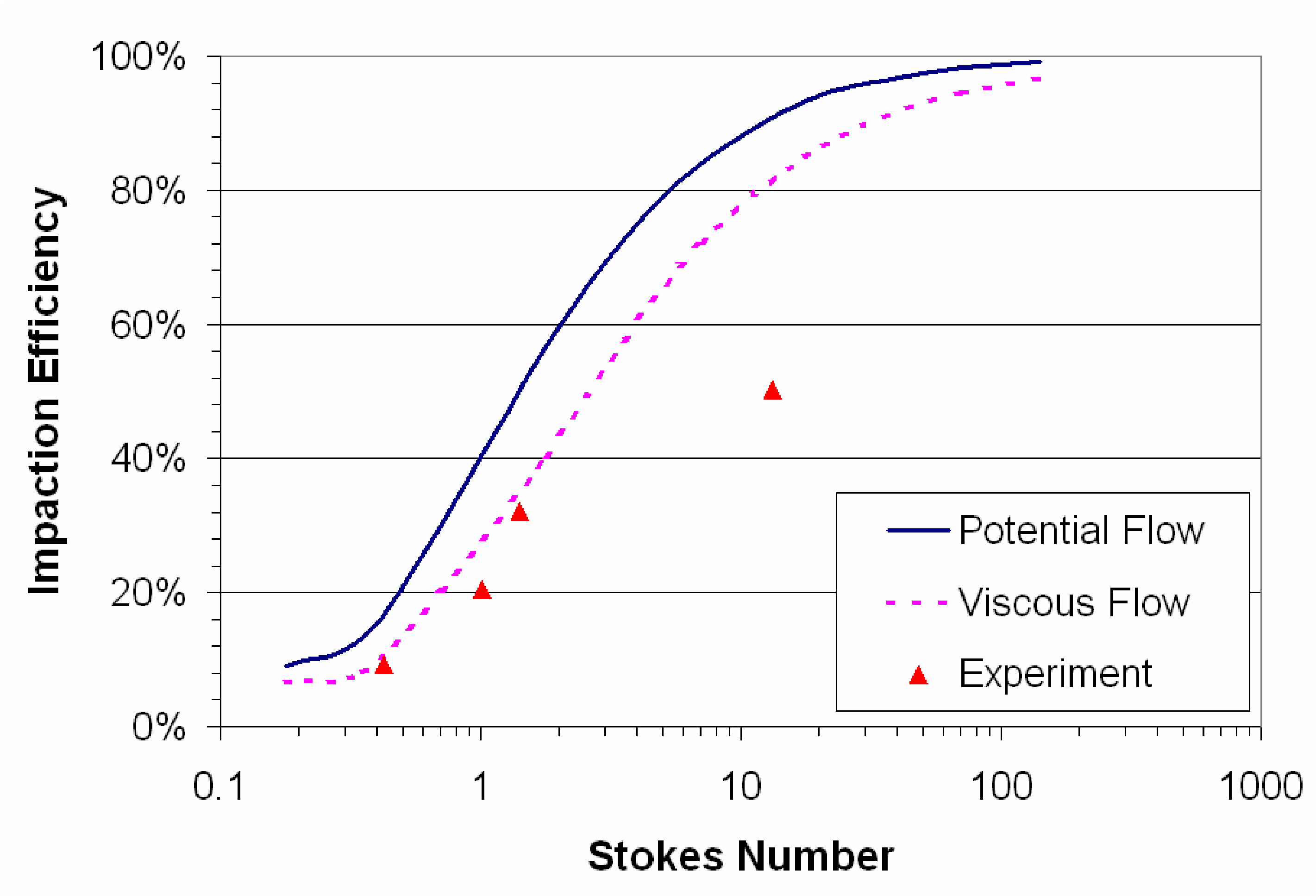
Vp = 10 m/s



Vp = 100 m/s

For small D_p, low V_p, viscous force dominates momentum, while for large D_p, high V_p, momentum force dominates viscous force.

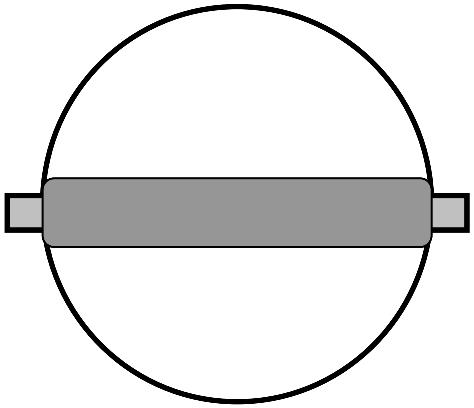
Results – Impaction Efficiency



Impaction efficiency is ~30% lower in Viscous flow than Potential flow.

Predictions for viscous flow within 8-10% of experimental data.

Two-step Approach



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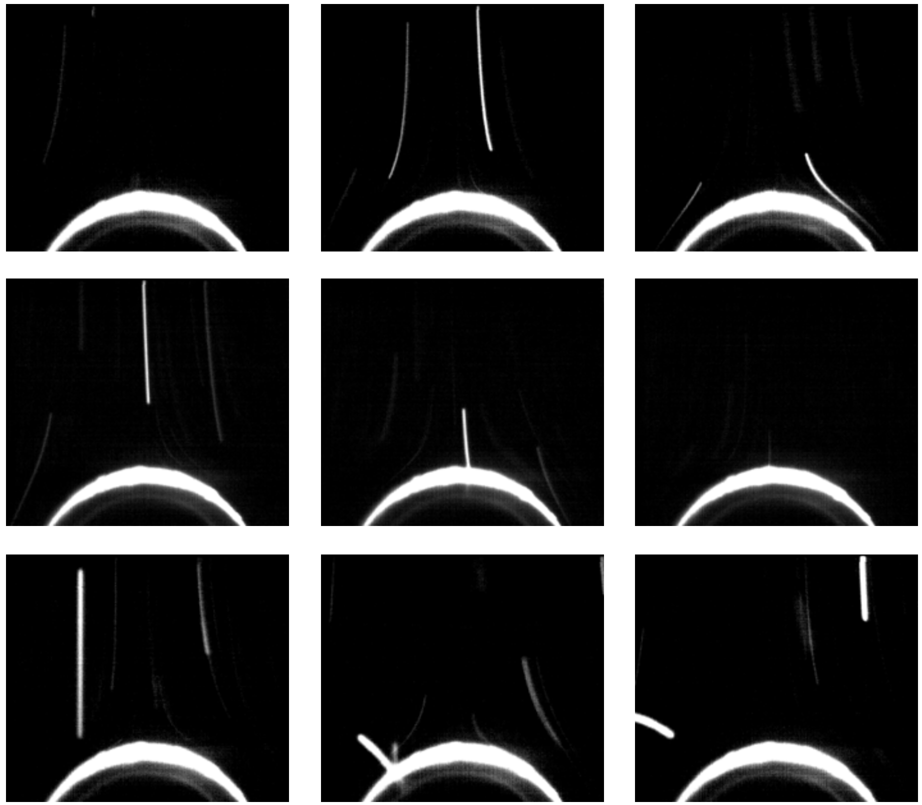
Results – Capture Efficiency



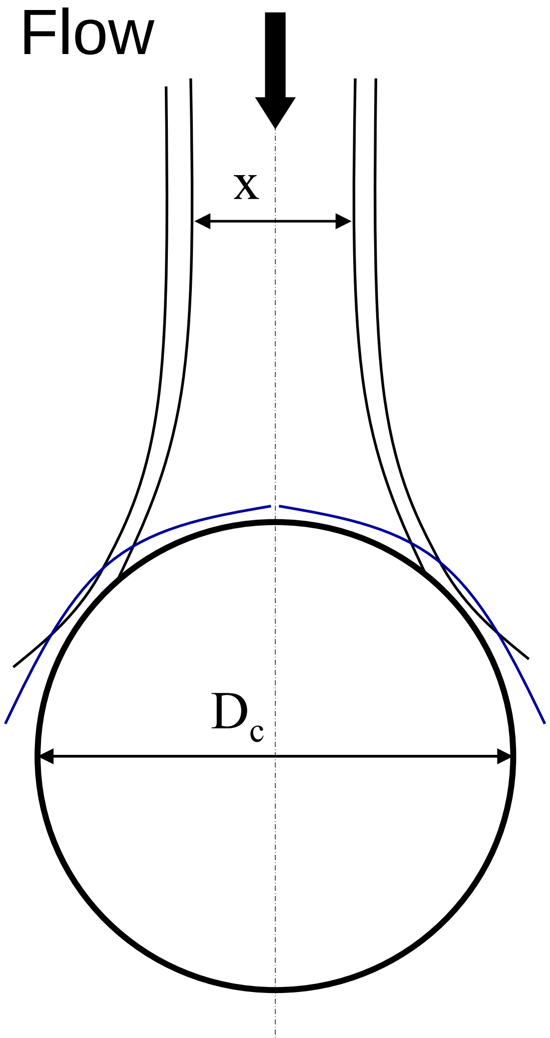
Particle Escape $V_p < V_{threshold}$

Particle Capture $V_p = V_{threshold}$

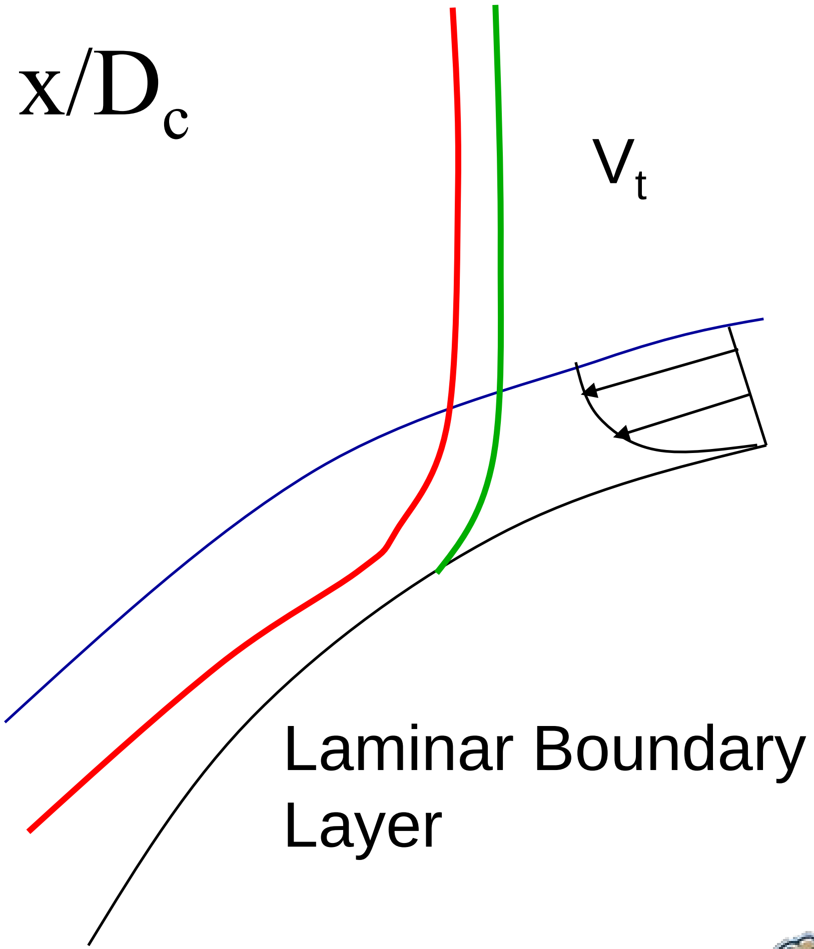
Particle Rebound $V_p > V_{threshold}$

$$V_{threshold} = F(V_{incident}, V_{gas}, T_{particle}, T_{surface}, C_{ash}, \mu_{surface}, \mu_{particle}, \theta_{impact}, \ldots)$$

Impaction Efficiency



$$\eta = x/D_c$$



Conclusions

- Viscous flow pattern creates a pressure distribution upstream of heat transfer surface reducing probability of particle impaction.
- Actual impaction efficiency is 30-40% lower than that predicted by potential flow correlation.
- Fluent model predicts impaction efficiency within 8-10% of experimental data. Experiments need to be performed over complete range of Stokes number.

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