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Spouting behavior of binary mixtures of spherical and cylindrical particles

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Spouting Behavior of Binary Mixtures of Spherical and Cylindrical Particles

Douglas W. Marshall, Technical Lead

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May 22 - 27, 2016



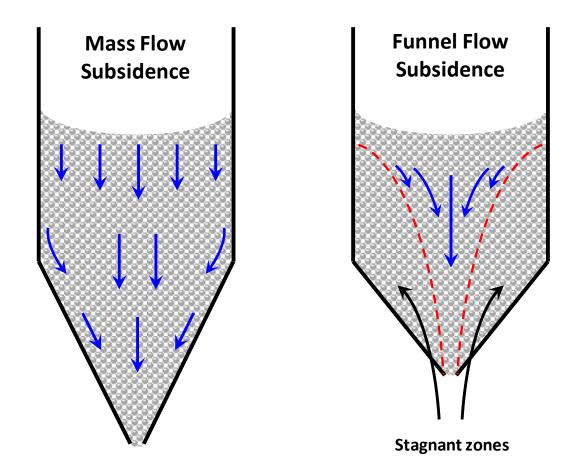
Outline

- Why a explore a binary mixture?
- Test Configuration
 - Full size, 2-D spouted bed
 - Dual gas paths (primary and auxiliary)
- U_{ms} determination
- Observed bed circulation patterns
- Conclusions

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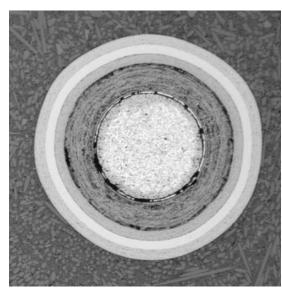
Definition of Mass or Funnel Flow Subsidence



Background Information

- High Temperature Gas-cooled Reactor (HTGR)
 - Graphite moderated, helium cooled reactor (750°C \leq T_{exit} \leq 900°C)
 - Fuel kernels 425 μm 500 μm; 10.8 11.2 g/cm³
 - Kernels hermetically sealed in 4 coating layers (TRISO particle)
 - Layers form the primary containment for fission products







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Hypotheses

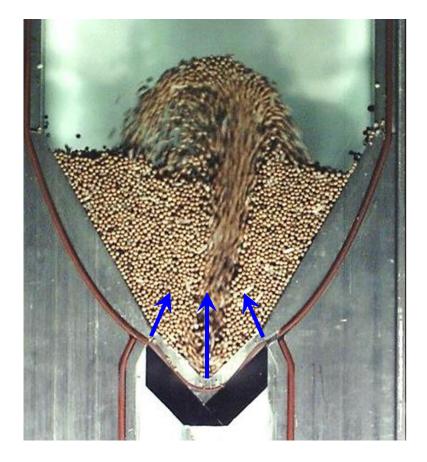
- Basis
 - Spherical particles are more prone to funnel flow
 - Cylindrical particles are more prone to mass flow
- Hypotheses
 - A binary admixture of will exhibit attributes of both particles
 - Admixing cylindrical particles with fuel particles will promote mass flow and improve product consistency and sphericity

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2-D Test Bed

- 25.6 mm x 152 mm
- 60° included angle
- Dual gas paths
 - Primary
 - Auxiliary (0.23 mm @ 25°)
- Multi-orifice nozzle
 - 90° included angle
 - Three 3.2 mm orifices
- Pressures fluctuations measured upstream of the nozzle



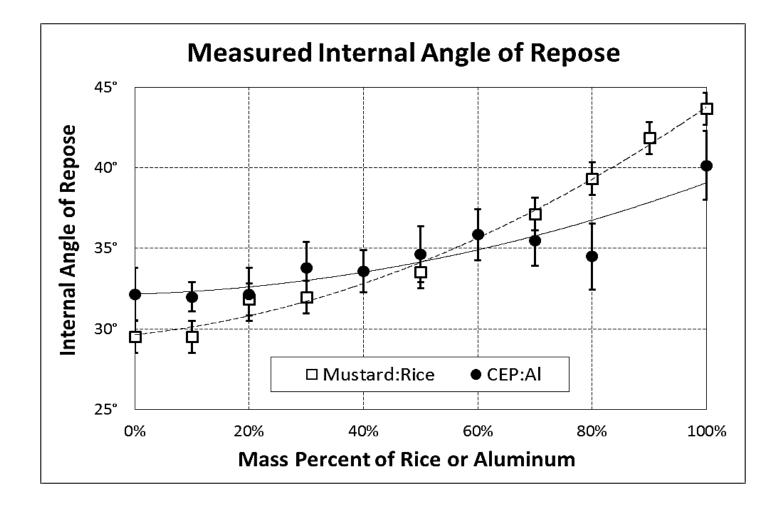


Scope of Testing

Particle Property	Yellow mustard seed	Long grain white rice	CARBO ECONOPROP (CEP)	Aluminum rodlets
Particle density (g/cm ³)	1.20	1.46	2.61	2.70
Mean particle diameter (mm)	1.90	1.82	0.66	0.76
Mean particle length (mm)		6.51		3.18
Aspect ratio		3.58		4.18
Sauter diameter, d ₃₂ (mm)	1.90	2.40	0.66	1.02
Volume diameter, d _v (mm)	1.90	3.19	0.66	1.40

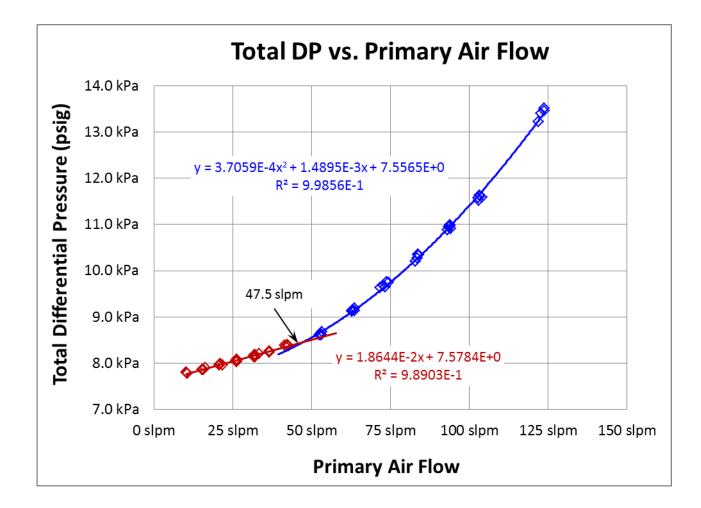


Internal Angle of Repose



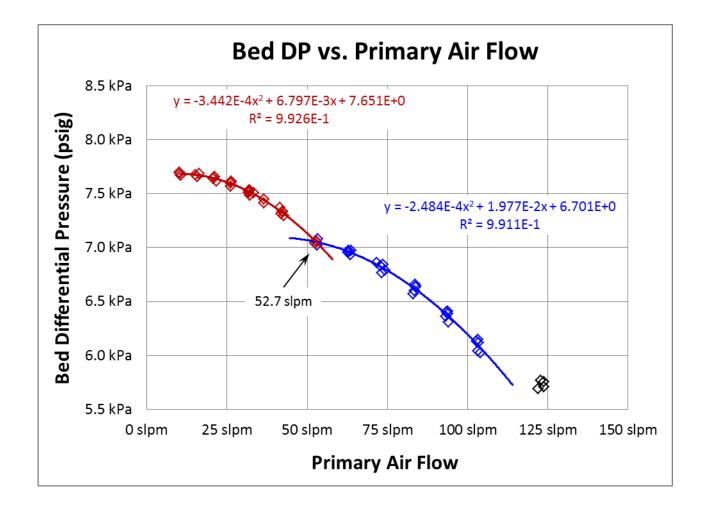


Total Differential Pressure



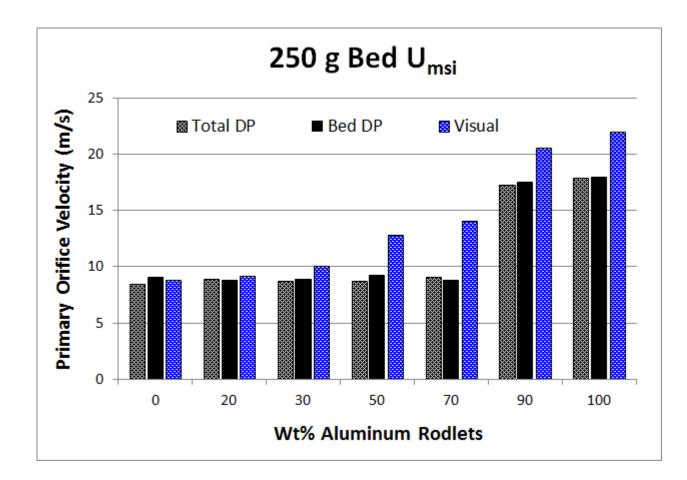


Bed Differential Pressure



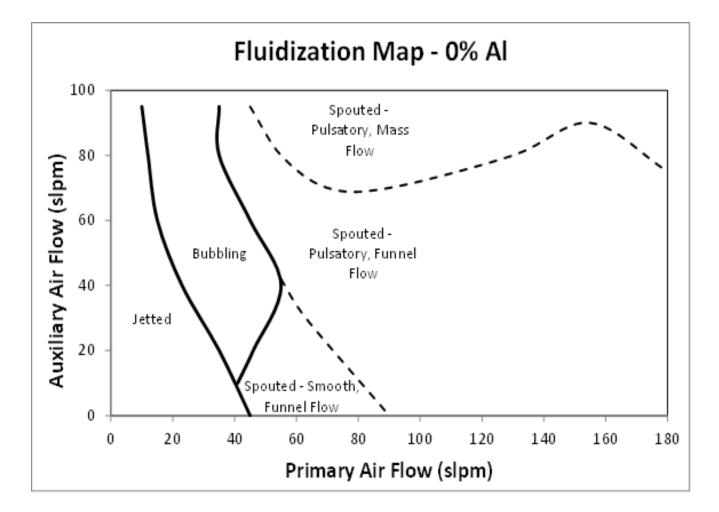


Extrapolated vs. Observed U_{msi}



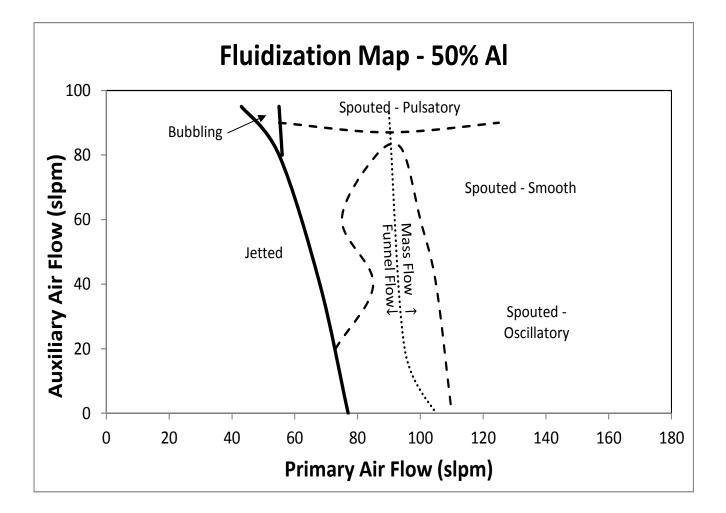


Fluidization/Spouting Maps



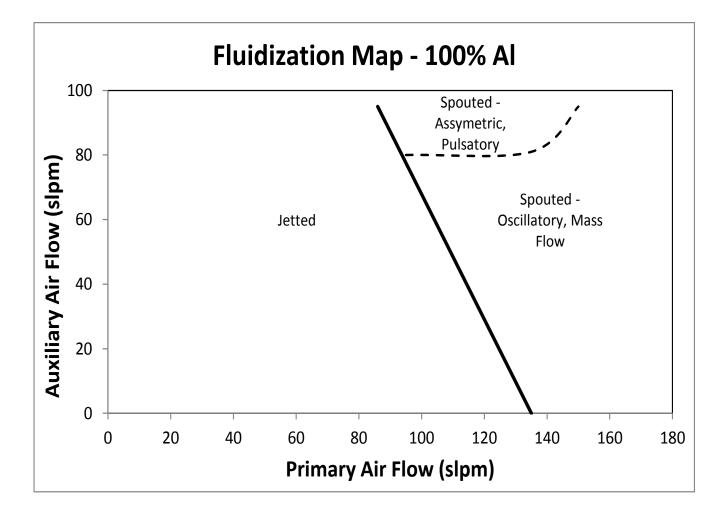


Fluidization/Spouting Maps





Fluidization/Spouting Maps



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Observations

- Auxiliary gas flow
 - Induces bubbling between jetted and spouted regions
 - Promotes mass flow
- Stable spouting
 - Often associated with funnel flow
 - Easily achieved above 50 wt% rodlets
- Pulsatory spouting
 - Most often associated with spherical particles
 - Pulsations promote mass flow subsidence

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Observations

- Funnel flow subsidence
 - Stagnation along walls is problematic
 - Fountain often narrower than the bed diameter
 - Cylindrical particles align with flow streamlines
 - Minor particle phase segregates to the spout "wall"
- Mass flow subsidence
 - Little or no stagnation
 - Fountain width fills freeboard diameter
 - Cylindrical particles align horizontally
 - Low particle segregation



Applicability to Nuclear Fuels

- Would likely improve product quality
- Product already meets specifications
- Liability for radioactive waste generation, added unit operations, reduced throughput, etc. not worth the benefit



Questions?

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