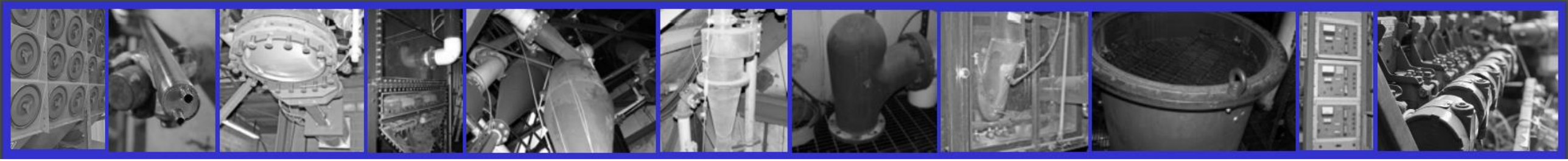

Considerations for Practical Industrial CFD Simulations of Fluidized Systems

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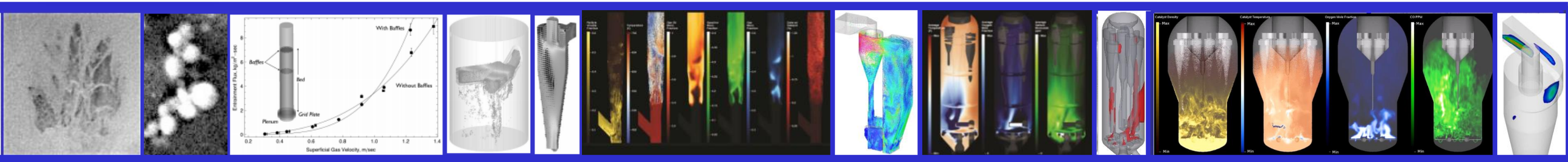
[b] PSRI Particulate Solid Research, Inc. *Applying the Fundamentals*

[a] cfd Fluidization Simulation Software and Services



Motivation

Where are we today?

New plant design:

- 7 years to operations
- 60% meet design specs within 2 months
- Shutdowns ~ 4 years

Operational support

- Reactive changes at shutdown
- Often too little time for detailed analysis

How we get there?

Digital solutions including CFD

- Root cause analysis support
- Virtual testing
- Identify areas of optimization

Integrated into design and operational processes

- Expand R&D, intelligent scale-up, targeted PDUs, etc.
- Digital assets at the ready

Where we want to be?

New plant design:

- 4 years to operations
- 90% meet design specs within 2 months
- Shutdowns ~ 7 years

Operational support

- Predictive shutdown planning
- Rapid analysis response

Basis of CFD Models for Fluidized Systems

Fundamentals

- E.g. Conservation of mass, momentum, energy
- Typically well understood

Empirical models

- Based on test data
- Often require calibration for different systems

Sample empirical models used in:

- Hydrodynamics (drag, stress, collisions, etc.)
- Thermal (heat transfer, radiation, etc.)
- Chemical reactions (reactions, rates, etc.)

CFD Model Calibration Process

Baseline CFD Model

Baseline Results

Relevant Experimental or Operational Data

Are Results Useful?

No

Are the Physics Sufficient?

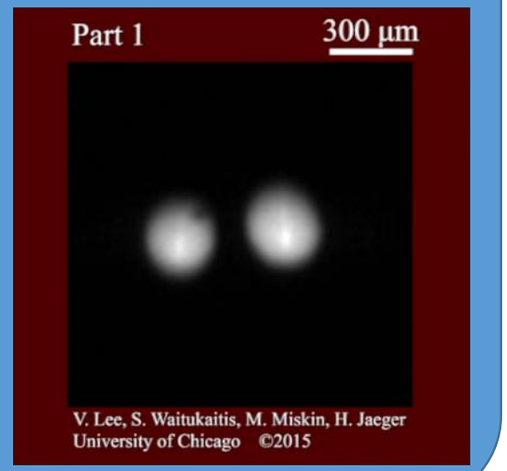
No

Yes

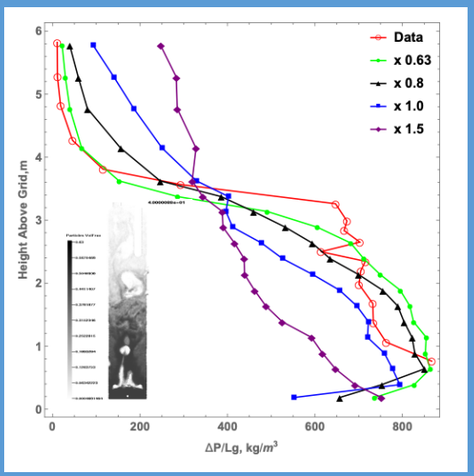
Yes

CFD Model Ready for Use (Scale-up, trouble-shooting, etc.)

Model Development



Model Calibration



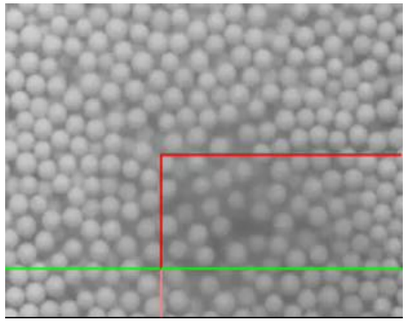
What Data are Needed for Calibration?

Operational data can be useful for calibration when simulating an existing unit

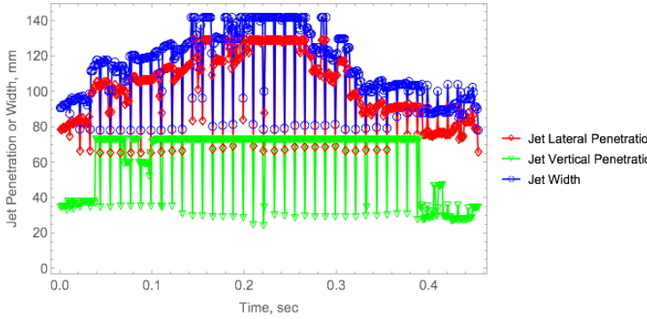
- Usually limited (some pressure, temperature, etc.)

Experimental data is needed when calibrating models for units which are not yet built

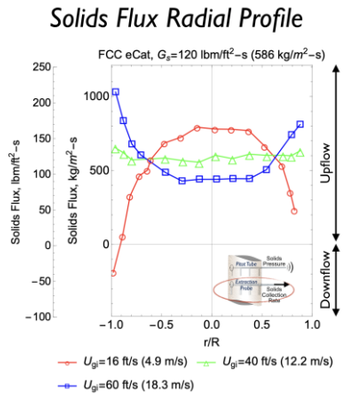
- Experiments should be large enough to minimize wall effects
- Sample data includes:
  - Bed density or **Δ**P/Lg
  - Minimum fluidization and minimum bubbling velocities
  - Deaeration behavior
  - Entrainment flux & PSD
- Some data is regime specific
  - Jet penetration for fluidized beds
  - Radial fluxes and radial volume fraction profiles for risers

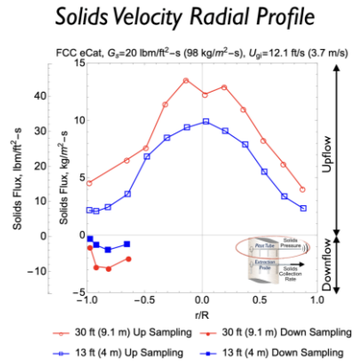


Lateral Jet in Fluidized Bed of Geldart Group D Particles



Large-Scale Riser flow of Geldart Group A Particles

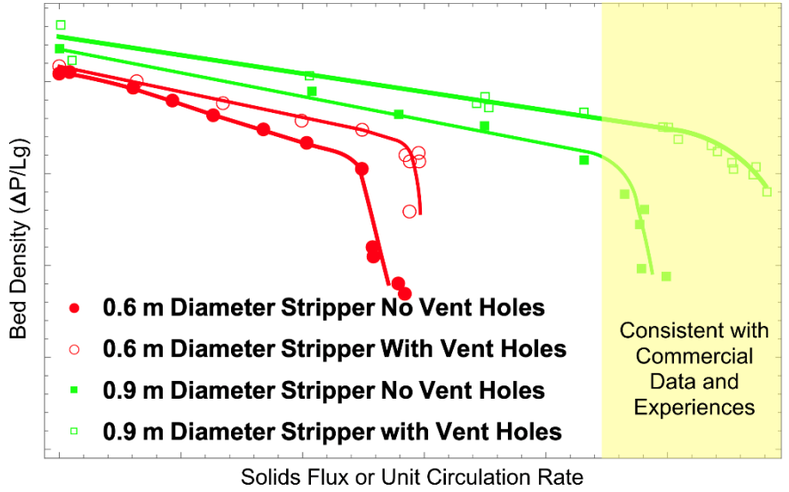




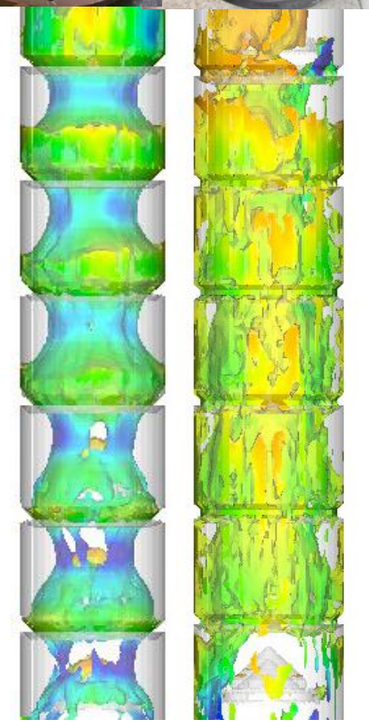
Scale Matters

Sample stripper experiment performed at diameters of 0.6 and 0.9

- Test and CFD qualitatively showed vent holes delayed the onset of flooding at either scale
- Larger scale tests were needed for quantitative comparisons



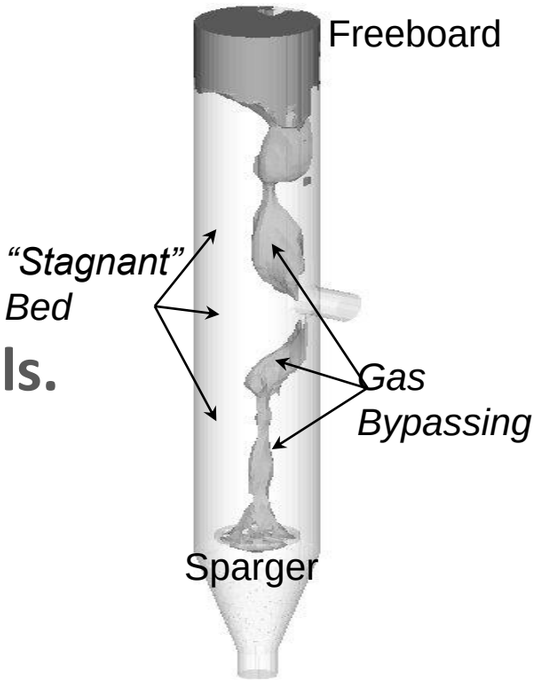
Cross-section with reasonable downward solids flux



Without holes

With holes

Similarly, gas bypassing can occur in deep beds of Geldart Group A materials. It is often missed in pilot studies, but can be present in commercial operations (Wells, 2000).



Practical Advise

Know what questions the CFD model should answer

- Don’t always try to answer every question in the same model
- Know what time frame is meaningful to your industry

Calibrate once when possible

- If a model requires tuning for each case, it’s likely the physics or numerics are insufficient

Simulate current or historical operations before virtual testing of changes (when possible)

- This answer questions like: will it improve? Are there downside risks? What do the results mean? How does this compare to my unit?

Start early in the planning process

- Allow time to properly build, calibrate, and understand the CFD model.

Be proactive

- Calibrated baseline models should be part of any digitalization strategy, and enable rapid response when needed.

Summary

CFD can augment traditional procedures for scale-up and troubleshooting fluidized systems

Many empirical models require calibration. Resources exist:

- Commercial CFD software packages
- Large-scale test facilities

Care should be taken to use meaningful data for validation and calibration

- Relevant physics captured, proper scale, etc.
- Know how the model will be used in advance (qualitative vs. quantitative)

Be proactive

- Calibrated baseline models can be done in advance as part of a digitalization strategy

Questions

We welcome your questions

For additional information please contact: