Fluidized Bed Reactor Application for Catalytic Pyrolysis of Waste Plastic

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ENCINA

Overview

Encina's Technology Process

Front

- Utilizing material recycling technologies to achieve reactor specifications
- Integrated existing material recycling technologies into advanced processes
- Optimized material handing process to meet the specification of the reactor
- Designed for Encina's mixed stream sources

Middle

- Proprietary Plastic Fluid Catalytic Cracking (PFCC) reactor unit
- Employs conventional FCC concepts found in current petrochemical facilities
- Reactor design and catalysts configurated for handing waste plastic streams instead of oil and NGLs from a traditional refinery process

Back

- Conventional chemical processing technologies from the reactor effluent
- Utilizes configurations used in chemical facilities globally
- Circular basic chemicals and hydrocarbon liquid products from renewable sources
- Products prepared for existing commodity market use and acceptance

Scale-Up Process

- **Bench scale units**: Fixed and fluidized beds
  - Assess the catalyst performance
  - Build fluidization curve - Calibrate the CFD model

- **Larger Fluidized Bed**:
  - Study the effect of feeding rate, operating T, and catalyst formulations on the yield of the products - Validation of the kinetic model

- **Demonstration unit**:
  - Demonstrate plastic preparation, conversion, and products separation processes
  - Establish the full catalyst circulation loop
  - Explore the effect of operation conditions on yield
  - Study feed material dispersion, temperature profile, and entrainment at different operation conditions

- **Large-scale cold flow test**:
  - Study the effect of Encina IP design on hydrodynamic at different flow regimes
  - Better understanding of the separation technology
  - Evaluate the effect of internals on hydrodynamic
  - Finding optimal operation conditions for Encina's separation technology

- **Commercialization**:
  - Optimizing existing designs
  - Mitigate commercialization risks

Drag Calibration: 6-inch fluidized bed

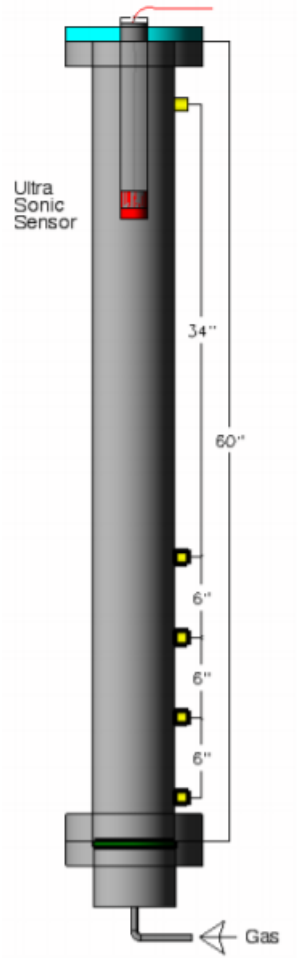
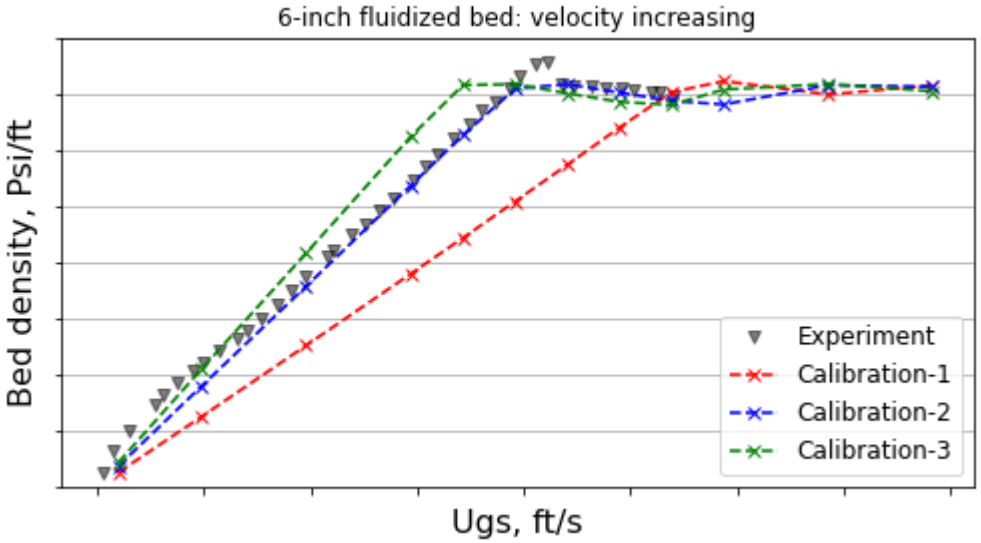


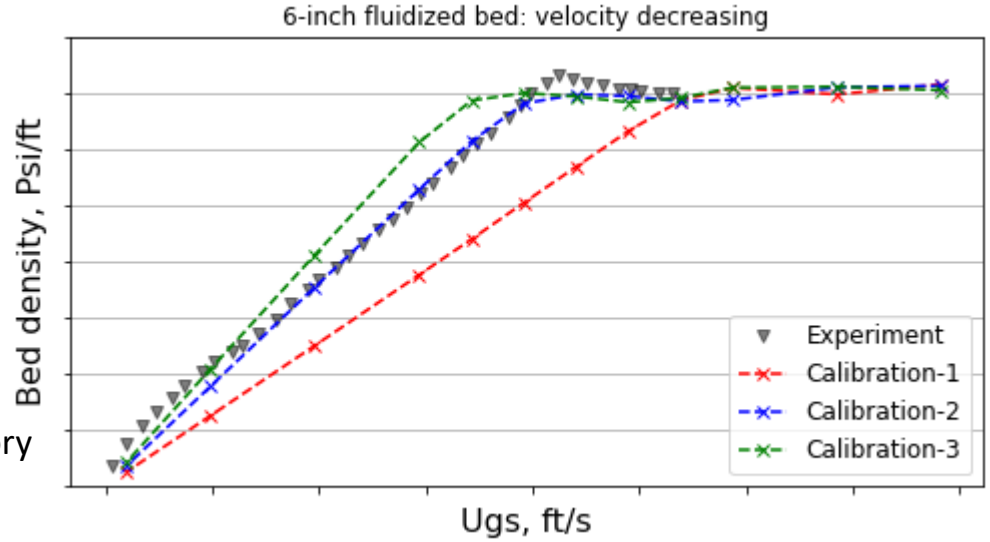
Figure 1: Schematic drawing of 6-in minimum fluidization test unit

Pressure BC

Flow BC

Particle inventory





Drag Calibration: 8-inch fluidized bed

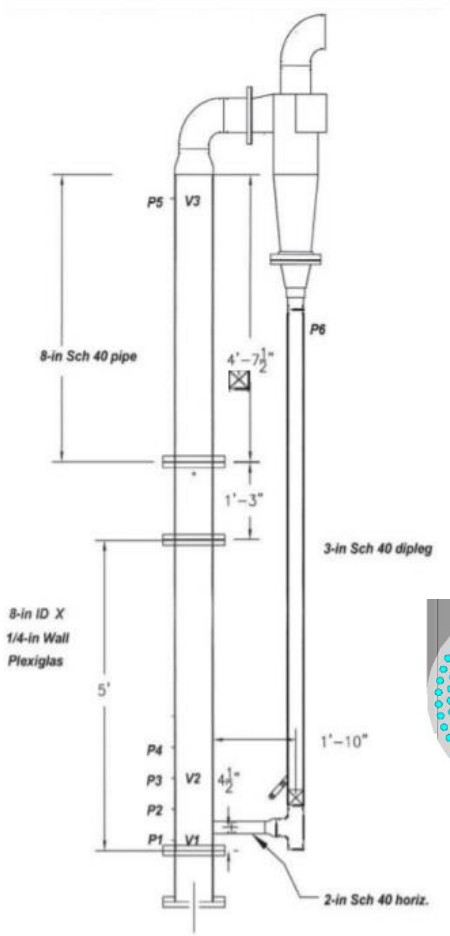
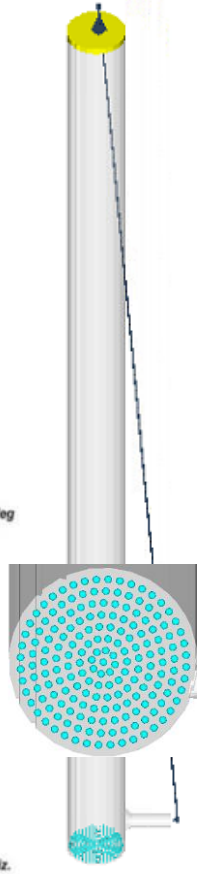


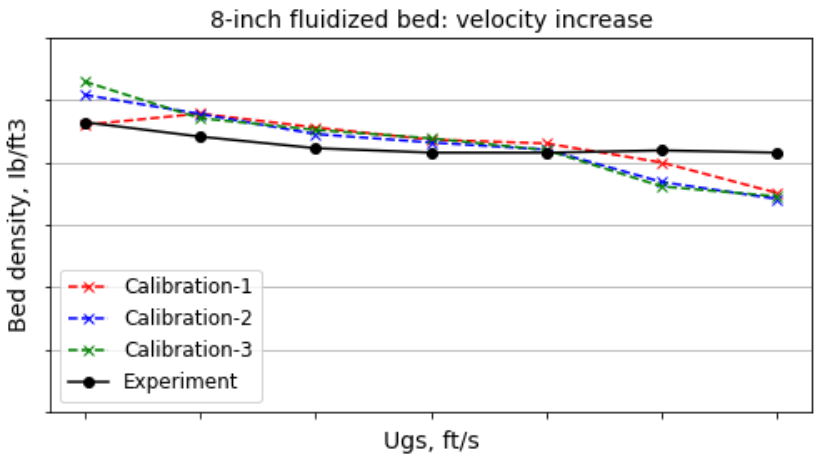
Figure 3: Schematic drawing of 8-in high velocity fluidization test unit

Pressure BC



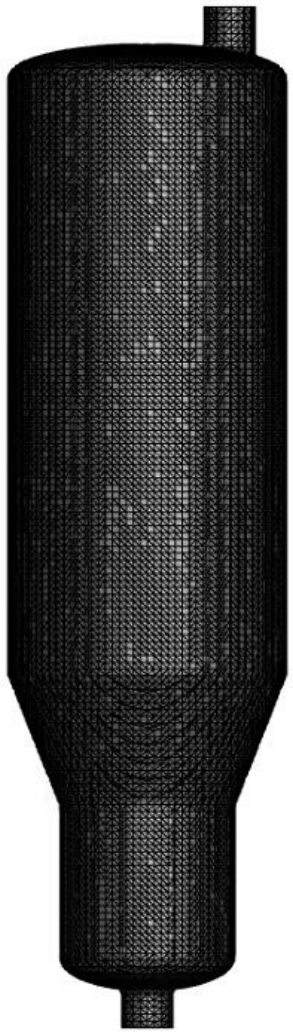
Injection BC

Particle inventory



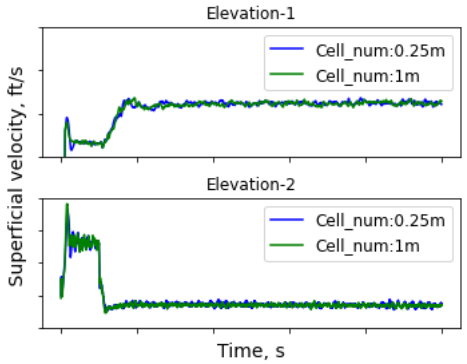
- The error is within 10%
- CFD predictions match the experimental results well for the mid-range velocities
- It's difficult to match the experimental curve slope

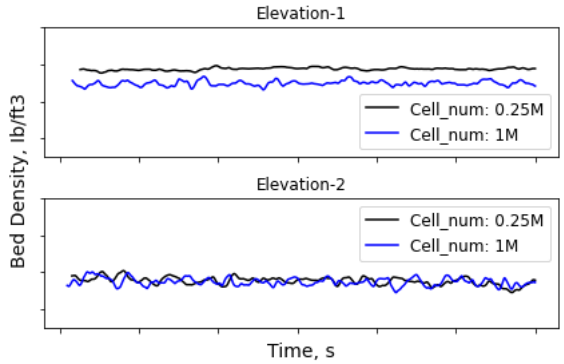
Grid validation:

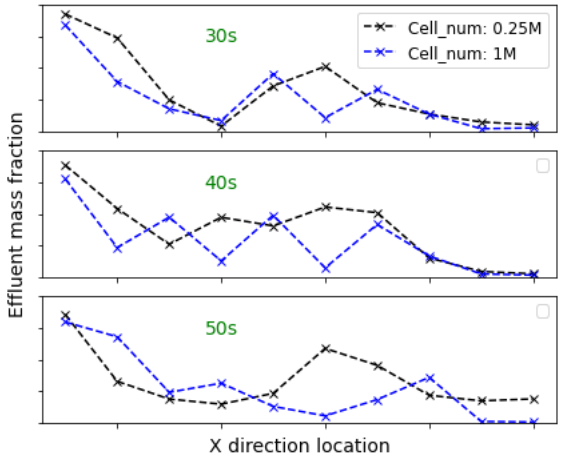


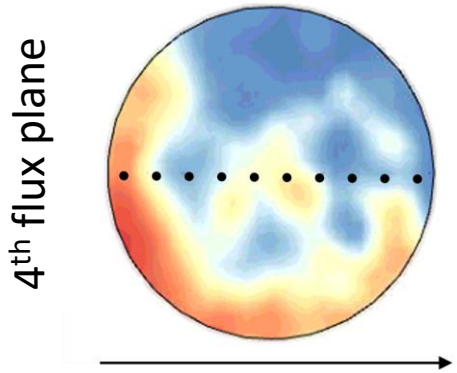
- Number of grid cells: 0.25M vs 1M
- Number of real cells: 148,390 vs 587,217
- Grid cell size: 0.0967m vs 0.06m
- Number of clouds: 10.6M vs 19M
- Computational time: 18hr/100s vs 60hr/50s

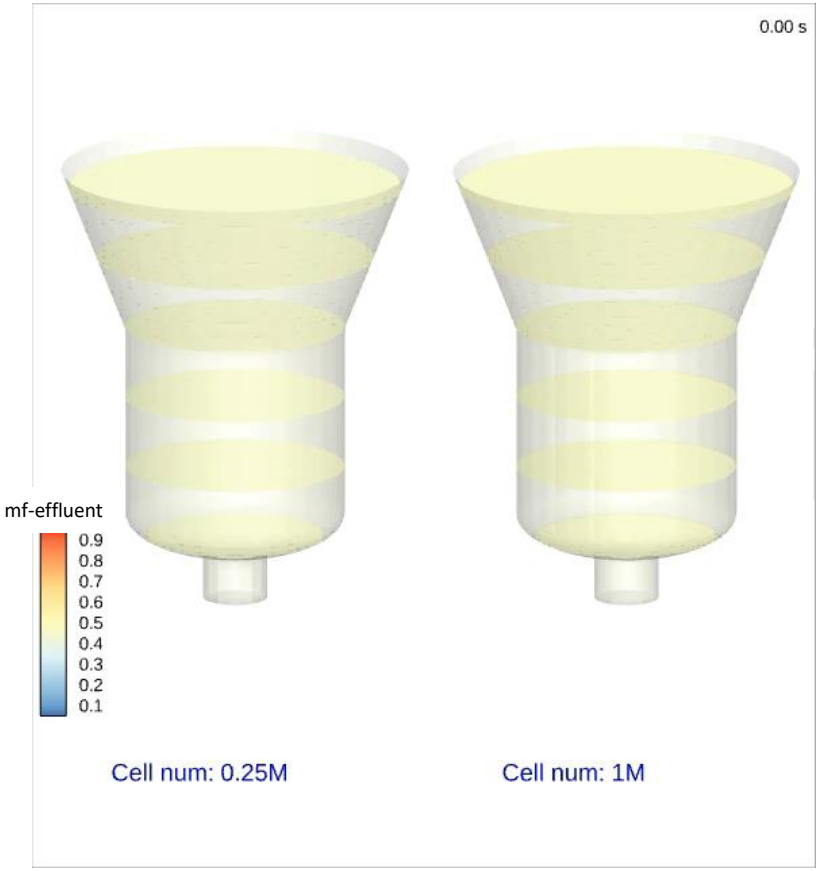
Grid validation:



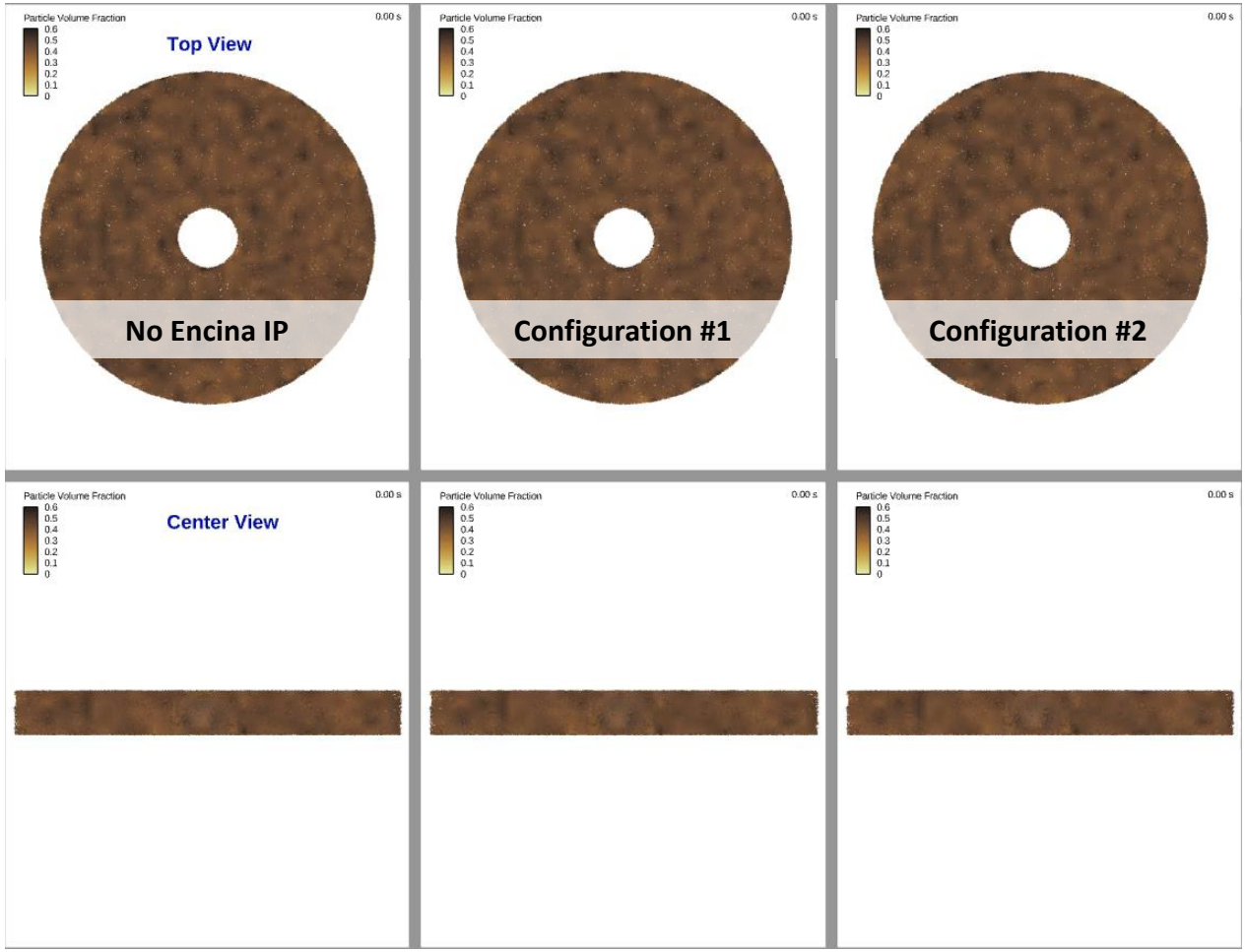








Encina Reactor IP perspectives



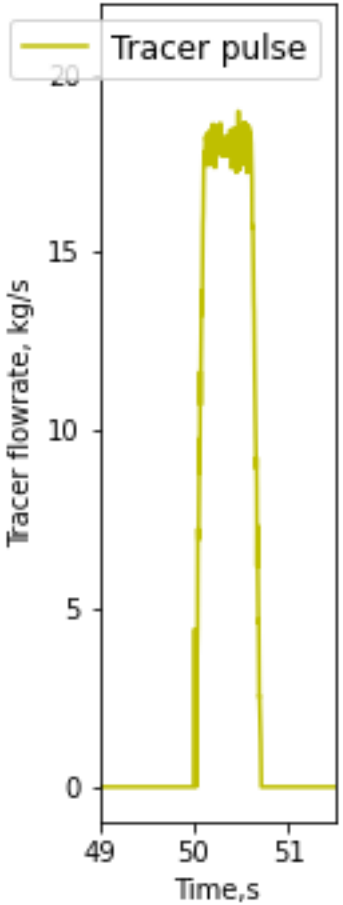
No Encina IP:

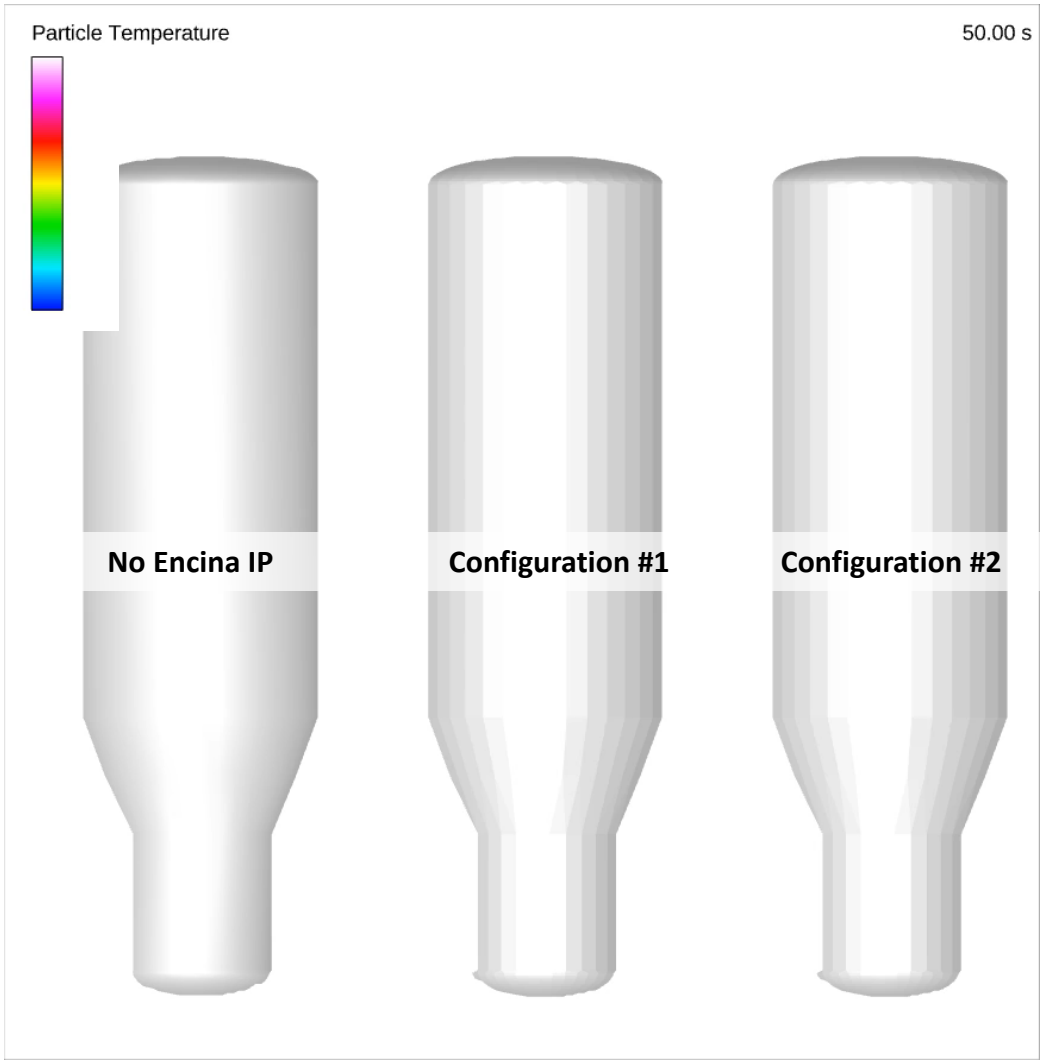
- Channeling fluidized bed observed
- Poor particles and gases mixedness

Encina IP configurations:

- More uniform particles and gases mixedness

Encina Reactor IP perspectives



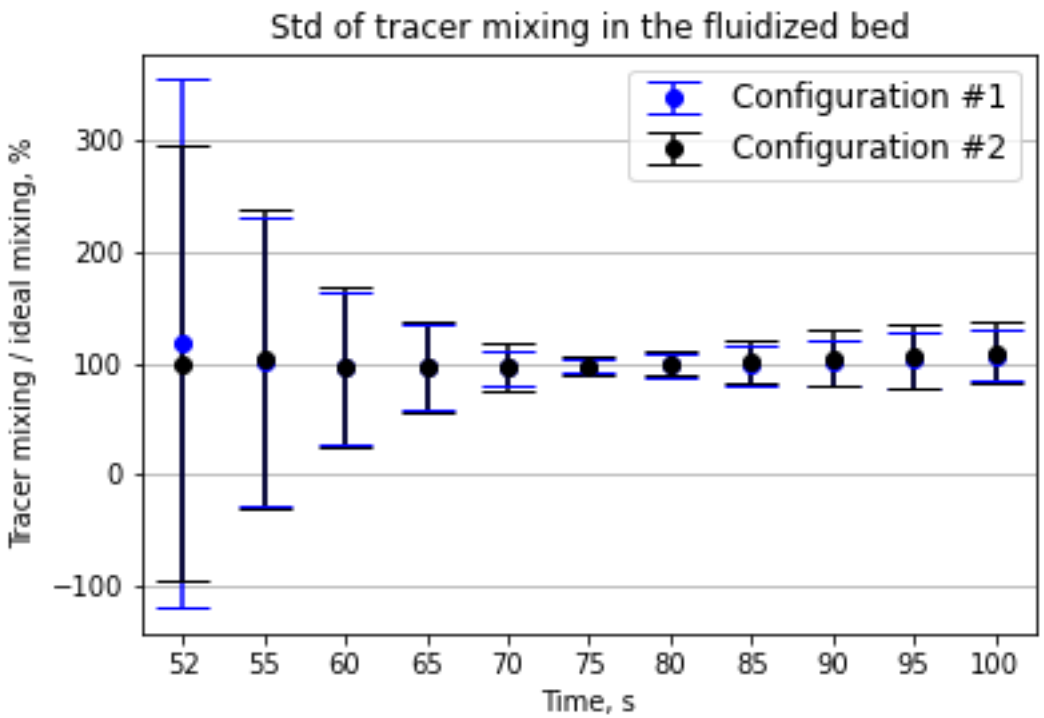


Encina IP configurations:

- Better particles and gases mixedness
- More stable fluidized bed
- Less particle entrainment

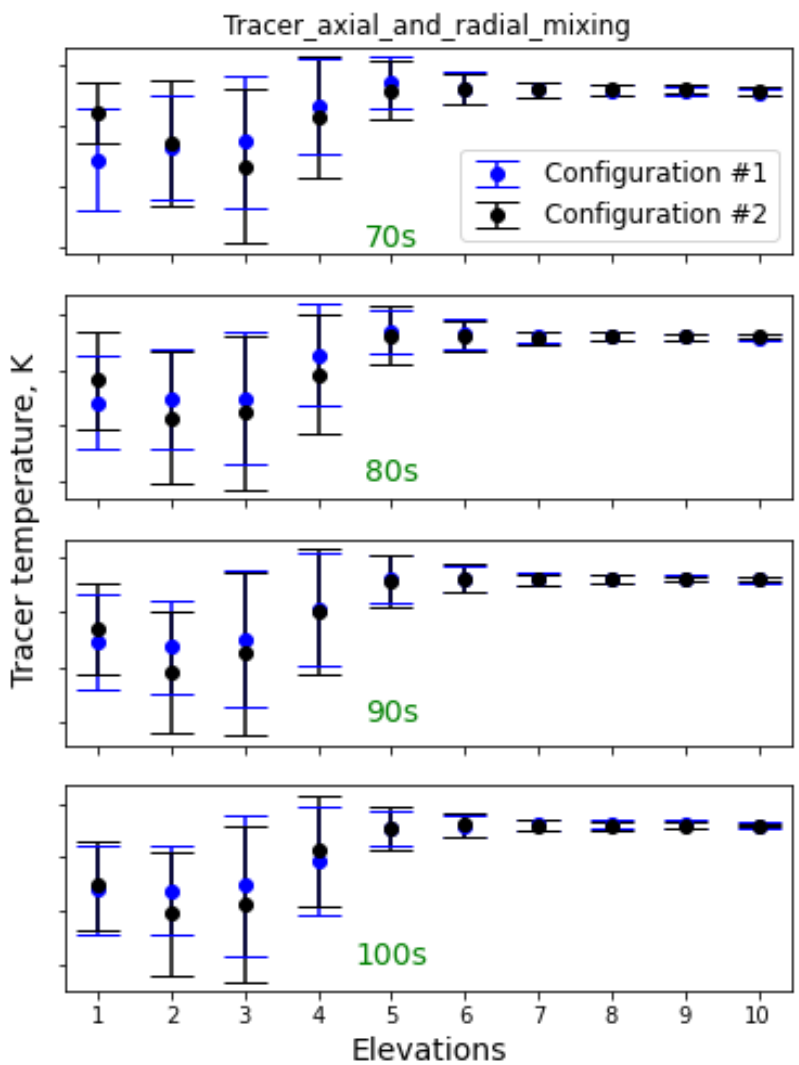
- Temperature maldistribution in the lower bed

Particle mixedness



- Tracer mixing: Weight% of tracer at a selected elevation
- Ideal mixing: Assuming tracer particles were evenly distributed across the entire fluidized bed
- It takes about 20s for achieving good particle mixedness

Particle mixedness



- Higher elevation fluidized bed showed consistent temperature for both axial and radial mixing
- Lower temperature observed in lower elevations and need to be eliminated
  - Critical temperature ensures the effective operation
- Larger temperature variation noticed in the lower bed
  - Indicating a poor radial mixedness

Design improvement

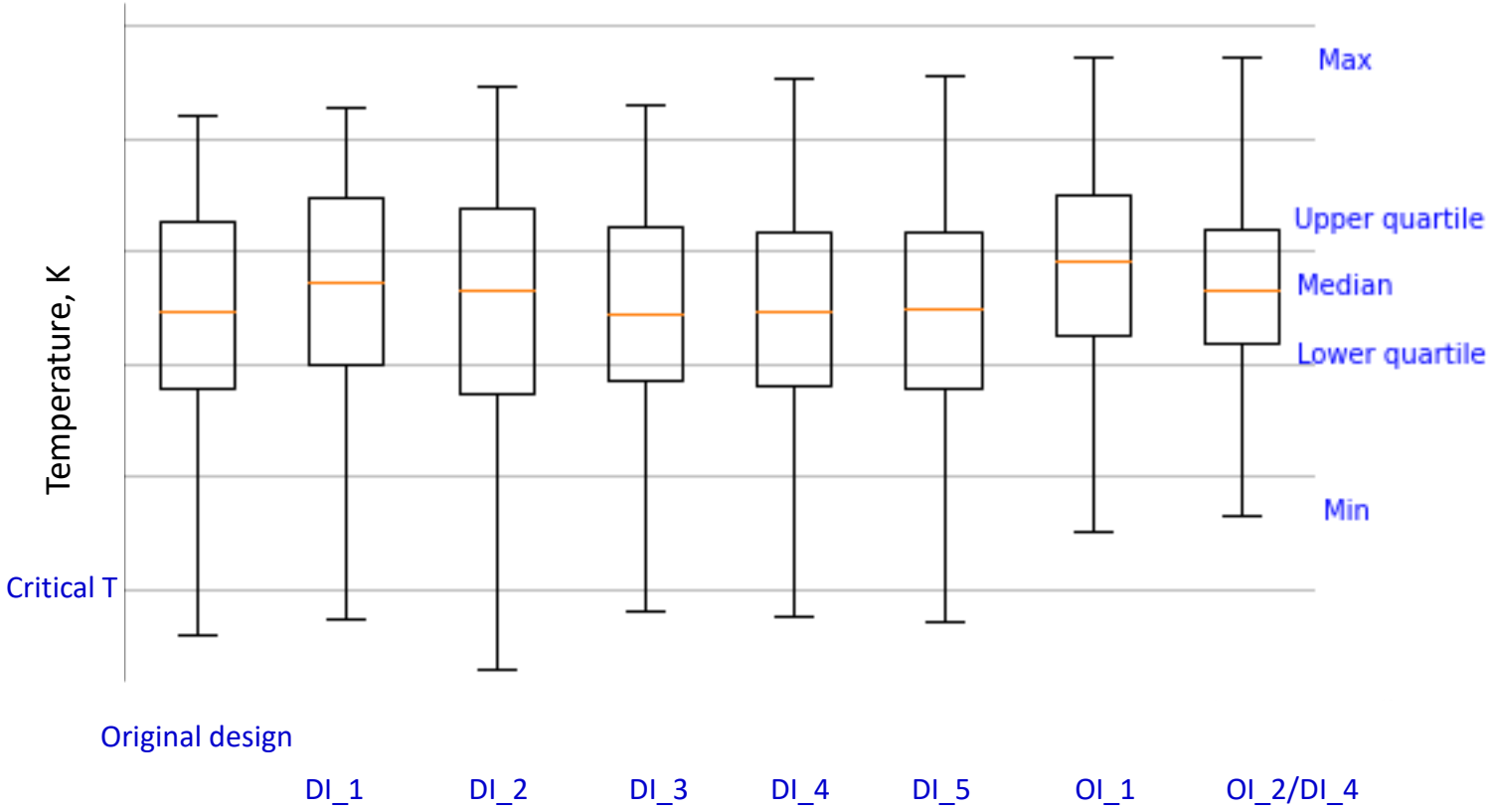
Particle T

Original design | DI_1 | DI_2 | DI_3 | DI_4

Operation improvement

Original design | OI_1 | OI_2/DI_4

Design/Operation improvement



Conclusion:

- Different sizes of fluidized bed reactor were modeled with CPFD Barracuda
  - Velocity and bed density well predicted by adjusting the existing drag model
  - It is challenging to match the experimental pressure fluctuation and particle entrainment results at the high velocity range
  - The CFD codes showed difficulties in detecting particle-particle interactions
- CPFD Barracuda is an effective and useful tool for the scale-up process
  - Optimizing the operation conditions
  - Building engineering correlations