BubbleTree: a Toolset for CFD Bubble/Cluster Analysis

Akhilesh Bakshi[1,2], Kyle Buchheit[1,3], Christos Altantzis[1,2], Terry Jordan[1], Tingwen Li[1,4], Dirk Van Essendelft[1]

[1]US Department of Energy, National Energy Technology Laboratory, Morgantown WV; [2]Massachusetts Institute of Technology, Cambridge, MA ;
[3]Oak Ridge Institute for Science and Education, Oak Ridge TN; [4]AECOM Corporation, Morgantown WV

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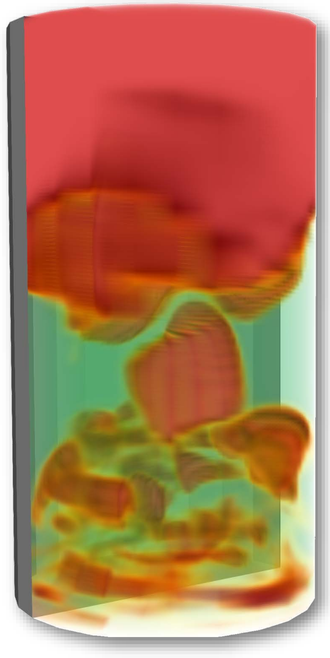
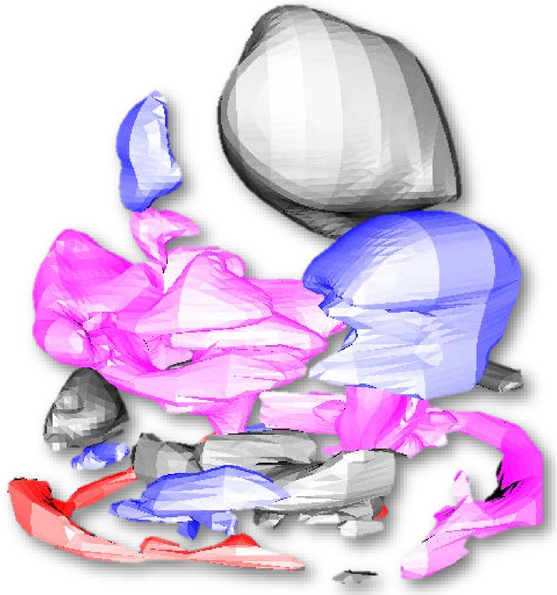
3D CFD ➡ Region Detection ➡ Tracking ➡ Quantitative Analysis

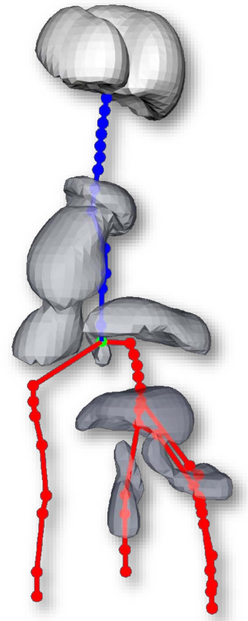
Bubble Analysis



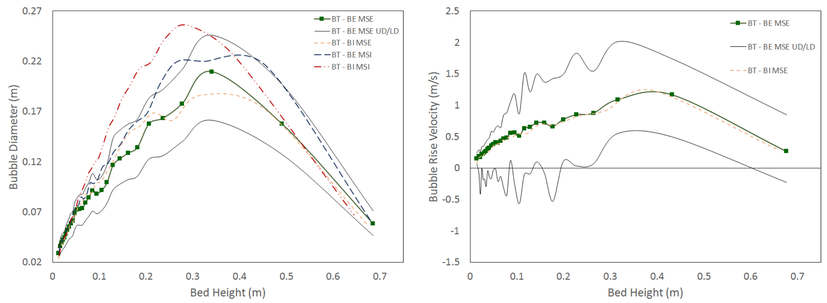
This is a 3D CFD simulation of a fluidized bed in MFiX
- 50cm bed, 50cm static bed height, 1.15mm LLDPE, 0.8g/cc particle density, 72cm/s inlet velocity (3 UMF)
- Data saved at 100Hz for analysis

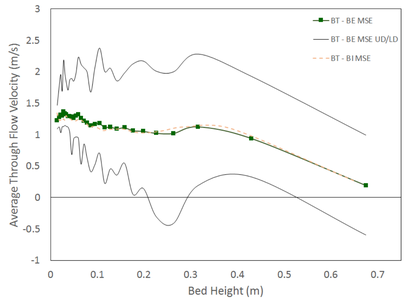


The BubbleTree toolset was then applied to the saved data
- Used Python and VTK to detect regions (bubbles in this case)
- Developed a custom tracking code to do Lagrangian region tracking, associate neighbors, and detect merge and split events
- Grey bubbles: normal; blue bubbles: splitting; Red Bubbles: merging; Pink bubbles: merging and splitting
- Can calculate material/energy fluxes through the region surface



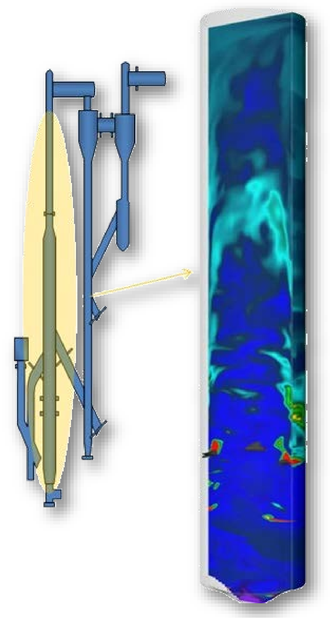
The visualization of the tracking capability through several merge events
- Tracks regions through time and merge/split events
- Green dot: position of the seed region
- Red lines/dots: past positions of regions associated with seed region
- Blue lines/dots: future positions of regions associated with the seed region
- Grey Regions: select region surfaces along the tracking path



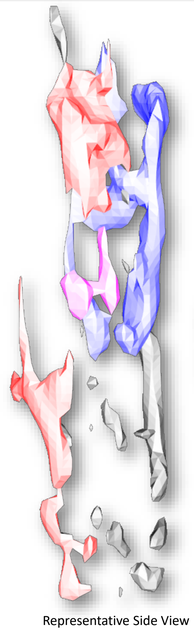


Quantitative analysis of bubbles
- Since all bubbles are detected, tracked and known in quantitative fashion, statistics can be developed that represent averaged behavior in a wide variety of ways
- Here, bubble diameter, rise velocity, and through flow velocity have been analyzed
- Through flow velocity is a key consideration in reactor bypass and represents the relative velocity of the gas through the moving bubble

Cluster Analysis



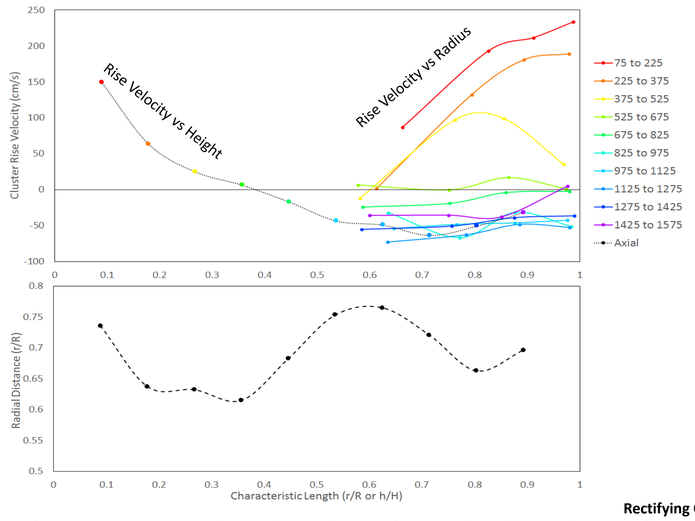
This is a 3D CFD simulation of a circulating fluid bed riser at NETL
- 30.4cm dia, 1680cm high, 880μm LLDPE, 0.863g/cc particle density, 681cm/s inlet velocity
- Data saved at 200Hz for analysis
- Solids cluster against the walls in gas rather than gas bubbling in bed



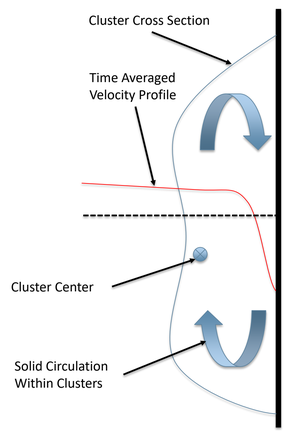
Representative Side View

Representative Top View
(not showing merge splits)

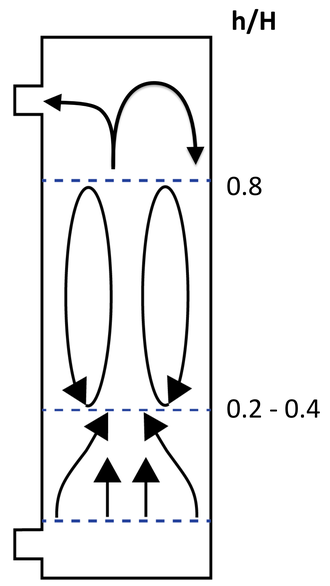
The BubbleTree toolset was applied to detect and track clusters



Analysis revealed some new behavior that is not evident by time averaging solids velocity
- Core-annular flow is quite a bit more complicated than originally understood
- On average, large clusters rise in the bed to about 0.2 to 0.4 h/H and fall above that
- A convergence zone is created in the 0.2 to 0.4 h/H region and clusters extend towards the middle
- The inward extension compresses/accelerates the gas which shears the clusters apart and the solids rise in the core
- The gas must bend and accelerate to exit and the solids get flung out of the flow to form new clusters at the head which shower down the back and help establish new cluster downflow in the mid section



Rectifying Cluster Motion with Time Averaged Solids Velocity
- Time averaged solids motion is still negative in the very near to wall region even when cluster motion is upward which suggests that solids circulate downward on the outside of clusters but move upward on the inside as they are sheared by the upward gas.
- The start of negative solids velocity occurs radially outside the detected centers of the clusters which suggests strong circulation within the clusters relative of bulk motion
- Clusters are dynamic but persist through time which suggests that the solids move as a group and that cluster tracking gives a good measure bulk solids motion along the walls



A new conceptual model of net solids motion in a riser
- Lower: Up through core and net up along wall
- Middle: Up through core and down along wall
- Top: Part of Core Exits, part hits top and establishes cluster downflow for mid section

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