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# Computer Simulation of Liquid-Solids Slurries for Wastewater Treatment

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# COMPUTER SIMULATION OF LIQUID-SOLIDS SLURRIES FOR WASTEWATER TREATMENT

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Processing of liquid-solids slurries for wastewater treatment involves handling of dissolved solids and undissolved solids with readily suspended to rapidly settling behaviors. Given a significant loading of dissolved or readily suspended solids, the effective carrier-fluid rheology may exhibit complicated non-Newtonian effects. A simulation-based assessment of wastewater treatment requires

sophisticated computational fluid dynamics (CFD) flow code with submodels sufficient to address this potentially diverse range of physics. Reynolds-Averaged Navier-Stokes (RANS) models are the current workhorse.

Simulation is always limited by available computational resources and physics parameterizations. With advances in computational engineering in parallel processing environments and physics submodel development for computer simulation codes, many limitations are either being removed or are being moved to

higher-order details. CFD-RANS models are now able to meet challenges for simulating liquid-solids slurry flows in complicated configurations.

Industrial wastewater may contain a significant fraction of undissolved solids with potentially broad particle size and density distributions. Granular-Eulerian multiphase modeling is an example of a CFD-RANS technology that has been formulated to handle this kind of application. In a Granular-Eulerian multiphase model, each gas, liquid, or solids constituent is treated

Figure 1. Multiphase mixing in an industrial process vessel: Flow (left), Velocities (Right)

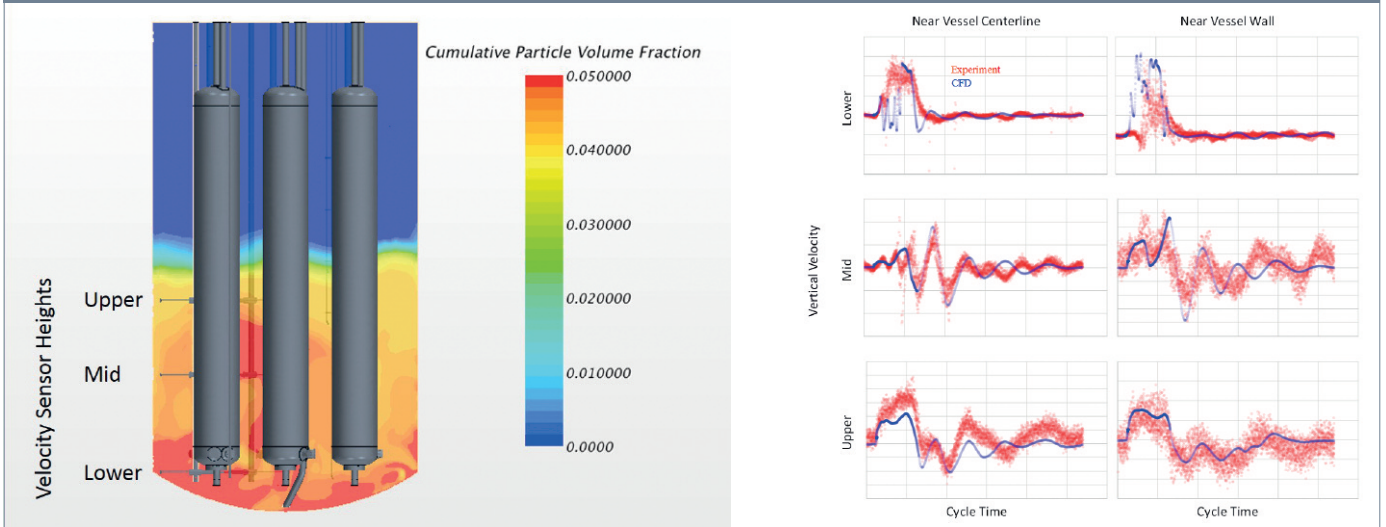
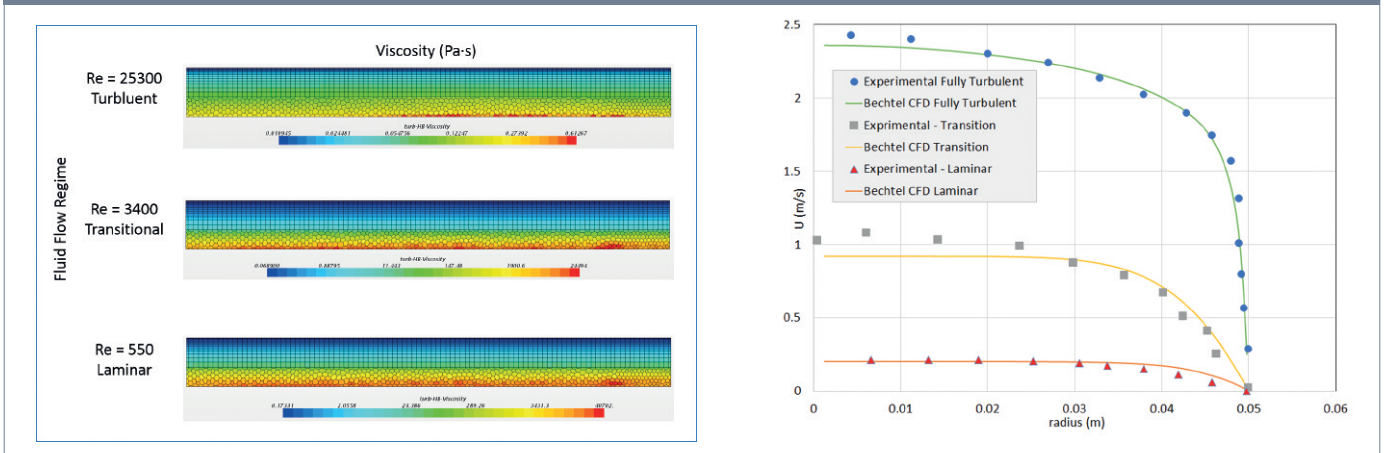


Figure 2. Flow of a Herschel Bulkley Fluid in a Pipe: Flow (left), Velocities (Right)



as a separate continuous modeling phase. Submodels are used to parameterize interactions and behaviors at boundaries.

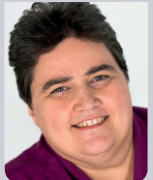
Comparisons of computational results (from a commercial CFD code CD-adapco/Star-CCM+) to experimental data show the fidelity that can be achieved. Figure 1 (left) is an instant from a simulation of mixing of a polydisperse loading of undissolved solids in a Newtonian carrier fluid. The mixing is performed in a vessel prior to the next step of the treatment process. The total solids loading in the vessel is 10% by weight. Approximately half of the solids are readily suspended. The upper part of the vessel is gas. The particle distribution is characterized by 6 solids phases with representative particle sizes and densities. The simulation presented in this article models an existing physical model experiment of the mixing of the waste in the vessel. The simulation geometry is derived from a CAD model of the experimental apparatus. In both the simulation and the experiment, time histories of velocity are sampled at six points in the bulk flow with the velocity sampling locations at lower, mid, and upper levels. Three locations provide velocities near the vessel centerline. Three locations provide velocities near the vessel outer wall. Comparisons of the CFD-RANS predicted velocities to the experimental data, Figure 1 (right), confirm model fidelity to real-world physics.

Dissolved and undissolved readily-suspended solids in industrial mixing vessels and other liquid-solids slurries may be modeled using an effective fluid rheology and density. Contemporary CFD solvers include a broad range of rheology submodels, a non-Newtonian Herschel-Bulkley fluid being an example.

In a Herschel-Bulkley fluid, the apparent viscosity of the fluid depends on the local shear rate. In regions of high local shear rates, a Herschel-Bulkley fluid behaves like a Newtonian fluid. As local shear rates reduce, a Herschel-Bulkley fluid becomes more viscous. The local shear rate in a turbulent flow occurs in the dissipation range of turbulence. CFD-RANS solutions provide energy-containing-range (mean-field) statistics, not dissipation range statistics. Without an appropriate model linking local shear rates to mean-field statistics, CFD simulations of Herschel-Bulkley fluids are well defined only for laminar flows where the dissipation range can be resolved explicitly.



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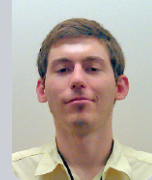
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A method to extend CFD modeling of Herschel-Bulkley fluids into the turbulence regime was recently presented at the Star-CCM+ Global Conference (Peltier et al, 2016). This model extension uses turbulence theory to estimate representative local maximum shear rate magnitudes from CFD-RANS data enabling simulations of Herschel-Bulkley fluids in the turbulence regime.

Figure 2 (left) shows CFD predicted viscosities for flow in a pipe of a Herschel-Bulkley fluid in the laminar, transitional, and turbulence regimes. The slice shown is from the pipe centerline to the upper outer wall. Comparisons

of the CFD predicted velocities to experimental data, Figure 2 (right), confirm model fidelity to real-world physics.

The examples shown for simulation of liquid-solids slurries underscore that capabilities of contemporary commercial CFD flow codes are rapidly advancing and support a conclusion that a simulation-based assessment of wastewater treatment is possible with an expectation for fidelity to real-world physics. ■

**References**

Peltier, J., Rizhakov, A., Rosendall, B., Inkson, N., and Lo, S., 2015. Evaluation of RANS Modeling of Non-Newtonian Bingham Fluids in the Turbulence Regime using STAR-CCM+®. STAR-CCM+ Global Conference Location: San Diego, CA, March 15-18, 2015.