Slurries in Catalyst Manufacture: Mixing with Complex Rheology

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Introduction

The manufacture of many catalysts involves the precipitation, crystallization, and addition of solid particles to liquid systems, creating slurries with complex rheologies: pseudo-plastic, dilatant, and typically visco-elastic. A typical high volume example is an aqueous mixture of zeolite and clay used in manufacture of fluid cracking catalysts. This kind of mixture provides the model used in the simulation reported here. Previous work on mixing in shear-thinning fluids has experimentally and computationally explored the role of radial impellers in the creation of separated segregated regions of flow typically called caverns [1]. These caverns are comparable to the separated regions seen in laminar Newtonian flows [2].

In this offering, the role of more industrially relevant axial impellers are explore for shear-thinning fluids in a three-impeller stirred tank. A Finite Element Method (FEM) is used to predict mixing behavior, and experiments are performed using a model fluid to validate the behavior. The simulations are then used to explore and optimize injection location in the stirred tank

Materials and Methods

A cylindrical stirred tank simulated is 24.0 cm in diameter and 48.0 cm in diameter. Three 45º-pitched blade impellers are equally spaced within the tank and have a 1:3 impeller diameter to tank diameter. A power-law fluid model is used with a pre-factor m = 45 Pa s and power-law exponent n = 0.2 as a typical slurry rheology provided by a catalyst manufacturer. The FEM solutions of the velocity fields in the stirred tank are run in parallel on a cluster of three Pentium4 1GHz processors. The mesh is constructed using the computer-aided drafting and design program (CADD) software provided by ICEM CFD (Berkeley, CA), and the solver software comes from Acusim (Mountain View, CA).

To study the mixing experimentally, a cylindrical stirred tank is constructed out of Plexiglas® and surrounded by a square secondary tank to remove optical distortions of the curved surface. The model fluid used in this system is a dilute (0.01%) solution of Carbopol in water which is transparent and has a measured power-law exponent n = 0.2-0.3. Tracer studies are performed using water-soluble food dye mixed with Carbopol solution.

Results and Discussion

The initial study of the stirred tank through the simulation is done by injecting 400 passive scalar particles arranged in a 0.5 cm square near the bottom impeller and tracking the intersection of these particles with a single plane which bisects the tank (a Poincaré section). In Figure 1, the distribution of the intersections of those 400 points is shown for the first 300 seconds at an impeller speed of 300 RPM. The results of this study show a top to bottom transport. This is surprising because past studies of this type of fluid have shown cavern formation with little inter-cavern transport.

To ensure that this behavior was not a numerical artifact; experiments using Carbopol in water were run using similar conditions. The results confirm the simulations.

Significance

Slurries in catalyst manufacture are never the end product. Understanding the optimal position for injection and the time-scale in which mixing takes place could be of great help to both small scale and large scale manufacture of catalyst. These rheologically induced mixing effects are not anticipated and should be studied further.

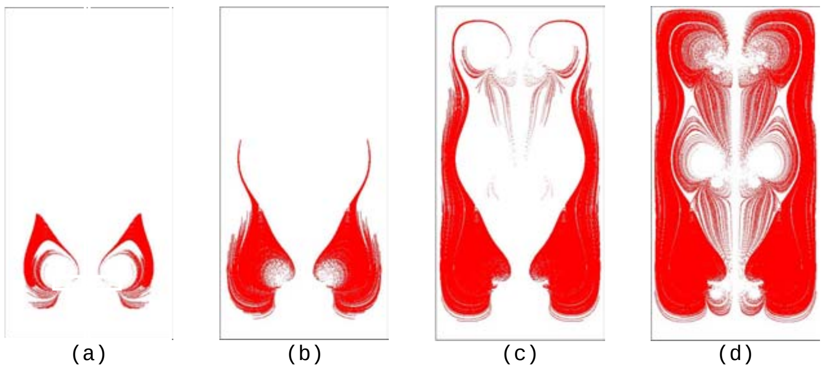

Figure 1. The Poincaré section a 400 point 0.5 cm x 0.5 cm box in the stirred tank with an impeller speed of 300 RPM.

References

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2. Lamberto DJ, Alvarez MM, Muzzio FJ. *Chemical Engineering Science* 56 (2001).