Simulation And Experimental Validation Of Mixing Performance In A Batch Mixer

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Abstract

This study presents a combined simulation and experimental investigation of mixing performance in a batch mixer, with the goal of validating simulation results and identifying optimization potential. The focus is on evaluating mixing times and flow fields to enhance process efficiency, particularly by reducing batch cycle time and minimizing dead zones.

Physics simulations were performed using COMSOL Multiphysics and the CFD Module, applying a time-dependent study that coupled turbulent flow with transport of diluted species. The frozen rotor approach was employed to model the impeller-driven flow field. These simulations provided detailed insights into the temporal evolution of mixing and the spatial distribution of flow patterns within the mixer. Experimental validation was conducted using laser-induced fluorescence (LIF) and particle image velocimetry (PIV) techniques. These optical methods were applied to a laboratory-scale batch mixer based on a production design from Henkel, with vessel diameters of 110 mm and 190 mm. Two hand dishwashing detergents with different viscosities were selected to represent realistic mixing conditions.

The comparison between simulation and experimental results demonstrated strong agreement in both flow field characteristics and mixing time. This validation confirms the reliability of the simulation approach for predicting mixing behavior in industrial batch mixers. The findings highlight opportunities for process optimization, such as reducing mixing times and eliminating dead zones, which can contribute to shorter batch cycles and improved product homogeneity. These insights can support future design improvements and operational strategies in batch mixing processes.

Reference

Kögel, Lena etal, Identifying Optimization Potential in a Batch Process for the Production of Detergents and Cleaning Products, Conference: Jahrestreffen DECHEMA/VDI-Fachgruppen Mischvorgänge, Hochdruckverfahrenstechnik und Mehrphasenströmungen, 2025 10.13140/RG.2.2.13484.58247/1.

Figures used in the abstract

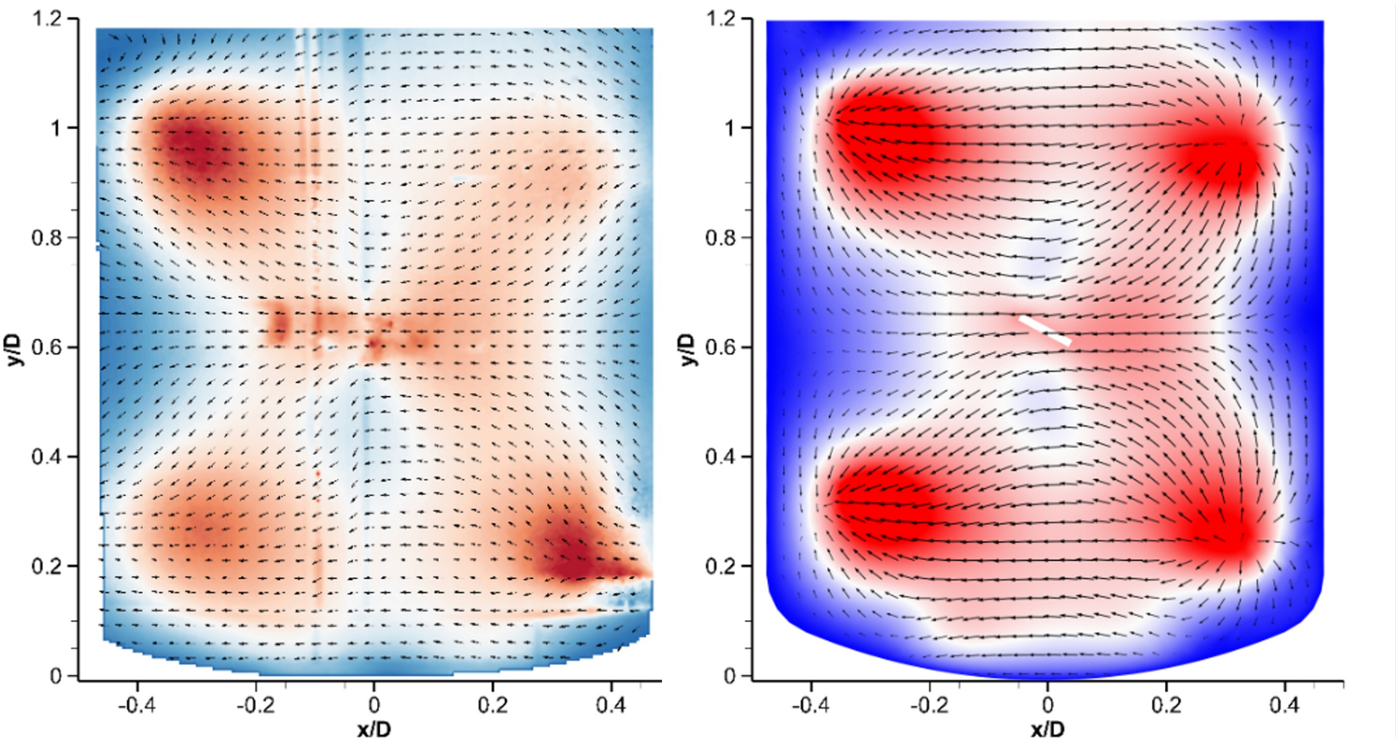

Figure 1 : Comparison of flow field results from PIV measurement (left, experiment) and frozen rotor (right, simulation)