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Measurement of Lagrangian Tracks in a 3 L Stirred Tank Reactor using 4D Particle Tracking Velocimetry with Shake-the-Box

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Abstract

Stirred tank reactors are widely used in the chemical industry and bioprocess engineering and, consequently, a large number of scientific publications deal with the characterization of those apparatuses. However, there is very little information about the flow conditions. This is mostly due to the fact that these apparatuses are generally made of stainless steel, which restricts optical access. Furthermore, three-dimensional flow field measurements are still not trivial and involve costly equipment, therefore, investigations often reduce to two-dimensional PIV measurements. Nevertheless, recent works (Rosseburg et al., 2018; Taghavi and Moghaddas, 2020; Kuschel et al., 2021) impressively show the formation of compartments which hinder and delay mixing. However, these measurements are based either on instantaneous concentration profiles by means of pLIF measurements or on a two-dimensional projection of the system and thus do not allow conclusions about the development of the three dimensional compartments and the exchange rates between the compartments. In this work, for the first time, instantaneous flow field measurements with high spatial and temporal resolution are performed in the entire volume of a 3L stirred tank reactor based on 4D particle tracking velocimetry. The highly resolved particle trajectories further allow detailed Lagrangian analysis of the mixing dynamics inside the reactor, data that was previously inaccessible.

1 Experimental Method and First Results

The fluid dynamics of a 3L stirred tank reactor are investigated (see Figure 1) using 4D particle tracking. This measurement method allows not only the analysis of the three dimensional flow fields but also the analysis of the Lagrangian trajectories, and thus, the material transport in the reactor. Fluorescent and

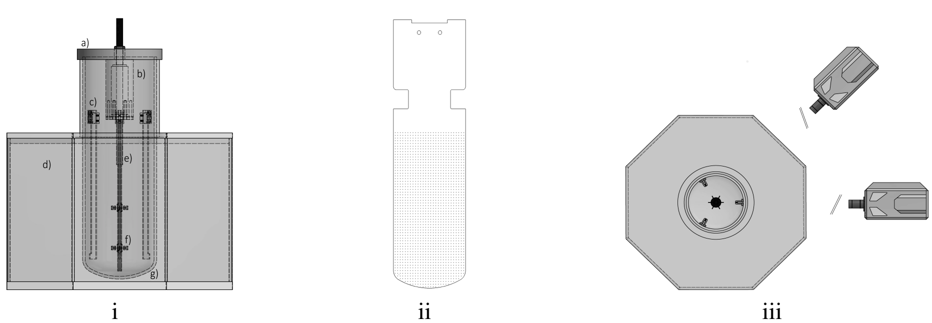
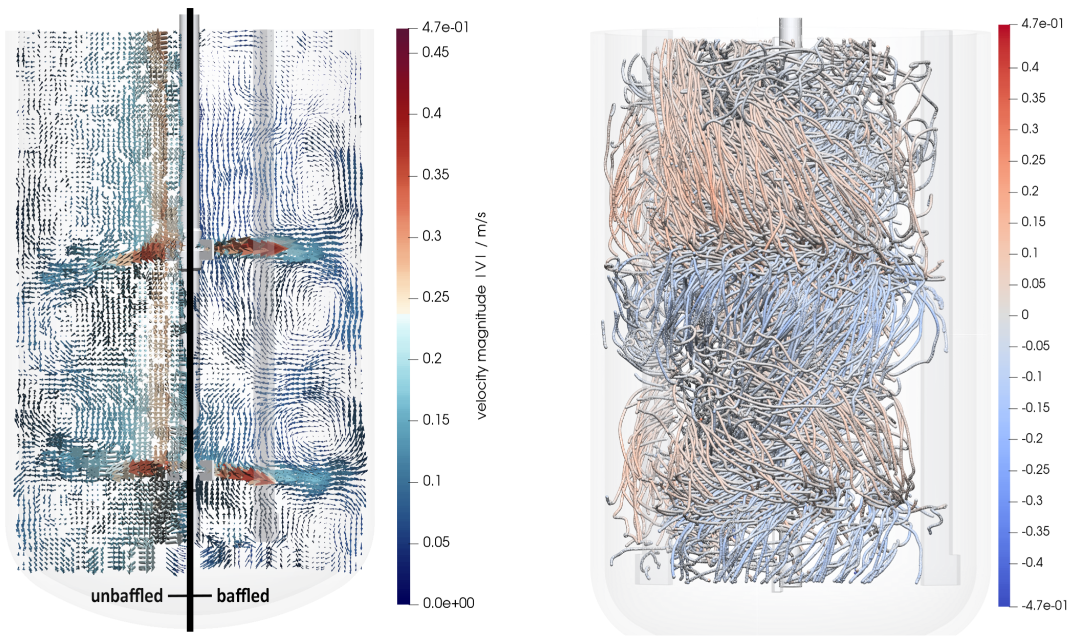


Figure 1: Exemplary representation (i) front view (1:5), ii) calibration target, iii) top view (1:10)) of the stirred tank setup : a) reactor lid, b) bearing box, c) baffle and baffle holder, d) octahedral glycerol basin, e) stirrer shaft, f) Rushton turbine

buoyancy-neutral particles with a diameter of 150-180 µm are dispersed in the reactor and illuminated with four customized light sources build in-house using high power LEDs (OSRAM). To track the particles, a camera setup consisting of four high-speed cameras as well as a recording and synchronization system from LaVision (Göttingen, Germany) is used. Two identical camera models are installed one above the other at angles of 30°, while the two camera pairs are mounted at an angle of 45° to each other (see Figure 1 (c)). The "Shake-The-Box" method is used to determine the Lagrangian tracks, which is currently the most efficient particle tracking algorithm available (Schanz et al. (2016)). The acquisition of the images as well as the application of the 4D-PTV algorithms are performed with the commercial DaVis software and the FlowMaster module from LaVision (Göttingen, Germany). The images are recorded with a spatial resolution of 148 µm/px and a temporal resolution of up to 800 Hz.
In Figure 2 first results are depicted. The instantaneous and time-averaged flow fields for a baffled and an unbaffled 3L stirred tank reactor (see i) are presented. In the oral presentation a first analysis of the measured Lagrangian tracks (see Figure 2 ii), but also the mixing dynamics will be discussed.



i ii

Figure 2: i) Time-averaged flow field on a sectional plane through the stirrer shaft. (left: without baffles, right: with baffles). ii) Selection of 1% of total trajectories in the system (modified velocity magnitude indicates up- or downwards motion, red: movement upwards; blue: movement downwards).

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