Experimental Characterization: Flow Fields and Mixing Dynamics of UFX Turbines

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Introduction

Motivation

- Axial impellers are widely used in stirred tank reactors due to their effective bulk flow, especially in suspension processes [1]
- Beyond power characteristics, the characterization of impellers requires detailed analysis of flow profiles and mixing velocities to adequately assess their hydrodynamic performance [2]

➡ Emphasizing benefits of modern impeller design for mixing performance

Research objectives

Use of laser-optical methods, Particle Image Velocimetry (PIV) and Planar-Laser-Induced Fluorescence (PLIF), following established approaches reported in previous studies [3,4], to investigate

➡ the influence of impeller clearance and inter-impeller spacing to derive design recommendations

➡ flow fields of UFX turbines in single- and two-stage systems

➡ mixing time to identify potential dead zones within the vessel

Methods

Experimental details

- Methodology: Stereo-PIV (Particle Image Velocimetry) for flow velocity profile and PLIF (Planar Laser Induced Fluorescence) for mixing time distribution
- Measurement with 3D-printed impeller: UFX-Turbine (0.45D) and Pitched-Blade Turbine (PBT) (0.38D) for comparison in a dished bottom tank (H/D=1) with D_i= 110mm and six rectangular baffles in 30%-glycerol-water mixture

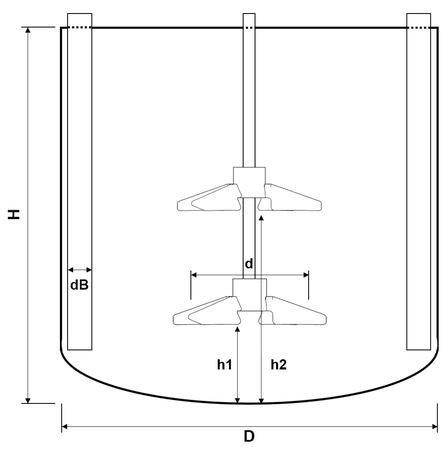


Fig. 1: Sketch of the dished bottom reactor geometry

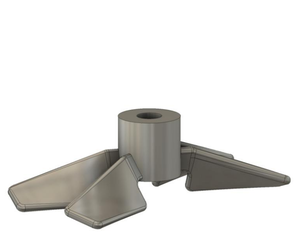


Fig. 2: Model of the used impeller: UFX Turbine

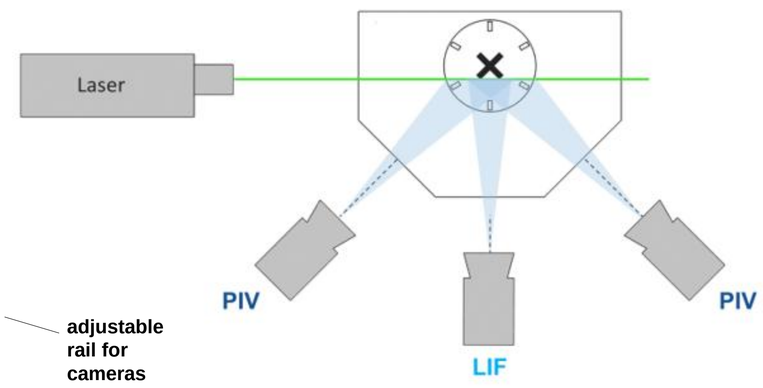


Fig. 3: Experimental setup of the measurements; Depending on the method, either two (PIV) or one (LIF) camera was used

Results and Summary

Results

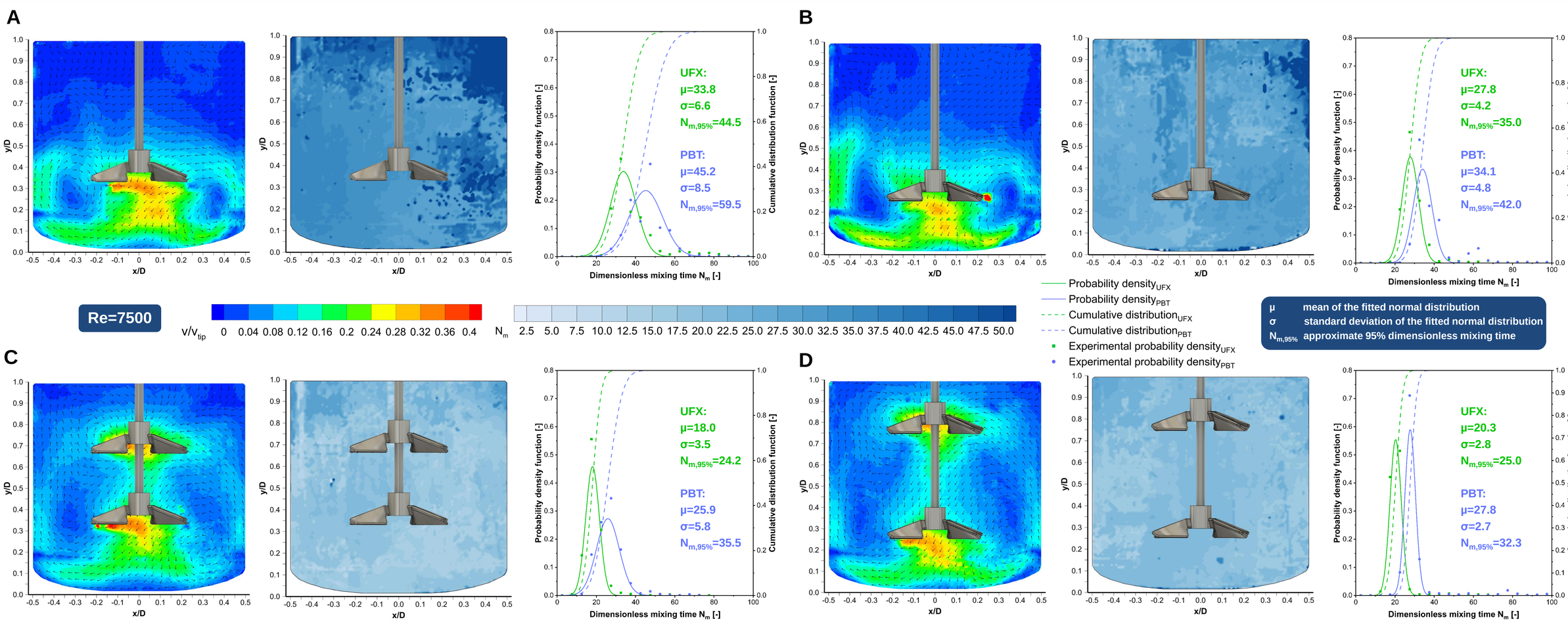


Fig. 4: Flow Fields and Mixing Characteristics of Different UFX-Turbine configurations

A/B: Single stage UFX with A: h/D=1/3 and B: h/D=1/4, C/B: two-stage UFX turbines with C: h_1/D=1/3 and h_2/D=2/3, and D: h_1/D=1/4 and h_2/D=3/4

Results of mixing time analysis: normal distribution (UFX)

Results of mixing time analysis: normal distribution (PBT)

UFX: Main Findings

- Experimental results confirm superiority of two-stage systems for H/D = 1, with single-stage reactors exhibiting low mixing in the upper region, identified by comparatively low velocities (blue) and long mixing times (dark blue), a trend that is consistently reflected in the dimensionless mixing time results
- Single-stage: increased mixing times in upper right vessel region. Flow field and mixing time characteristics confirm advantageous impeller installation of h/D=1/4 for UFX turbine, as axial flow is more strongly deflected in the dished bottom, resulting in improved circulation and a larger reactor volume fraction being effectively mixed
- Two-stage: More even flow velocity distribution, negligible slightly reduced velocities in central region near lower impellers
- LIF measurements indicate a nearly uniform mixing time throughout the reactor, also reflected by low standard deviation of the fitted normal distribution, demonstrating efficient tracer distribution and mixing
- Only minor differences observed for increased or reduced inter-impeller spacing
- While single-stage operation is feasible, a two-stage installation should be preferred

UFX vs PBT

For better classification, UFX results are compared with well-established PBT:

- PIV velocity fields are highly comparable (PBT results not shown here)
- LIF measurements consistently show that the UFX achieves 20–40% lower dimensionless mixing times compared to the PBT across all configurations.

➡ Highlighting versatility of UFX turbine configurations as promising addition to the available axial stirrer range

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Literature:

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