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Simulation and Control of Drop Size Distributions in Stirred Liquid/Liquid Systems

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Keywords: Liquid/liquid dispersion, Drop size distribution (DSD), Control interface, Control design, DQMOM, CFD

Background and Motivation

Control of the particle distribution of liquid/liquid dispersions:

- Optimization of mixing processes used e.g. in chemical industry
- Recent developments enable reliable and affordable CFD investigations
- There are no mathematical tools available for the control of liquid/liquid dispersions

Research goals:

- Implementation of the DQMOM algorithm to approximate the DSD into the flow solver
- Coupling of the flow solver to the control unit
- Design of controllers for the coupled system

Physical Setup:

- Rushton turbine DN150 with 90% water and 10% toluene, treated as a single-fluid
- Simulations with $\approx$ 240 rpm $\longrightarrow$ Reynolds Number ≈ 18.000

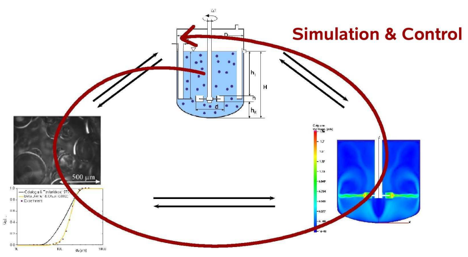

Figure 1. Schematical illustration of the project

Implementation Approach

Design of the Control Setup:

- Coupling of the flow solver FASTEST3D to MATLAB for simulation design and control
- Use FASTEST3D and the DQMOM to compute the moments $m_0, m_1, \ldots, m_N$ of the DSD in the reactor
- Use MATLAB *Control Toolbox* to control the DSD

Definition of the Control Problem:

- Take the stirrer speed ω as input and the Sauter diameter d_{32} and the standard deviation σ as observed and controlled output
- Define the target value d_{32}^* and the optimal control problem:

$$\mathcal{J}_{(\alpha,\beta)}(d_{32}, \sigma, \omega) = |||d_{32}(\omega) - d_{32}^*||| + \alpha||\sigma(\omega)|| + \beta|\omega| \longrightarrow \min \qquad (*)$$

Identification:

- Use test functions ω^k and compute input/output data $[\omega^k \leftrightarrow d_{32}^k, \sigma^k]$ (Figure 3) to tune the surrogate linear state space model

$$\dot{x} = Ax + B\omega$$
$$\begin{bmatrix} d_{32} \\ \sigma \end{bmatrix} = Cx + D\omega$$

- Approximate $(^*)$ using e.g. linear quadratic controllers of the identified model

Recent Result:

- Currently no optimization results due to poor quality of generated input/output data

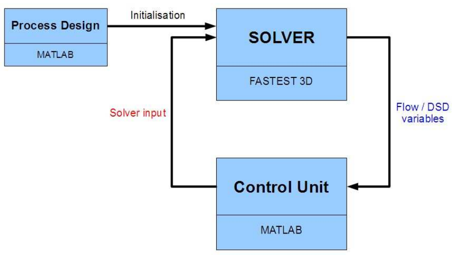

Figure 2. FASTEST3D/MATLAB coupling

Upcoming Issues

- Improve robustness of the numerical simulations through dimensionless formulations
- Validation of numerical results with experimental findings
- Design of model specific and robust controllers for simulations and experiments

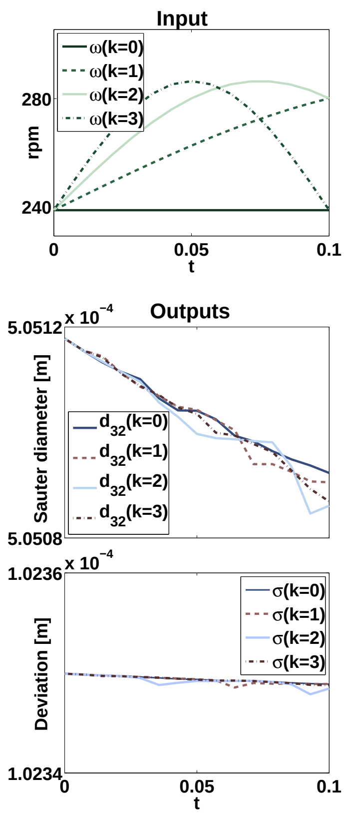

Figure 3: Input/output data for the input testfunctions ω^k, $k = 0, 1, 2, 3$

Partners Involved

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