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

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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 \( \approx 240 \text{ rpm} \rightarrow \text{Reynolds Number} \approx 18,000 \)

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 \( \omega \) as input and the Sauter diameter \( d_{32} \) and the standard deviation \( \sigma \) as observed and controlled output
- Define the target value \( d^{*}_{32} \) and the optimal control problem:

\[
J(\alpha, \beta)(d_{32}, \sigma, \omega) = \left \| d_{32}(\omega) - d^{*}_{32} \right \| + \alpha \| \sigma(\omega) \| + \beta |\omega| \rightarrow \min \quad (*)
\]

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

\[
\dot{x} = Ax + B\omega \\
d_{32} \sigma = Cx + D\omega
\]

- 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

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

Partners Involved

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