Control of Drop Size Distributions in CFD-Simulations via Identified Linear State Space Models

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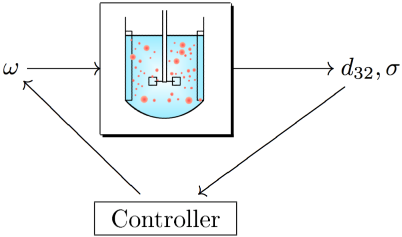
Background



The capability of influencing the unsteady behavior of a mixing process may help

- to minimize settling times and to obtain a desired state at a given time
- to save energie
- to react on disturbances

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Controller Design

Some Variants

- PID control
  - → needs online measurement data
- Analytical synthesis of a controller from the mathematical model
  - → not feasible for specific plants
- Identification of a surrogate model by means of measurement data
  - → universal approach
  - → characteristics of the plant are taken into account
  - → can be further improved by feedback

Two Candidates Of Parametrized Linear Models

- Direct discretization of the input/output map

$$\mathbf{G} : \omega \mapsto [d_{32}, \sigma]$$

  + direct approximation of the system behavior
  + analytical estimates of the error

- Linear state space models

$$\begin{aligned} \dot{x} &= Ax + B\omega \\ [d_{32}, \sigma] &= Cx \end{aligned}$$

  + well developed theory for the controller design

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Modellidentification

General approach

1. Choose/generate a data basis $[d_{32}, \sigma]_i = [d_{32}(\omega_i), \sigma(\omega_i)]$ corresponding to testfunctions ω_i
2. Identify the parameters of a model $\mathbf{M}$ such that

$$\mathbf{M}\omega_i \approx [d_{32}, \sigma]_i$$

   for all test functions ω_i

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Design of Experiment or How to Choose the Test Functions

Practical considerations

$\rightarrow$ Capture the system's behavior by a small number of simulations

Mathematical considerations

$\rightarrow$ The test functions should be linearly independent and

$\rightarrow$ can be combined to further input signal in a unique fashion

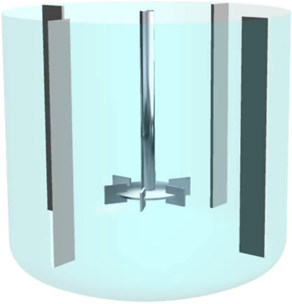
Physical Setup

The mixture

- Toluene/Water

Geometry

- DN 150
- 6-blade-stirrer
- H/D = 1
- d/D = 0.33

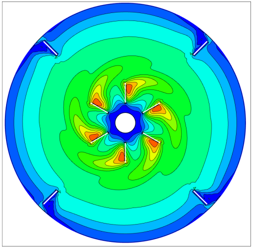


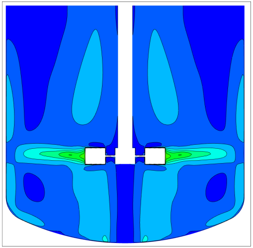
Experimental setup

- Stirrerfrequency around 400 rpm
- Disperse phase rate $\varphi = 0.1$

Setup Flow Simulation

- Inhouse (TU Darmstadt) flow solver FASTEST-3D
- Finite volume method on $2.5 \cdot 10^5$ cells
- RANS standard k-ϵ
- Euler implicit
- One phase simulation for the flow of the mixture
- PBE for the dispersion
- Initialized by the computed steady state for $\omega = 400$ rpm





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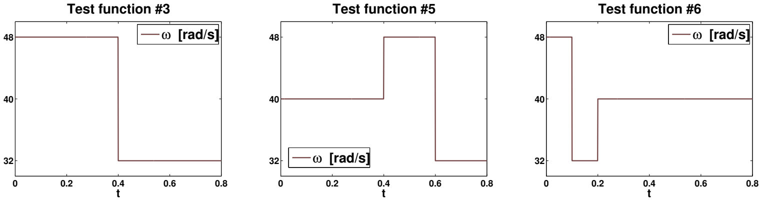
Test functions

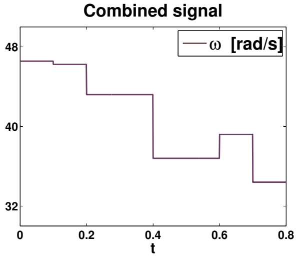
9 jump functions



→ can be combined to piecewise constant input signals

→ implemented and simulated

→ output extracted as mean value over the block between the stirrerblades

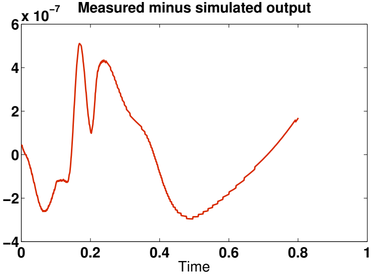


Validation of the model

Data base: system response for the jump functions

1. State space model by MATLAB Identification Toolbox

   → good prediction of "missed out" data



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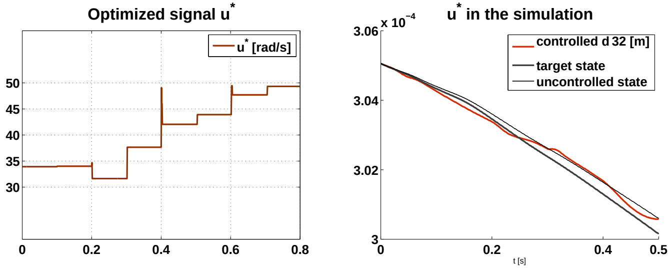
and the controller

1. Directly discretized I/O map by own implementation
    - Used to compute a control u^* for an aspired course of d_{32}
    - Reimplemented in the simulation to check the model quality



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Discussion

Wrap up

- Identification of a linear surrogate model
- Optimized data base by DOE
- Prediction and control performance checked

Critical points

- Time consuming generation of the data base
- Linearizations may be not a valid approximation
- Link to the real experiment

Acknowledgements

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