

Hybrid Modeling of Batch and Filtration Processes Using Simulink and Stateflow

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Abstract: This work presents the design and simulation of a hybrid system combining batch and continuous unit operations, implemented in Simulink using Stateflow. The study uses a representative industrial process consisting of batch reactors, a buffer tank, and filtration units to illustrate the principles of hybrid modeling, where discrete operating modes interact with continuous dynamics. The batch reactors are modeled through a standard operation procedure through four operational states - fill, react, drain, and cleaning - governed by concentration and volume thresholds. To improve process continuity, multiple reactors operating with time offsets are introduced, generating intermittent flows that are smoothed through a buffer tank with proportional level control. Downstream, filtration units are modeled using mode-based logic with operation, cleaning, and standby states, incorporating pressure-driven dynamics and efficiency-based separation. The system is extended to multiple filters coordinated by a supervisory control structure that governs load distribution and cleaning schedules. Stochastic variability in filter fouling is introduced to better reflect realistic behavior, highlighting its impact on system performance and flow stability. The work further investigates numerical considerations, particularly the influence of timestep selection on simulation accuracy and physical consistency. Overall, the implementation demonstrates how hybrid modeling using Simulink and Stateflow provides a powerful and intuitive framework for representing systems with interacting discrete and continuous dynamics. The graphical and state-based nature of these tools enables transparent integration of control logic with physical process models. This highlights the strong potential of hybrid modeling through Simulink and Stateflow for the design, analysis, and simulation of complex industrial process systems.

Keywords: Hybrid systems, Process modeling, Supervisory control, Mode-dependent dynamics, Scheduling
