A Holistic Approach for the Model-based Control of Crystal Size, Shape and Purity in Integrated Continuous Crystallization – Wet Milling – Classification Systems

Rojan Parvaresh, Wei-Lee Wu, Zoltan K. Nagy
Purdue University, Davidson School of Chemical Engineering, West Lafayette

Specific aims: *"To develop and provide the first proof-of-concept simulation and experimental demonstration of a full population balance model-based design space determination, digital design, and nonlinear predictive control approach for batch and continuous crystallization processes integrated with wet milling and classification/recycle system, in order to achieve desired crystal size and shape distribution. The effects of recycle on crystal purity and size, and overall system dynamics will be investigated. The system will be generalized to simulate crystallization and other unit operation networks with various applications"*
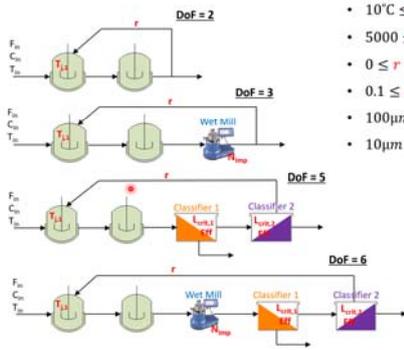
Crystallizer – Wet Mill – Classifier

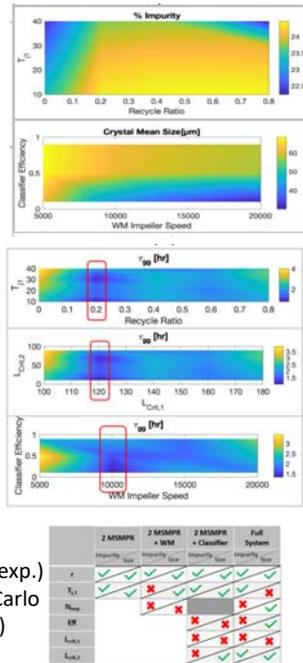Classification system design ($S = \frac{e^{EX} - 1}{e^{EX} + e^{E} - 2}$)

Impurity model development
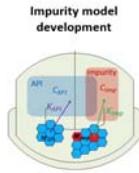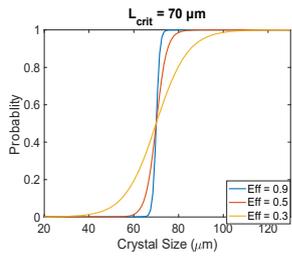
α : partition coefficient
K : relates solid phase (M) to liquid phase (C)

- $10°C \leq T_{j1} \leq 40°C$
- $5000 \leq N_{imp} \leq 20000$
- $0 \leq r \leq 0.9$
- $0.1 \leq E_1 = E_2 \leq 0.9$
- $100\mu m \leq L_{crit,1} \leq 180\mu m$
- $10\mu m \leq L_{crit,2} \leq 90\mu m$

- 2-level DoE (4, 8, 32, 64 exp.)
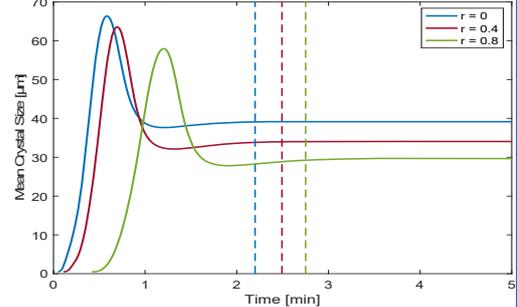- Full Monte Carlo (10,500 exp.)

DoF = 2
DoF = 3
DoF = 5
DoF = 6

Design space analyses

Attainable region for an integrated system

Full System
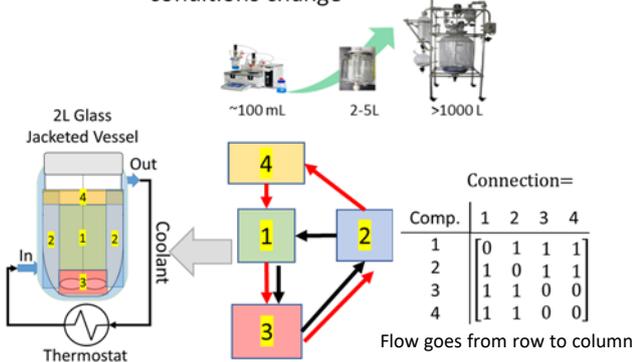2 MSMPR+WM
2 MSMPR+Classifier
2 MSMPR
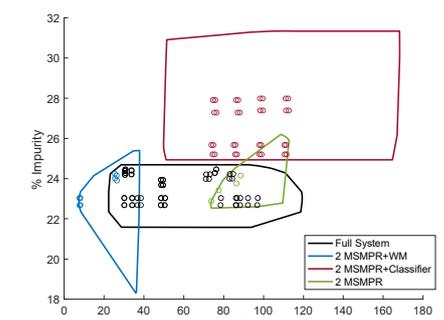
Dynamic model – Startup

Application – Scale-up

- Batch crystallization scale-up issues:
 - Crystallizer geometry, scale, and operating conditions change

2L Glass Jacketed Vessel

Connection=

Comp.	1	2	3	4
1	0	1	1	1
2	1	0	1	1
3	1	1	0	0
4	1	1	0	0

Flow goes from row to column

- Unseeded batch thermocycling temperature profile
  - Heat transfer delayed in compartment 1 (bulk phase) and compartment 3 (impeller)

Comp1 Comp2 Comp3 Comp4
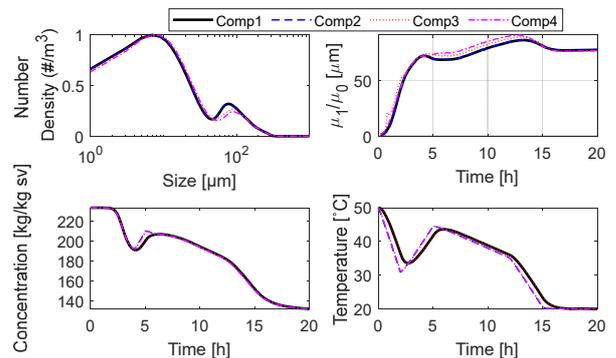
Future Plans

- Experimental validation
- Crystallizer network applications
  - General multi-compartmental model for scale-up effect simulation for industrial crystallization
- 2D simulation of the integrated system
- Model based Quality-by-Control (QbC):
  - Develop a moving horizon estimation (MHE) based nonlinear model predictive control using the mechanistic model for size, shape and purity control for the integrated process.
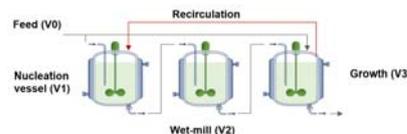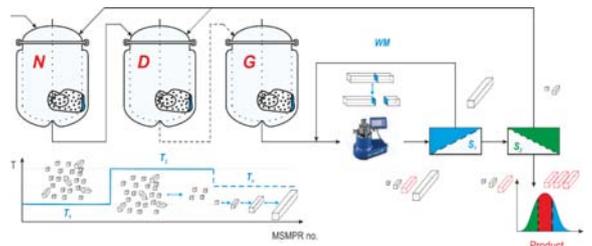
	V0	V1	V2	V3
V0	0	1	0	1
V1	0	0	1	0
V2	0	0	0	1
V3	0	1	0	0