Autonomous structure formation processes in spray fluidized bed agglomeration

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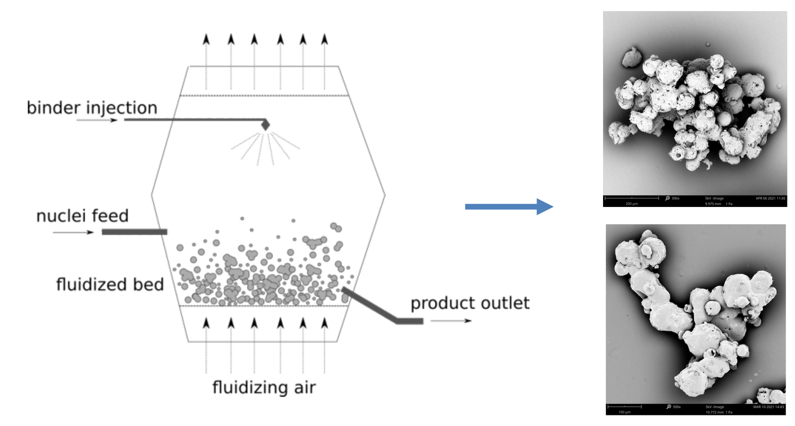
APP SPP 2364

MOTIVATION AND CHALLENGES

Spray fluidization: major process technology for agglomeration
Agglomerate structure determines **product properties**



Key challenges

- **Lack of** dynamic models describing agglomerate structure formation in continuous spray fluidized beds
- **Need for** deliberate and intentional agglomerate structure formation in spray fluidized beds
- Inline monitoring and process control of structure formation are still in an **infant state**

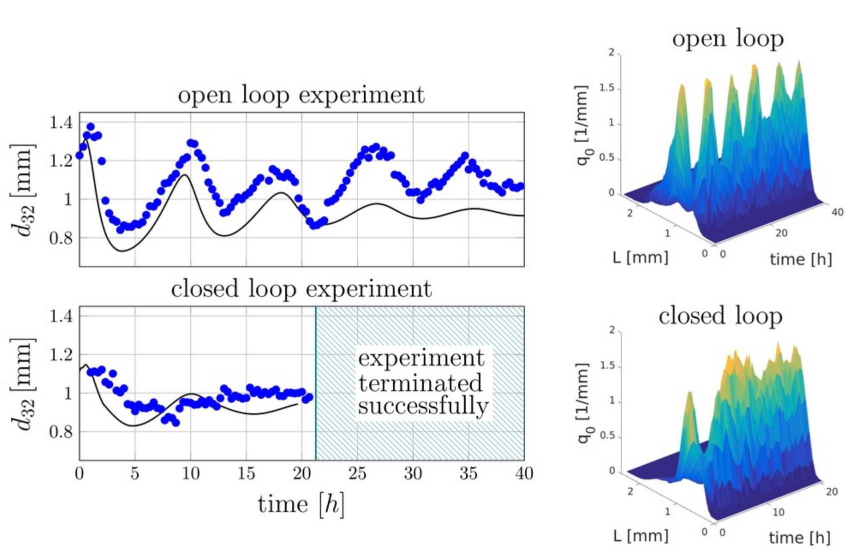
PROJECT OBJECTIVES

- **Theoretical and experimental investigation of structure formation dynamics**
- Elucidation of process-structure and structure-property relationships
- **New realtime-capable, dynamic models** for agglomerate structure formation in **continuously operated** fluidized bed spray agglomeration (with and without recycle)
- **Novel multi-rate model-based soft-sensor** for agglomerate structure formation
- Development, implementation and evaluation of **new process control schemes** for structure formation in SFB agglomeration processes

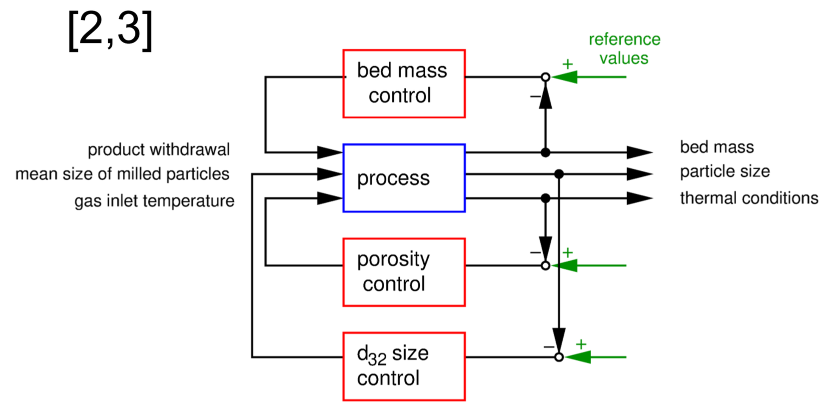
PRELIMINARY WORK

WG Kienle

- Spray fluidized bed **layering granulation** with WGs Bück, Tsotsas and Heinrich (TUHH):
  - **Particle size control** to stabilize unstable operating points [1]



- **Simultaneous particle size** and **porosity control** for the production of particles with tailormade properties [2,3]

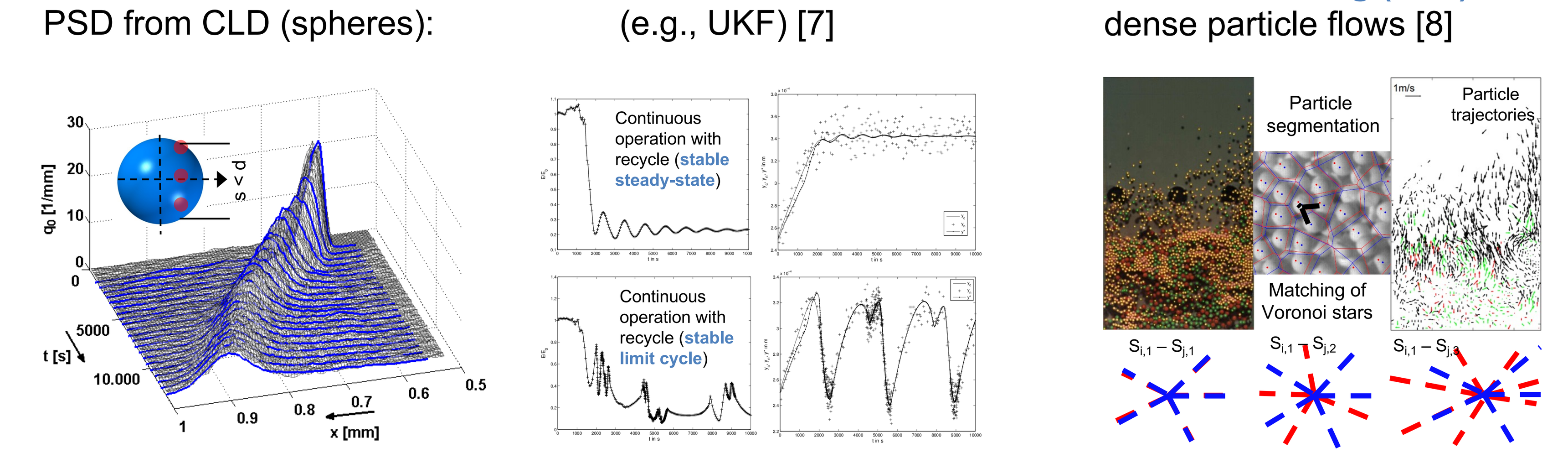


- Spray fluidized bed **agglomeration** (WGs Bück, Tsotsas):
  - PBM in combination with **data driven kernel identification** for quantitative prediction of steady states [4]
  - Nonlinear control of particle size d_{32} using a nominal process model [5,6]

WG Bück

Online determination of particle properties in **layering granulation** combining process models, simulation data and experiments

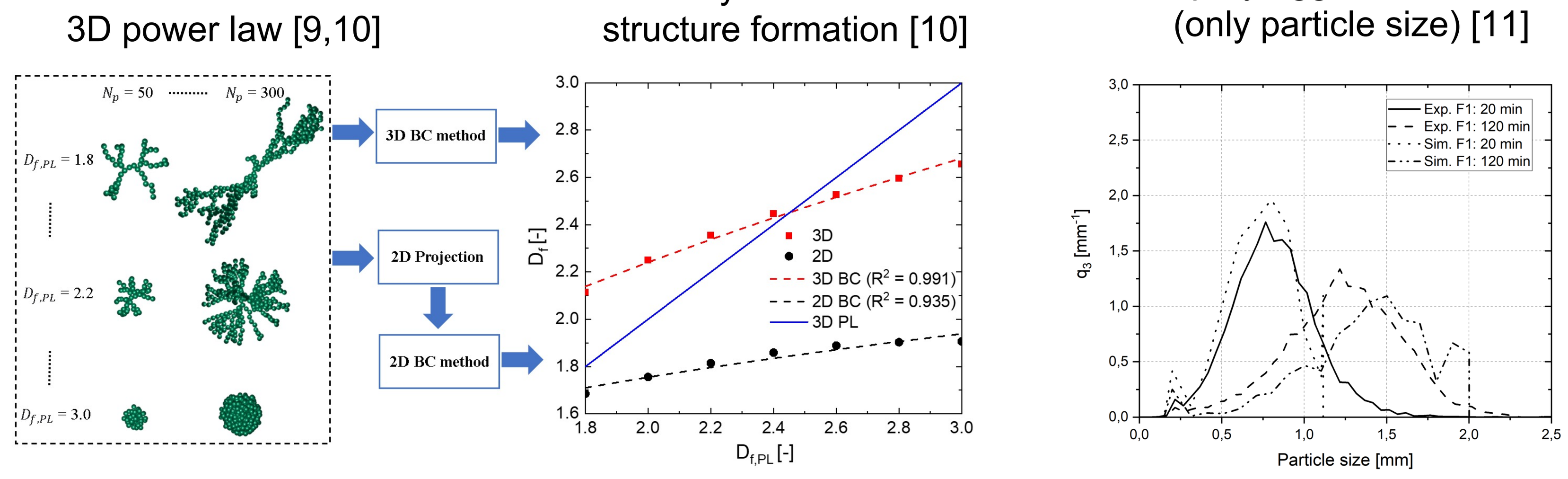
- **Online measurement** of PSD from CLD (spheres):
- **State estimation** (e.g., UKF) [7]
- **Particle tracking (PTV)** in dense particle flows [8]



WG Tsotsas

Characterization of **fractal properties of agglomerates, Monte Carlo modeling (MC)** of process dynamics and agglomerate formation

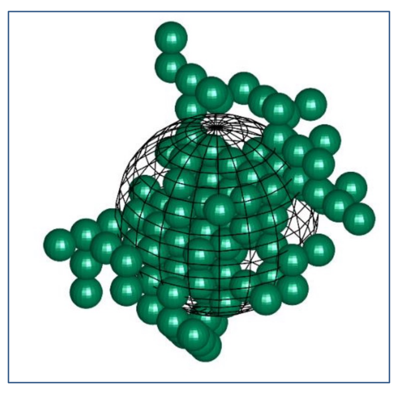
- **Aggregate morphology models:** 2D Box count vs. 3D power law [9,10]
- **Unified MC models** for batch dynamics and structure formation [10]
- MC model of **continuous** spray agglomeration (only particle size) [11]



WORK PROGRAM AND METHODS

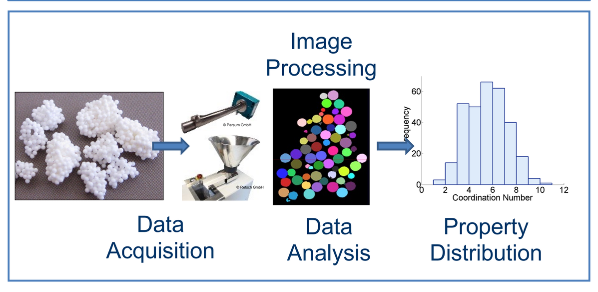
Morphogenesis (WG Tsotsas)

- Under steady state or dynamic operation, one-pass vs. vibratory disintegrator loop
- Structural characterization and advanced modeling (kinetic Monte Carlo simulation)
- Agglomerate breakage, particle outflow



Online measurement (WG Bück)

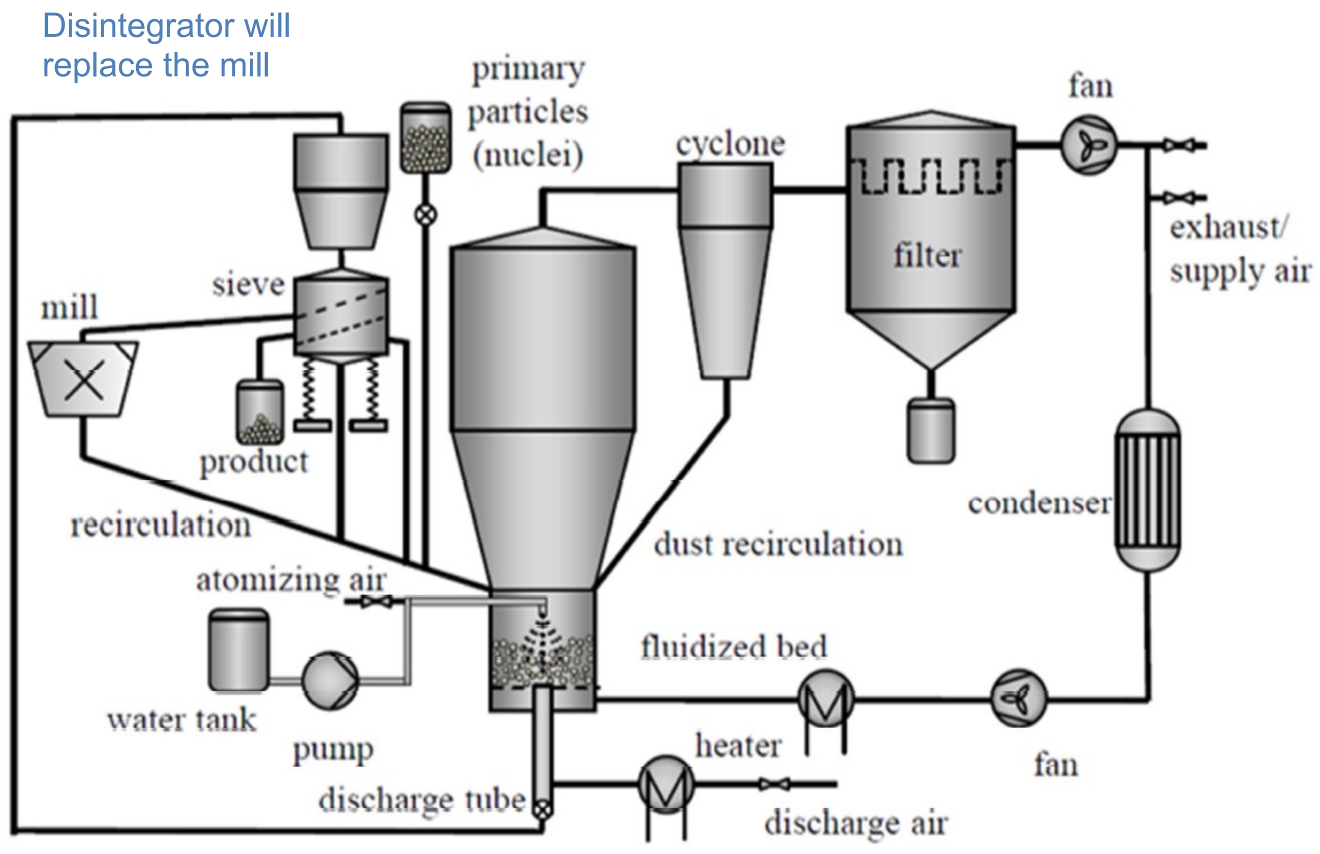
- Particle structure determination from dynamic image analysis (DIA)
- Advanced particle structure determination from image sequences
- Multi-rate soft sensor for structure elucidation (inline, offline data on multiple time scales)



Plant experiments (WGs Tsotsas, Bück and Kienle)

Control concepts (WG Kienle)

- Development of realtime capable models using hybrid and data-driven approaches
- Particle size control based on Parsum probe measurements
- Nonlinear control of particle size and structure formation using novel multi-rate soft sensor
- Comparison with robust linear approaches
- Plantwide control with disintegration cycle

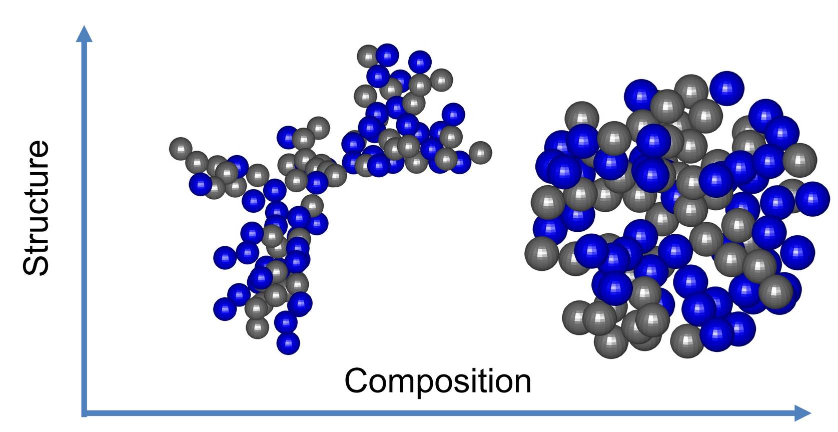


OUTLOOK PERIOD II

Extension of

- Structural models,
- Process models,
- Sensor and control methods, and
- Online implementation

to **hetero-agglomerates**



Additional complexity and design opportunity

SELECTED COOPERATIONS

- **Antonyuk/Palis:** Machine learning, Lyapunov-based nonlinear control
- **Graichen/Huber/Schmidt:** Hybrid modeling of particle formation, inline measurement and process control schemes
- **Heinrich/Skiborowski:** Modeling and optimization of FB layering granulation
- **Hermann/Kwade**: Modeling of structure formation, measurement augmentation
- **Lorenz/Mangold/Sager:** Physical modeling of particulate processes, machine learning, optimization and state estimation
- **Nirschl/Meurer:** Model-based control and soft-sensing of particle formulation processes

[1] Neugebauer, Bück, Kienle et al., Powder Technol. 354, 2019, 765-778.
[2] Neugebauer, Bück, Kienle et al., Chem. Eng. Technol. 43(5), 2020, 813-818.
[3] Neugebauer et al., IFAC-PapersOnLine 53(2), 2020, 11422-11427.
[4] Otto, Bück, Tsotsas, Kienle et al., Adv. Powder Technol. 32(7), 2021, 2517-2529.
[5] Otto, Kienle et al., IFAC-PapersOnLine 54(3), 2021, 231-236.
[6] Otto, Kienle et al., J. Process Control 110, 2022, 99-109.
[7] Bück, Kienle, Tsotsas et al., AIChE J. 57(4), 2011, 929-941.
[8] Hagemeier, Bück, Tsotsas et al., Particuology 22, 2015, 39-51.
[9] Singh, Tsotsas et al., Energies 14, 2021, 7221.
[10] Wang, Tsotsas et al., Chaos, Solitons & Fractals 2022 (in press)
[11] Du, Bück, Tsotsas et al., Powder Technol. 396, 2022, 113-126.

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