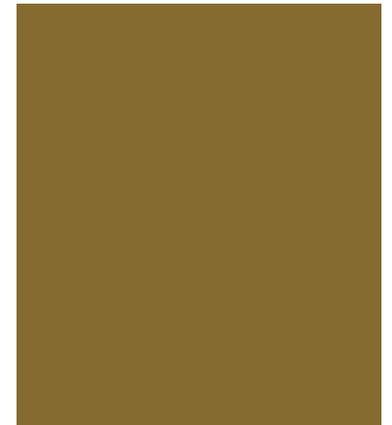


Education Perspectives and Outreach IFPRI 2020 AGM

- Education trends & opportunities
- Elsevier Powder Technology:
 - IFPRI Collection
 - Recent Reviews
- Systems Perspective – Classification

Paul Mort pmort@purdue.edu
Purdue University
Dept of Materials Engineering,
Center for Particulate Products and Processes (CP3)
7/1/2020



Personal perspective

- IFPRI representative for Procter & Gamble, 1995-2018
 - Particle Formation ————| Granulation, Extrusion, Compaction
 - Dry Flow ——————| Dense flow rheology (Tardos, Behringer, Daniels/Vrend); IFPRI Collaboratory
 - Systems ——————|
- Continuing IFPRI association
 - Elsevier outreach (IFPRI Corner) ————| Perspectives, reviews
 - Consultant: Education
- Purdue University, 2019-current
 - Department of Materials Engineering
 - Center for Particulate Products and Processes (CP3)
 - Training and education
 - Research, systems focus (modular processes, PAT, control)
 - Industrial outreach

Strong IFPRI influence on teaching and research:

- MSE 512 Powder Processing
- Dense powder flow, “intermediate” regime
- Granulation – mechanical & fluidized-bed

Trends in Education

- On-line is here:
 - Synchronous, and
 - Asynchronous on-demand.
 - Higher Ed “iron triangle” of inter-dependent challenges:
 - Affordability,
 - Accessibility,
 - Excellence.
 - Professional & continuing education:
 - Integrate on-line w/ on-campus.
 - Push/Pull for data science:
 - Add a new requirement, vs.
 - ✓ Integrate with existing.
 - Opportunity for business and educational innovation:
 - Knowledge changes faster than careers.
 - Content renewal.
 - Lifetime education.
 - Context: on-line students having diverse background & experience,
 - Professionals in Eng.-Management programs (non-thesis MS).
 - How to make this work for Particle Science & Engineering?
 - Hands-on / on-line?
 - Relevant data science tools
 - Career path?
- Industrial relevance**
- On-line instrumtn., virtual labs**
- Data tools: distributed systems, process/structure/property relations**
- Purdue MSE: Performance coatings; Battery materials; AM (aero, medical, superalloy).**
- On-line: Sustainability. (economic perspective)**
-

MSE512 Powder Processing, Fall '21

Survey course contents:

- Particle characterization, size and shape distributions
- Sorption isotherms, surface area
- Wetting, surface tension, and capillary forces
- Particle interfacial phenomena
- Crystallization and dissolution
- Suspension rheology, stability, settling, separation
- Particle mixing, scale of scrutiny
- Shrinking core reaction models
- Sintering
- Size reduction, dry and wet milling
- Dry powder flow, handling, storage, safety
- Fluidization
- Granulation
- Atomization
- Drying
- Extrusion
- Compaction
- Powder bed additive manufacturing
- Process systems integration
- Particulate product design

Guest lecture topics!

Supplemental Tools. Students will be provided with practical tools for solving problems in the form of spreadsheet models, Python workbooks, and other data analysis tools. Tools will be provided in context of homework problems, and are intended to be useful beyond the immediate course scope.

Purdue CP3 modular design



Purdue CP3 modular install in FLEX high-bay

Biologics Modular, LLC, Brownsburg, IN



FLEX building High-Bay, Purdue Discovery Park

CP3 Characterization Lab



Particle analysis:

- Malvern Mastersizer
- Malvern Morphologi (w/ Raman)
- JM Canty SolidSizer
- Innopharma Eyecon
- Riffing & sieving

Flow, packing, permeability:

- Granutools test suite
- Freeman FT4 Rheometer
- Anton Paar MCR
- Hanson Flodex
- Shultze & Peschl rotational shear cells

Mechanical Testing:

- MTS and Instron Load Frames
- Vankel Tablet Hardness
- Shimadzu microindenter

Moisture, surface, thermal:

- DVS Intrinsic Plus
 - Mettler Moisture Balance
 - Perkin Elmer TGA
 - Krüss tensiometer
- Tomography
- Bruker Skyscan MicroCT

Looking forward to IFPRI AGM in 2023!



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IFPRI Collection

Highlights pre-competitive research, perspectives, and topical reviews that are industrially relevant; Elsevier provides 1 year open access.

Next:

- W. Hendrickson, “The History of the International Fine Particle Institute and Some Thoughts on the Challenges and Successes of Particle Processing”
- D. Scott, “In-Process Characterization of Suspensions and Slurries: Review of Recent Advances”

Editorial ● Full text access

Editorial note for the launch of IFPRI Corner in Powder Technology

15 March 2020

Page 810

 [Download PDF](#)

Mini review ● Full text access

Particle technology education in the 21st century – Outcomes from the IFPRI sponsored workshop in Sheffield, April 2017

James D. Litster, James N. Michaels, Karl V. Jacob

15 April 2020

Pages 144-149

 [Download PDF](#) [Article preview](#) ▾

Follow up on CRC 1411/FAU/IFPRI workshop?
W. Peukert, R. Klupp-Taylor

Mini review ● Full text access

Grinding aids for dry fine grinding processes – Part I: Mechanism of action and lab-scale grinding

Paul Prziwara, Arno Kwade

20 September 2020

Pages 146-160

 [Download PDF](#) [Article preview](#) ▾

Part II: Continuous and Industrial Grinding, in review.



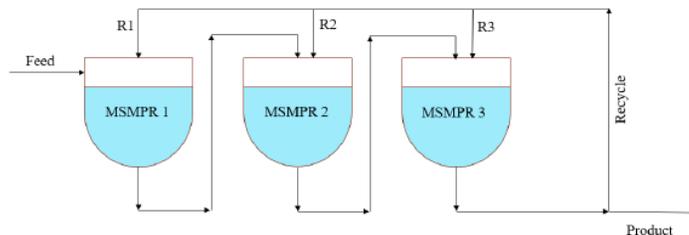
Consider review pipeline in context of
 Powder Technology (doi.org/10.1016/j.powtec...) –
 Selected review articles since June 2020 (1 year):

	Modeling Systems	Characterization	Formation	Dry Flow	Size Reduction	Wet Systems
<ul style="list-style-type: none"> Z. Cheng, J.H. Leal, C.E. Hartford, J.W. Carson, B.S. Donohoe, D.A. Craig, Y. Xia, R.C. Daniel, O.O. Ajayi, T.A. Semelsberger, “Flow behavior characterization of biomass Feedstocks,” 2021.04.004. 		✓		✓		
<ul style="list-style-type: none"> R. Hazlett, C. Schmidmeier, J.A. O'Mahony, “Approaches for improving the flowability of high-protein dairy powders post spray drying – A review,” 2021.03.021. 		✓	✓	✓		
<ul style="list-style-type: none"> N. Alhaji, N.J. O'Reilly, H. Cathcart, “Designing enhanced spray dried particles for inhalation: A review of the impact of excipients and processing parameters on particle properties,” 2021.02.031. 		✓	✓			
<ul style="list-style-type: none"> F. Chowdhury, M. Ray, A. Sowinski, P. Mehrani, A. Passalacqua, “A review on modeling approaches for the electrostatic charging of particles,” 2021.05.016. 	✓	✓				
<ul style="list-style-type: none"> B. Liu, J. Wang, J. Zeng, L. Zhao, Y. Wang, Y. Feng, R. Du, “A review of high shear wet granulation for better process understanding, control and product development,” 2020.11.051. 	✓	✓	✓			
<ul style="list-style-type: none"> Y. Zhou, J. Zhu, “A review on fluidization of Geldart Group C powders through nanoparticle modulation,” 2020.12.011. 			✓	✓		
<ul style="list-style-type: none"> R. Tarodiya, A. Levy, “Surface erosion due to particle-surface interactions - A review,” 2021.04.055. 	✓	✓			✓	
<ul style="list-style-type: none"> M.E. Haque, M.S. Hossain, H.M. Ali, “Laminar forced convection heat transfer of nanofluids inside non-circular ducts: A review,” 2020.10.042. 	✓					✓

Industrially relevant topic: Classification

(coming from a Systems perspective – difficult to fund as stand-alone)

Zoltan Nagy: wet classifier is critical to crystallization, seeded via recycle loop



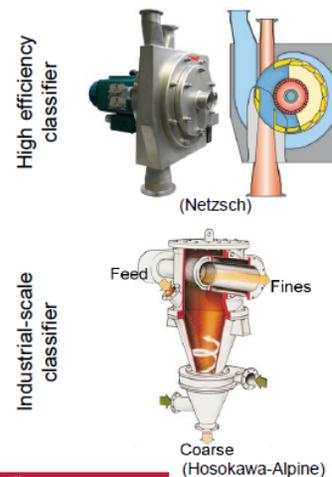
- Investigate effect of recycle on
- Start-up dynamics and duration
- On shape of CSD
- Mean size increases in cascade if MSMPR compared to batch
- Mean size increases with recycle
- CSD becomes broader with recycle
- Importance of mill and/or classifier for precise distribution shaping control

PURDUE
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Arno Kwade Group: air classifier is critical to grinding control and efficiency.

Air classification with additives

Equipment available:



Process variables:

- Classifier wheel speed
- Mass feed rate
- Injection air volume rate

Will be observed:

- Efficiency curve:
 - Cut size
 - Separation curve sharpness
 - Fine particles bypass to coarse outlet
 - Fish hook effect
- Caking on internal walls
- Relevance of classifier design



Previous IFPRI Reviews/Projects with critical reference to classifiers or cyclones:

- 2017, Yang, “In-Line Sensors for Real-Time Measurement and Analysis of Bulk Dry Powder”
- 2003, Williams, “Tomography: On-line Characterisation of Particulate Suspensions Using a Multi-sensor Approach”
- 2000, Leschonski, “Parameters of Controlled Grinding”