Fouling in Mass Transfer

25th PROCESS INTENSIFICATION NETWORK MEETING

21 June 2017, Merz Court, Newcastle University

Unit Operations and Processes

Unit Operation	Process
Separation	Screening, sieving
	Classifying, sorting
	Gas-solid separation
	Solid-liquid separation
	Flotation
	Dust precipitation
	Classification, thickening
	Particle size analysis
Mixing	Dry mixing
	Wet mixing
	Stirring
	Suspending, dispersing
	Fluidized bed
Comminution	Dry grinding
	Wet grinding
Particle size enlargement	Agglomeration
	Briquetting
	Granulating
	Pelletizing
	Sintering
	Tabletting
Conveying	Mechanical conveying
	Vibratory conveying
	Pneumatic conveying
Storage	Silos, hoppers, stockpiles
Batching	
Metering	

Industries affected by fouling

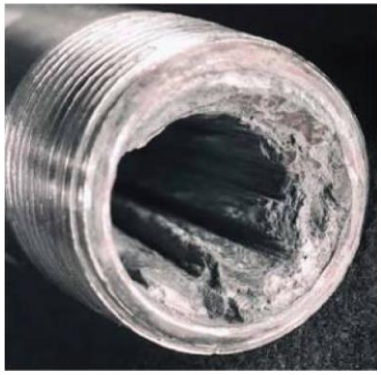
- Chemical Industry
- Refinery Process
- Food Processing
- Minerals
- Metallurgical
- Ceramics
- Pharmaceutical and Bio Processing
- Water Systems
- Pulp and Paper Industry
- Power Generation/Cogeneration
- Refrigerants
- Chilled Media
- Waste Heat and Energy Recovery

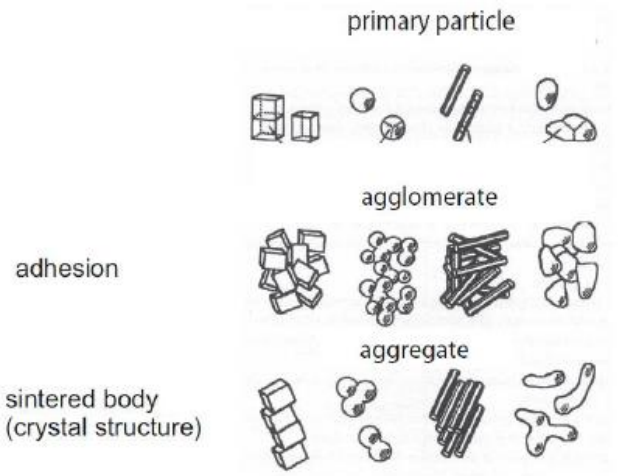
W. Pietsch, Agglomeration Processes: Phenomena, Technologies, Equipment, Wiley-VCH Verlag GmbH, Weinheim, 2002.

Disadvantages

- Poor powder flow
- Blockage of the storage tank
- Increased resistance to heat transfer (reduced thermal exchange capacity of the equipment)
- Decreased efficiency (production, separation etc.).
- Decreased throughput and cost efficiency
- Increased erosion of equipment surfaces
- Increased pressure drop
- ……

Fouling, Scaling, Caking





primary particles

⇩

agglomeration by physical interactions of primary particles (agglomerate)

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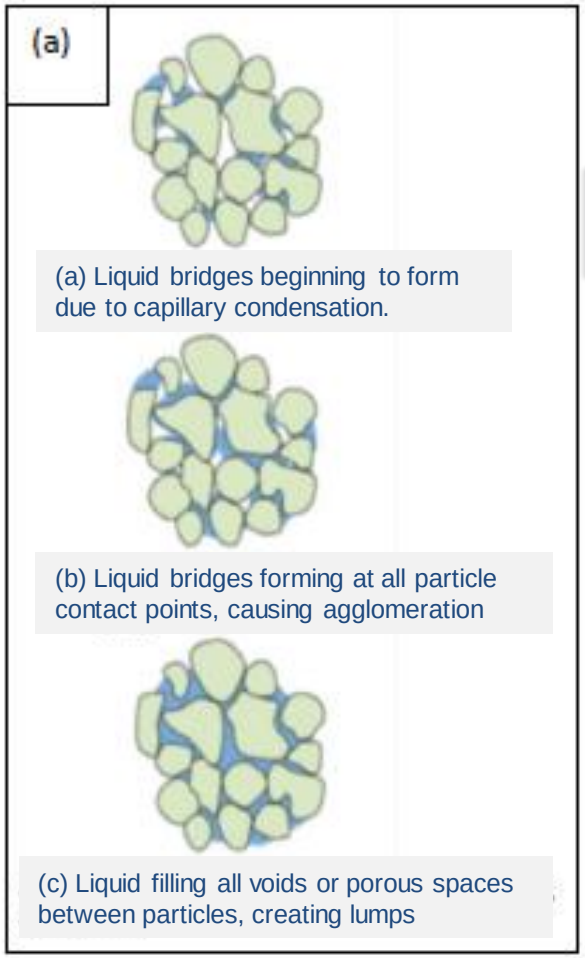
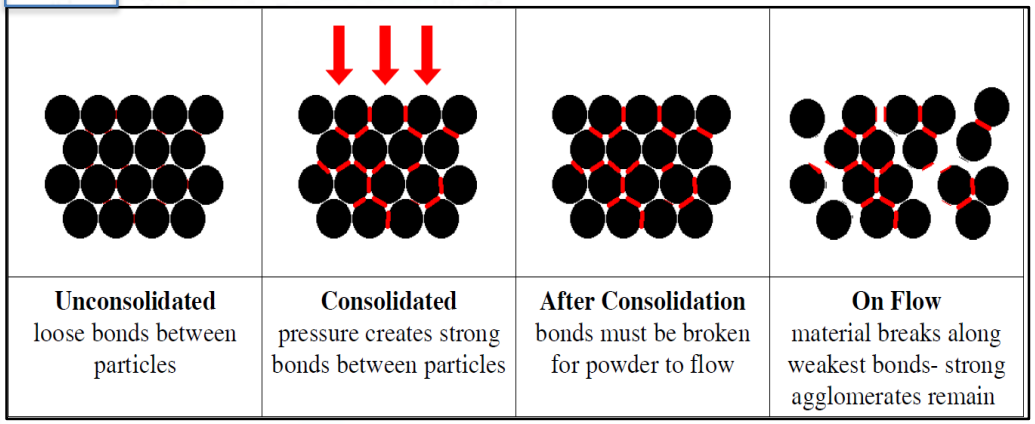
new formed particle (aggregate)

- http://www.hcheattransfer.com/fouling1.html
- J. Paternina, "Preventing moisture caking, the unwanted agglomeration," CSC Publishing, 2014.
- D. Walter, "Primary Particles – Agglomerates – Aggregates," in *Nanomaterials*, D. F. (DFG), Ed., Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany., 2013, pp. 9-24.
- N. R. Dando and S. J. Lindsay, Hard Grey Scale, in *Essential Readings in Light Metals*, *Operations*, *Chapter 89*, John Wiley & Sons, Inc., ISBN: 9781118635742, 2013. pp. 602-607).

Powder Storage



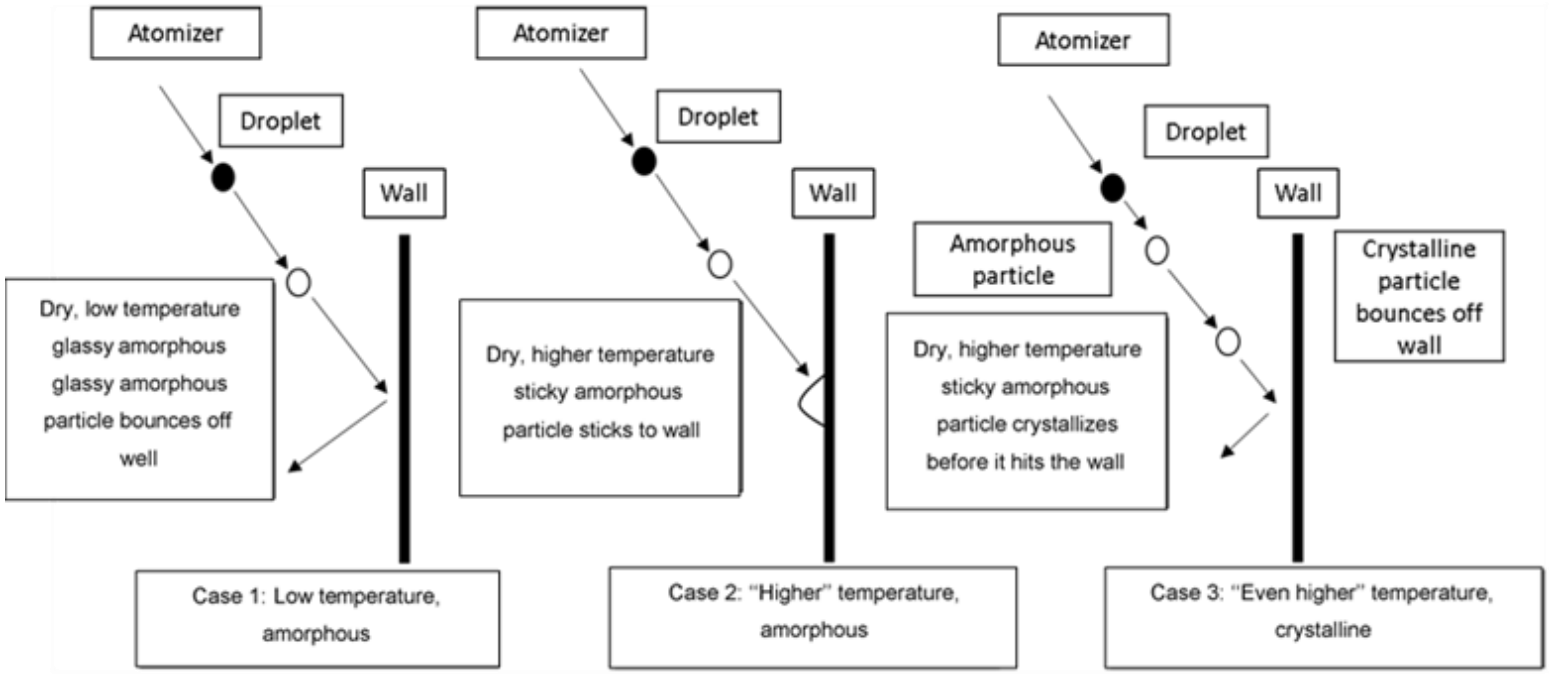
(b)



An illustration of the effect of consolidated pressure on powders during storage and flow

- Adapted from: J. Paternina, "Preventing moisture caking, the unwanted agglomeration," CSC Publishing, 2014.
- Mercury Scientific Inc., "Caking and Agglomeration Testing".Flowability Application Bulletic 4.

Spray Drying



Different trajectories for the spray-dried particles in spray dryers

Adapted from: T. A. Langrish, "Spray Drying and Crystallization," in *Spray Drying Technology*, vol. 1, M. W. Woo, A. S. Majumdar and A. R. Daud, Eds., Singapore, 2010, pp. 61-76.

Quantifying the Bulk Cohesive Strength of Caking

- Direct Shear Test
- Tensile Test
- Penetration Test
- Crushing Test or Uniaxial Compression

Quantification of Powder Flow

- Jenike Flow Index
- Hausner Ratio
- Angle of Repose
- Angle of Slide

Important Parameters

Powder properties	Size
	Shape
	Size distribution
	Hardness
	Chemical composition (elements)
	Surface chemistry
	Crystal structure
	Hygroscopy
	Moisture content
	Roughness
	Density
	Surface area
	Porosity
	Solubility
	Solubility with temperature
	Electrical/Magnetic/Thermal properties
	Flow rate
	Corrosive behaviour
	Rheological properties (viscosity)
	Zeta Potential
Properties of fluids	Chemical composition
	Flow rate
	Density
	Temperature
	Rheological properties (viscosity)
	Variation of Viscosity with temperature
	Corrosive behaviour
Surface properties	Geometry and orientation of the surface
	Materials properties (alloy composition etc.)
	Temperature
	Electrical/Magnetic/Thermal properties
	Tribological properties (erosion, corrosion etc.)
Environmental conditions	Temperature (constant, cycle)
	Relative humidity
	Consolidating pressure

Mitigation

- Modified ambient conditions
- Modified process parameters
- Design considerations
- Chemical Methods (chemical additives)
- Mechanical Methods (mechanical vibration of the surfaces etc.)
- Coating of surfaces
- Stabilization of colloids (Electrostatic and polymeric)

http://ibd-project.eu/

"Intensified by Design® for the intensification of processes involving solids handling"

OBJECTIVES

IbD will make a landmark advance in bridging the technological and knowledge gaps in the area of Process Intensification in processes involving solids. It will create a comprehensive devices- and processes design-platform for the industrial realisation of Process Intensification involving solids handling. It will bring to the industry an ergonomic, flexible, scalable IbD platform that performs fast reiterations of processes and device designs.

Budget :	11 MEUR
Partners:	22 (from 8 countries)
Duration:	36 Months

Funded under: H2020-EU.2.1.5.3. - Sustainable, resource-efficient and low-carbon technologies in energy-intensive process industries
Topic: SPIRE-8-2015- Solids handling for intensified process technology

Coordinator: INNOVACIO I RECERCA INDUSTRIAL I SOSTENIBLE SL, Spain

Effective Handling of Bulk Solids with Focus on Reduction of Erosion and Scale Formation

Aim: Reduction of **impact erosion** and **scale formation** in pneumatic conveying of alumina and calcium carbonate

- Understand the mechanisms involved with scale formation & erosive wear of particulate materials
- Modelling and controlling of scale formation and erosion through process modifications and using process analytical technology
- Industrial implementations
- 2 PhD studies

Partners

- **Industry**
  - Hydro Aluminium ASA
  - GE Power Norway AS
  - Omya Hustadmarmor AS
  - Follatech AS
- **R&D Collaboration in Norway**
  - University College of Southeast Norway
  - SINTEF Materials and Chemistry
- **International Collaboration**
  - Light Metals Research Centre (New Zealand)
  - Aston University (UK)

Total Budget: 16 MNOK

Funded by:

- Norwegian Research Council through the BIA programme
- Hydro Aluminium ASA, GE Power Norway AS & Omya Hustadmarmor AS