Fouling/Scaling/Caking during Heat and Mass Transfer

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Tel-Tek is a Norwegian R&D institute with focus on more efficient production processes and reduced emissions

Competence areas

- ✓ Pneumatic transport, cyclones, fluidized bed
- ✓ Silo Design
- ✓ CO_2 capture technology and CCS system solutions
- ✓ Design of process units
- ✓ Software development within process efficiency
- ✓ Smart Manufacturing
- ✓ Flow technology/CFD
- ✓ Process simulations
- ✓ Environmental evaluations (e.g. climate, waste, environmental aspects with CCS)
- ✓ Bio energy from waste
- ✓ Low Carbon Economy

Key figures

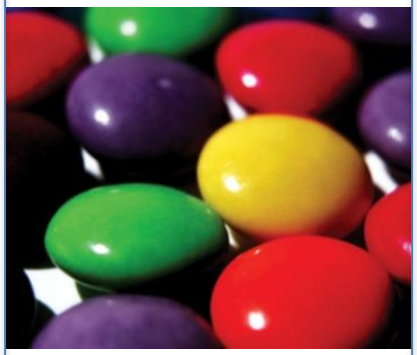
- ✓ Established: 1986
- ✓ Turnover (2015): 31 MNOK
- ✓ Employees: 30 (24 MY)

Values

- ✓ Robust
- ✓ Generous
- ✓ Enthusiastic
- ✓ Knowledge building

Effective processes for a climate friendly future

Powder technology

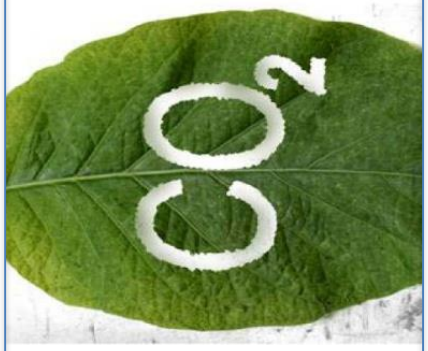


- Transport
- Storage
- Handling
- Separation
- Characterization

Energy

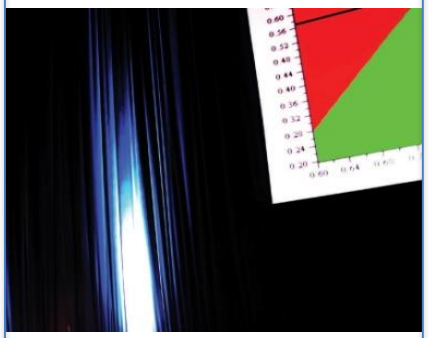
- CO_2 capture combined with bioenergy
- Biogas
- Combustion and environment
- Modelling and flow
- Energy effective processes
- Calculation of cost-optimal energy utilization

CCS*



- Post-combustion capture technology
- CO_2 transport and infrastructure
- Degradation of amines
- Early phase cost estimation
- Solutions for energy-producing and energy-intensive industry
- CO_2-lab

Smart Manufacturing



- Multivariate
  - analysis/diagnostics
  - modelling
  - simulation
  - optimization
- Understanding/ hypothesis
- Verification
- Implementation

* Carbon capture and storage

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Ongoing projects:

- Improving Efficiency of Offshore Drill-cuttings Handling Process"; NFR- PETROMAKS II- 2014-ongoing; € 2,000,000.
- Effective Handling of Bulk Solids with Focus on Reduction of Erosion and Scale Formation; € 2,000,000
- Intensified by Design® for the intensification of processes involving solids handling"; EU H2020-SPIRE-2015; 2015- ongoing; €500,000

Key Areas:

- Oil & Gas- bulk handling
- Offshore applications
- Food & Feed industry-
- Mineral processing-
- Shipping- bulk transfer systems
- Pharmaceutical-
- Solar-cell industry- handling of solar grade Si
- Polyethylene-

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

Project reference: 680565
Funded under: H2020-EU.2.1.5., H2020-EU.2.1.5.3.

Topic: SPIRE-08-2015 - Solids handling for intensified process technology
Call for Proposal: H2020 - SPIRE

PI Modules

Fouling remediation strategies for the built-in PI modules

Fouling/Scaling/Caking

- Heat Exchangers
- Powder Storage
- Separation
- gas – solid, solid-solid, liquid-solid (cyclones, spray dryers etc.)
- Mixing
- Blending
- Transportation
- Comminution (Milling)
- Synthesis of Nanoparticles
- ……

Pictures from:

(1) Understanding powder caking By Tim Freeman, Freeman Technology (http://powderinfonews.com/tema-artikler/understanding-powder-caking/)
(2) Modern electronic solutions offer a safe, easy alternative to chemical or physical descaling methods. By Jan de Baat Doelman, Scalewatcher North America, Inc. (https://www.maintenancetechnology.com/2013/06/controlling-limescale-deposits-and-industrial-fouling/)

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
- ……

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
- Fireside Fouling
- Refrigerants
- Chilled Media
- Waste Heat and Energy Recovery

Types of heat exchangers

- Shell and Tube
- Plate and Frame Heat Exchangers
- Spiral Heat Exchangers
- Compact Heat Exchangers (Printed-circuit heat exchangers, Brazed plate heat exchangers, Welded plate-and-frame etc.).
- Evaporative Coolers
- Direct Contact Heat Transfer
- Boilers
- Air Cooled Heat exchangers
- Water Cooled Tubular Condensers
- Agitated Vessels
- Furnace and Air Preheaters
- Scraped Surface Heat Exchangers
- Spinning disc heat exchangers

Epstein's 5x5 matrix: Categories and sequential events of fouling

	Precipitation	Particulate	Chemical Reaction	Corrosion	Biological
Initiation	M			L	
Transport	M	M	M	M	M
Attachment	M			L	
Removal	M			L	
Aging	L	L	L	L	L

M – Received most attention, L- received least attention
In addition to Epstein matrix, some other categories of fouling can also be included, e.g, crystallization & scale formation and freezing fouling.

Source:

- ***N. Epstein, Heat Transfer Engineering, vol. 4, p. 43, 1983***
- ***J. G. Knudsen, "Analysis of the fouling process," in Fouling in Heat Exchangers, Beggel House, Inc., 1999, pp. 3.17.3-1.***

Analysis

Condensation of moisture

Moisture Migration

Consolidated Pressure

Critical during Powder Storage

Particle-Particle and Particle Wall Forces

- Lifshitz- vander Walls Forces
- Capillary Forces
- Electrostatic Forces
- ……..

Transport Mechanisms

- Diffusion
- Electrophoresis
- Thermophoresis
- Sedimentation
- ……..

Parameters affecting Fouling

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 heat transfer surfaces etc.)
- Coating of surfaces
- Stabilization of colloids

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