Deterministic ratchet technology for large-scale separation of particulate suspensions

Jaap Dijkshoorn, Maarten Schutyser, Martijn Wagterveld, Remko Boom

Food Process Engineering Group, Wageningen University
Wetsus, European Centre of Excellence for Sustainable Water Technology

combining scientific excellence with commercial relevance
Deterministic ratchets – what and how?

- Gaps > particles
- Obstacle columns placed in an angle (\(\alpha\))
- Structure fluid into flow lanes
- \(D_{\text{particle}} > 2D_{\text{fc}}\) (red) obstacles can push particles laterally
- \(D_{\text{particle}} < 2D_{\text{fc}}\) (green) particles follow the flow direction
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Youtube: jshholm

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For quality of life
Applications

Suspension separation and fractionation

- Original: biomedical diagnostics (e.g. tissue, blood)

- Other interesting industries
  - Food: filtration beer/wine
  - Biotechnology: concentration of algae
  - Laundry: removal of detergent and dirt (a.o. emulsions)
  - Water treatment: flocs
The main challenge

Microfluidic device with a throughput of ~1 ml/min

The objective:
Investigate deterministic ratchet technology for large-scale application
Investigate deterministic ratchet technology for large-scale application

Suspension separation at moderate Reynolds numbers

Lubbersen et al., *Chemical Engineering Science* (2012)
Investigate deterministic ratchet technology for large-scale application

Suspension separation at moderate Reynolds numbers

Separation and recovery improves with increasing flow rate

*Particles go to outlet 5*

Lubbersen et al., *Chemical Engineering Science* (2012)
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Visualization of fluid flow

Vortex formation

Forced particles in displacement direction, improving the separation efficiency

Lubbersen et al., *SEPPUR* (2013)
Investigate deterministic ratchet technology for large-scale application

- Fractionation of 32-38 µm (red) and 90-106 µm particles (blue)
- In: $V_{\text{red}} = V_{\text{blue}}$

Investigate deterministic ratchet technology for large-scale application

Sparse deterministic ratchet:

- Lower risk of particle accumulation
- Reduced pressure drop
- Improved manufacturability

- Challenge = Pressure distribution

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Sieves to mimic obstacle structures

- Allows increased aspect ratio obstacles and therefore throughput

- Improves manufacturability:
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- Sieve-based particle separation
- Pressure distribution impairs separation

Improving pressure distribution by changing outflow conditions
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Conclusions

- Increased flowrates improves separation
  - At moderate Re, vortices assist separation
- Separation using sparse obstacle arrays
  - Lower pressure drop
  - Reduced risk of particle accumulation
  - Easier/cheaper to manufacture
- Use sieves mimic obstacles
  - Allows larger cross section (=larger single unit throughput)
  - Easier/cheaper to manufacture compared to obstacles
Future plans

Establish design rules
  – Create fundamental understanding

Design of bench-scale system
  – Practical systems

Evaluation & Conceptual design of complete process