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Detailed Simulation of Particle and Liquid Distribution in the Mixing Zone of a Twin-Screw Granulator

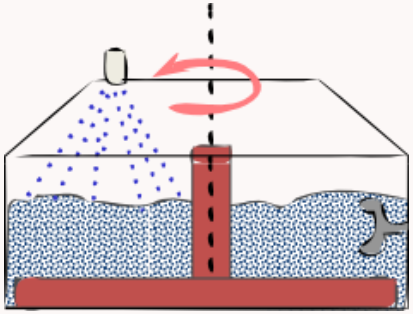
A. Kumar, S. Radl, J.G. Khinast, K.V. Gernaey, T. De Beer, I. Nopens

Wednesday, November 11, 2015: 9:38 AM

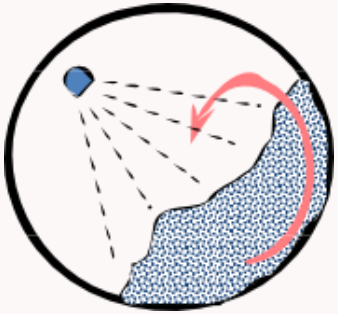
254A (Salt Palace Convention Center)

Traditional to new granulation method

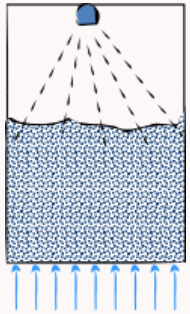
High-shear mixer



Drum



Fluidised-bed

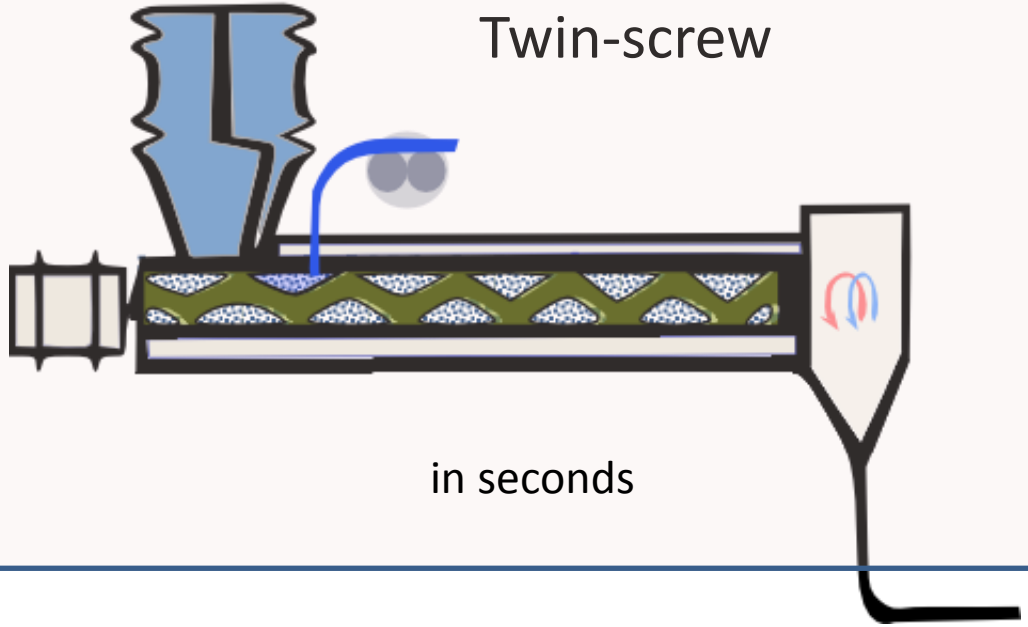


From minutes to hours

Batch

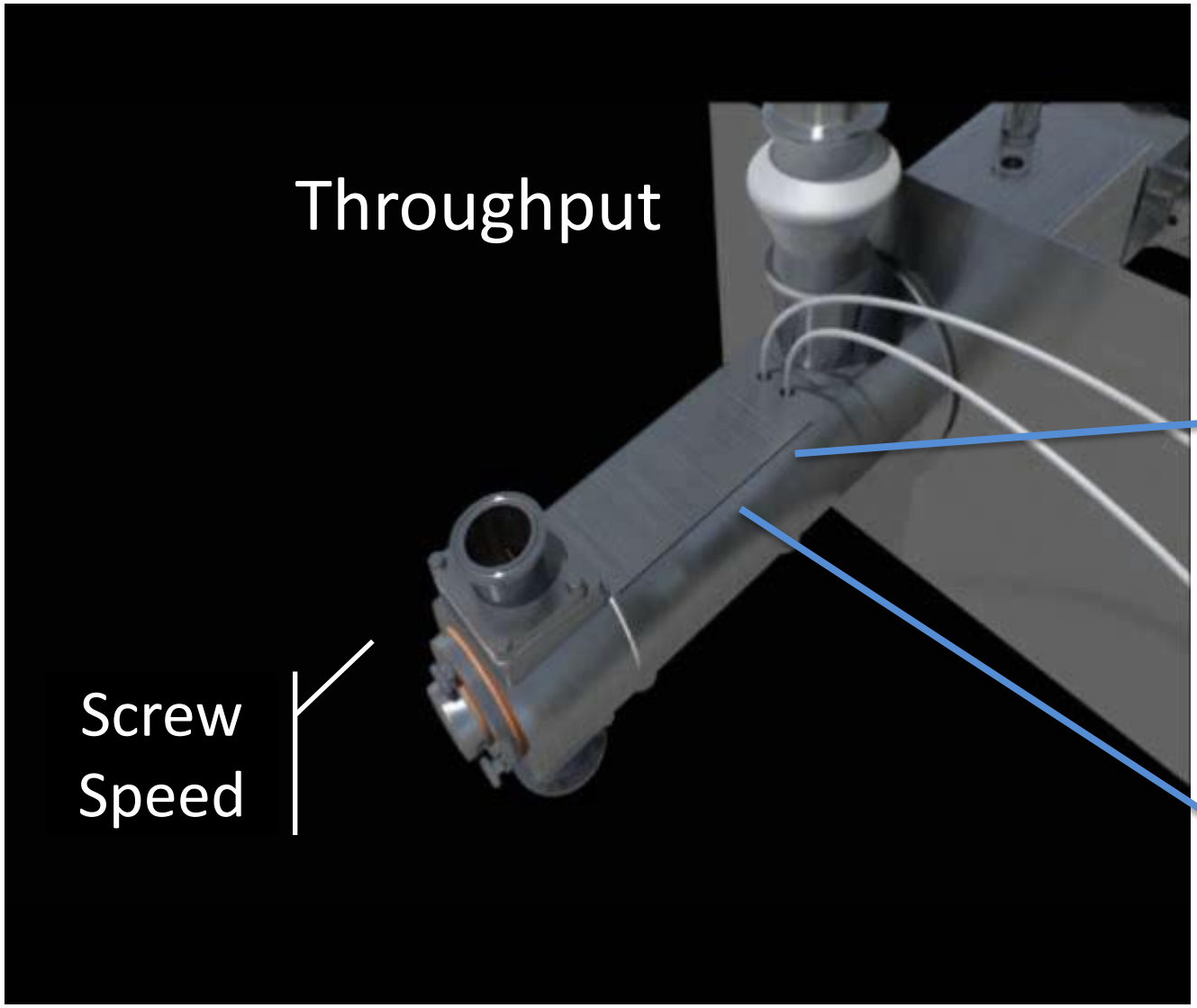
Continuous

Twin-screw

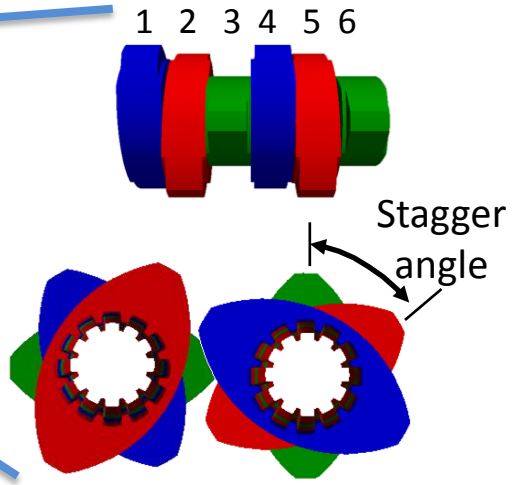


in seconds

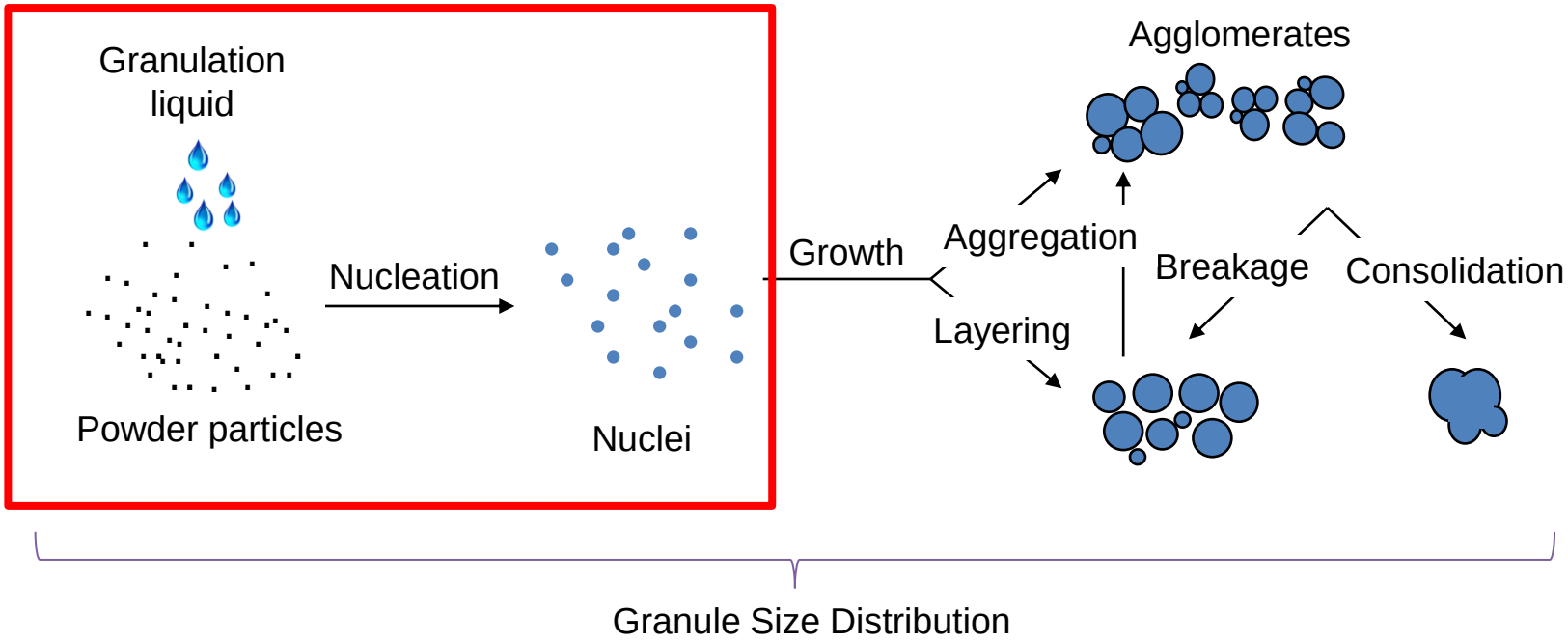
Design of granulator screw, screw speed, material feed rate control granulation



Kneading discs at certain stagger angle



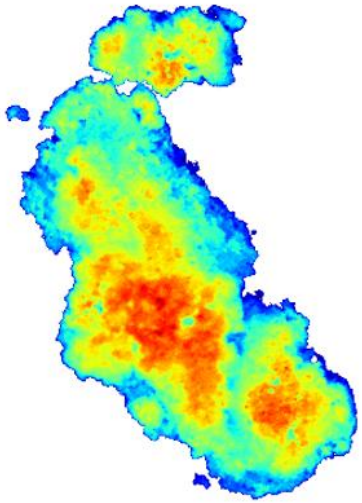
Wet Granulation involves different events which are *queueing*



Characterizing liquid distribution in TSG is crucial both at micro and meso-scale

Experimental investigation

(meso-scale)

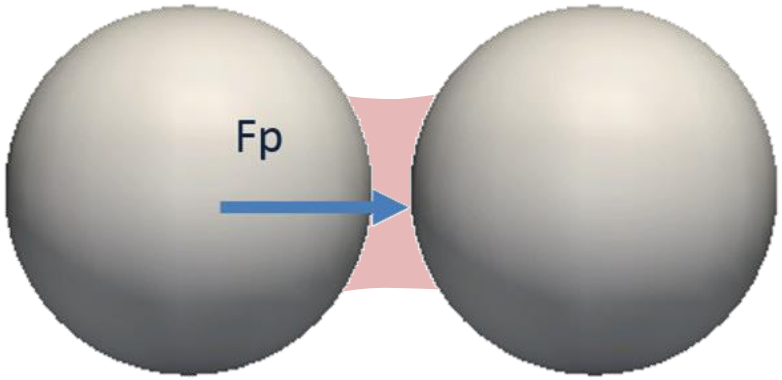


Spectroscopy

Abstract (572d), Presentation today at 4:25 PM
Ballroom B (Salt Palace Convention Center)

Particle scale modelling

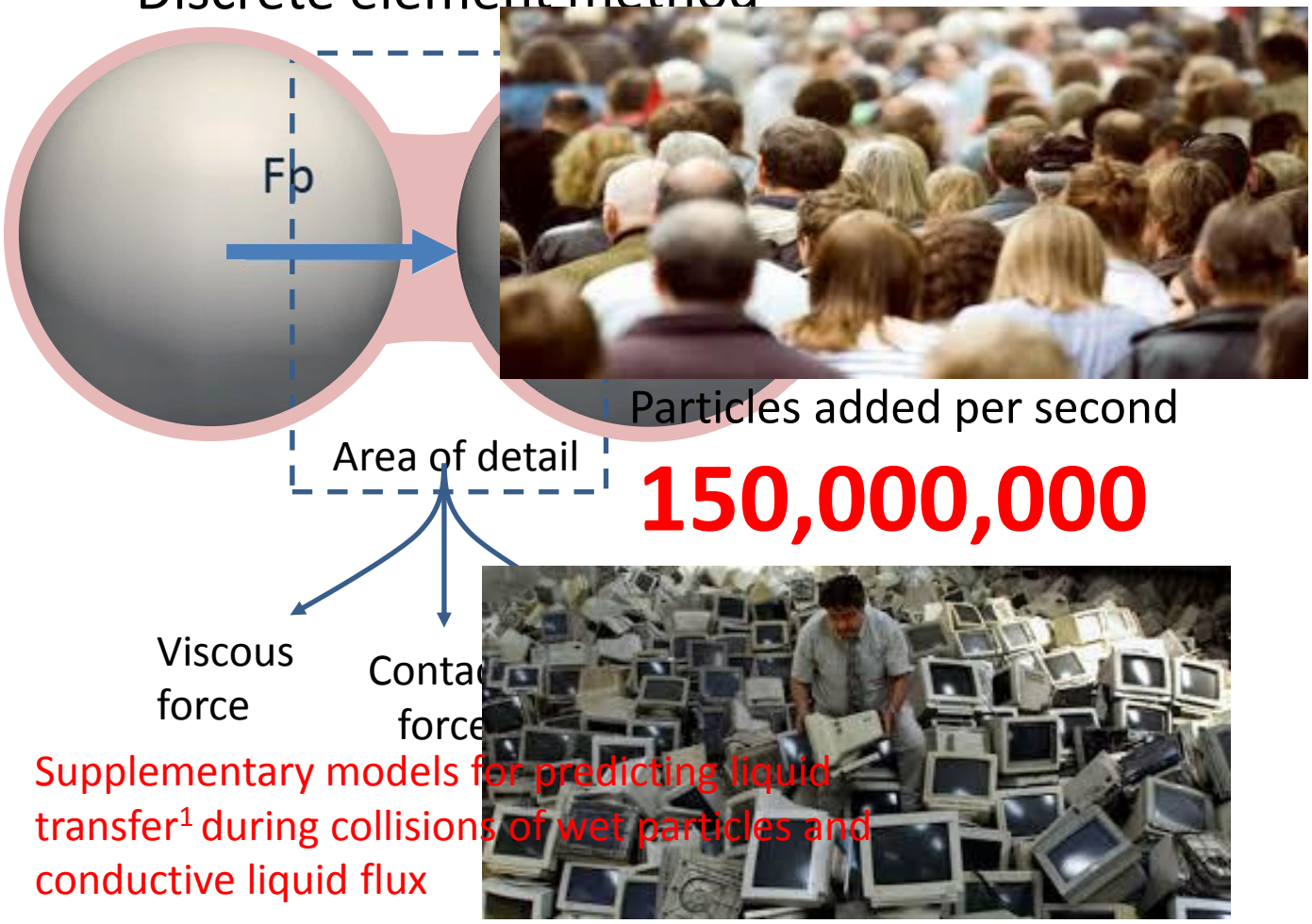
(micro-scale)



Discrete element method

Particle scale for detailed investigation of liquid distribution

Discrete element method



Particles added per second

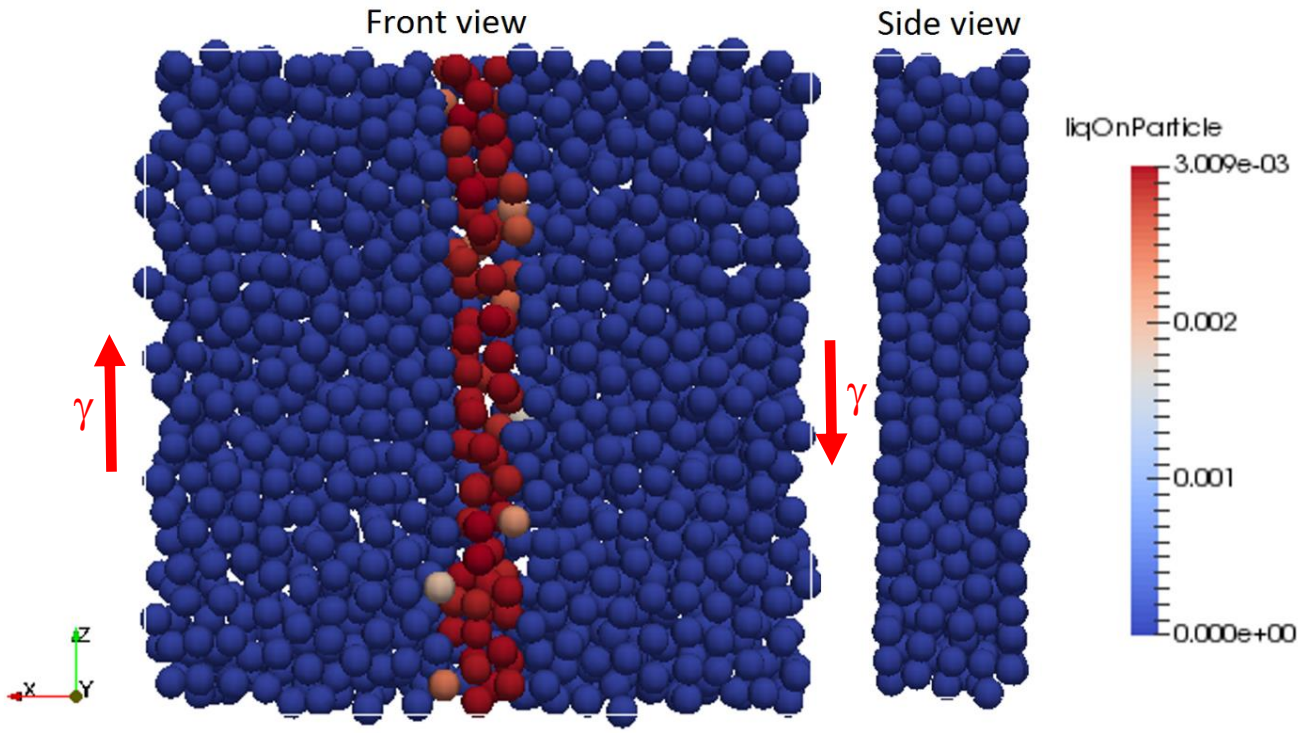
150,000,000

Supplementary models for predicting liquid transfer[1] during collisions of wet particles and conductive liquid flux

Source: metro.co.uk

[1]Mohan et al., *Powder Technology*. (2014)

Setup for simple shear simulation

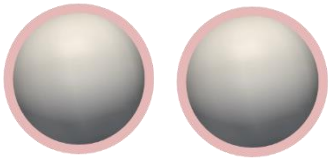


LIGGGHTS

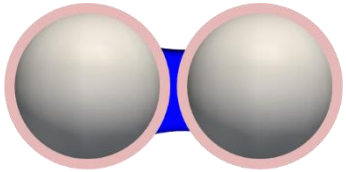
$$\gamma^* = \gamma d_p^{3/2} \sqrt{k_n/\sigma_p}$$

- Approximately 1500 particles in a periodic box (S/D_p=15)
- Shear gradient in x-direction (Lees–Edwards boundary conditions)
- Stiffness based on dimensionless shear rate γ^*
- Particles in the center are wet ($L_p^* = 1$) other dry ($L_p^* = 0$)

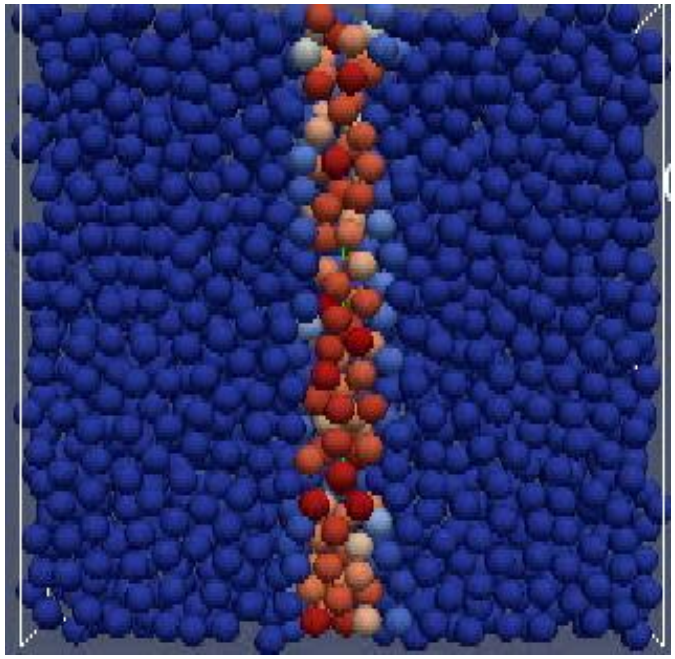
Liquid distribution was tracked applying simple shear to particles in a periodic box

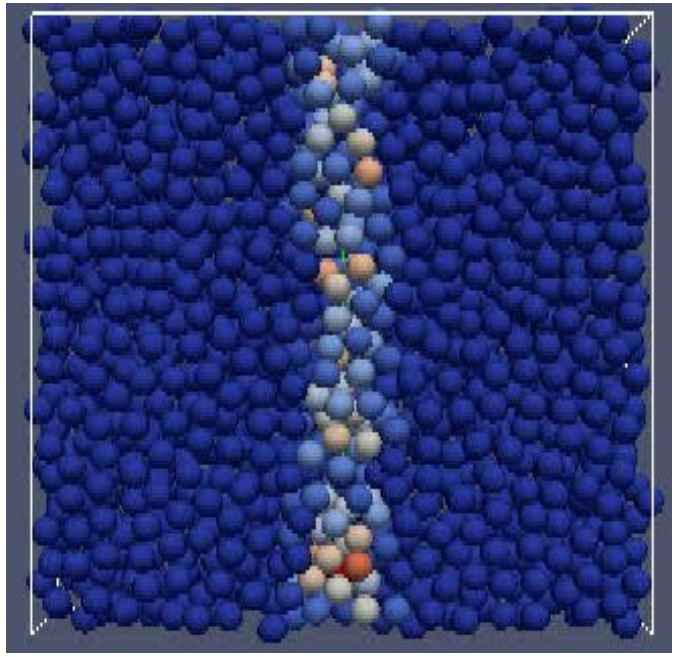


Liquid on Particle surface

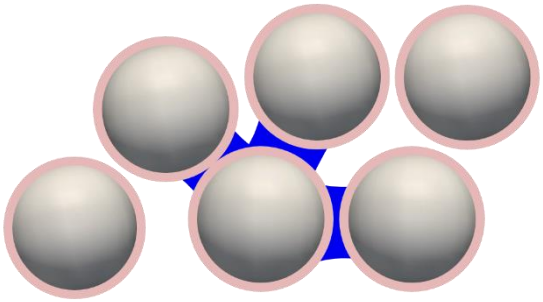


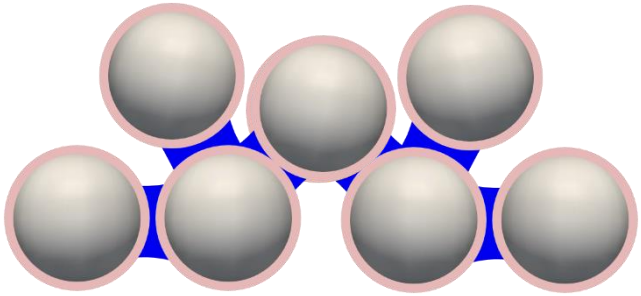
Liquid in Bridges

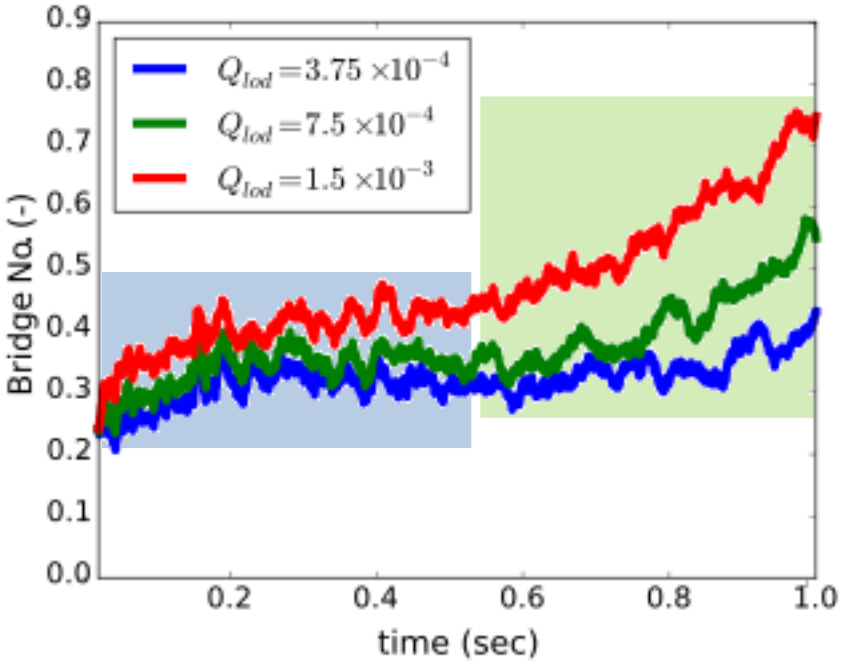


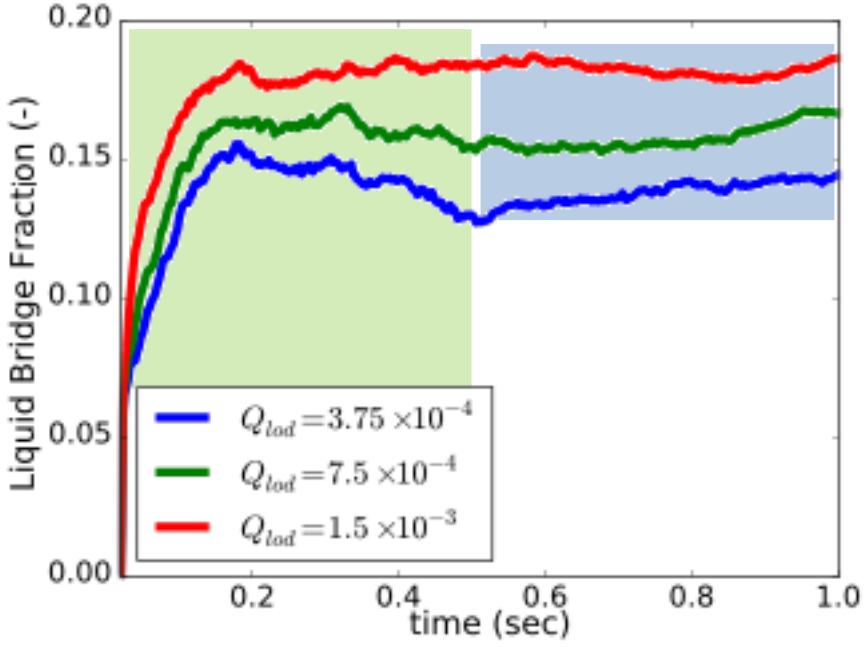


Overfilled-liquid bridges formed quickly which formed more liquid bridges later

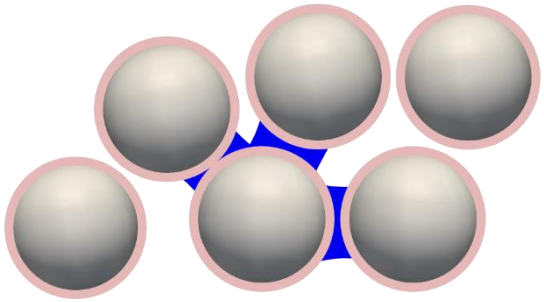


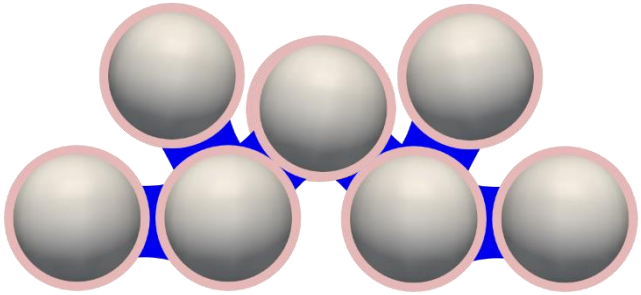


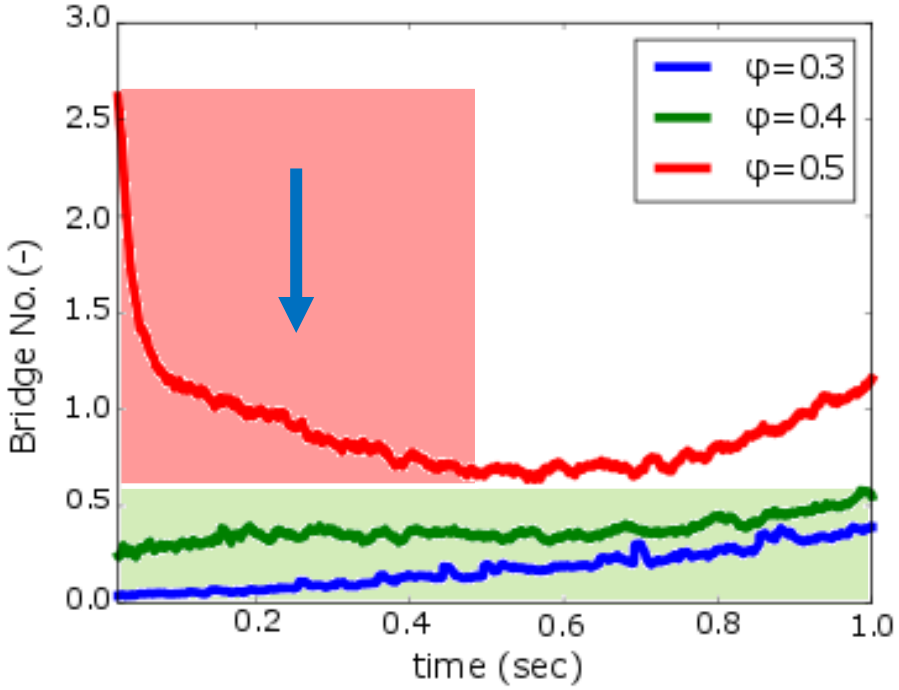


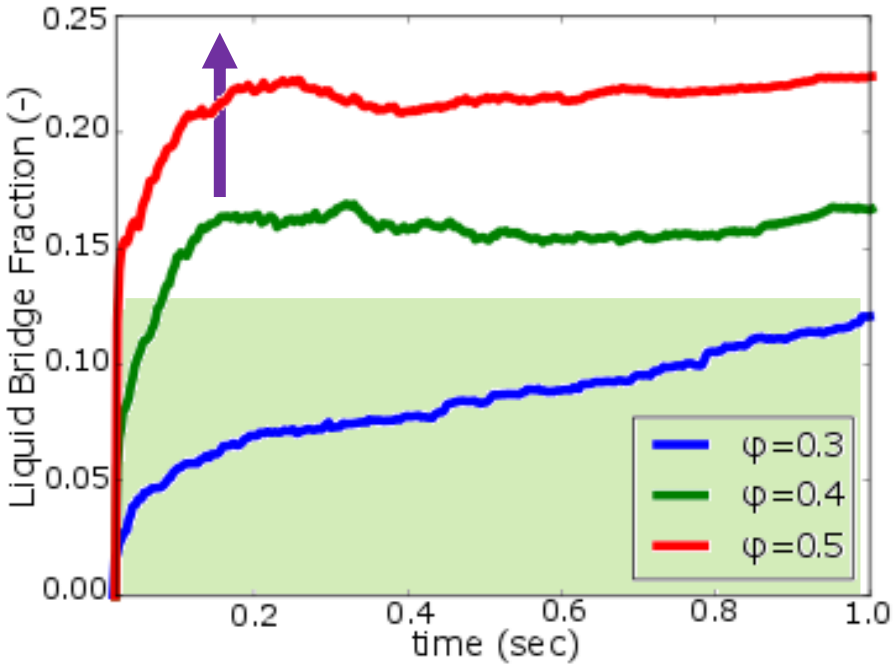


Weak liquid bridges break to transfer liquid to stronger bridges at a high fill ratio



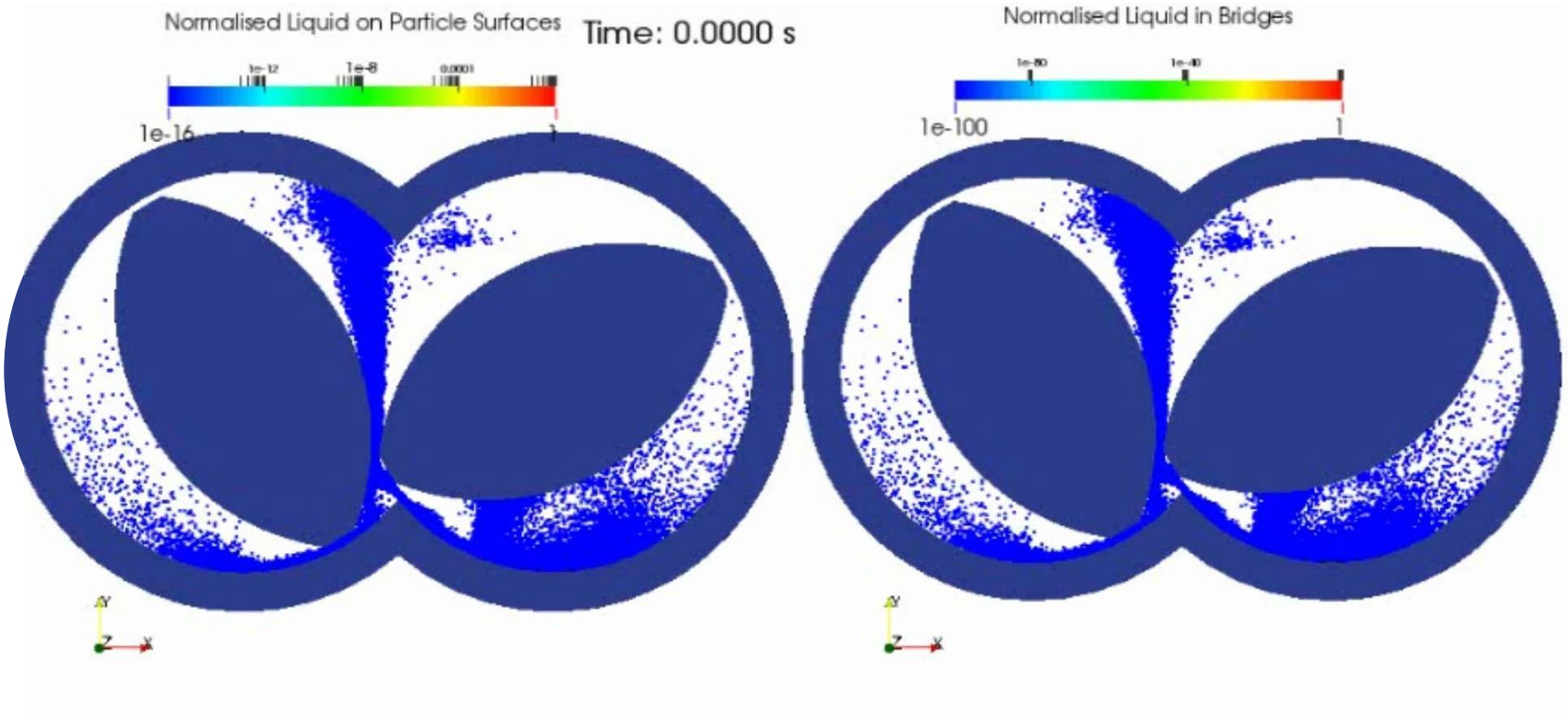




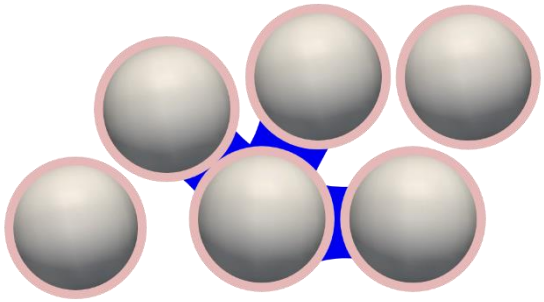


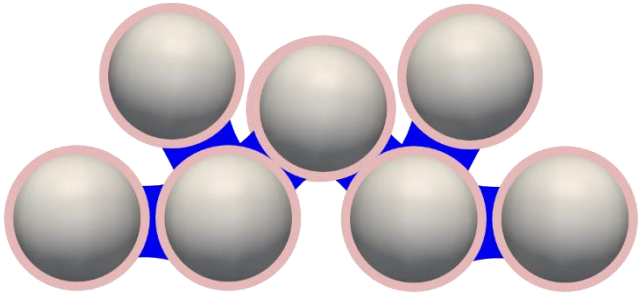
Knowledge transferred from simple shear to complex shear field in TSG mixing zone

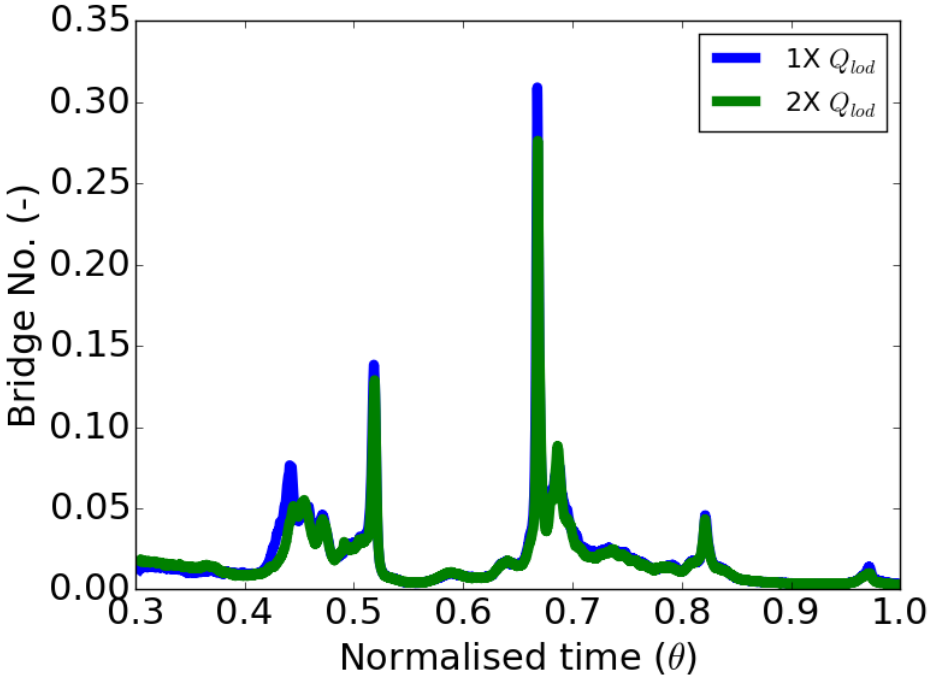
Approximately 45000 particles

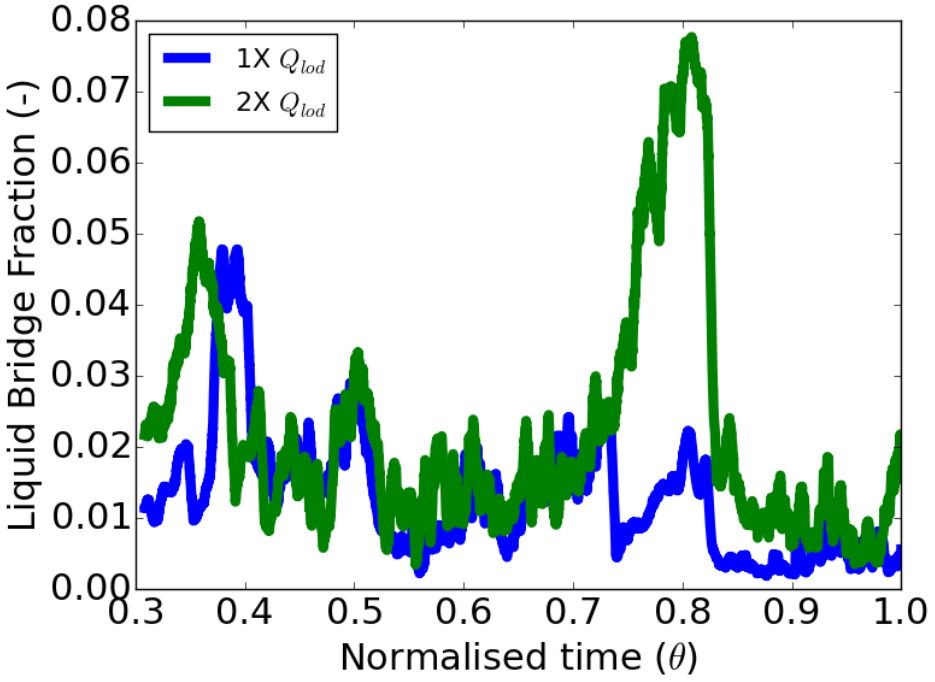


More liquid resulted stronger bridges, but coordination number remained same

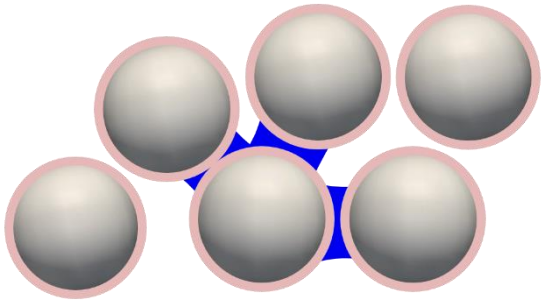


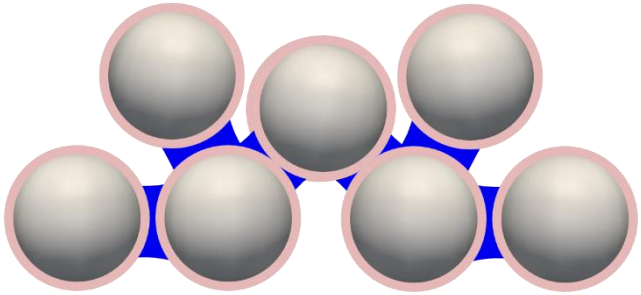


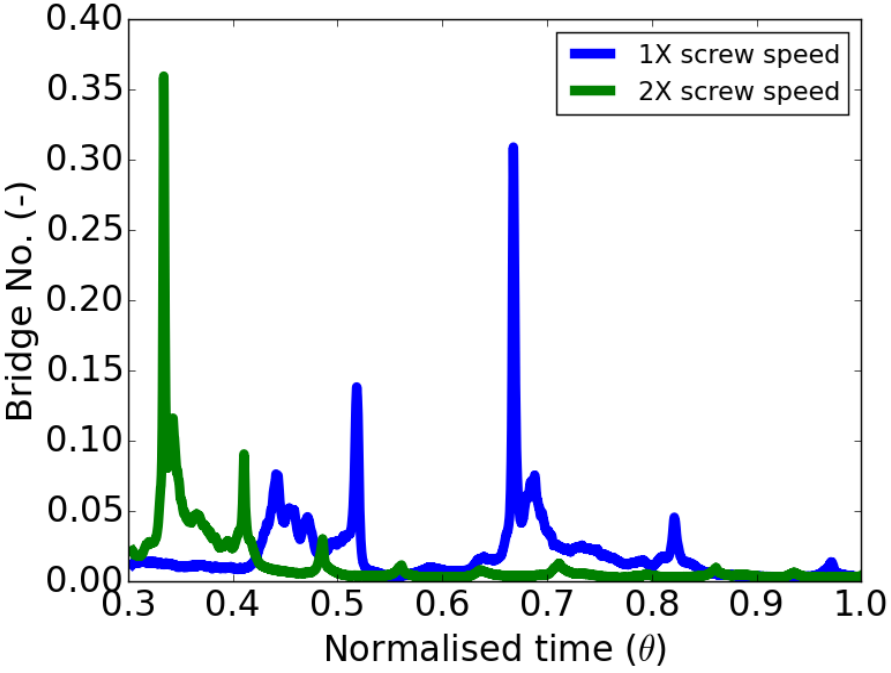


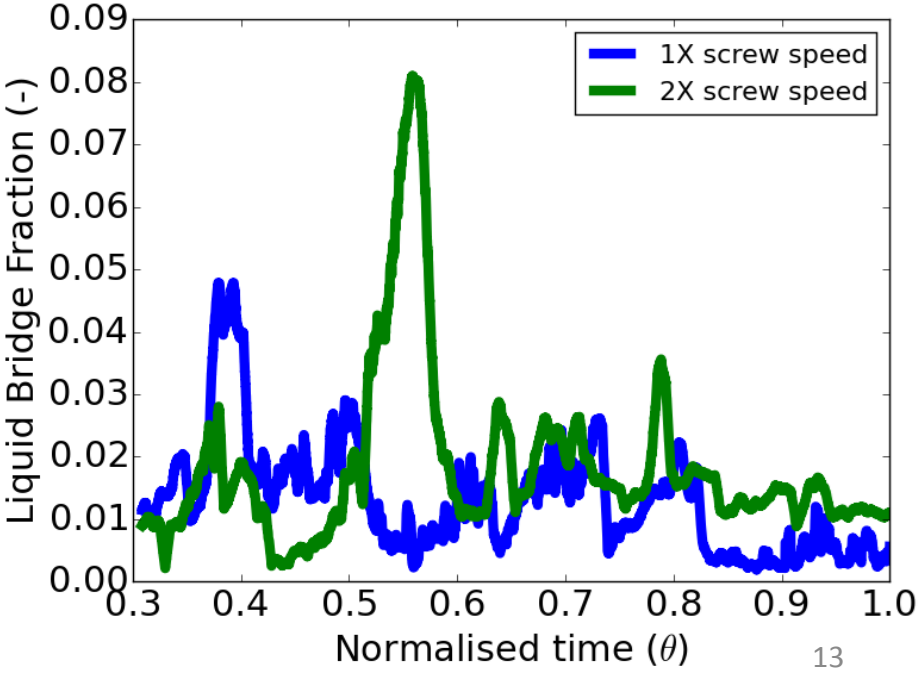


Higher shear resulted rapid liquid transfer from surface to bridges, but also breakage

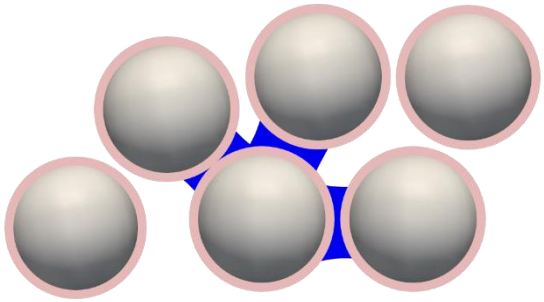


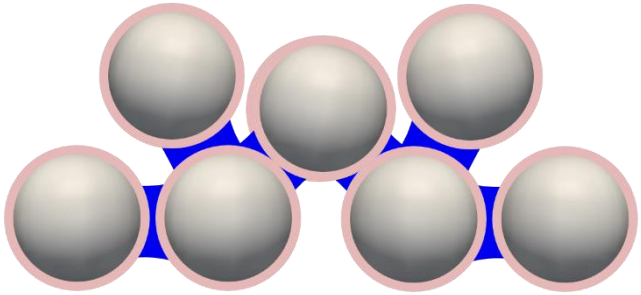


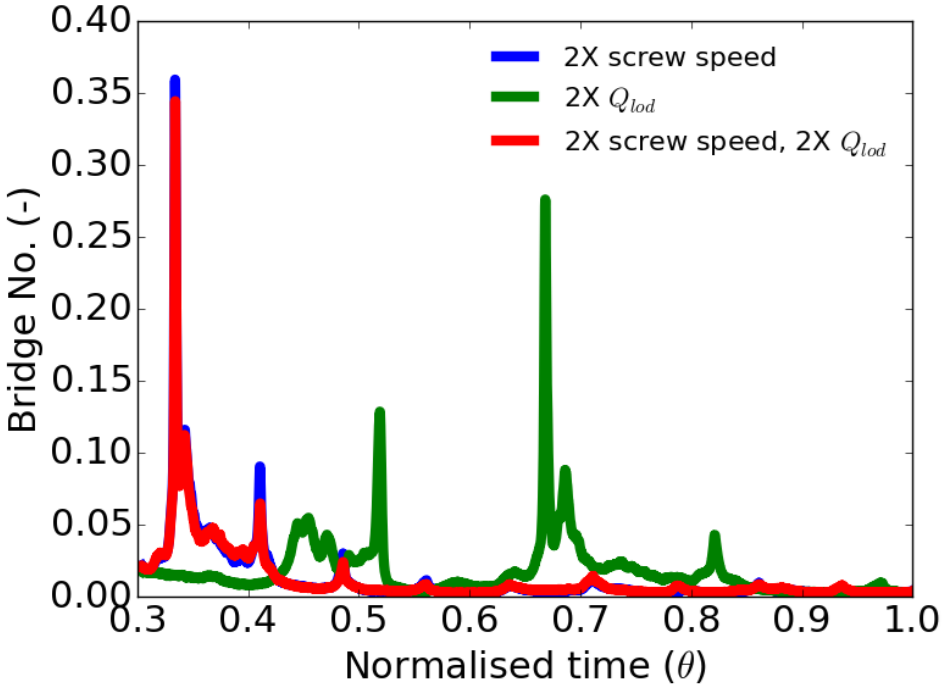


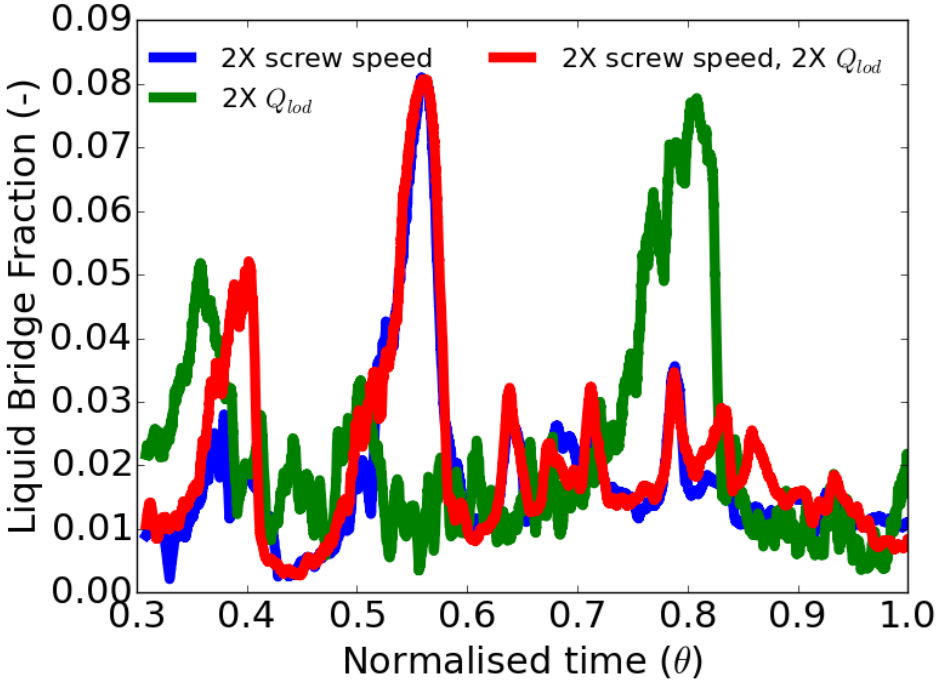


Higher shear and liquid loading resulted rapid and stronger liquid bridge formation









Summary

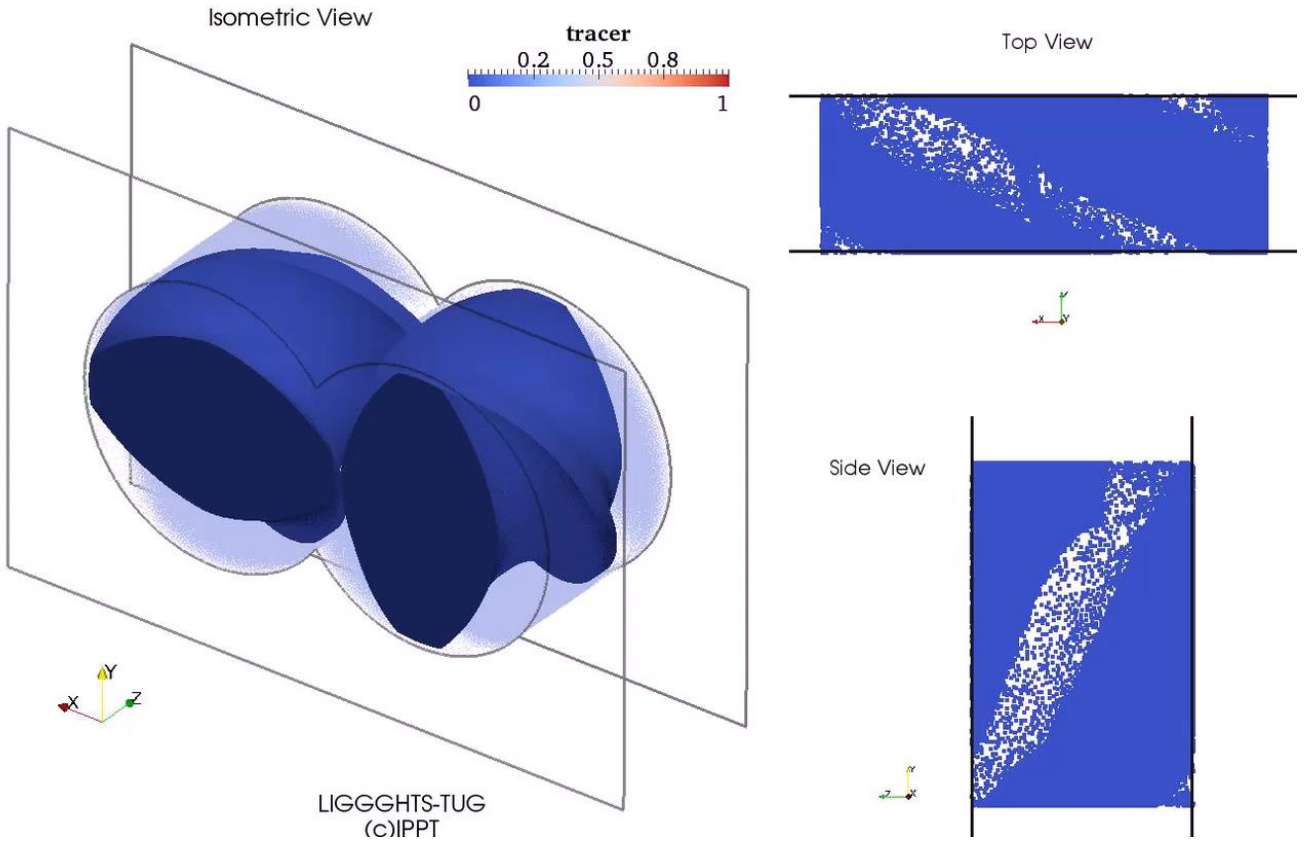
1. Particle scale simulations studies using simplified geometry can be used for **detailed analysis of liquid transfer**.
2. Simulating complete TSG is difficult, but particle scale simulation of **a 2D-section** is useful for a first understanding.
3. Simultaneous increase in **screw speed** and **liquid-solid ratio** was identified to be important for solid-liquid mixing and granulation in TSGs.

Perspective

1. Development of closures **population balance models**.
2. Exploring non-conventional **screw element geometries.**

Outlook

Particle scale simulations allow the analysis of particle mixing rates (and hence final product quality) **in a screw section** (movie shows **non-cohesive system,** a force is applied in the axial direction to model the effect of a pressure gradient)



Aknowledgements

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