Novel Visual Probing of Shear Stress Distribution inside Pharmaceutical Powder Packing within Constrained Geometries using Photo Stress Analysis Tomography (PSAT)

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Understanding the bulk behaviour of particulate products based on single-particle properties is of strategic importance.
Eg. **Size effects:** Our research explains why relatively big particles often do not break inside particulate packing under mechanical loading. That is because, solid particles can experience liquid-like behaviour when the size of a particle is about 5 times greater than the average size of its surrounding particles (Size Ratio SR>5).

Fundamental level understandings of particulate systems: Multiscale Modelling and Measurement systems have helped in the past

E.g.

Link between single-particle properties and macroscopic properties in particulate assemblies: role of structures within structures

More details in:

Photo Stress Analysis Tomography (PSAT)

* Works based on birefringent property of materials

Stress-Optic Law: \( (\sigma_1 - \sigma_2) = \frac{N}{t} f_\sigma \)
Here, we develop PSAT for pharmaceutical powder processing applications

Step-1: Developing sensor powders (pharmaceutical excipients) with μm size distribution

JASA-100
Size range: 300-800μm
Cohesive (angle of repose = 38°)
Hausner ratio =1.2 (flowable)
Bulk density 0.6g/cc

Step-2: To investigate stress distribution profiles inside two-dimensional conical particulate containers (and later to understand fill effects on flow properties)

θ (θ=30°, 45°, 60° and 90°)
In general, lower opening angle tends to developing more uniform distribution of maximum shear stress across container width at different heights and vice versa.
Step-3: DEM Simulations of macroscopic flow properties

DEM: Mass flow rate increases for decrease in conical (exit) angle

+ PSAT analysis suggests that increase in cone angle increases the chances of non-uniform spread of shear resistance zones inside powder containers
CONCLUSIONS

- For the first time, photonic stress tomography is applied to probe the local distribution of maximum shear stress field within powder assemblies inside hopper geometries.

- The study provides valuable links between signatures of microscopic stress fields to potentially macroscopic flow characterisation of particulate processes.

- The results indicate that the mass flow rate of powders from hopper increases for decrease in internal angle as in such cases, the direction of major principle stress aligns with the direction of gravity. Further, the magnitude of maximum shear stress distribution across the width of the hopper tends to be more uniform for decrease in internal angle of the hopper.

- PSAT promises to be a potential tool for designing powder flow processing equipments more efficiently in future.
Future/on-going works

- PSAT developments and DEM modelling of pharmaceutical powder processes

E.g. Stress profiles in compressed pharmaceutical powder excipients

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Available in poster form

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