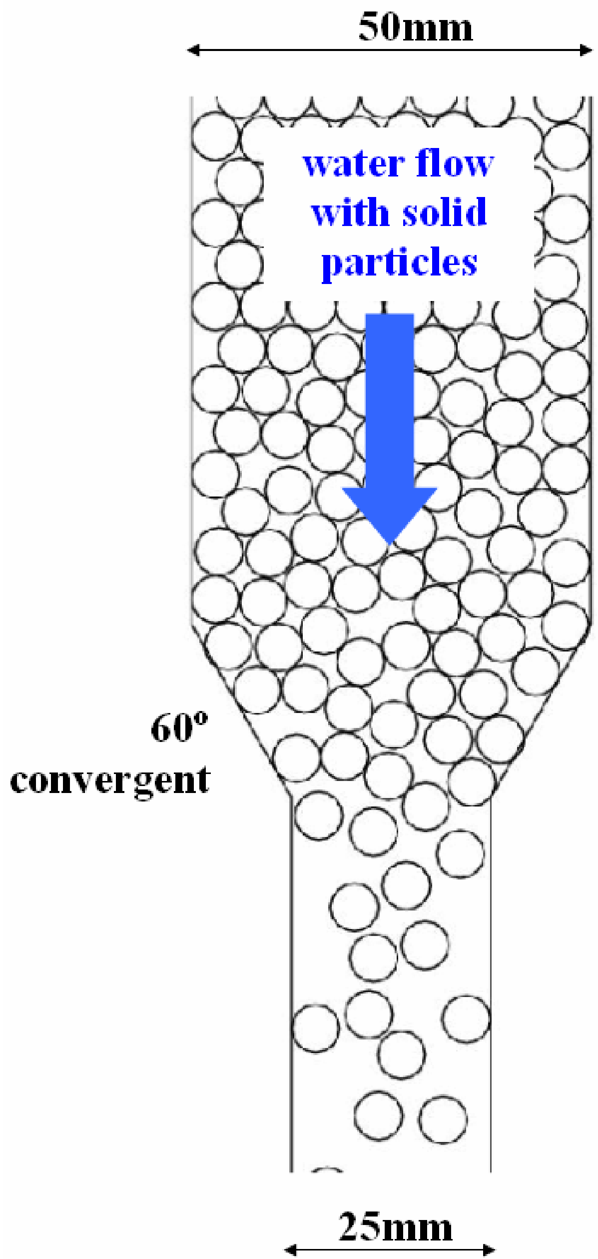
Modeling of accumulation of particles upstream of conduit constrictions

– high concentration, large and cohesionless particles

Andrew Parry

Schlumberger

Granular and liquid flow



- $\rho_p/\rho_f \sim 2$
- $0 < d_p < \sim 5mm$
- $0 < U_f < \sim 1m/s$
- high solids loading

Outline

- **Model without flow forces**
- Model with algebraic flow forces and prescribed fluid velocity distribution
- Model with algebraic flow forces and fluid velocity distribution from numerical solution to flow field
- Conclusions and perspectives

Multi-body dynamics algorithm of Fortin, Millet and de Saxcé*

- implicit with non-smooth contact dynamics

for this presentation a 2D mono-dispersed version without cohesion forces is used

$$\vec{U}_p^{n+1} = \vec{U}_p^n + \frac{1}{m}\left(\vec{F}\delta t + \sum_c \vec{S}^{n+1}\right)$$

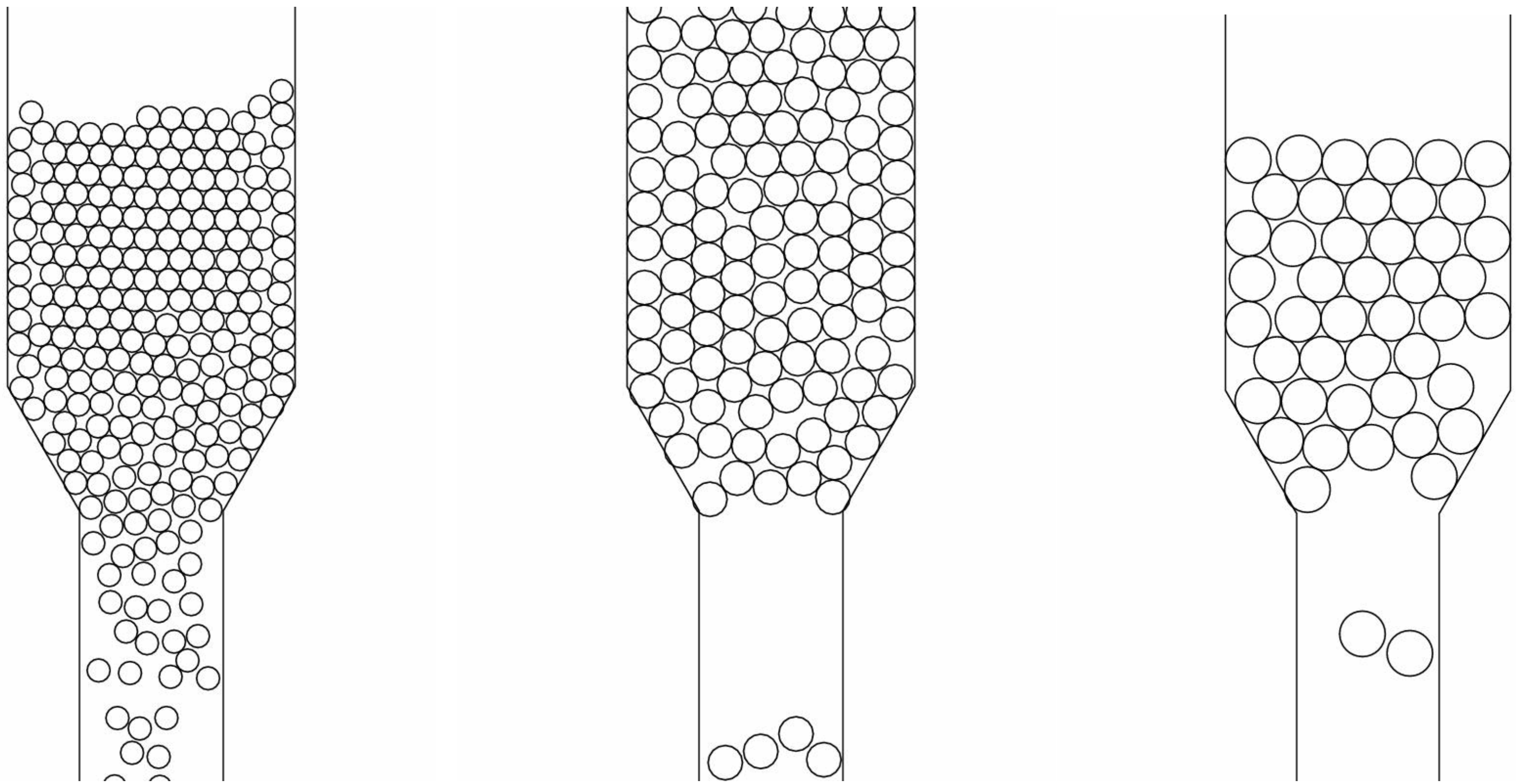
$$\omega_p^{n+1} = \omega_p^n + \frac{1}{I}\sum_c S_\omega$$

where $\vec{S}$ and S_ω are the translational and rotation impulses due to collision c

*J. Fortin, O. Millet and G. de Saxcé, 'Numerical prediction of granular materials by an improved discrete element method', Int. Jou. for Num. Meth. in Engineering, 2005, 62:639-663

Result animations for gravitation flows without fluid forces

$d_p = 4mm$ $d_p = 6mm$ $d_p = 8mm$



ρ_p=1000kg/m³, normal and tangential restitution coefficients = 0.8, 0.9

friction coefficient = 0.5

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Flow forces from semi-empirical relation by Ergun*

$$\vec{F} = \frac{\pi \mu d_p}{6\varepsilon^3}\left(150(1-\varepsilon)+1.75R_{ep}\right)\left(\vec{U}_f - \vec{U}_p\right)$$

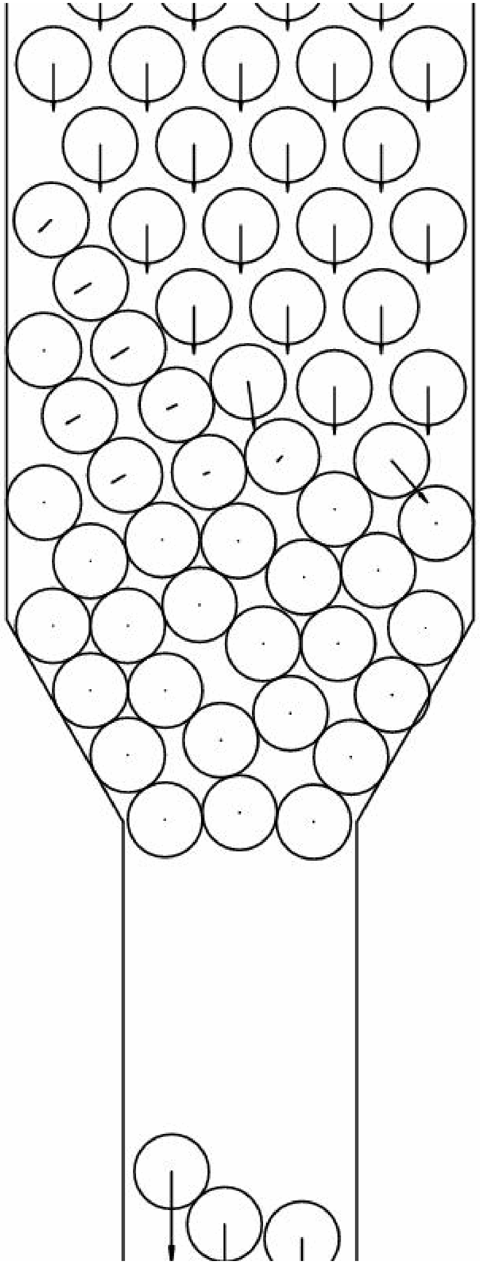
where μ is the fluid viscosity and ε is the void fraction

*S. Ergun, ‘Fluid flow through packed columns’, Chem. Eng. Prog., 48(2):89-94,1952

Result animation for:-

1m/s water superficial velocity

d_p = 8mm



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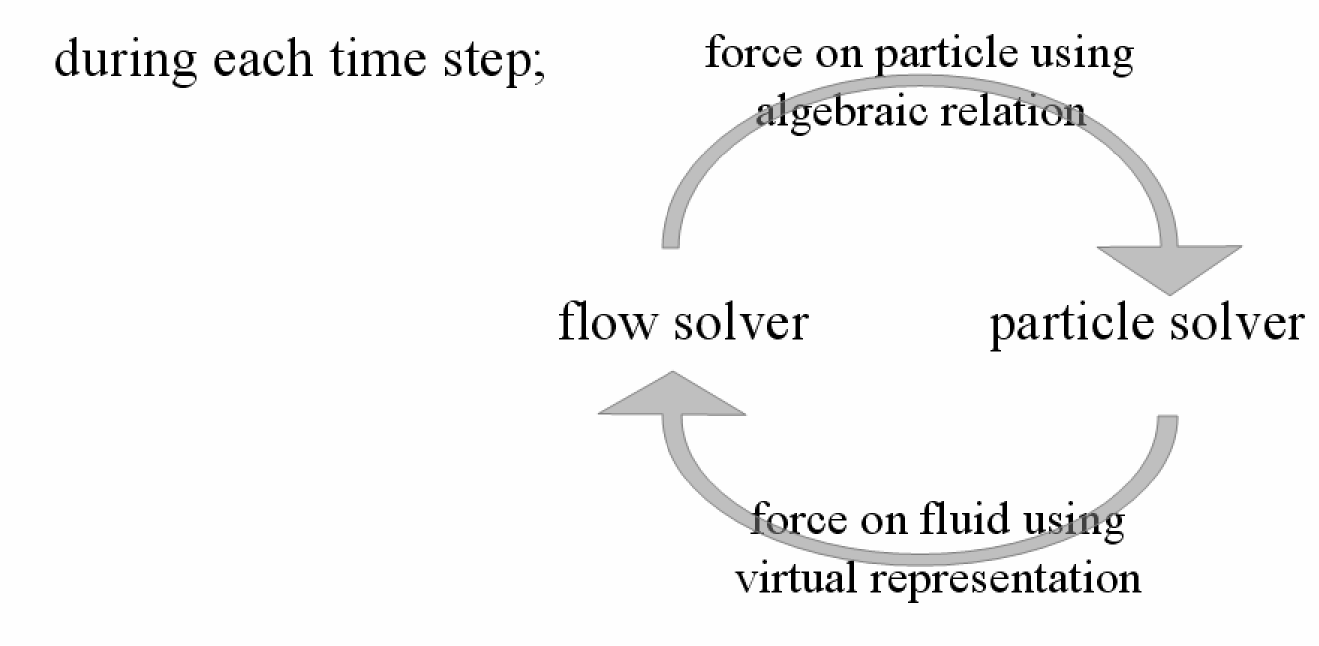
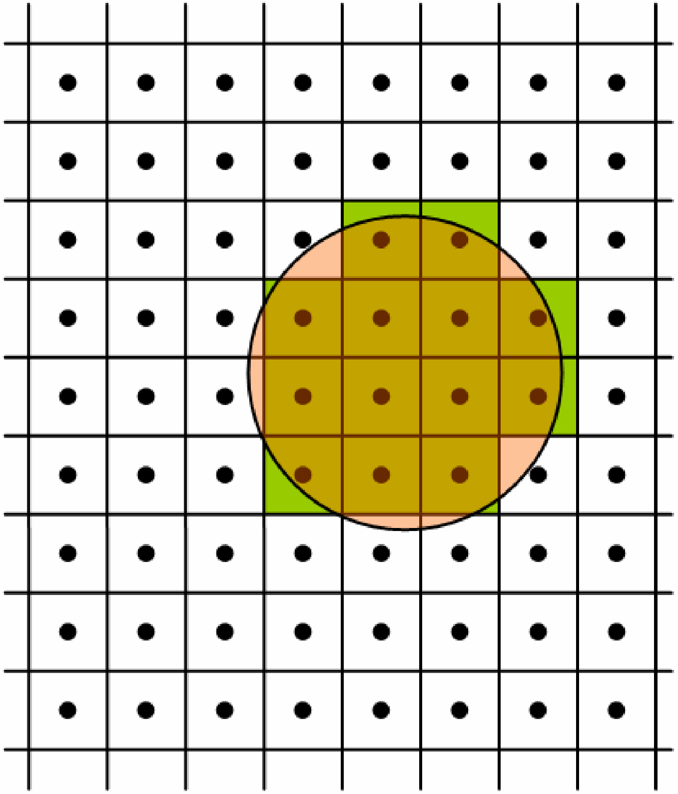
Application of the PSI-Cell method of Crowe et al.*

to large particles



* C. T. Crowe, M. P. Sharma an D. E. Stock, ‘The Particle-Source-In-Cell (PSI-Cell) Model for Gas-Droplet Flow, J. Fluids Engin., 1977, 325-332

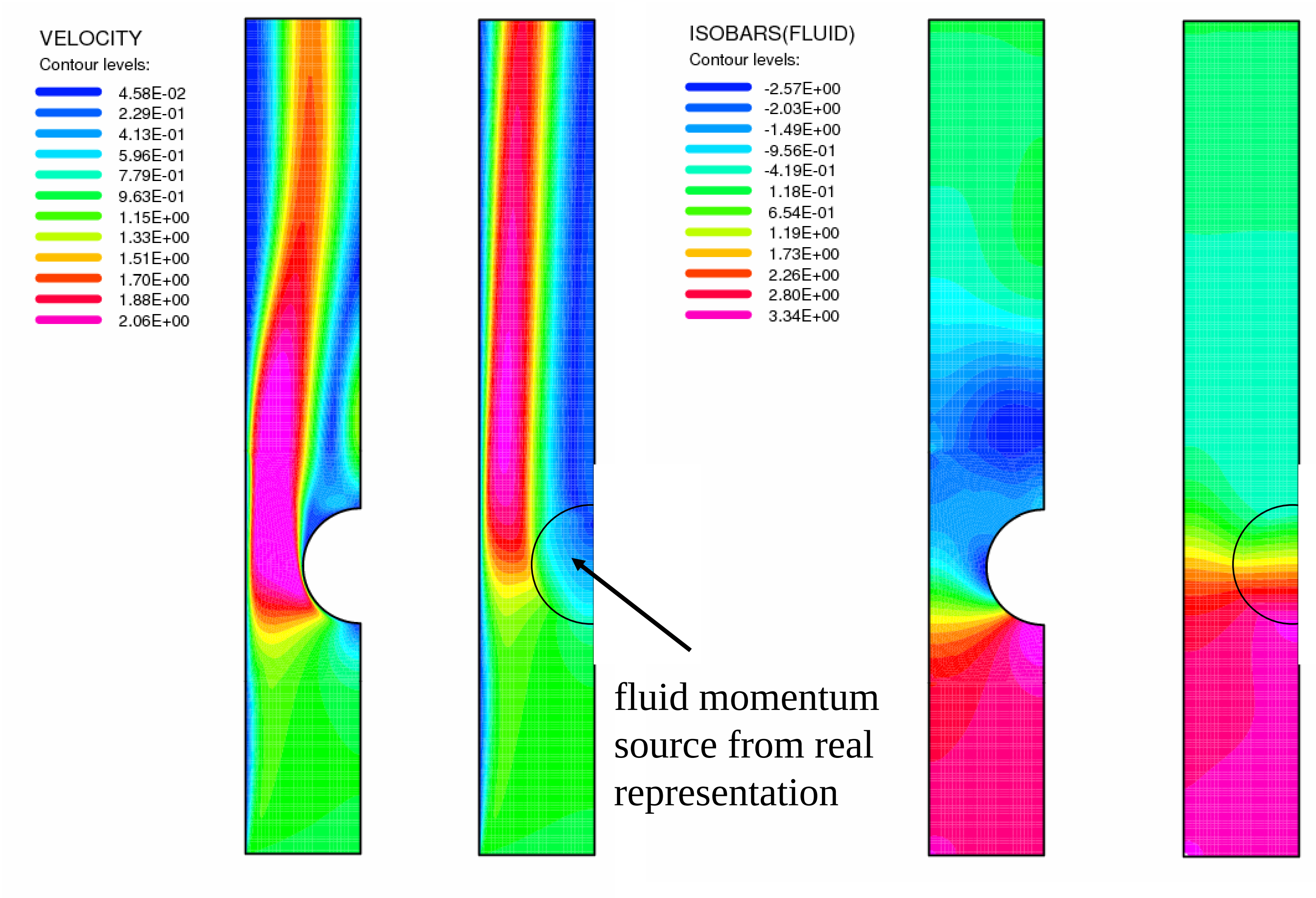
Virtual representation of solid within the fluid



1. Stair-case representation of cylinde
   orange cylinder -> set of green cell

2. Force on fluid acting from cylinder
   is distributed over all green cells

Test of flow past a confined cylinder, $R_{ep} = 400$



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2D predictions of mono-dispersed particles transported through a conduit reduction without cohesion show

- Blockage of conduit by bridging/arching upstream of reduction, without and with fluid forces acting on the particles
- A critical particle size above which bridging occurs

Work on methodology for particle interaction with numerically generated flow field based on extension of PSI-Cell method is in progress

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