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The University of Queensland, Australia — CREATE CHANGE

Proppant transport in complex fracture features

Numerical simulations of suspension flow within a temperature-dependent viscosity fluid using a coupled LBM-DEM approach

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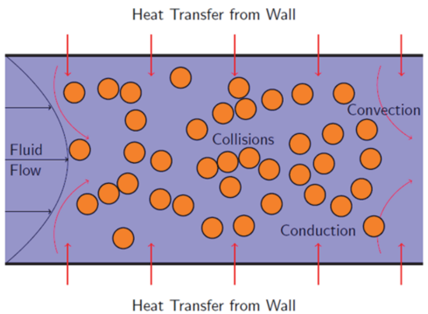
Introduction

It is well known that there are many complicated factors involved in the hydraulic fracturing process, particularly the pressure and temperatures associated with the depth of operations. These conditions make field and experimental measurements both expensive and difficult to acquire. Numerical modelling provides a cost-effective approach to experimenting with different treatment options before hydraulic fracturing is applied in the field.



Model Description

LBM – Fluid/Energy (Guo et al. (2007))

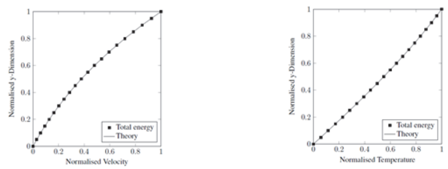
Populations moving in direction *i* on a grid at time *t*:

f_i represents fluid mass g_i represents total energy

These evolve in time through:

$$\underbrace{f_i(\boldsymbol{x}+\boldsymbol{c}_i\Delta t, t+\Delta t) - f_i(\boldsymbol{x},t)}_{\text{Streaming}} = \underbrace{\Omega_i(\boldsymbol{x},t)}_{\text{Collision}} + \underbrace{F(\boldsymbol{x},t)}_{\text{Forcing}}$$

Validated with thermal Couette flow with viscosity changing with temperature via $\mu = \mu_0 e^{-\beta T}$ (Myers et al. 2006).



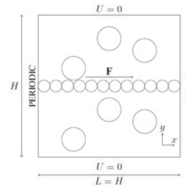
DEM – Solids

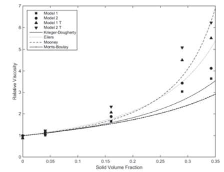
Determine particle motion from Newton's 2nd Law:

$$\sum F = ma$$

Forces may include gravity, drag, contact, lubrication etc.
Drag calculated by method of Noble and Torczynski (1998).

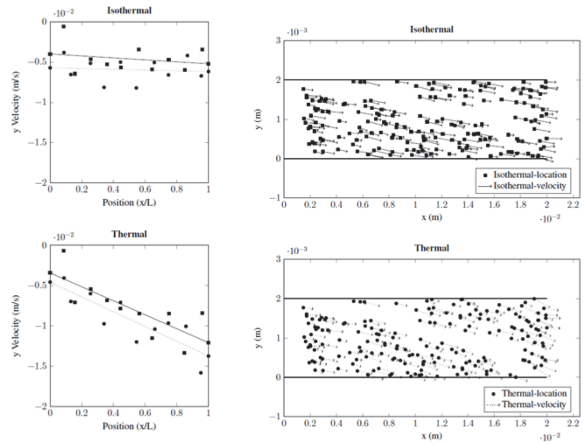
Coupled model validated for single and multiple particle flow.





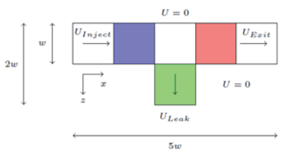
Straight Fracture

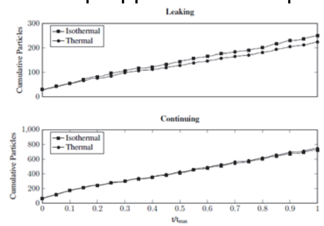
Proppant flowing along a straight fracture and settling under gravity within a temperature-dependent fluid.

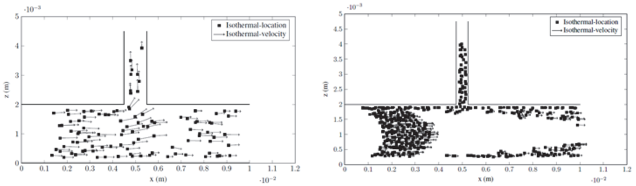


Leaking Fracture

Addition of side channel from which proppant can escape.

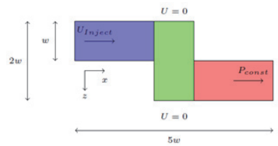


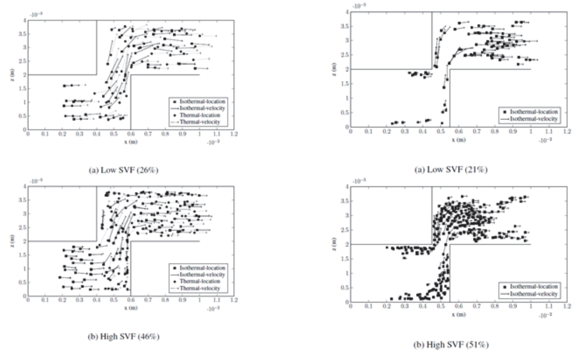




Stepped Fracture

Addition of direction changes to a single fracture channel.
Range of particle sizes in each simulation.





Summary

- Developed a numerical model for studying complex thermal suspension behaviour
- Found numerous examples of where temperature-dependent viscosity and particle size has impacts on proppant motion in fracture geometries

References

- Guo, Z., Zheng, C., Shi, B., Zhao, T.S., Thermal lattice Boltzmann equation for low Mach number flows: Decoupling model, Physical Review E, Vol. 75, No. 036704, 2007.
- Noble, D.R., Torczynski, J.R., A lattice-Boltzmann method for partially saturated computational cells, International Journal of Modern Physics C, Vol. 9, No. 8, 1998.
- Myers, T.G., Charpin, J.P.F., Tshehla, M.S., The flow of variable viscosity fluid between parallel plates with shear heating, Applied Mathematical Modelling, Vol 30, p.799-815, 2006.

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