The University of Queensland
AUSTRALIA

Proppant transport modelling using thermal LBM-DEM

PhD Candidate: Jon McCullough *Advisors:* Dr Christopher Leonardi and Dr Saiied Aminossadati
School of Mechanical and Mining Engineering

Project Description

Hydraulic fracturing is a necessary tool to access the unconventional oil and gas reserves (such as shale and coal seam gas) needed to meet short-to-medium term global energy demand. It has been widely used as a panacea to improve the production of a well without a complete understanding of the physical mechanisms occurring.

Proppant transport through a fracture is known as a key factor governing the efficacy of a treatment. Greater understanding of how this occurs during an operation may enable optimisation of fracturing treatments.

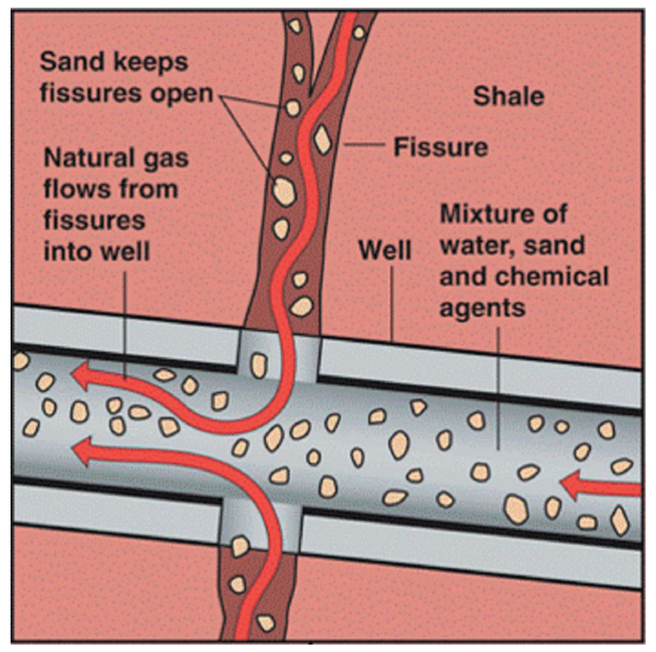
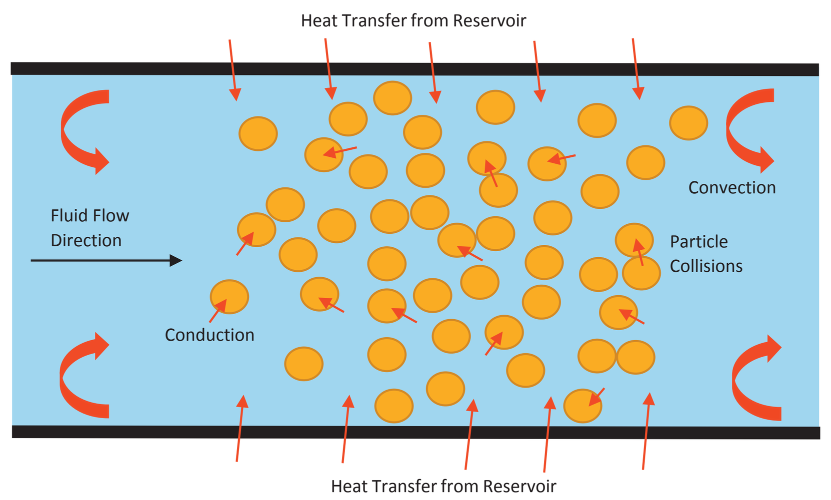


Image: A. Granberg from http://www.energy.ca.gov/almanac/naturalgas_data/overview.html

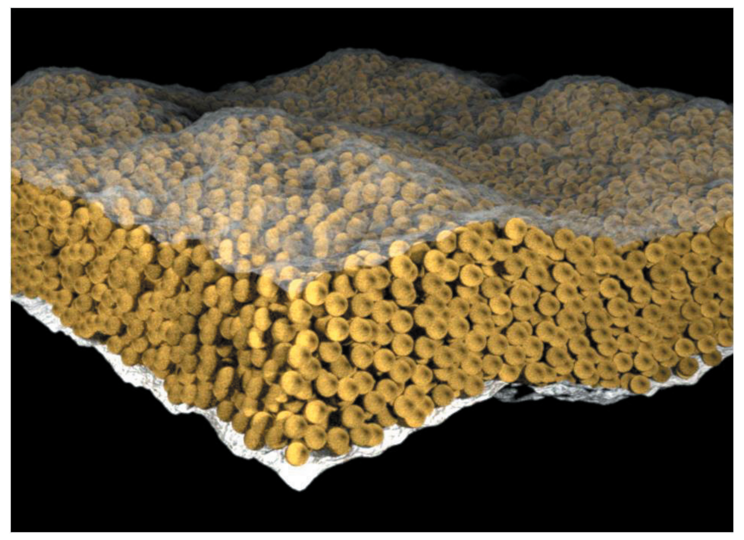
Numerical Modelling



Complex solid, fluid and boundary properties makes detailed prediction of the movement of the proppant during a treatment almost impossible.

It is also difficult to perform experiments that replicate the physical conditions experienced during fracturing. These factors mean that numerical modelling is an ideal way to efficiently improve the physical understanding of fracturing processes and make predictions of its behaviour.

Thermal LBM-DEM Modelling



Conventional modelling techniques inaccurately treat proppant as a continuous property of the fluid. This approach loses physical details of the collisions occurring in the system.

This study uses a combined approach to resolve thermal suspension behaviour. The particles are modelled using the discrete element method (DEM). Particle motion is determined through numerical integration of Newton's second law.

$$m\ddot{\boldsymbol{x}} = F_{Drag} + F_{Contact}$$

The hydrodynamics of the simulation are resolved through the lattice Boltzmann method (LBM). In this approach, distribution populations (f_i) are transmitted and relaxed upon a Cartesian grid of nodal locations. Macroscopic fluid properties are found as a function of these populations.

$$f_i(\boldsymbol{x} + \boldsymbol{c}_i\Delta t, t + \Delta t) = f_i(\boldsymbol{x}, t) - \frac{1}{\tau_f}\left[f_i(\boldsymbol{x}, t) - f_i^{eq}(\boldsymbol{x}, t)\right] + \frac{1}{Ac^2}\boldsymbol{G} \cdot \boldsymbol{c}_i$$

A second, g_i, population captures all thermal behaviours.

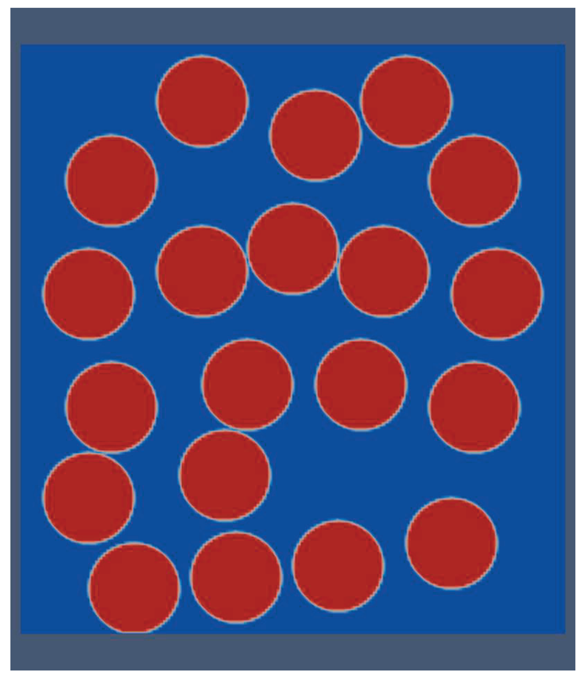
$$\sum_i f_i = \rho \qquad \sum_i f_i \boldsymbol{c}_i = \rho \boldsymbol{u} \qquad \sum_i g_i = T$$

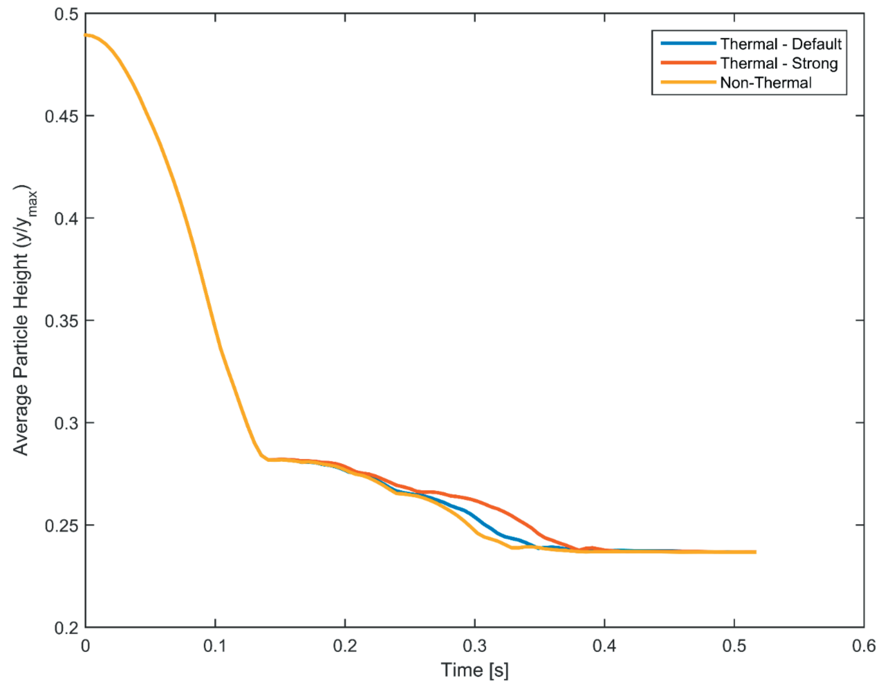
Appropriate conjugate heat transfer between the proppant and the surrounding fluid has been achieved using extra forcing terms in the relaxation of the thermal population.

Example Results

2D Test case of settling particles:

- 20 settling particles in a flowing channel
- Examine impact of thermal interactions
- 'Proof of concept' model illustration





The longer settling times in the thermal cases indicate that understanding this behaviour could improve proppant transport and help design better fracturing treatments.

Continuing Work

This model is currently able to capture changing thermal interactions within a particle suspension. Incorporating the change in physical properties of the fluid phase with temperature will capture the complex behaviour of fracturing fluids used in industry.

UQ-CCSG
Centre for Coal Seam Gas