THERMO-VISCOUS FLUID EFFECTS ON PROPPANT TRANSPORT

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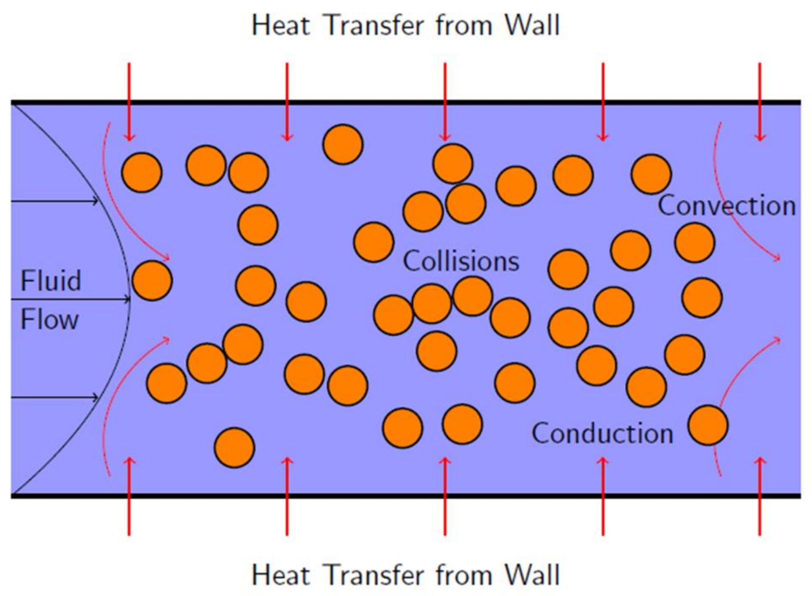
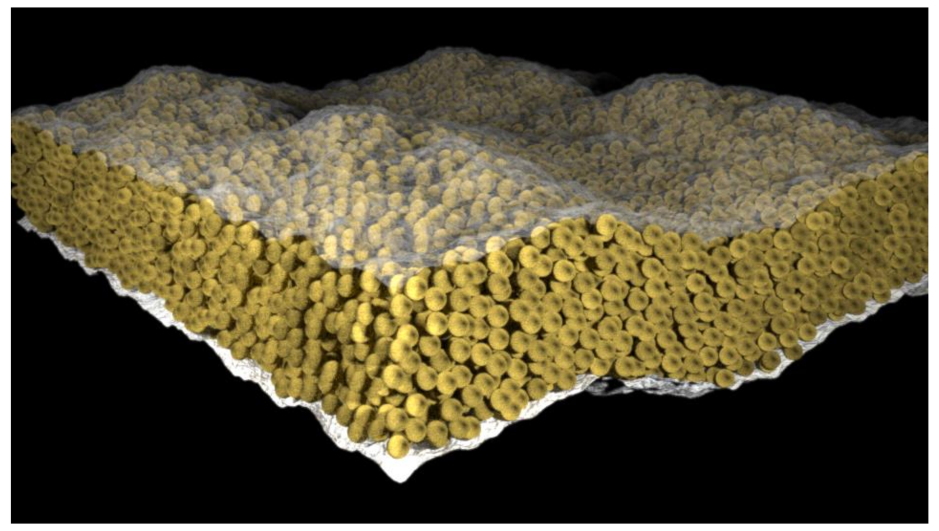
PROJECT BACKGROUND

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.

However, the combination of solid proppant particles suspended within a fluid is still a challenge to model numerically. This is particularly true for large systems exposed to changing environmental conditions.



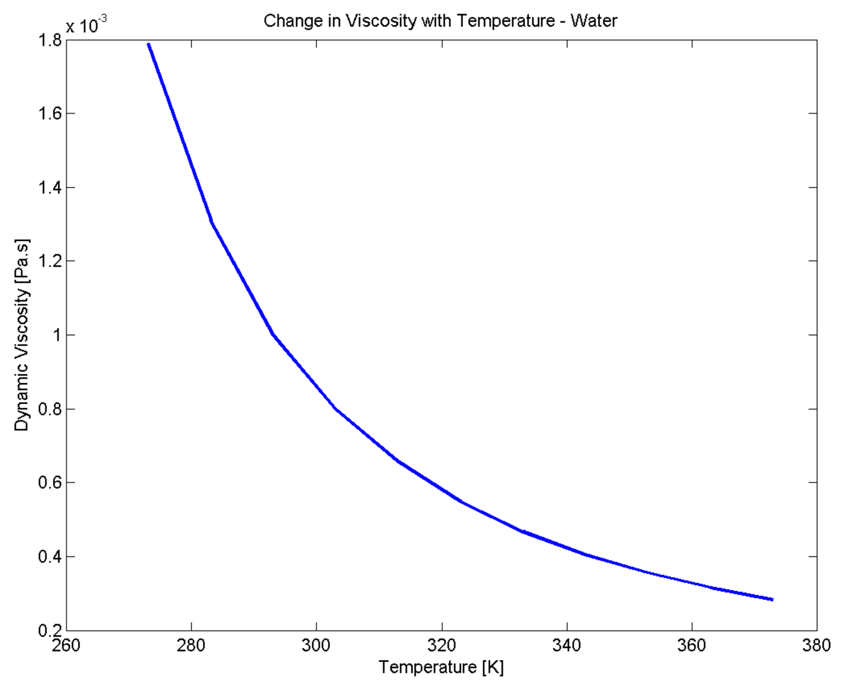
CURRENT STUDY



Many previous numerical works (e.g. Ribeiro and Sharma (2013)), assume that the working fluid used in a fracturing treatment has constant material properties.

In reality, properties such as viscosity and density can change significantly over the temperature range observed within a stimulation treatment.

This study aims to construct a numerical approach for modelling suspensions exposed to a temperature gradient. Focus is given to changes in the transport of the solid phase (proppant) by the fluid.



METHODOLOGY

A coupled system of numerical methods is proposed:

Lattice Boltzmann Method – Fluid/Energy

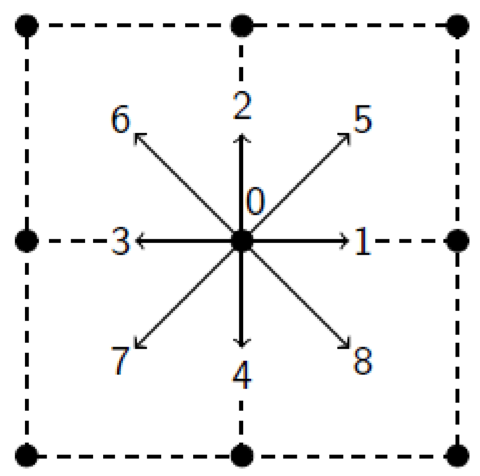
Populations moving in direction *i* on a grid at time *t*:

f_i represents fluid mass g_i represents energy

These evolve in time through:

$$f_i(\boldsymbol{x}+\boldsymbol{c}_i\Delta t, t+\Delta t) - f_i(\boldsymbol{x},t) = \Omega_i(\boldsymbol{x},t) + F(\boldsymbol{x},t)$$

Streaming Collision Forcing

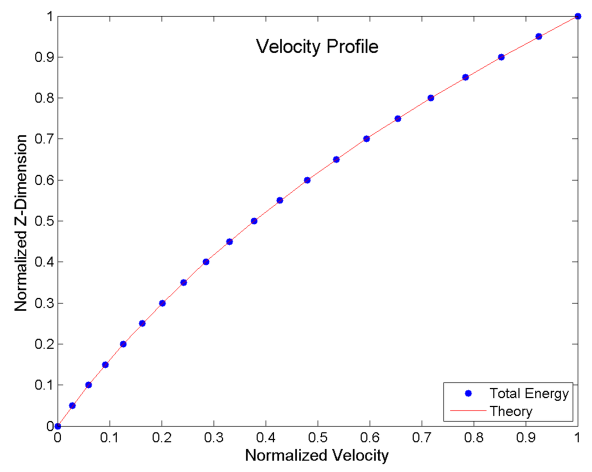


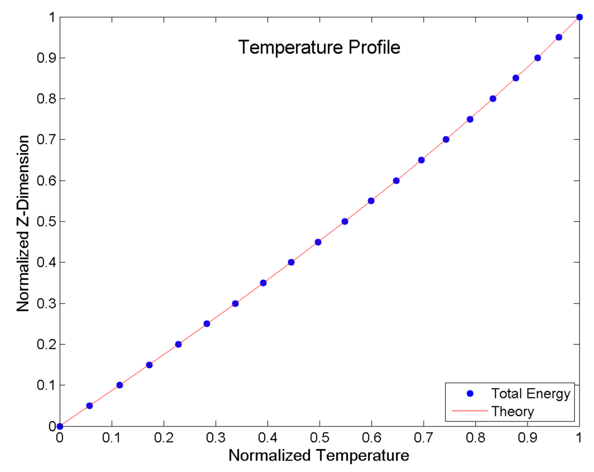
$$\Omega_i(\boldsymbol{x},t) = \frac{1}{\tau}\left(f_i^{eq}(\boldsymbol{x},t) - f_i(\boldsymbol{x},t)\right)$$

Collision relaxes populations towards equilibrium

This approach represents the fundamental conservation equations, for further details see Guo et al. (2007).

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





Discrete Element Method - Solids

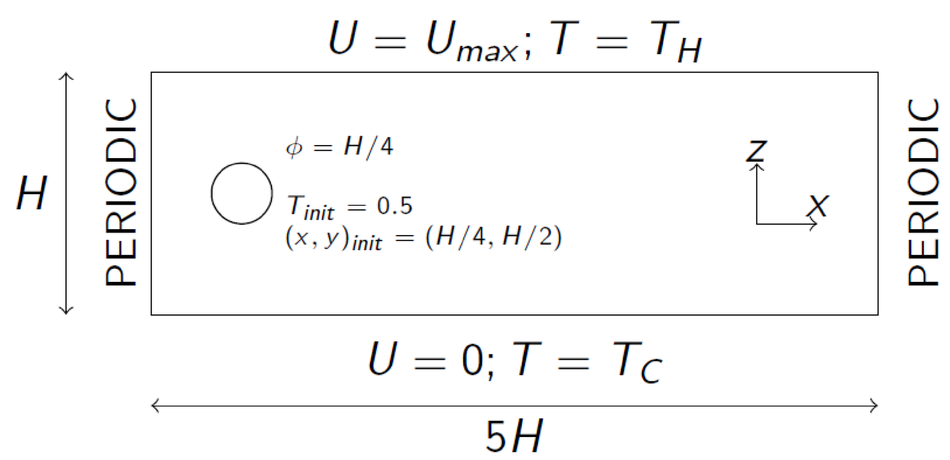
Determine particle motion from Newton's 2nd Law:

$$\sum F = ma$$

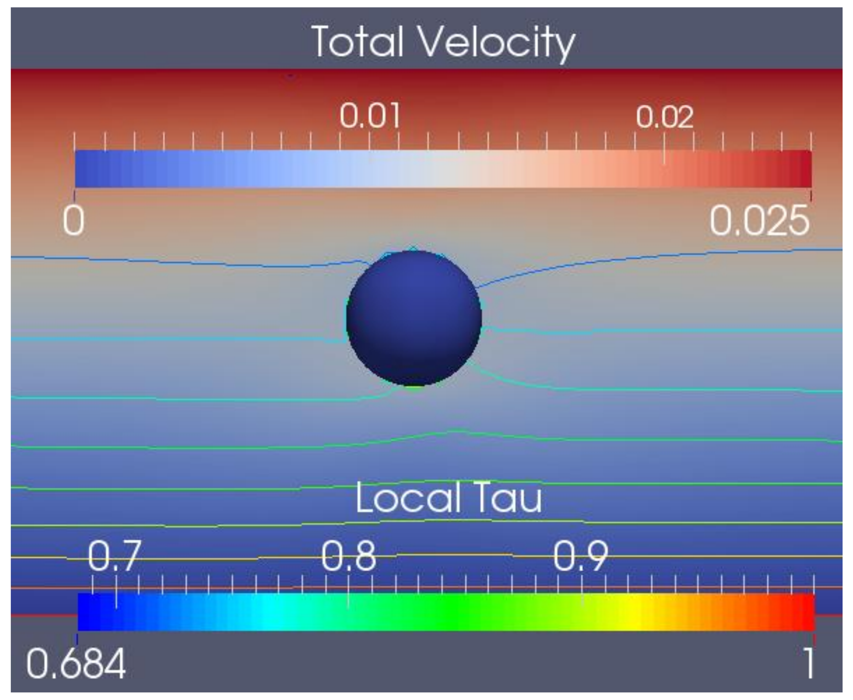
Forces may include gravity, drag, contact, lubrication etc. Drag calculated by method of Noble and Torczynski (1998).

Test Case – Particle Motion in Thermal Couette Flow

Condition #1 - as in figure;
Condition #2 – swap T_H and T_C

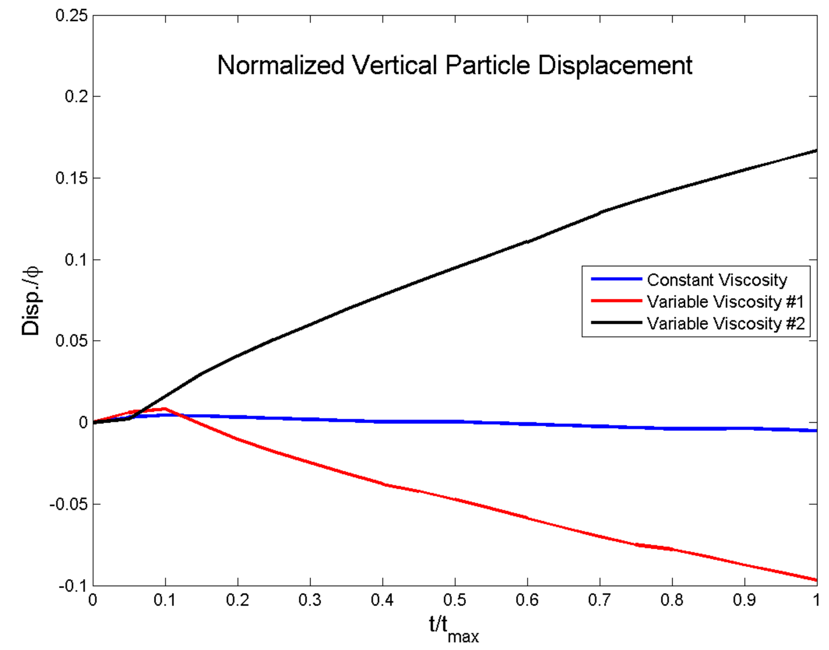


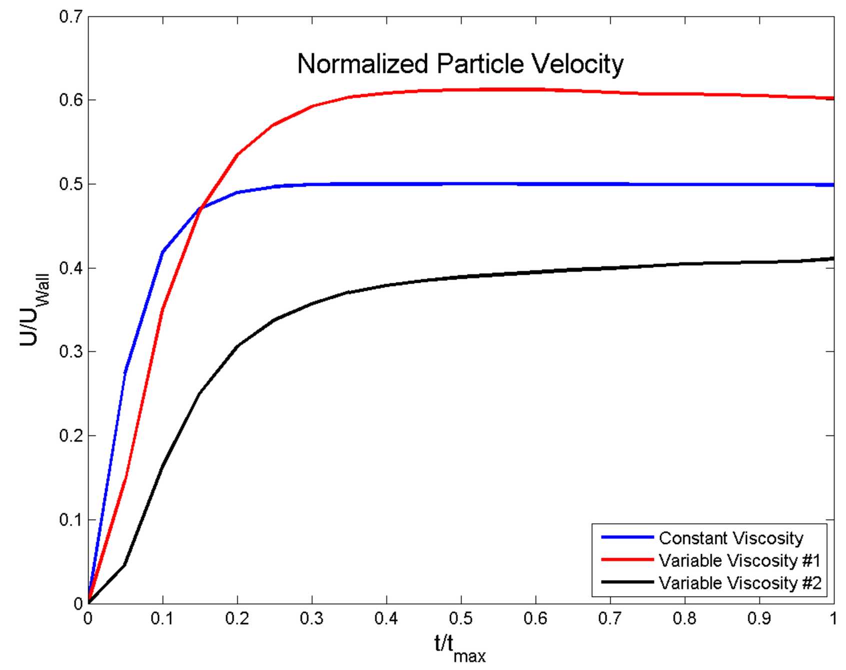
RESULTS



Both displacement and velocity of the particle change significantly when a thermally dependent viscosity is included. Due to the asymmetry of the flow.

Local changes are easily captured with LBM framework. Resolving these is necessary for a full understanding of proppant transport in a fracture.





Top: Condition #1 flow around moving particle. Background = velocity, Contours = τ_{local} (LBM measure for viscosity)
Middle: Vertical particle displacement comparison
Bottom: Particle velocity comparison

FUTURE WORK

- Increase volume fraction of proppant
- Extend to 3D model – currently in progress
- Introduce more complicated geometries

References:

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