Internet Appendix A46: Mining Engineering

A46.1 Illustrative Pitch Template Example on Fracking

Pitcher's Name	Jon McCullough	**FoR category**	Mining Engineering	**Date Completed**	23 July 2015
(A) Working Title	Numerical simulation of heat transfer in confined particle suspensions: Thermo-rheological behaviour of hydraulic fracturing fluids				
(B) Basic Research Question	How can the effect of heat transfer on the physical behaviour of particle suspensions such as hydraulic fracturing fluids be better resolved and understood?				
(C) Key paper(s)	Feng, Y., Han, K. and Owen, D., *Advances in computational modelling of multi-physics in particle-fluid systems*, in: E. Onate, R. Owen (eds.), Particle Based Methods, vol. 25 of Computational Methods in Applied Sciences, Springer, Netherlands, 2011, pp. 51-88, doi: 10.1007/978-94-007-0735-1_2 Hashemi, Z., Abouali, O. and Kamali, R. (2014), Three dimensional thermal Lattice Boltzmann simulation of heating/cooling spheres falling in a Newtonian liquid, *International Journal of Thermal Sciences* , *82*, 23 – 33, doi: 10.1016/j.ijthermalsci.2014.03.008				
(D) Motivation/Puzzle	A considerable portion of the world's oil and gas reserves are stored in underground reservoirs of low porosity. Here stimulation techniques such as hydraulic fracturing (or 'fracking') are usually necessary to facilitate the economic extraction of the resource. Improved understanding of the physical mechanisms and phenomena occurring within this process however is necessary to improve its performance both environmentally, socially and economically. Modelling of such systems requires capturing the physics of a number of interacting behaviours such as viscous fluid flow, particle collisions, fluid-solid interactions, heat transfer mechanisms and varying geometry. Combining these considerations with sufficient accuracy, stability and efficiency is an ongoing research challenge in numerical modelling.				
THREE	**Three** core aspects of any empirical research project i.e. the "**ID**io**T**s" guide				
(E) Idea?	The behaviour of hydraulic fracturing fluids is inherently complex due to the geometry of a fracture, the heating of the fluid by the reservoir and its nature as a suspension of solid particles within the fluid. With hydraulic fracturing operations occurring up to 4km underground it is difficult to obtain experimental data on how the fluid behaves and thus to optimise the process. An alternative approach to improving understanding of its behaviour is necessary. By design, continuum based numerical models solve the macroscopic variables of a system by dividing the solution domain into multiple small regions and averaging system behaviour in each of them. This approach cannot resolve features of the system that occur at length scales less than the finite cell dimensions used. On the other hand, the full resolution of the molecular interactions of a system becomes intractable for practically sized systems due to the large number of particles needing to be resolved. Direct numerical simulation techniques like the lattice Boltzmann method (LBM) and discrete element method (DEM) provide options to develop models that can capture fluid and solid interactions from a mesoscopic perspective that can minimise the need to adapt to the restrictions imposed by continuum or molecular modelling. Development of a numerical model within an LBM-DEM framework would enable physical flow behaviours of a hydraulic fracturing fluid to be better understood. The result of this would be tailored operations with existing and new formulations that minimise impacts such as pumping time, operational scope and running costs.				
F) Data?	- Numerical data generated by running simulations under a range of conditions for test geometry, input conditions and fracturing fluid formulation. This will occur for both the validation and verification of model components and detailed fracturing fluid investigations. - Post-processing of data likely to be done with *Paraview*, *MS Excel* and *Matlab/Python* - Validation and verification of numerical model against classical/analytically tractable layouts for each component (particularly Poiseuille flows in 2D and 3D channels/pipes). Comparison against relevant experimental data would be ideal if such information can be obtained. - Storage of data will need to be managed carefully. Even a simple simulation can easily generate gigabytes worth of information of which only a small subset may actually be of interest. Make use of existing IT hardware to store important analysed data. - Data, both analysed and raw, will need a formal framework of the associated metadata to explain what was trying to be done with each trial, the input variables, the version of the model for later review and understanding. - Output information of interest would include: velocity and temperature flow profiles, heat transfer between fluid and solid surfaces, particle migration behaviour and rheological measures (e.g. effective viscosity resulting from particle presence and heat transfer).				
(G) Tools?	Physical apparatus necessary includes code development and post-processing software (available as open-source or through UQ IT/EAIT agreements), storage space and back-up for active and archival data, desktop computer hardware (for small simulations and code development) and access to supervisor's server (large simulations).				

TWO	**Two** key questions
(H) What's New?	The individual numerical components of LBM and DEM outlined in this proposal aren't new (including their combinations to varying extents) and nor is the numerical modelling of the hydraulic fracturing process. However, the development of a direct numerical model harnessing the strengths of a thermal LBM coupled to DEM to resolve a wide range of physical behaviours would combine the separate facets of existing knowledge in a more detailed manner and be an improvement on current literature. The particular application to the flow of hydraulic fracturing fluids is a further novel aspect of this research.
(I) So What?	The hydraulic fracturing process has many opponents, particularly on environmental grounds. Better understanding of the flow mechanisms of hydraulic fracturing would aid in developing operational strategies that can alleviate these concerns. Reducing the external impact of bore sites (such as through minimising the number of bores used for a reservoir and their operational time) while still enabling the economic extraction of hydrocarbon resources could be a tangible benefit of this research.
ONE	**One** bottom line
(J) Contribution?	The development of a numerical model within a LBM-DEM framework that can directly resolve a wider variety of thermodynamic, hydrodynamic and rheological behaviours relevant to confined particle suspensions than is achieved with existing methodologies.
(K) Other Considerations	**Collaboration –** Supervisor has contacts with experts in the modelling of particulate systems in both UK and USA. Leveraging of these to optimise the development of the model would be desirable. There are a number of researchers within the School of Mechanical and Mining Engineering with interest and expertise in the numerical modelling of heat transfer in fluids from a 'conventional' modelling perspective. There would be potential to take advantage of their knowledge for both model development and comparison between techniques. Sourcing of experimental data to compare to numerical results would also necessitate some collaboration. **Target Journals** – *International Journal of Heat and Mass Transfer* or *Granular Matter* for initial papers depending on whether the work in the paper is focused more on heat transfer methods (IJHMT) or particle behaviours (GM). These are both A-level journals on the Australian Research Council's 'Excellence in Research for Australia' list. *Journal of Computational Physics* or *Computer Methods in Applied Mechanics and Engineering* as target A*-level journals for more significant papers produced towards the end of candidature. Such journal levels and time-frames have been seen to be met by other engineering PhD candidates. **Risks: *No Result* –** LOW: There is sufficient literature on the respective components to provide suitable background towards development of a complete model. The application of such a model to hydraulic fracturing would still yield informative results. ***Competitor* –** MODERATE: The development and application of LBM and DEM techniques is ongoing, widespread and, at times, obscure. There are some existing models that capture features of what is desired here but none (to current knowledge) that capture all of them. The ongoing development and scope of these models is unknown. It is thought that the application of such a model to hydraulic fracturing context would be novel. ***Obsolescence* –** LOW: Focus of project is largely the development of the model rather than its direct application to hydraulic fracturing, as such the ongoing debate over the use of such stimulation techniques is of reduced concern**.** Particle suspensions are also relevant to a wide variety of scientific and engineering disciplines meaning the model would be useful in other fields. **Scope –** Taking advantage of existing numerical frameworks (both from supervisor's previous research and open-source resources) reduces the potential to be over-ambitious in the aspects being developed in the model.