8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

SIMULATION OF FINES MIGRATION USING A COUPLED NON-NEWTONIAN LATTICE BOLTZMANN MODEL AND DISCRETE ELEMENT METHOD

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Key Words: *lattice Boltzmann method, non-Newtonian fluids, discrete element method, solid-fluid interaction, fines migration, block caving.*

ABSTRACT

Fines migration in a block cave can be characterised by the faster movement of fine material towards the draw point in comparison to larger, blocky material. This phenomenon can result in the percolation of waste material into the fragmented orebody, thereby reducing the concentration of mineralisation in the caved material and consequently reducing operational efficiency [1].

A greater understanding of the kinematic behaviour of fines and ore within the cave during draw is integral to the solution of this problem. Some of the current approaches include field marker monitoring, laboratory scale experiments, and computational techniques such as the discrete element method (DEM). Whilst the DEM has been successfully employed to simulate the dynamics of large blocks in a cave during draw, the extension of this approach to include the migration of fines would require the simultaneous solution of elements greater than 2m (blocks) and smaller than 50mm (fines). In an industrial size, 3D model this method would require in the order of 10^8 particles and subsequently be intractable.

In this paper, a novel computational approach is presented that incorporates the lattice Boltzmann method (LBM) in a nonlinear form for the simulation of the fines with the DEM for the simulation of large blocks in a fully coupled framework. The LBM [2,3] has emerged as an alternative to conventional computational fluid dynamics (CFD) methods, which employ a spatial and temporal discretisation of the Navier-Stokes equations. Some of the advantages of the LBM over Navier-Stokes CFD include the potential for using a Eulerian grid, high space-time resolution, full scalability on parallel computers, as well as efficient and robust implementation in complex fluid domains [4].

A key advantage of the LBM over traditional CFD [5] is its ability to be efficiently and robustly coupled to a large number of discrete elements. The main computational obstacles in Lagrangian CFD approaches are the need for continuous mesh geometry adaptation to prevent severe mesh distortion, and the generation of a valid mesh for dense particle flows where sustained discrete element contact is a dominant physical phenomenon. In the context of the LBM, a number of LBM fluid-solid interaction technique have been developed, one of which is the immersed moving boundary method

by Noble and Torczynski [6]. Employing DEM to account for particle-particle interactions gives rise to a fully coupled LBM-DEM computational framework capable of simulating dense phase particle suspensions. The explicit time stepping scheme of both LBM and DEM, when coupled using a dynamic time step update algorithm, makes this strategy a competitive numerical tool for the simulation of particle-fluid systems. Such a coupled methodology was first proposed by Cook et al [7] in simulating particle-fluid systems dominated by particle-fluid and particle-particle interactions.

To model the motion of fine particles in a block cave as a non-Newtonian fluid the standard LB formulation must be extended to capture the constitutive behaviour of a bulk material. In the relatively small volume of work dedicated to nonlinear fluids, the power law model is the most popular choice for description of the behaviour of non-Newtonian fluids in the LBM. For example, the implementation of power law fluids within the LB formulation has been undertaken [8] to investigate both pseudoplasticity (shear thinning) and dilatancy (shear thickening) behaviour. A similar approach is adopted in this work along with investigations of Bingham plastic and Mohr-Coulomb [9] material models in the LBM.

This paper presents some of the issues relevant to this novel approach to fines migration modelling, such as fluid-solid interaction, the coupling of explicit schemes, and the characterisation of a bulk material as a non-Newtonian fluid. Preliminary 2D results are presented which indicate the capability of the framework for application in field-scale, 3D problems.

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