Simulation of water-clay flow in dam break with SPH method

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Abstract

In the field of Civil Engineering, non-Newtonian fluids such as water-cement mix, SCC (Self Compacted Concrete) and benthonic are widely used. In this article, water-clay mix flow in dam break problem is studied numerically. Water-clay mix rheology is assumed as Bingham fluid. As the water-clay mix flow in the dam break problem is a free surface flow with large deformation, SPH method is used for the simulation. To verify the simulation results, the predicted results such as free surface shape and leading edge position have been compared with experimental data. The simulation is then used to determine parameters of motion which are difficult to measure in the laboratory. These results include exciting mass from gate position at each time step, height of fluid at a particular point, and leading edge velocity. The results also indicate that SPH method is accurate enough for simulation of non-Newtonian fluid flow with free surface problems.

Keywords: SPH method, Dam break, Non-Newtonian fluid, Water-clay mix, Bingham fluid.

1. Introduction

Non-Newtonian fluids are widely applied in industry and Civil Engineering. Water-clay mixture, benthonic, and concrete are non-Newtonian fluids which used in constructing of the structures. To enhance the efficiency in using these materials and their effects on the structures, the reaction between these materials with the structures should be determined. Momentum equations govern for all fluid behavior and flow characteristics such as velocity, pressure, fluid height, and density changes can be predicted. Momentum equations are partial differential equations for which, so far, no exact solution has been found and usually are solved numerically.

The numerical methods are classified into two general groups based on the type of discreting solution domain. The first group is the mesh-base numerical methods in which the points have a fixed place during the solution such as finite difference method (FDM), finite element method (FEM), and finite volume method (FVM). The other group of numerical methods is known as mesh-less methods. In these methods, the continuum domain of simulation is discreted into finite number of point and can freely move all over the solution domain. These points can have mass, volume, density, and speed. The mesh-less method such as SPH can satisfactorily model the free surface flow problems with large deformation, moving boundary, and problems with complex geometry where the generated mesh is complicated.

In the previous studies, water flow in dam break problem was simulated with SPH method. Leading edge position, water surface shape, and variation of water height at specific locations were determined [1, 2, 3]. Hosseini et al. (2007) presented a new fully explicit SPH algorithm for simulation of power-law, Bingham-plastic, and Herschel-Bulkley fluid flows. The performance of the proposed algorithm is assessed by solving three test cases including a non-Newtonian dam-break problem, flow in an annular viscometer, and a mud fluid flow on a sloping bed. The results obtained were in close agreement with the available experimental and numerical data [5]. Lee et al. (2010) applied two algorithms of the SPH method (weakly compressible and truly incompressible algorithm) for simulation of two problems; i.e., water column collapsing in a rectangular tank, and ski-jump spillway downstream of a dam reservoir. They concluded that the incompressible algorithm model predicts flow characteristics more accurate compared to weakly compressible algorithm predictions [4].

In the present investigation, the dam break of the water-clay mixture is studied numerically. The gate