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A Comparison between Finite Element and Smoothed Particle Hydrodynamics' Simulations of Dam Break

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Abstract

Modeling of free surface flows is one of the main challenges in computational fluid dynamics (CFD). Dam break, as a free surface flow producer, is very important in industrial and environmental works and is usually applied to evaluate the performance of numerical modeling methods. In a dam break, because of a sudden break of a holding barrier, a large amount of water is accidentally released downstream. In this study, two numerical models for solving the dam break problem are developed and the efficiency of them is compared together. In the first model, Navier-Stokes equations for incompressible fluid are solved using a Characteristic-Based Split (CBS) finite element method on an unstructured triangular grid. The second numerical model solves the aforementioned equations with a meshless method entitled as Smoothed Particle Hydrodynamics (SPH) method. The results show that the developed SPH model provides better efficiency and accuracy than the CBS finite element method.

Keywords: Free Surface Flow, Dam Break, Finite element, Characteristic-Based Split, Smoothed Particle Hydrodynamics.

1. INTRODUCTION

Free surface flows in hydrodynamics are very important in industrial and environmental works but they are difficult to simulate. In other words, modeling of free surface flows is one of the main challenges in computational fluid dynamics because boundary conditions are required on an arbitrary moving surface. Dam break is one of the most well-known free surface problems. In many practical situations it is very important to know the maximum water height resulting from a dam break caused by a sudden break of a holding barrier. In a dam break, a large amount of water is accidentally released downstream. For this reason, the numerical schemes must be able to model the sudden variations of the hydraulic parameters without introducing spurious oscillations.

The marker and cell [1] and volume of fluid [2] methods, as Eulerian models, are two of the best models for simulating such flows. They have been successfully applied for modeling of free surface flows but in spite of successful use of these methods, they are so complicated for programming. Furthermore, numerical diffusion due to solving Navier-Stokes equations on a fixed Eulerian grid arises especially when free surface deformation is very significant [3]. In addition to Eulerian models, Lagrangian models can also be used for modeling of flows involved with free surface. These models have not drawbacks that the Eulerian models suffer from them. In the Lagrangian grid-based methods such as Finite Element Method (FEM) [e.g. 4], the grid is attached on the material and therefore it moves with the material. However, in spite of its advantages, Lagrangian grid-based methods are practically very difficult to apply for cases with very large deformations. Recently, particle methods have been developed in which instead of grid, particles are used for calculating purposes. Smoothed Particle Hydrodynamics (SPH) method [5, 6] is the most popular meshless method employed for modeling of free surface flows. The SPH is a pure Lagrangian, particle-based method in which the state of a system is represented by a set of particles, which possess individual material properties and move according to the governing conservation equations.

In this study, the dam break problem is modeled using two different Lagrangian numerical schemes. One of them is a Characteristic-Based Split (CBS) finite element method, which is a mesh-based model, and another is a meshless one entitled as SPH method. The efficiency and accuracy of these two models in modeling of dam break are investigated and compared together by experimental data.