Numerical Simulation of Unsteady One-Dimensional Dam-Break Flows Using TVD MacCormack Scheme

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Abstract

Dam break phenomenon is still of paramount important issue in the field of hydraulic engineering. Predicting the critical conditions due to dam-break flows indicates more field studies requirement. The MacCormack numerical scheme is a classical second order explicit scheme for the simulation of unsteady one-dimensional dam-break flows. It is well known that classical second order schemes show oscillatory behavior near discontinuities and can generate or maintain a shock in the solution. In this paper, the classical MacCormack scheme is presented and extended to a finite difference predictor-corrector TVD (Total Variation Diminishing) scheme by implementing a conservative dissipation term to the last step of classical version. MacCormack's scheme with and without TVD correction is used to simulate one-dimensional dam-break problem. The accuracy of the computed solutions are verified with an analytic solution and experimental data. It is found that using TVD scheme, any unphysical oscillation in the vicinity of strong gradients in the numerical solution is avoided. Furthermore this algorithm improved the performance of the MacCormack scheme and for the one- dimensional case, a satisfactory agreement between computed and experimental results obtained.

Keywords: unsteady Dam-break flows, MacCormack scheme, Predictor-corrector TVD scheme, numerical simulation, One-dimensional.

1. INTRODUCTION

Flooding caused by failure of a man made dam are a threat to mankind civilization all over the world. The need for more and more water storages and electricity as modern sources of energy in the densely populated regions are compelled to build dam along large rivers around living spaces which increases the risk of more injury to the residents. Thus, in many countries, the determination of the parameters of the wave, likely to be produced after the failure of a dam, is required by law, and systematic studies are mandatory.

The common computational methods used to evaluate the disaster risk range for a potential hazard can be classified into three categories: empirical formula methods, discrete element methods and continuum modeling methods. The continuum modeling method considers the moving mass to be a fluid and can therefore be depicted by the incompressible Navier-Stokes equations. These equations can then be further reduced to the two-dimensional (2D) shallow water equations by a depth-averaged procedure(Chaojun et al., 2012[1])

Based on the assumption of hydrostatic pressure distribution and incompressibility of water, the one-dimensional dam-break unsteady flows can be described by the Saint-Venant equations. These equations represent the conservation of mass and momentum along the direction of main flow. Since the Saint-Venant equations are a hyperbolic system of partial differential equations, they may generate a shock in the solution. In analyzing this type of equations, two mathematical difficulties are encountered: Discontinuous solutions do not satisfy the partial differential equations because the derivatives are not defined at discontinuities. This brings out the necessity of introducing the weak form of the equations. The other difficulty lies in the non-uniqueness of the solutions. The entropy condition is known to provide the weak solution of physical meaning as well as the uniqueness of the solution.