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Simulating surf zone hydrodynamics using a two phase flow model

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ABSTRACT

A novel two phase flow surf zone model, which may account for the effect of entrained air under breaking wave, has been developed. A variation of conservative Level Set Method is used to capture the air-water interface. This method allows the model to run stably up to hundreds of waves without significant mass loss. Air-water interface is well controlled and maintained even after long time integrations. Therefore, this model could be potentially used to simulate scour which occurs over many wave cycles.

In this presentation, we will introduce the detailed algorithm and our tests on the spilling breaking wave simulation. Although the computational results are strongly influenced by the numerical schemes, we have identified a scheme that can fairly accurately predict the phase averaged surface elevation, location of breaking point and undertow.

KEY WORDS: surf zone, CFD, two phase flow, conservative level set method

INTRODUCTION

Most existing surf zone CFD models are based on single phase flow assumption which ignores the air phase for the convenience of computation. Miyata (1986)'s model is regarded as the first such model. As no turbulence modeling was considered, his method is often regarded as Direct Numerical Simulation (DNS). Lin & Liu (1998) employed more advanced k-epsilon based nonlinear Reynolds stress model. Detailed 2D turbulent flow structures for spilling breaking waves were described and discussed. Bradford (2000) compared the results from one and two equation turbulence models. Zhao (2004) developed a more accurate two-dimensional multi-scale turbulence model to study breaking waves. Several attempts for 3D simulations of breaking waves have also been carried out. Christensen & Deigaard (2001) and Christensen (2006) used different LES models (simple SGS and k-equation based SGS model) and free surface models (MAC and VOF). Their results revealed many important flow structures in spilling, weak plunging and strong plunging breaking waves. Watanabe et al.(2005)'s results helped to exposure the complete 3D vortex structures under breaking waves.

On the other hand, Lubin et al. (2006) is the pioneer in the development of two phase flow model. The overturning motion, the splash-up occurrence and the complicated dynamics under plunging breaking waves were accurately captured in their model. However, it is unclear how accurate this model can predict water level elevation and breaking point as their computational domains only cover one or two wavelengths. Two phase flow models can be very useful when the effects of air entrapment and air water interaction need to be considered. However, some difficult issues remain to be tackled before a reliable 'complete' two phase flow solver can be developed.

In this study, we focus on developing a two phase viscous flow model for spilling breaking wave simulation. The development of a two phase turbulent flow model is still ongoing while this report is being prepared. However, we found that a variation of conservative Level Set Method works well for capturing the air-water interface and conserves mass well at the same time. This surface capturing scheme is further developed for a curvilinear coordinate system and incorporated into an incompressible flow solver. Computational results of spilling breaking wave show reasonable agreement with previously published results.

GOVERNING EQUATION

One fluid Navier-Stokes equations

In this study, the turbulent air and water two phase flow is described using the incompressible one-fluid Reynolds averaged Navier-Stokes (RANS) equations,

$$\frac{\partial u_i}{\partial t} + \frac{\partial (u_i u_j)}{\partial x^j} = -\frac{1}{\rho}\frac{\partial p}{\partial x^i} + \frac{1}{\rho}\frac{\partial \tau_{ij}}{\partial x^j} + g_i \qquad (1)$$