

Using RANS to Simulate Breaking Wave on a Slopping Bed

Chih-Min Hsieh

Institute of Navigation Science and Technology, National Kaohsiung Marine University
Kaohsiung, TAIWAN, China

Robbert R. Hwang

Institute of Physics, Academia Sinica
Nankang, Taipei, TAIWAN, China

Ming-Jyh Chern

Department of Mechanical Engineering, National Taiwan University of Science and Technology
Taipei, TAIWAN, China

Wen-Chang Yang

Taiwan Ocean Research Institute, National Applied Research Laboratories
Taipei, TAIWAN, China

ABSTRACT

The paper describes the development of a numerical model for the simulation of breaking waves on a slopping bed. The significant benefit of the present study over the traditional way of analyzing wave propagation problems is to apply the RANS (Reynolds Averaged Navier-Stokes) process and the embedding method by taking account of the fully nonlinear, viscous and turbulent effects on the physical problem. The model is employed to simulate the flow kinematics and the turbulence effects in the RANS equations. Based on a staggered computational mesh, an explicit numerical algorithm is employed with a predictor-corrector procedure of pressure and velocity field computation. To track the free surface movement with wave breaking, the volume of fluid (VOF) method is employed. Coupling the volume of fluid method (VOF) and the embedding method, the treatment on free surface problem and complex bottom topography can be easily reached. In comparing with the existing measured data, a good agreement is found between numerical results and measured data. The predicted wave deformation, mean velocity field, and turbulence distribution under the breaking wave are presented and discussed.

KEY WORDS: Wave breaking; a slopping bed; VOF; embedding method.

INTRODUCTION

Wave run-up has been studied for many years, because breaking waves in a surf zone play an essential role in nearly all coastal processes. For example, strong turbulence which enhances the sediment transport in surf zone is generated after waves break. Due to the effect on sediment transport, wave breaking may cause many problems in the coastal region, such as beach erosion and damage to coastal structures.

In order to determine run-up of Cnoidal waves, a series of theoretical and experimental studies have been performed. In the early 1950s, researchers began to investigate run-up of Cnoidal waves on a

plane beach through laboratory experiments. For example, Battjes (1988) found that a spilling breaker experiences a mild slop and its wave form remains highly symmetric until breaking. In the last few decades, several experimental methods have been developed to measure the velocity field under the free surface. Nadaoka *et al.* (1989) used a fiber-optic laser Doppler velocimeter (LDV) to study the turbulent flow field under a breaking wave on a 1:20 slope. Ting and Kirby (1994, 1995 and 1996) employed LDV and wave gauges for plunging and spilling breakers on a 1:35 slope. Chang and Liu (1999) used Particle Image Velocimetry (PIV) to investigate turbulence in a spilling breaker, and characterized the importance of each term in the turbulence kinetic equation during the breaking process.

In the past few years, due to the advance of computing technology, the numerical wave tank (NWT) has been widely applied in coastal engineering. Currently, there are four basic types of numerical models which have been used to simulate the run-up of water waves: (1) non-linear shallow water wave equation, (2) Boussinesq type models, (3) the Laplace's equation, and (4) Navier -Stokes equations. Zelt (1991) used the Boussinesq-type equations in Lagrangian form to simulate shoreline movement.

However, the inviscid wave model may fail to capture important phenomena regarding the interaction of viscous fluids interacting with solid structures. So far, only a few of numerical models have been proposed for problems of viscous water waves interacting with a slopping bed. In order to simulate the process of viscous flow interacting with submerged breakwaters, the Navier-Stokes equations with fully nonlinear free surface boundary conditions are considered in this study.

The current numerical models based on the Navier-Stokes equations to simulate breaking waves can be classified into three groups. The first group is to solve the Navier-Stokes equations directly, without any turbulence model (Miyata, 1986). The second group utilizes the space-filtered Navier-Stokes equations. (e.g., Zhao and