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Finite Element Modelling of Scour Around a Subsea Structure in Steady Currents

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ABSTRACT

In this study a three-dimensional finite element numerical model is established for simulating local scour around a subsea structure in steady currents. The flow is simulated by solving the Reynolds-Averaged Navier-Stokes equations with a k-ω turbulent model closure. Both suspended load and bed-load sediment transport rates are included in the model. Efforts are made to reduce the computational time associated with three-dimensional morphological modelling. These include the use of wall-function to avoid resolving the near-wall boundary layers, large morphological time step and parallel computing techniques. Scour around a submerged wall mounted vertical circular cylinder is simulated. The effect of the cylinder height on the scour is investigated.

KEY WORDS: *local scour; circular cylinder; subsea structure; Navier-Stokes equations; turbulence*

INTRODUCTION

When a subsea structure (such as subsea caisson, pipeline, vertical pile, etc.) is placed on the sandy sea bed, scour may happen because the existence of the structure increases the sediment transport rates locally around the structure. Local scour around subsea structures is one of the key factors that affect the structures' stability. Most of resent studies on local scour concerned with local scour below a pipeline. Local scour below a pipeline was often approximated by a two-dimensional model (Brørs, 1999; Liang et al., 2005).

Flow and scour around a vertical pile is fully three-dimensional. Investigations showed that the horseshoe vortex, the streamline contraction and the vortex shedding are the main reasons that lead to the scour around a vertical pile (Sumer and Fredsøe, 2002, Roulund et al., 2005). To simulate the scour around a vertical pile, three-dimensional models must be applied. Some numerical investigations have been carried out to simulate flow and local scour around a vertical pile (Olsen and Kjellesvig, 1998; Tseng et al., 2000; Roulund et al., 2005). Most of previous numerical models for scour calculation only considered the bed load sediment transport rate (Olsen and Kjellesivg, 1998; Roulund et al., 2005). It is speculated that the model without the suspended load sediment transport would underestimate the scour depth and scour rate under severe environmental conditions. This is because the dominant sediment transport mode under severe environmental conditions is the suspended load sediment transport.

In practical engineering, the subsea structures (such as subsea caisson, gravity anchor, foundation of the platform etc.) are widely used. The investigation of the scour around a submerged structure is rare compared with that on the vertical surface-piercing pile. In this paper, a three-dimensional model is developed for simulating the local scour around a subsea structure. The flow model is based on the Reynold-averaged Navier-Stokes equations with a k-ω turbulence closure. Both bed load and suspended load sediment transport rates are included in the model. The governing equations are solved by a finite element method. The streamline upwind scheme is employed to ensure the stabilization of the model. A parallel program code based on Message Passing Interface (MPI) is developed. Scour around a submerged wall-mounted vertical circular cylinder is simulated and the effect of the cylinder height on the scour is studied.

FLOW MODEL

The governing equations for flow calculation are the Reynold-Averaged Navier-Stokes (RANS) equations. In the simulation of the scour, the bed level changes during the calculation. The governing equations are solved in a moving mesh. Once the bed level is updated after each morphological time step, the nodes of