The Numerical Simulation of Local Scour around Offshore Pipeline

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ABSTRACT

The pipelines buried in soil may become span when they are scoured by current, which may lead to the pipeline failures. Therefore it is of important interest to study the scour around an offshore pipeline exposed to current. In this paper, a vertical two-dimensional numerical model for local scour beneath an offshore pipeline exposed to current is developed. The flow field around the pipeline is simulated by solving the Reynolds-averaged Navier-Stokes equations with k-ε turbulence closure. Both suspended and bed load sediment transports are considered in the scour model. The analysis of flow field and simulation of scour is validated by several examples. And the relationship between the scour depth and some factors is studied by numerical simulation. These studies can be used to guide the safety maintenance of pipelines.

KEY WORDS: offshore pipeline; flow field; local scour; numerical simulation; span; the Reynolds-averaged Navier-Stokes equations with k – ε turbulence closure; scour depth.

INTRODUCTION

The offshore pipeline is the key technique for offshore oil development, so it is called the “lifeline” for offshore oil engineering. The pipelines buried in mud or sand in shallow sea may become span when they are scoured by current (Yan, 1999, Wang, 2004, Hu, 2005), and if the length of span of pipeline is too large, the pipeline maybe fail because of strength, buckling and fatigue damage, therefore there is great engineering significance to study the scour of offshore pipeline. Now the method of studying the scour of offshore pipeline include the experiment, theoretical analysis and numerical simulation, and the main method is the experiment study. The experiment has numerous advantages, however it also has some drawbacks, such as high cost, time consuming, the limit of simulation condition, etc, and the numerical simulation method has been becoming an important method of the scour study of offshore pipeline (Han, 2007). In scour simulation, the solution of flow field has a great influence to the result of scour simulation. There are two kinds of method of simulation for flow field, one is the potential flow model (Chao, 1972) which is easy to solve, convenient for application, and can predict the biggest height of scour, however which can not well simulate the scour profile at the downstream of pipeline. The other method is the turbulence model (Brors, 1999, Lin, 2005, Liang, 2005) which is solved by using the complicated method and has increased computational cost, however which can simulate the vortex shedding at the downstream of pipeline, so it can well simulate the shape of seabed at the downstream of pipeline (Sumer, 1988).

In the literature (Einstein, 1950, Engelund, 1976) the sediment transport is divided into two types, the transport of suspended sediment and the transport of bed load. The bed load is thin sand near the seabed, which does not leave the seabed while moving; the suspended sediment can distribute to the whole flow field because of convection and diffusion. In the early numerical simulation of scour, the transport of suspended sediment is usually not considered, for example, in 1976 Leeuwestein give a sediment transport model in which the suspended sediment transport is not considered. As development of numerical simulation technology, the transport of suspended sediment is beginning to be considered too, such as literature (Van Beek, 1990, Brors, 1999, Liang, 2005a, Liang, 2005b).

Based on the current study situation, in this paper the k – ε turbulence model is used to simulate the flow field, and the transports of the suspended sediment and the bed load are used to simulate the movement of sediment.

MATHEMATICAL MODELS

This part gives the flow field model, sediment transport model and scour model.

Flow Model

The Reynolds-averaged Navier-Stokes equations with k – ε turbulence closure

The Reynolds-averaged Navier-Stokes equations with k – ε turbulence closure is composed of Reynolds time-average equations, continuity equation and k – ε equations. In the 2D Cartesian coordinate system the Reynolds time average equations are: