TWO-PHASE FLOW SIMULATIONS OF SCOUR AROUND VERTICAL AND HORIZONTAL CYLINDERS

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INTRODUCTION

Scour around structures is a major engineering issue that requires a detailed description of the flow field as well as sediment transport processes. Due to enhanced suspended load associated with vortices generated around structures, sediment transport cannot be solely related to bed shear stress, such as Shields parameter based formula. In order to address this issue, we used a multi-dimensional two-phase flow solver, sedFoam-2.0 (Chauchat et al., GMD 2017) implemented under the open-source CFD toolbox OpenFOAM. Three configurations are studied and compared with experimental and numerical data from the literature. First, the 2D configurations of an horizontal cylinder lying on a sediment bed (Mao, 1986; Sumer et al., 2001) are investigated. Then, the 3D configuration of the scour around a vertical cylindrical pile reported by Roulund et al. (2005) for rigid-bed and live bed cases is investigated.

NUMERICAL MODEL

For all configurations, the revisited k-omega model from Wilcox (2008) is used for the turbulent stress and the granular rheology μ(I) is used for the granular stress.

RESULTS

The process of scour under a pipeline is usually decomposed into three stages (Sumer et al., 2001): the onset, corresponding to the formation of small gap underneath the pipe; the tunneling stage during which the channel formed below the pipe is enlarged and sediment is transported downstream under the accelerated flow; the lee-wake erosion in which the vortices triggered by the cylinder contribute to further transport sediment in the downstream direction. We demonstrate that the two-phase flow model is able to reproduce almost quantitatively the onset of scour. Figure 1 shows the comparison of the bed elevation at t=90s between the two-phase flow model and Mao's (1986) experiment. This result shows that the tunneling stage is well reproduced by the two-phase flow model. Using the revisited k-omega model from Wilcox (2008) we are able to reproduce the vortex shedding downstream the pipe and the lee-wake erosion stage.

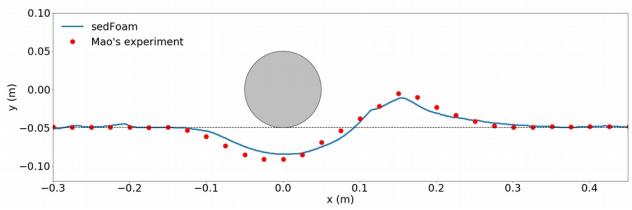

Figure 1 - Comparison of the scour under an horizontal cylinder between sedFoam and Mao (1986) experimental results 90s after the onset of the experiment.

For the 3D configuration, the hydrodynamic has been validated on the rigid-bed case (Nagel et al. (2017)). A typical snapshot of the live-bed simulation at t=300s of dynamics is presented in figure 2. It shows the vertical elevation of the iso-surface of sediment concentration α = 0.57, a proxy for the quasi static bed elevation. The numerical simulation is further compared with Roulund et al. (2005) results for the dimensionless scour depth upstream and downstream the pile. The two-phase flow model is able to reproduce almost quantitatively the scour mark development.

Beyond the applications presented here, this contribution is a proof of concept that two-phase flow numerical simulations are now possible for complex flow configurations. Beyond the proof, the analysis of the numerical simulation results in term of dimensionless sediment transport flux versus Shields parameter allows to get more insight into the fine scale sediment transport mechanisms involved in the scour process.

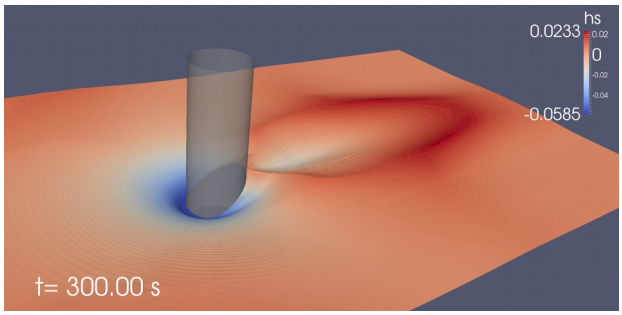

Figure 2 - Bed elevation after 300s of dynamics.

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