Offshore & Dredging Engineering

Technische Universiteit Delft

Numerical modelling of sedimentation in Trailing Suction Hopper Dredgers

Damen Dredging Equipment is a yard dedicated to the dredging industry. One of the ships Damen offers is the Trailing Suction Hopper Dredger (TSHD). The performance of such a TSHD is measured in terms of the production: the amount of sediment loaded in the hopper per unit time. The overflow loss, the material lost overboard, can easily reach up to 30%, which causes a significant decrease of the production. In addition, the turbidity plume caused by these overflow losses can have a negative environmental impact.

Damen is interested in estimating and reducing these overflow losses. Different models to estimate the amount of material lost overboard exist. All these models have their pros and cons. The analytical model of Miedema & Vlasblom(1996) gives a quick and good estimate of the overflow losses, but gives no insight in the flow inside the hopper. The 2DV model of Van Rhee(2002) is able to accurately simulate the flow inside the hopper, but has a large computation time. The 2DV model developed in this thesis provides a good estimate of the overflow losses, gives insight in the flow inside the hopper, and has an acceptable computation time. Due to parallel computation, it is even possible to do 3D simulations of detailed hopper geometries with different in- and overflow configurations.

The new 2DV model was developed in OpenFOAM. At the start of this thesis, it was possible to model mixture flow in OpenFOAM. The sand bed that develops as a result of sedimentation could not be modelled yet. Several features had to be added to OpenFOAM to overcome this problem. The sand bed was regarded as a solid body inside the computational domain. The bed was fixated by the Volume Penalization Method of Angot(1999) and sedimentation was modelled by adding a moving mesh. Appropriate boundary conditions were applied at the bed interface for the momentum and turbulence balance. The conservation of mass is satisfactory, since the error is less than 0.1% for the loading of a hopper.

The closed flume experiments of Van Rhee(2002) have been used to validate that sedimentation is simulated accurately. By comparing hopper simulations with the hopper experiments of Van Rhee(2002), it was shown that the flow in the hopper was also simulated accurately. The computed overflow losses are, however, slightly underpredicted. The current version of OpenFOAM can calculate with only one particle fraction. In reality, the smaller fractions of the Particle Size Distribution are pushed upwards, causing the overflow losses to be higher.

The 2DV model gave a deeper insight to the phenomena in the hopper. It was possible to derive several equations which describe the flow in the hopper. With these newly derived formulas, a simple phenomenological model was developed. In this model, the hopper is divided in two perfectly mixed layers. By calculating the vertical movement of these layers, the results of the 2DV model could be reproduced.

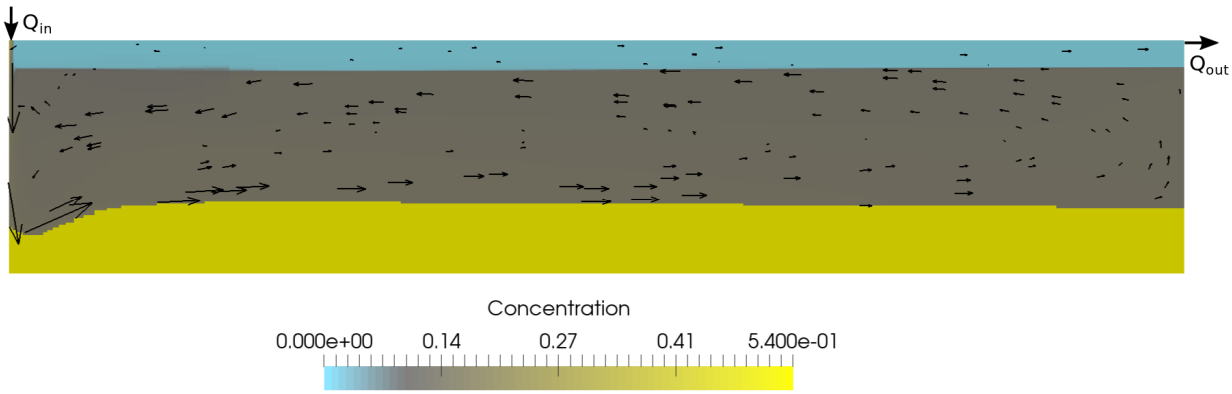

Figure 1: Concentration and velocity simulated with the 2DV model

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