Numerical Model of Sediment Transport in Free Surface Flow

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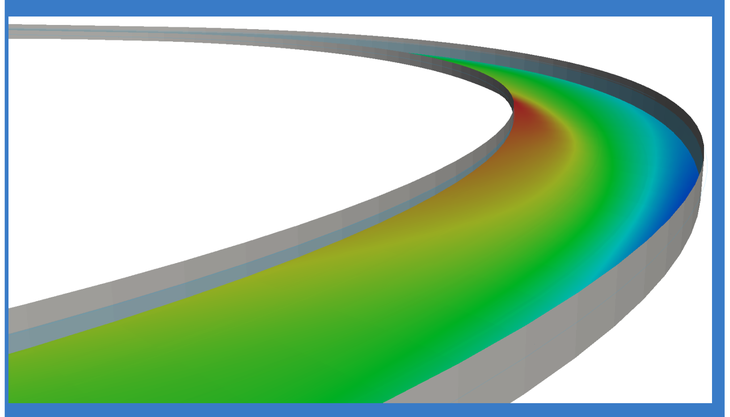


ABSTRACT

A 3D numerical model for simulation of free surface flow and sediment transport with sand bed deformation is presented in this study.

The flow solver is based on the Ghost Fluid Method finite volume solver `gfmFoam`, which will be incorporated in the next release of `foam-extend` package.

The sediment module incorporates suspended load and bed-load transport, with sand bed elevation evaluated using the Exner equation. Deformation of sand bed due to sediment deposition and scour is performed by the automatic mesh motion solver.

Validation of the model is carried out on a 140° channel test cases with movable sand bed.

Introduction

Simulation of flow and sediment transport in channels, rivers and shallow seas is a challenging, but important problem due to the impact of sediment erosion and deposition on river beds, sea beds and marine objects. Coupling between the fluid flow and sediment transport is required in order to achieve satisfying results. This includes accurate predictions of the flow and free surface waves, realistic shear stress values, correct suspended and bed-load sediment transport calculations with stable bed motion capabilities.

Mathematical Model

Suspended load transport of sediment is modelled by the convection-diffusion equation:

$$\frac{\partial c}{\partial t} + \nabla\bullet\left(\mathbf{U} - v_s\frac{\mathbf{g}}{|\mathbf{g}|}\right)c = \nabla\bullet(\nu_t\nabla c) \ ,$$

where c is the sediment concentration, v_s is the sediment fall velocity and ν_t is sediment diffusivity.

Bed-load transport is modelled by an explicit expression and discretised using the Finite Area Method (FAM):

$$\mathbf{q}_b = q_0\frac{\tau_b}{|\tau_b|} - C|q_0|\cdot\nabla_s\eta \ , \qquad (1)$$

where τ_b is the bed shear stress vector, C is a constant (1.5 - 2.3), ∇_s is a surface gradient and η is bed elevation.

Bed elevation η is evaluated using the Exner equation (FAM):

$$\frac{\partial\eta}{\partial t} = \frac{1}{1-n}\left[\nabla\bullet\mathbf{q}_b + D - E\right] \qquad (2)$$

Bed-load transport vector is directly coupled with the Exner equation.

Flow and Sediment Transport in a 140° Channel With a Mobile Bed

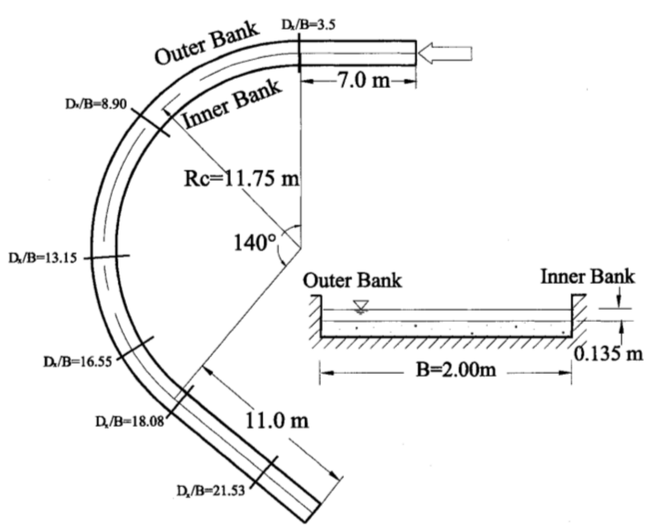
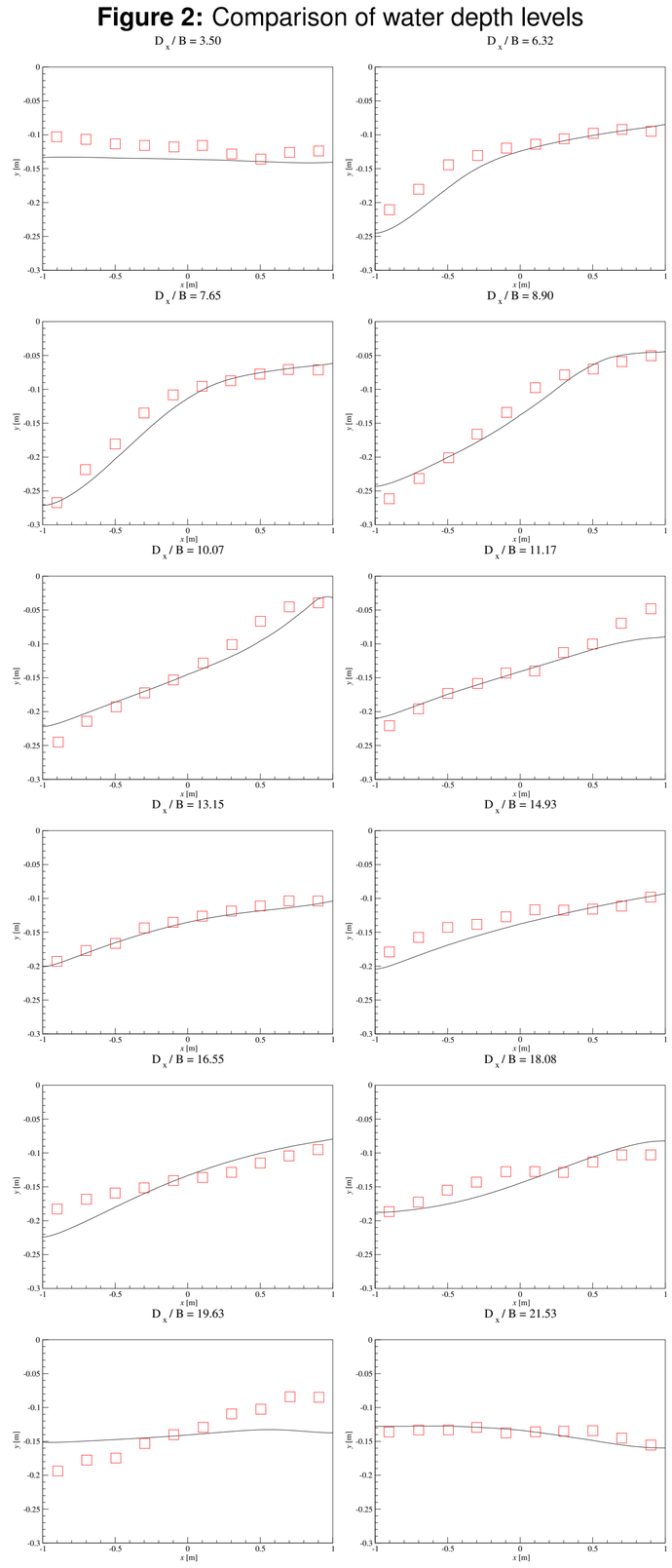


Figure 1: Experimental set-up of a 140° channel

Flow and sediment transport in a 140° channel is simulated. The channel is covered with a 30 cm sand layer, where suspended transport, bed-load transport and bed deformation occur simultaneously. Bed depth measurements performed by *Olesen (1985)* are used for validation. The case is considered steady-state, since the experiment reaches equilibrium conditions. Comparison between the simulated and measured water depth levels at various sections of the curved channel are shown.

Figure 2: Comparison of water depth levels



Conclusion

Numerical model for simulation of free surface flow and sediment transport was presented here. Results from a curved channel simulation show very good agreement with the experimental data in most sections, which can be further improved with a better definition of inlet and outlet flow boundary conditions. Further validation is required.

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Zagreb, 2017

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