Numerical modelling of impulse wave forces on dams

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Abstract

Large impulse waves are generated in reservoirs by, e.g., landslides and iceberg calving. Impulse waves result in significant forces when impacting dams and it is important to take these forces into account when designing a dam. The prediction of forces due to extreme waves is still subject to large uncertainties. Analytical models are available for wind waves, while empirical equations, relying on a limited number of experiments, are employed for more extreme waves. These equations are validated in the present study through numerical modelling with the open source toolbox solids4foam in foam-extend. The model is successfully validated with available laboratory measurements and an analytical model for two experiments. A computational example is presented for a hypothetical, yet realistic, case, revealing a good agreement between the numerical results and predictions based on an existing empirical equation.

Keywords: foam-extend, impulse wave forces, long waves, numerical modelling, wave-structure interaction.

1 Methodology

solids4foam (Cardiff et al., 2018) in foam-extend 4.0 was used in the present study to model impulse waves impacting dams (Fig. 1). This toolbox solves fluid-solid interaction problems with a Finite Volume discretisation. The fluid and solid domains are separately solved and coupled through a partitioned approach.

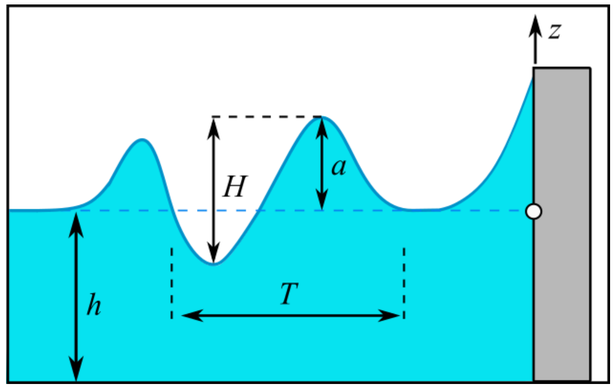

Figure 1: Sketch of waves impacting a dam.

2 Results

The numerical model was validated with experiments of Mallayachari and Sundar (1995) and the analytical solution of Tadjbakhsh and Keller (1960). The wave pressure $p/(\rho g H)$ is compared with experiments and the analytical model for two tests at water depth h = 0.315 m with wave height H = 0.023 m and period T = 0.950 s (Fig. 2a) and H = 0.048 m and T = 0.873 s (Fig. 2b). In both cases an excellent agreement was achieved (Fig. 2).

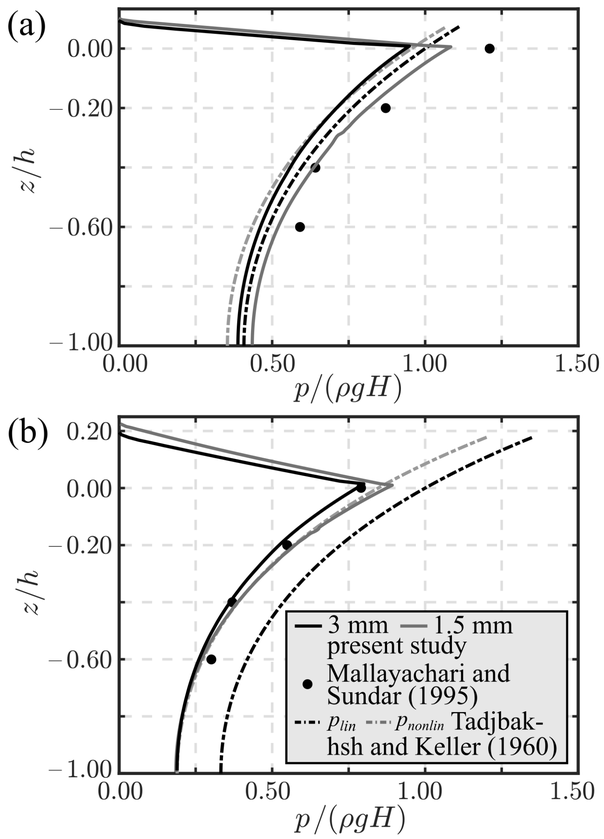

Figure 2: Comparison of the numerical pressure $p/(\rho g H)$ with Mallayachari and Sundar (1995) and Tadjbakhsh and Keller (1960) for two tests.

The numerical model was used to estimate the force F on a 50 m high dam due to a solitary wave with a wave amplitude relative to the water depth of a/h = 0.38. $F = 8.01 \cdot 10^6$ N/m resulted from the simulation, showing a deviation of only 3.6% with a prediction from Heller et al. (2009).

3 Conclusions

- An available numerical model was used to investigate impulse wave forces on dams;
- The numerical model was successfully validated with available laboratory measurements and an analytical model;
- Impulse waves impacting dams may generate significant additional forces to the hydrostatic force;
- A hypothetical case was simulated, showing an excellent agreement with a prediction based on Heller et al. (2009);
- A detailed numerical investigation of impulse waves impacting dams will be conducted to support impulse wave hazard assessment in reservoirs.

References

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