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Application of the SPH method in turbulent free-surface flow for simulation of debris accumulation during flood events

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Flood events represent a recurring natural hazard requiring accurate prediction of hydrodynamic forces on structures and debris accumulation patterns. This master thesis evaluates the capability of the Smoothed Particle Hydrodynamics (SPH) method, specifically through the SPlisHSPlasH software implementation, to simulate three-dimensional turbulent free-surface flows with dynamic rigid bodies.

The methodology employs a systematic validation approach through progressively complex configurations. First, turbulent flow behaviour is isolated and analysed in a two-dimensional pipe configuration with Reynolds number $Re = 1.7 \times 10^7$, where the numerical velocity profile correctly fits the analytical solution derived from Generalized Hydraulic Equations. Subsequently, free-surface flow characteristics are examined through a horizontal channel with Reynolds number $Re = 1.8 \times 10^5$ and a parabolic obstacle, correctly capturing hydraulic jump phenomena and head loss distributions despite local pressure instabilities inherent to the SPH formulation.

The final validation integrates both phenomena in a laboratory-scale bridge configuration with $Re = 1.5 \times 10^4$ and with seven floating wood logs. The simulation successfully reproduces obstacle formation at the bridge entrance, with distinct behaviours observed between pressurized and free-surface flow conditions. Quantitative analysis reveals accurate head loss predictions and flow distribution patterns, though with the requirement that particle size remains below one-fifth of the rigid body characteristic dimension to ensure numerical stability.

While certain limitations exist, particularly concerning local pressure calculations and the necessity for manual tuning of physical parameters, this study demonstrates that SPlisHSPlasH can effectively simulate complex hydraulic phenomena relevant to flood engineering applications. The continuous development of the software and capability to handle coupled fluid-structure interactions yield it as a valuable tool for hydraulic engineering analyses, encouraging more systematic adoption in the field.