VALIDATION OF PLUNGING BREAKING WAVE CFD PREDICTIONS

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Key words: Plunging Breaking Waves, Coupled level-set VoF.

Summary. The predictive capability of volume-of-fluid (VoF) and coupled level-set/VoF (CLVoF) interface capturing schemes are compared for breaking wave simulations. Preliminary results demonstrate that CLVoF schemes predict the breaking wave plunger better than VoF, whereas the latter is more dissipative.

1 INTRODUCTION

Breaking waves are classified as: plunging, spilling, surging, and collapsing. Plunging breaking is characterized by the wave forming a tube-like feature that spills onto the forward face of the wave. This spilling of the crest onto the forward face causes a violent crash and large amounts of turbulence during breaking. For fording vehicles, which are of interest to the authors, such breaking waves can results in excessing loading and results in loss of traction.

The objective of this research is to validate the predictive capability of CFD models and solvers in predicting plunging breaking waves, as a mean to assess their capability as a vehicle fording analysis tool. This research builds on the previous work of Chambers and Bhushan1 focused on simulations of solitary wave run up on a 1:15 slope using OpenFOAM. They performed simulations for several solitary wave heights ($H_0$) varying from $H_0/h_0 = 0.06$ to 0.6, where $h_0$ is the initial water depth, and the predictions were compared with experimental data2 and potential flow results3. They reported good wave decay predictions in the surging regime, i.e., $H_0/h_0 < 0.37$. For the plunging breaking wave regime, $H_0/h_0 > 0.4$, the wave breaking pattern was predicted well (Fig. 1). However the peak wave height at the plunge was under predicted, which was attributed to the numerical dissipation associated with volume-of-fluid (VoF) interface capturing scheme. Herein, the above research is extended using a ‘computational methods and simulation toolkit’ Proteus, which provides coupled level-set/VoF (CLVoF) interface capturing scheme. The solver is applied for dam break cases with and without obstacle and solitary wave run-up, and the results are compared with OpenFOAM predictions, and available experimental data and numerical predictions4,5.

2 RESULTS

Dam break case without obstacle is performed for initial water height if 0.6m. As the water column collapses the leading edge of the flow makes its way toward the right side of the tank. The water reaches the right wall of the tank at 0.6 seconds and the momentum of the flow carries the water up the tank wall. At 1 second the water reaches its maximum height and starts to fall back on itself, forming a sharp plunder. The plunger collides with the fluid at the bottom at 0.6 seconds, forming a pocket of air. It also generates a secondary plunger moving towards the left, while the bottom layer of the fluid is still moving to the right (Fig. 2). The secondary plunger collides with the fluid at 2.4
seconds, and the flow becomes increasingly chaotic thereafter. Both OpenFOAM and Proteus show similar flow pattern, however the latter provides a more defined air pocket and plunging breaking.

3 CONCLUSIONS

The ongoing research focuses on validation of CFD predictive capability for plunging breaking waves, which are of interest for fording vehicle. The study compares the OpenFOAM and Proteus predictions for dam break and solitary wave run-up cases, and the effect of VoF and CLVOF interface capturing schemes are discussed. Dam break case demonstrate that the breaking wave plunger is better defined in CLVOF scheme compared to that in VoF. The solitary breaking case is in progress. The final version of the paper will compare CLVOF and VoF scheme predictions, including an analysis of turbulence characteristics at air-water interface.

Figure 1. Comparison of OpenFOAM wave shape predictions (blue line) for plunging breaking wave with $H_0/h_0 = 0.45$ with potential flow results (red triangles) and experimental data (black rectangles).

Figure 2: Comparison of Proteus (left) and OpenFOAM (right) predictions for dam break case at $t = 0.15s$.

REFERENCES

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