A Numerical Study on the Accuracy of Nonlinear Wave Generation and Wave-Current Coupling in OpenFOAM

孫, 浩東
九州大学大学院総合理工学府総合理工学専攻機械・システム理工学メジャー

https://hdl.handle.net/2324/7431334

出版情報：九州大学, 2025, 修士, 修士
バージョン：
権利関係：

A Numerical Study on the Accuracy of Nonlinear Wave Generation and Wave-Current Coupling in OpenFOAM

SUN HAODONG

1 Background introduction

Tension Leg Platform (TLP), is a type of floating platform gaining its popularity in marine engineering in recent years, featured in its high vertical stability (Roll, Pitch, Heave), been moored through a tension mooring system that anchors it to the seabed. However, this structure has a relevantly lower stability in the horizontal direction, typically under the influence of waves and currents, the motion amplitudes of Surge, Sway, Roll, and Pitch might increase significantly. As a result, precisely generate the waves and reproduce wave-current coupling phenomena are significant for the design of TLP.

2 Research targets

This study focuses on the verification of nonlinear wave generation in OpenFOAM and the development of two solvers - stokesSecondwCurrent and overWaveDyMFoam within the framework of waves2Foam, aiming to extend the function of waves2Foam by adding these two solvers to the program and providing guidelines on wave generation as well as wave-current coupling reproduction for the engineering design of TLP. This research consist of three parts - wave generation, development of wave-current coupling solver and development of overset-mesh-based 6DOF motion solver.

3 Wave generation using waves2Foam

The feasibility and numerical accuracy of nonlinear wave generation using OpenFOAM and waves2Foam are systematically investigated. To validate the feasibility of these programs, simulations are conducted to generate identical waves using various wave models in both OpenFOAM and waves2Foam across multiple mesh resolutions. The accuracy performance of these wave models are evaluated and the model exhibiting the highest accuracy is selected for further study of its generality by generating wave with different parameters, including some extreme wave conditions. With the use of this model, a case which contains a 2D fixed floating body is simulated to confirm whether this model is capable of precisely forecasting hydrodynamic loads on marine structures. Subsequently, a study on improving numerical accuracy of nonlinear wave generation on relevantly coarser meshes is implemented, aiming to provide a guideline for achieving cost-effective numerical prediction for engineering application.

4 Development of wave-current coupling solver

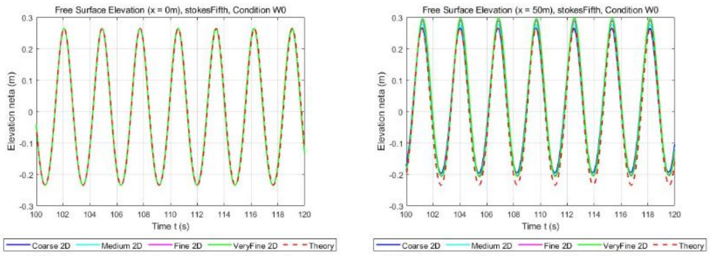
A user-defined wave-current coupling solver stokesSecondwCurrent is develop and its feasibility, accuracy performance and generality are evaluated. The solver is developed on the basis of Stokes nonlinear wave theory and be verified by comparing the numerical predication with theoretical values. The accuracy performance of the solver is subsequently investigated under multiple mesh resolutions and wave conditions, obtaining a guidelines for achieving high accuracy in terms of mesh requirements and the applicability of the solver. After that, the capability of the solver to accurately predict hydrodynamic loads on a floating body is validated by comparing the numerical results with benchmark experimental data. Finally, in order to seize cost-effective numerical results about wave-current interaction using the solver in practical engineering applications, this study also explores approaches to improve computational accuracy on relevantly coarser meshes.

5 Development of overset-mesh-based 6DOF motion solver

An overset-mesh-based 6DOF motion solver overWaveDyMFoam is developed and verified. The solver is created by combing the relaxation zone related code of waves2Foam with the source code of overInterDyMFoam, an application in OpenFOAM to conduct simulation based on overset mesh. By using this solver, the dynamic response of a 2D cubic-shaped free floating structure under wave loads is analyzed and be compared with the experimental data of a benchmark, validating the correctness and feasibility of the solver overWaveDyMFoam.

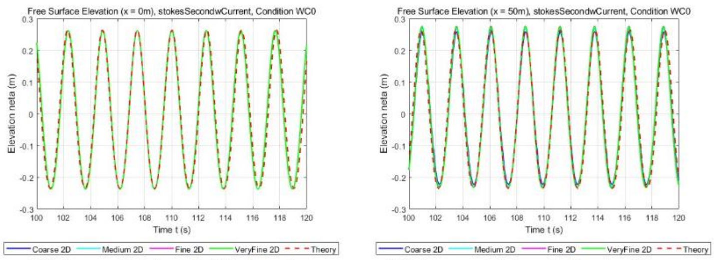
6 Conclusion

This research verifies the feasibility of generate large or even extreme nonlinear wave by waves2Foam and develops two solvers to address the lacks of the program - no built-in solver for wave-current interaction and does not support overset-mesh-based simulations. Practical recommendations for nonlinear wave generation using waves2Foam are provided, detailing the requirements for mesh resolution, computational domain configuration, and discretization schemes for physical variables. Moreover, through the symmetrical investigation on the stokesSecondwCurrent and overWaveDyMFoam solvers, the feasibility of them are verified and guidelines detailing their generality, suggested mesh resolutions and recommended numerical settings are also provided.



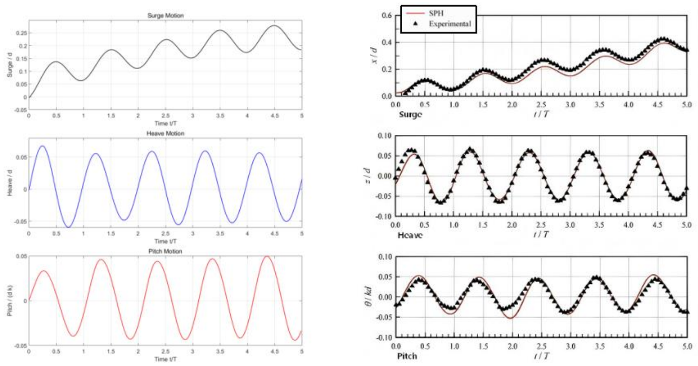
(a) The wave height at the inlet boundary (b) The wave height at the location 50 meters downstream from the inlet boundary

[Figure 1] The comparison on wave height between numerical results given by stokesFifth



(a) The wave height at the inlet boundary (b) The wave height at the location 50 meters downstream from the inlet boundary

[Figure 2] The comparison on wave height between numerical results given by stokesSecondwCurrent in waves2Foam and theoretical values



(a) The dynamic response of the floating body this research obtained (b) The dynamic response of the floating body given by the benchmark

[Figure 3] The dynamic response of the 2D cubic-shaped floating body in waves