Editorial

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This themed issue is the second of two that report on the CCP-WSI Blind Test Series 2, which is a study carried out as part of the Collaborative Computational Project on Wave Structure Interaction (CCP-WSI), funded by the Engineering and Physical Sciences Research Council (EPSRC) (Greaves *et al.*, 2015; CCP-WSI, 2020a, 2020b). Complex wave structure interaction (WSI) challenges are significant in the offshore renewable energy sector and in the protection of coastal communities, both of which are strategic priorities for the UK. Established in 2015, the CCP-WSI's overarching aim is to build a community of researchers and developers, and to provide a focus for software development and code rationalisation with applications in these UK priority areas. In doing so, the CCP-WSI provides strategic leadership for the WSI community, and generates impact through strategy-setting, knowledge transfer, and the development of strategic software and its support.

Numerical modelling is an important component of the toolset for designers and developers of machines and structures, operating in the marine environment and undergoing interaction with water waves. A wide range of numerical models are available to designers with the well-known trade-off between computational efficiency and model complexity being the main driver when selecting a particular tool for the scenario under investigation. Despite this, there remains considerable uncertainty over the required level of model fidelity needed to simulate the interaction of waves with offshore and coastal structures.

The CCP-WSI Blind Test Series' have been devised to provide a better understanding of this issue and to inform future development of numerical modelling standards. The blind tests encompass an assessment of the applicability and variability in use of different numerical codes used for WSI simulations with recommendations for their use in design. Published and promoted through the CCP-WSI website (CCP-WSI, 2020a) and network, numerical modellers are invited to use their numerical codes to simulate a series of specific WSI problems covering a wide range of relevant complexities. The specific

WSI cases relate to a set of bespoke experiments, which participants are invited to reproduce numerically without prior access to the physical measurements.

Presented in this two-part themed issue are the research contributions of the participants in the CCP-WSI Blind Test Series 2. This test series, shared as CCP-WSI Test Case 4 in the data repository (CCP-WSI, 2020b), is freely available as a long term data set for benchmarking of codes. It involves two different floating, surface-piercing structures (moored with a simple linear spring mooring) representing simplified wave energy convertors (WECs). The two geometries are: 1) a hemispherical-bottomed cylinder, and 2) a cylinder with a moon-pool, thus increasing the complexity in the latter case by introducing an 'internal' body of water. Each structure is individually subjected to the same set of incident wave cases consisting of 3 focused wave events with a range of steepness. The steepness of the waves is varied parametrically by altering the peak frequency (whilst maintaining the same crest height). These experiments may be used to assess the accuracy of the numerical methods in predicting the motion of the buoy and the load in the mooring line for cases of increasing complexity in wave steepness and float geometry.

In each experiment, the six degrees of freedom (6DoF) motion of the buoy is recorded as well as the load in the single point, linear mooring line. The free surface elevation in the vicinity of the buoy is also recorded by an array of resistive wave gauges. Participants in the blind test were invited to simulate the cases and then share their predictions of the 6DoF motions and mooring line load. A total of 30 volunteers took part in the CCP-WSI Blind Test Series 2, with international participation from 13 institutions. Eleven submissions were received in which a wide range of different solvers were used, including linear potential theory (LPT) and Navier-Stokes (NS) solvers in open-source, commercial and in-house codes, and covering hybrid (coupled) methods, partial-particle methods, finite element methods (FEM), finite difference

methods (FDM) and finite volume methods (FVM). Results from each of the participants in the study are shared and presented together in the Blind Test comparative paper (Ransley *et al.*, 2021), featured in this issue.

In the first part of the two-part themed issue on the CCP-WSI Blind Test Series 2, four contributions were presented, each taking a different numerical modelling approach to numerical simulation of the test cases. In this CCP-WSI Blind Test Series 2 themed issue Part II, three contributions are presented, together with the comparative paper for the Blind Test Series.

The first paper in this issue, (Brown *et al.*, 2021), uses a VOF scheme to solve the two-phase, incompressible, RANS equations, based on OpenFOAM (v5-0). The body motion is accommodated using dynamic mesh deformation, and the wave boundary condition is provided using the waves2Foam toolbox, and a relaxation zone is used to absorb the waves. Linear superposition of wave components, derived using an FFT of the surface elevation at a wave probe in the wave-only test, is used to generate the incident waves by way of an expression-based boundary condition. Test case simulations found that the accuracy of the heave predictions is high and similar to that achieved in reproduction of the waves without the structures present, but the accuracy of predictions for surge and pitch is lower. However, simulations conducted using a different mesh layout and turbulence model show substantial improvement in the predictions of surge.

In the second paper, Lin *et al.*, (2021) solve the two phase, incompressible, NS equations using a VOF scheme using OpenFOAM (v1706). Overset meshing is used to accommodate body motion and wave generation and absorption uses IHFOAM, incident waves generated are with second-order irregular wave theory, and components derived from the given theoretical spectrum. It is found that the maximum amplitude and period of heave, pitch and mooring force are predicted well, while the surge and pitch motion is predicted less well. The predicted motion response of the floating bodies are highly sensitive to the accuracy of the numerical wave reproduction. The instantaneous centre of rotation during wave-structure interaction in some cases was found to differ from the centre of mass, and this is suggested as a possible explanation for the differences in pitch motion between the numerical prediction and experimental measurements.

The third paper (van Rij *et al.*, 2021) describes a method utilising the commercial software STARCCM+ v13-02 (Siemens, 2019). The method solves an implicit, unsteady, 3D, RANS equations using the Eulerian multiphase VOF method for the free surface, and a dynamic fluid body interaction overset method. Wave are generated using an expression-based

boundary condition with 244 linearly superimposed wave frequencies derived from the theoretical wave descriptions. The STAR-CCM+ generated focused waves were found to predict the experimentally generated focused waves well and the motion responses are within 14.2% of the experimentally measured responses. It was also shown that, with a user-field function to concurrently model both wave forcing at the tank inlet and wave damping at the outlet, and systematic grid resolution and convergence studies, it was possible to reduce the computational grid size and cpu requirements significantly compared with previous work.

The final paper in this issue (Ransley *et al.* 2021) presents a thorough comparison of the different contributions taking part in the CCP-WSI Blind Test Series 2. Eleven different numerical methods are used in contributions to the test, ranging from those based on LPT to NS solvers, including mesh-based and partial-particle methods, in-house, open source and commercial codes as well as hybrid/coupled models. A quantitative analysis of the predictions made by the participants is presented. It was shown that, even with access to the physical data, significant differences were found in the quality of incident wave reproduction in the wave tank without structures present. This has direct impact on the ability to reproduce motion responses of the floating structure, as the accuracy of the predicted structural response appears to correlate with that of the incident wave reproduction, particularly in the case of heave motion.

Recommendations are given for analysis of test case contributions and comparisons and a discussion of different approaches available. A relatively smooth trade-off is observed between accuracy and efficiency in the numerical implementations investigated, and this is particularly evident for surge and pitch motion predictions. However, for the contributions using NS solvers, the range of computational resource utilised is very large and it is observed that providing best practice guidelines in this area would add considerable value to the WSI community.

REFERENCES

- Brown SA, Ransley EJ and Greaves DM (2021) Assessing focused wave impacts on floating wave energy converters using OpenFOAM. *Proceedings of the Institution of Civil Engineers – Engineering and Computational Mechanics* **174**(1): 4–18, <https://doi.org/10.1680/jencm.19.00036>.
- CCP-WSI - A Collaborative Computational Project in Wave Structure Interaction (2020a) <https://www.ccp-wsi.ac.uk/> (accessed 28/09/20).
- CCP-WSI - A Collaborative Computational Project in Wave Structure Interaction (2020b) http://www.ccp-wsi.ac.uk/data_repository/test_cases/test_case_004 (accessed 28/09/20).
- Greaves D, Mingham C, Zang J *et al.* (2015) A CCP on Wave/Structure Interaction: CCP-WSI, EP/M022382/. See <https://gow.epsrc.ukri.org/NGBOViewGrant.aspx?GrantRef=EP/M022382/1> (accessed 28/09/2020).

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- Lin Z, Chen H, Qian L et al. (2021) Simulating focused wave impacts on point absorber wave energy converters. *Proceedings of the Institution of Civil Engineers – Engineering and Computational Mechanics* **174(1)**: 19–31, <https://doi.org/10.1680/jencm.19.00038>.
- Ransley EJ, Brown SA, Hann M et al. (2021) Focused wave interactions with floating structures: a blind comparative study. *Proceedings of the Institution of Civil Engineers – Engineering and Computational Mechanics* **174(1)**: 46–61, <https://doi.org/10.1680/jencm.20.00006>.
- van Rij J, Yu YH and Tran TT (2021) Validation of simulated wave energy converter responses to focused waves. *Proceedings of the Institution of Civil Engineers – Engineering and Computational Mechanics* **174(1)**: 32–45, <https://doi.org/10.1680/jencm.19.00039>.