Editorial

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This themed issue is the first 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, which will feature in the second of the two themed issues.

In this themed issue on the CCP-WSI Blind Test Series 2 – part I, four contributions are presented, each taking a different numerical modelling approach to numerical simulation of the test cases:

- The first paper (Wang *et al.*, 2020) presents the use of a hybrid model, qaleFOAM, which combines the fully nonlinear potential theory (FNPT) model, QALEFEM, with the volume of fluid Navier Stokes (NS) equation solver from the open source code OpenFOAM, using a coupling boundary and domain decomposition method. Wave generation and absorption takes place in the FNPT domain, using self-adaptive wavemakers, and body motions are captured within the NS domain via mesh deformation. Results confirm the promising accuracy of the qaleFOAM in modelling both highly non-linear water waves and highly non-linear WSI problems with good convergence properties.
- A new model is proposed by (Giorgi, 2020) in which nonlinear kinematics and nonlinear Froude-Krylov force calculations are added to an LPT-based framework. A linear superposition of components, derived from surface elevation measurements provided for the wave-only tests and modified using Wheeler-stretching, is used to approximate the incident waves, which are assumed to propagate linearly. No viscous drag correction is included. The test case considers highly nonlinear wave conditions, represented by three steep focused waves, which are particularly challenging to model using potential theory-based mathematical models. Nevertheless, despite poor predictions of pitch/surge, the method shows good agreement in heave response and mooring load, and close to real-time computation.
- Numerical simulations presented by (Hughes *et al.*, 2020) use the wave energy code developed by the US National renewable energy laboratory (NREL), WEC-Sim. This open source code calculates the rigid body time-domain responses by solving the Cummins' equation with linear hydrodynamic coefficients, for each geometry, obtained using a frequency-domain, linear panel-method. Incident waves are derived from the instantaneous surface elevation and impulse response functions determined. The mooring is included as a linear spring and viscous drag coefficients approximated using a steady-state, single-phase,

NS solution or via empirical data. Nonlinear restoring or Froude-Krylov forces are not included. The authors report excellent agreement in prediction of some motions, but not all, possibly due to the highly non-linear WSI effects not being predicted by the linear model. Nevertheless, such linear models are shown to benefit from low computational expense when compared with other methods.

- A sensitivity analysis is presented in (Windt *et al.*, 2020) of the simulation of WSI using the open-source, FVM based code, OpenFOAM. This model solves the two-phase, incompressible, Reynolds-averaged NS equations via VOF interface capturing. Dynamic mesh-deformation accommodates the body motion. An impulse source method is used to generate the incident waves, with the source term determined via iterative calibration, and a numerical beach implementation is used for wave absorption. It is shown that the sensitivity to the quality of the surface elevation is significant for both WEC structures. The heave motion and mooring force are found to be less sensitive and the pitch is strongly sensitive to changes in system parameters. Overall, the study highlights the importance of accurate measurements of the physical system properties, including error margins.

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