Performance enhancement of the WaveTrain WEC through numerical optimisation

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Technical Background

The frequency response of Wave Energy Converters (WECs) that use purely the vertical (heave) component of wave motion, typically shows that they are too stiff and so their resonance period is too short compared to typical ocean waves. In contrast, a device moving in the horizontal (surge) direction has less restoring spring and so its resonance period is too long. It follows that a device moving at some intermediate slope angle could have an intermediate value of hydrodynamic stiffness and so be resonant at a more desirable part of the wave spectrum. However, tests on a more practical free-floating version of this concept - the Sloped IPS Buoy - showed that the performance reduced significantly and the bandwidth collapsed because the device started to pitch about the inclined plane.

This project is to investigate a proposed solution to the above problem - the 'WaveTrain' device, which was conceived and is being developed by Dr. Nick Wells of Joules E. E. S. Ltd. The current WaveTrain device consists of three Sloped IPS Buoy-type inclined-plane power modules, linked together by struts. Figure 1 below shows an experimental model of the WaveTrain device out of the water and prior to testing at the FloWave wave tank. Each power module is essentially an inclined body enclosing a water column, with a pneumatic turbine PTO system at the top. The power modules sit one behind each other relative to the wave direction and the struts have rotational (hinge) joints at each end. The idea behind this configuration is that the struts will allow free motion of the power modules in the inclined plane direction but will hinder motion normal to that. This should then mean that the large bandwidth power absorption of the constrained Sloped IPS buoy should also be seen for the WaveTrain device.

Last year Joules E. E. S. Ltd won funding from Wave Energy Scotland's Novel WEC programme to develop the WaveTrain device. Within the project, a multi-body time-domain numerical model of the WaveTrain device was developed at Edinburgh University by Dr. Jos van 't Hoff. The model uses WAMIT to obtain the frequency-domain hydrodynamic coefficients (added masses and added dampings etc.) and Matlab/Simulink/SimMechanics (see Figure 2) to convert the equations of motion into the time-domain. Also within the project, a series of wave tank experiments on model WaveTrain devices has taken place in Edinburgh University's Curved Tank and FloWave (see Figure 1) wave tanks. Preliminary validation of the numerical model has shown good results but there is a lot of fundamental work still to be done.

Methodology

The main aim of the project is to gain an in-depth understanding of how the device interacts hydrodynamically with the waves and with itself. With this fundamental understanding, the current non-optimal design of the power modules can be enhanced to improve power capture and/or reduce loads in the struts etc. Subsequently, the aim is to investigate the feasibility of changing the WEC geometry and other key parameters to optimise the power capture bandwidth.

The current array numerical model will be developed, again building up from that of the single isolated power module through the unlocking of certain locked degrees of freedom, the addition of sloshing in the water columns and the incorporation of various nonlinear hydrodynamic forces like the nonlinear Froude-Krylov forces. The accuracy of these improvements could be validated against the extensive existing experimental data.

Use of the resulting validated numerical code within an optimisation tool to find the best design (geometry, configuration and control) of the power modules to optimise the power capture of, and/or load reduction within, the WaveTrain device. Further aims include optimisation of the applied load and control characteristics using the pneumatic turbine PTO system to maximise mean annual power absorption.

There is a prospect of some additional tank test time to demonstrate experimentally the productivity enhancements developed through the numerical optimisation process.

Project Plan

Year 1: Understanding the complex hydrodynamics associated with inclined plane motion constraints and developing a working knowledge of the current time-domain numerical models. Identifying key geometry and mass ratio parameters and their influence on the system motions. Understanding the hydrostatic constraints associated with free-floating linked bodies.

Year 2: Develop enhanced numerical models and new parametric optimising routines.

Year 3: Evaluation of prototype system, refinement of the geometry and control parameters, estimation of possible power capture enhancements.

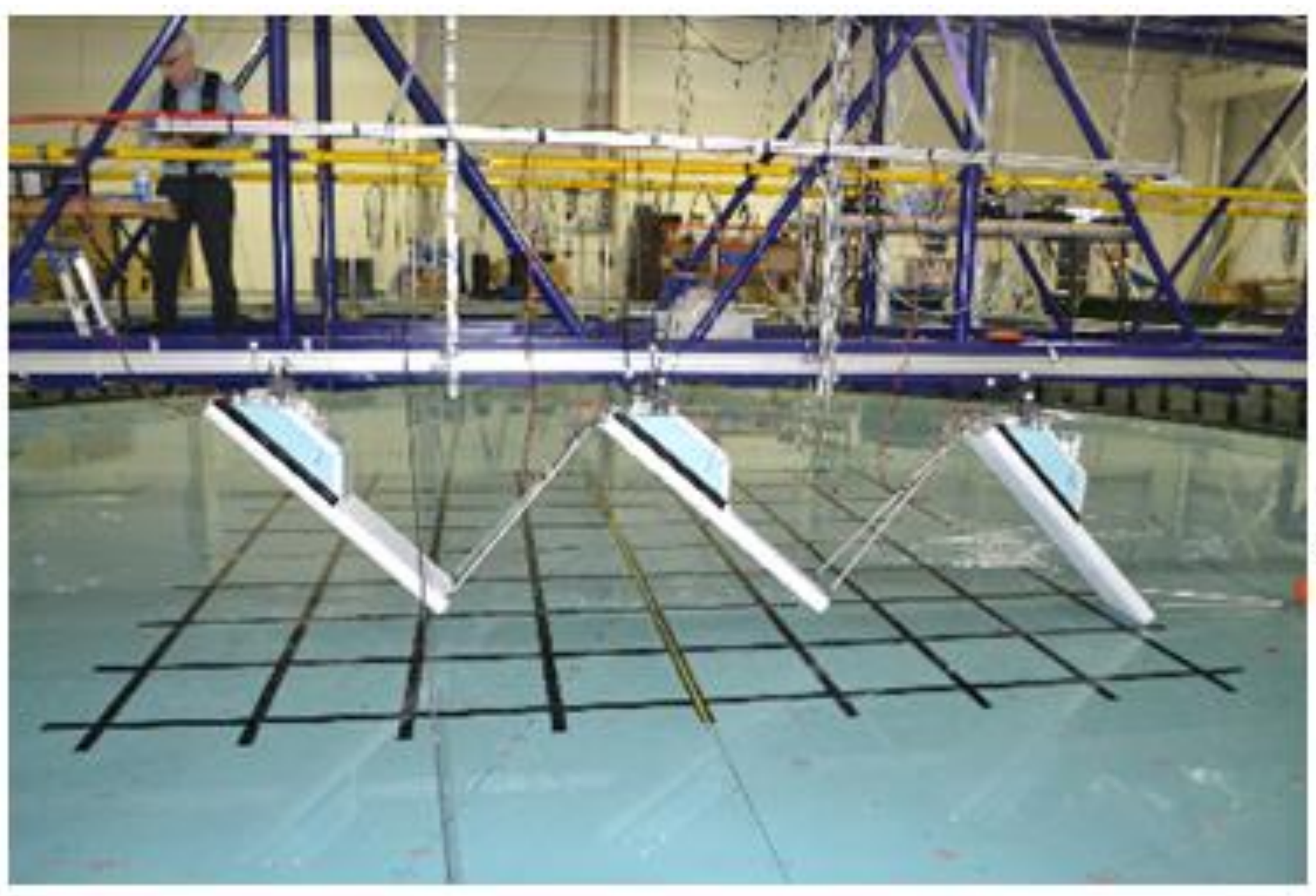

Figure 1: Experimental model of the WaveTrain device in the FloWave wave tank (the wave direction is from right to left).

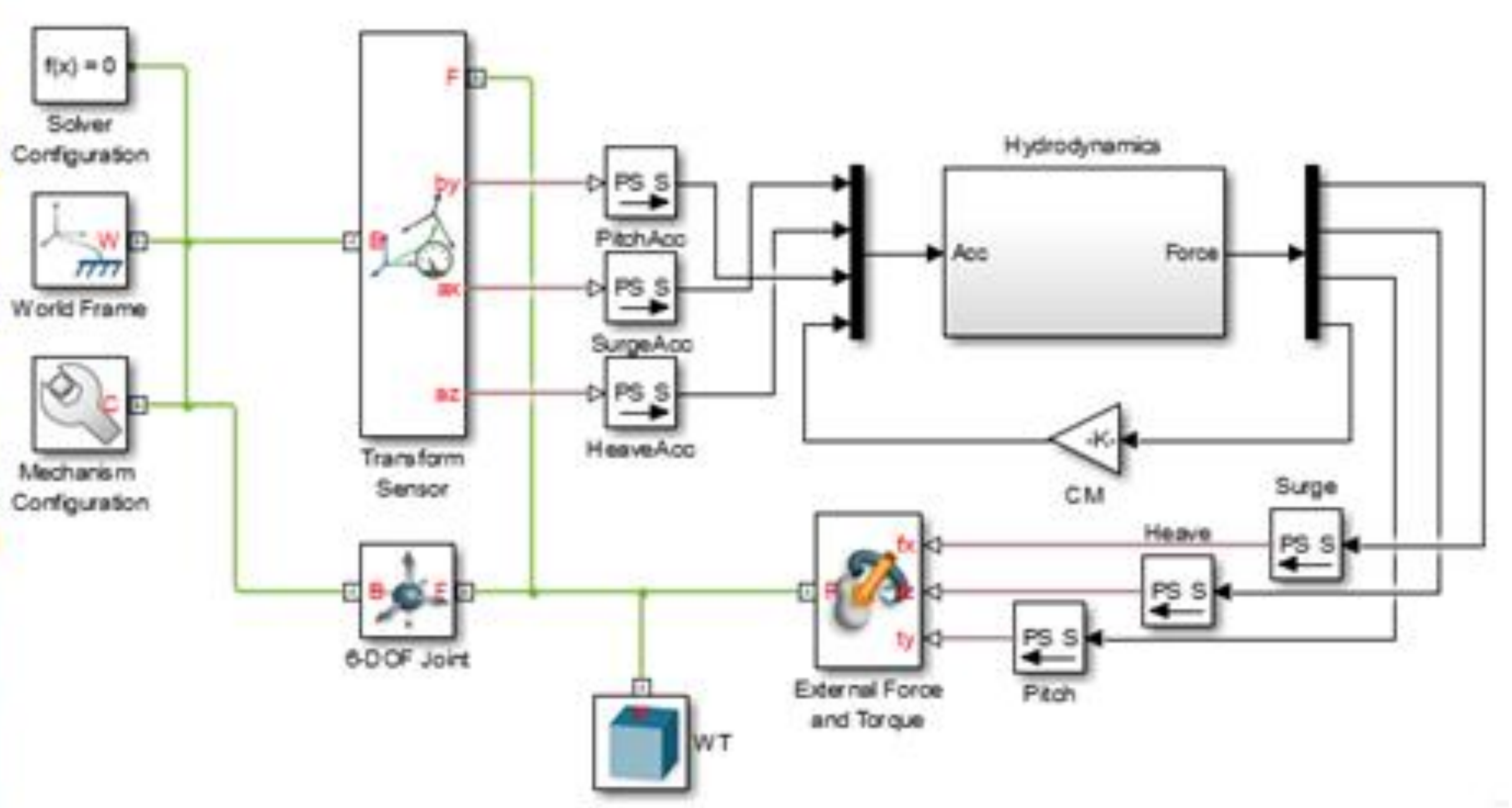

Figure 2: SimMechanics model for a single free-floating WaveTrain power module.

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