

Modeling and Design of an Adaptive Stiffness Wave Energy Converter

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We present a dynamic model and an experimental system of an integrated adaptive stiffness wave energy converter (WEC) that utilizes fluidic flexible matrix composites (F2MCs) as both the mooring and a power take-off (PTO) water pump. F2MCs exhibit varying axial stiffness depending on the working fluid pressure, so modulating the outflow hydraulic impedance (shown in Figure 1) allows for adaptation of the resonant behavior of the WEC. Reinforced hoses similar in construction to F2MCs (so-called “stretch hoses”) have been previously deployed and proven effective for offshore buoy moorings. Additionally, the use of F2MCs as water pumps for WEC PTOs has been theorized and tested in isolation (i.e., not integrated with a buoy or other floating body). Therefore, we have set out to: (i) develop an open-source dynamic model of an integrated adaptive stiffness WEC, (ii) design, fabricate, and component-test a lab-scale adaptive stiffness WEC, and (iii) perform wave-tank experiments to characterize system behavior and perform model-data validation. The dynamic model of the integrated system was developed using WEC-Sim and includes coupled representations of the surface buoy and the F2MC “hose-pump”. The buoy was designed to have low buoyancy stiffness and high mass so that it would resonate at wave periods achievable in scaled wave-tank experiments. All fabrication of the point-absorber buoy and F2MC hose-pump was completed in-house, and wave-tank experiments were conducted at the Coastal Studies Institute. A diagram of the wave-tank test vehicle is shown in Figure 2 (right). Through wave-tank tests, we demonstrated the viability of F2MCs as PTO water pumps in a fully integrated system and demonstrated the existence of a best-choice hydraulic impedance at each tested sea-state (Figure 2, left).

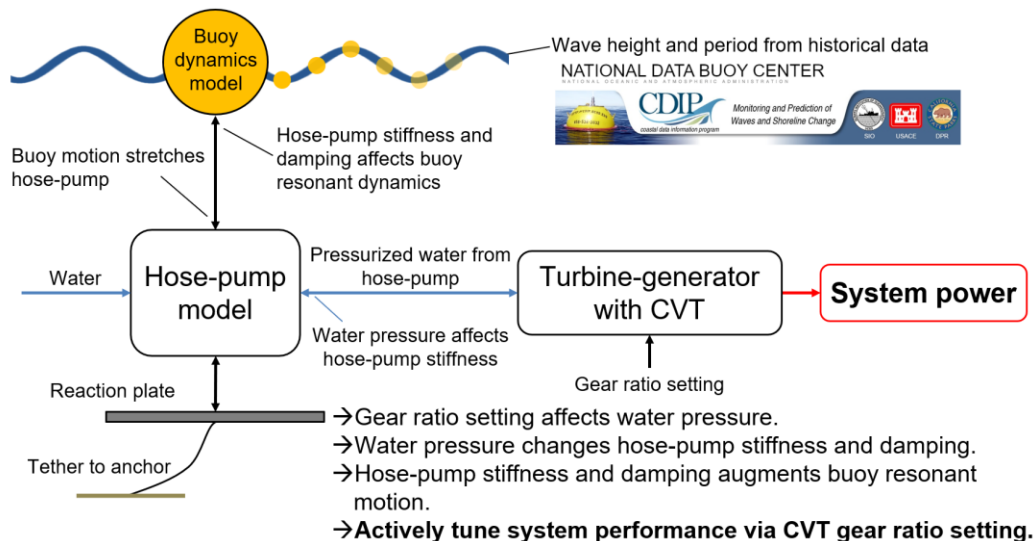


Figure 1: Block diagram showing coupling between major system components, including the surface buoy, the F2MC hose-pump, and the outflow hydraulic impedance (represented here as a turbine-generator with variable gearing).

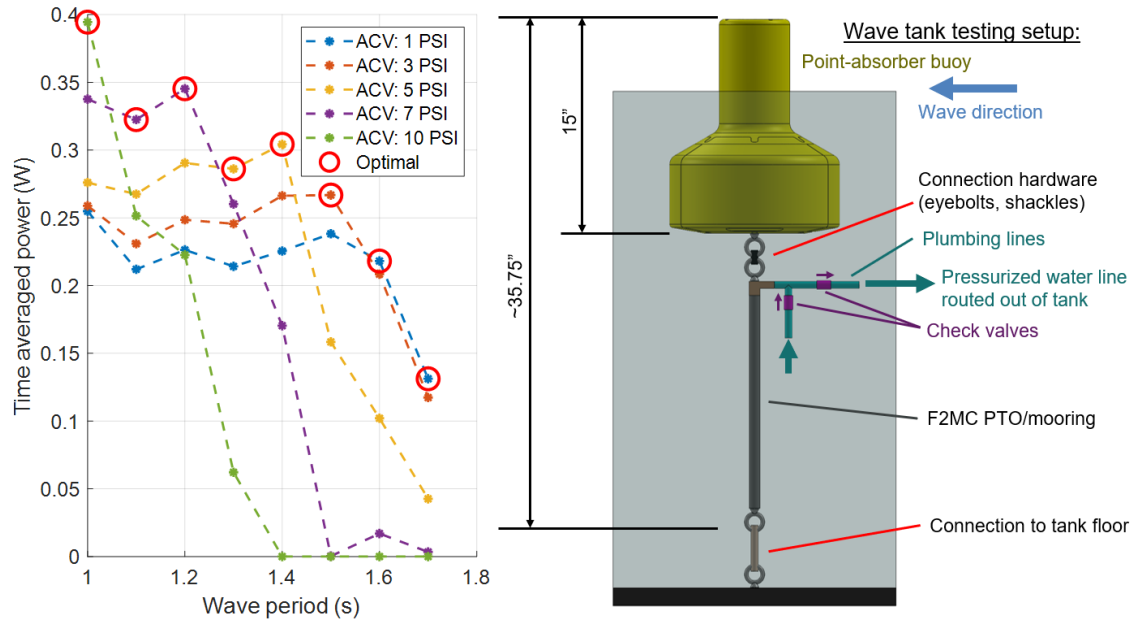


Figure 2: (Left) Time-averaged power versus wave period for the integrated system in monochromatic waves at the Coastal Studies Institute wave-tank. (Right) Computer-aided design model of the integrated system used in wave-tank testing.