Reduced-order model for hydrodynamic response of an oscillating surge wave energy converter

Alaa Ahmed*, Lisheng Yang**, Muhammad Hajj *, Raju Datla *, Lei Zuo**

*Department of Civil, Environmental and Ocean Engineering, Stevens Institute of Technology, Hoboken, NJ 07030

**Department of Naval Architecture and Marine Engineering University of Michigan, Ann Arbor, MI 48109

Abstract. Designing wave energy converters and testing them in ocean could be very expensive and complex, therefore requiring effective numerical modeling and simulations. The extensive cost of high-fidelity simulations can be inhibiting, especially in early stages of the design where different configurations need to be considered. Alternatively, a reduced-order model, based on representation of physical phenomena including added mass, radiation damping, and nonlinear unsteady hydrodynamics, can be used to optimize the geometry of the converter and in enhancing the control of the power takeoff. Here, we perform a systematic identification of representative terms for forces acting on an oscillating flap to develop a reduced-order model for its response in irregular waves.

Introduction

Because of its high density, wave power is considered as a renewable source that can support powering the grid, desalination power plants, remote communities, or coastal and deep ocean observation stations. One promising technology is the oscillating surge wave energy converter (OSWEC) [1], which consists of a flap hinged to the sea floor in shallow areas or to a submerged platform in deep waters. Using a power takeoff (PTO), energy is generated from its oscillating rotation under wave forcing. Simulating the hydrodynamic response can be carried out at multi-fidelity levels. High-fidelity simulations performed by solving the Navier-Stokes equations require extensive computing power and time. Medium fidelity simulations based on inviscid flow assumptions or linear wave theory require lesser time but remain expensive in the initial stages of the design iterations. On the other hand, a reduced-order model based on physical understanding and representation should yield a time-domain solution with an acceptable level of accuracy that can also be used in implementing PTO control. Difficulties in developing a time-domain model include accounting for the wave radiation and unsteady hydrodynamic forces and developing an evaluation of their relative magnitudes. In this paper, we will use validated free-decay and forced hydrodynamic numerical simulation to perform a systematic identification of the added mass, radiation damping and unsteady hydrodynamic forces. Particularly, a state-space model is used to replace the convolution term representing the radiation damping and a nonlinear term is used to represent the unsteady forces resulting from flow separation.

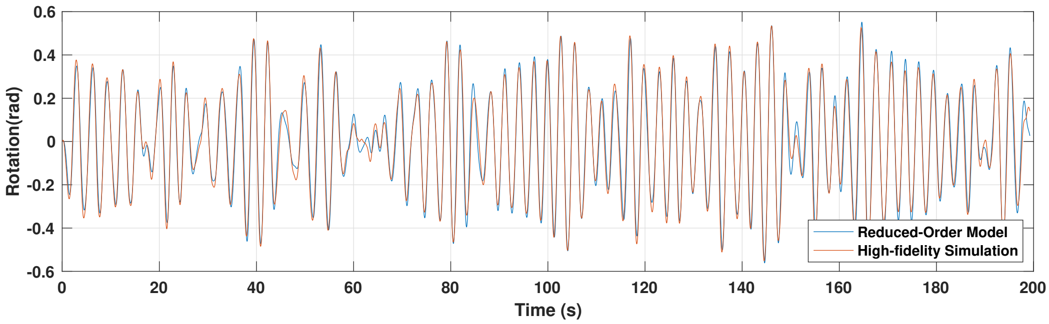

Figure 1: Comparison example of the OSWEC response under irregular wave excitation from high-fidelity and reduced-order model representations

Results and Discussion

Figure 1 shows a comparison between the results from developed reduced-order model and high-fidelity numerical simulations under irregular wave forcing. Based on RMS values, the error is less than 3% which indicates a high level of agreement. It is important to note that the computational time is reduced from 17 days for the high-fidelity simulation to only 13 minutes for the reduced-order model, which is significant when needing to determine potential power generated based on wave resources. In the full paper, we will stress the relative contributions and importance of the linear and nonlinear terms for different flap geometries. This characterization will be used to obtain approximate solutions for the hydrodynamic response and extended for implementation in the PTO control.

References

[1] Babarit, A., 2015. A database of capture width ratio of wave energy converters. Renewable Energy, 80, pp.610-628.