Experimental testing of a bi-stable point wave energy absorber under harmonic wave excitations

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Abstract. We present in this paper an experimental study dedicated to characterizing the response behaviour of bi-stable Point Wave Energy Absorbers (B-PWAs) under harmonic wave excitations. To this end, we fabricate a small-scale prototype of a B-PWA and analyze its response in an experimental wave flume under different wave frequencies and heights. Using the experimental data, we delineate the complex dynamical features and types of motion (small-amplitude, large-amplitude, periodic, aperiodic) that the B-PWA undergoes, and explore their influence on the power production capabilities of the device. We generate a design map in the frequency–amplitude parameters space that demarcates regions of qualitatively different response behaviors and use it to define an effective bandwidth wherein the B-PWA performs unique periodic large-amplitude oscillations yielding maximum power levels.

Introduction

Traditional point wave energy absorbers (PWAs) operate based on the principle of linear resonance whereby the frequency of the incident wave must match the natural frequency of the absorber to drive the buoy into the large-amplitue motions necessary to generate usable power levels. However, the overlap between the spectrum of the ocean waves and the PWA's resonance bandwidth is typically difficult to realize for two reasons. First, the natural frequency of the absorber is dictated by the stiffness of the hydrostatic (buoyancy) restoring force, which is typically very high resulting in a natural frequency that is much higher than that associated with naturally occurring waves in energetic marine sites. Second, the frequency of the incident waves is stochastic in nature resulting in a broadband energy spectrum that makes the resonance based approach less than ideal for wave energy absorption.

A large body of literature focused on divising active methods that help maintain the PWA in a proper tuning with the frequency of the incident energetic waves. Including the intentional introduction of a bi-stable nonlinear restoring element to broaden and shift the resonance bandwidth of the PWA towards lower frequencies [1-2].

Results and discussion

In this work, we design and construct a prototype of a B-PWA (Fig. 1 (B)) and test its response behavior under harmonic incident waves. Using the experimental data, we generate design maps in the frequency– amplitude parameters space that demarcate regions of qualitatively different response behaviors of the PWA. A sample of this design map is shown in Fig. 1 (A). Where the region remarked as B_L delineates the incident wave parameters that lead to significant power levels. While outside this region the B-PWA produces negligible power levels.

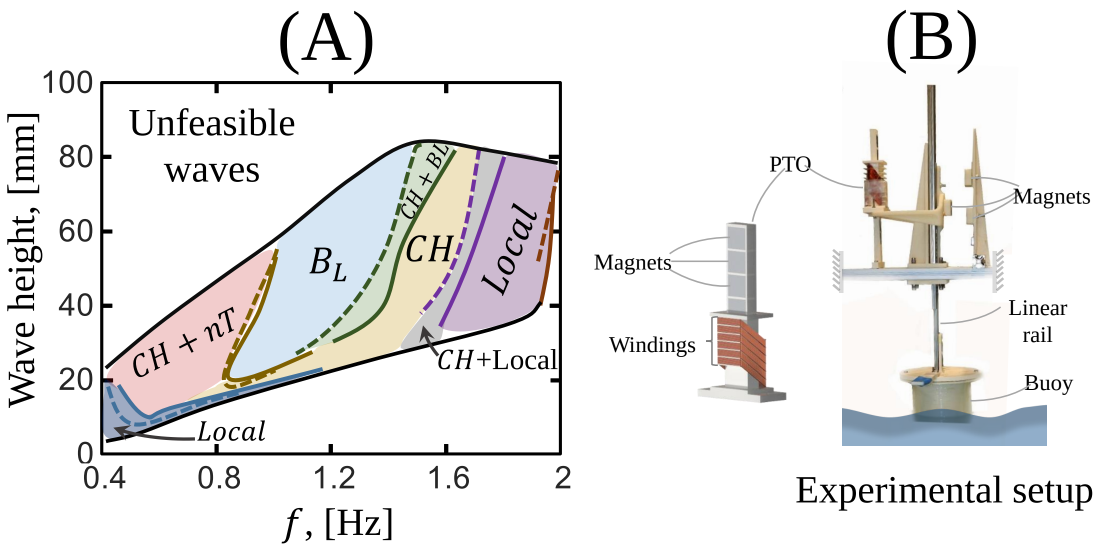

Figure 1: (A): A bifurcation map that demarcates qualitatively-different steady-state motions of the PWA for various combinations of wave heights and frequencies. B_L: large orbits, CH: Chaos, nT: n-period periodic orbits. (B): Overview of the experimental setup.

References

[1] Khasawneh M. A., Daqaq M.F. (2022) Response behavior of bi-stable point wave energy absorbers under harmonic wave excitations. *Nonlinear Dyn.* :1:21.

[2] Khasawneh M. A., Daqaq M.F. (2022) "Performance of bi-stable PWAs under irregular waves. *Nonlinear Dyn.* :1:17.