Design and Experimental Validation of a Two-to-One Internally Resonant Point Wave Energy Harvester

Mohammad Khasawneh*[1] and Mohammed Daqaq[2]

[1]New York University, Abu Dhabi – United Arab Emirates
[2]New York University Abu Dhabi (NYUAD) – Saadiyat Island, Abu Dhabi, UAE., United Arab Emirates

Abstract

Point wave energy absorbers (PWAs) are widely regarded as the simplest and most efficient method for harnessing wave energy (1). Despite their advantages over other methods, PWAs still face a limitation rooted in their reliance on establishing resonance conditions between the sea waves (excitation) and the absorber (resonator). This necessitates the natural frequency of the absorber to align with one of the dominant frequencies in the wave energy spectrum. However, in reality achieving resonance is a challenging undertaking. First, the high stiffness of the hydrostatic restoring force resulting from buoyancy yields an absorber's natural frequency that is typically much higher than the dominant frequencies in the wave spectrum. Lowering this frequency often necessitates adding heavy submerged bodies or incorporating complex mechanical and control solutions. Second, even when the natural frequency is tuned to match the dominant wave frequency, much of the wave energy remains unharnessed because the resonant bandwidth of the PWA is significantly narrower than the broad wave energy spectrum. Finally, operating at linear resonance can induce large-amplitude motions in rough seas, which may compromise the structural integrity of the absorber.
In a previous study (2), we proposed a novel PWA design to overcome these limitations. This design features a broader bandwidth, reduced sensitivity to variations in excitation frequency, and the ability to respond to wave frequencies as low as half the fundamental frequency of the absorber. It also avoids the sharp resonance peak associated with the response of linear PWAs. The key innovation lies in incorporating an additional mass suspended inside the buoy via a nonlinear restoring force, creating an auxiliary oscillator. The natural frequency of this auxiliary oscillator is tuned to the dominant frequency of the wave spectrum and to half the natural frequency of the primary oscillator. When subjected to low-frequency wave excitation, the auxiliary oscillator resonates, transferring energy to the primary oscillator through a two-to-one internal resonance mechanism. This interaction generates a reasonably large-amplitude motion for the buoy over a wide frequency range, which can then be converted into electricity using Faraday's law of induction.

Our earlier work (2) validated this concept through numerical simulations under regular and random wave excitations, as well as tested it using an electrodynamical shaker. The present study focuses on advancing this concept by building a prototype and conducting experimental tests under real wave excitation in a laboratory-scale wave flume.

*Speaker

References

(1) Daqaq, M. F., Giorgi, G., & Khasawneh, M. A. (2024). Deliberate introduction of a nonlinear restoring element to point wave energy absorbers: a review and assessment. *Nonlinear Dynamics*, 1-37.

(2) Khasawneh, M. A., & Daqaq, M. F. (2021). Internally-resonant broadband point wave energy absorber. *Energy Conversion and Management*, *247*, 114751.