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Numerical analysis of the interaction of monochromatic waves with a semi-enclosed, rectangular, surface-piercing cavity

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ABSTRACT

A current leader in wave energy converter (WEC) design is Edinburgh-based Mocean Energy Ltd. Their WEC, while superficially resembling an attenuator, is capable of extracting energy from ocean wavelengths longer than the device itself (McNatt and Retzler, 2020). This appears to be the result of a resonance occurring within the "wave channels" at either end of the device. This low frequency resonance bears a strong resemblance to a Helmholtz-type mode (Cummins et al., 2022).

The present work seeks to investigate wave channel resonance by exploring the related problem of the interaction of monochromatic waves with a semi-enclosed, rectangular, surface-piercing cavity in two-dimensions (Figure 1). A combination of an analytical approach and high-fidelity CFD are used to establish the dominant mechanism driving the response, and the effect of viscous dissipation and surface nonlinearities on the occurrence and magnitude of fluid resonance in the cavity bounded by the plate. Additionally, the work seeks to test the hypothesis that the resonant behaviour exhibited by this arrangement is an example of Helmholtz resonance.

Results indicate fluid resonance within the cavity is strongly Keulegan–Carpenter (KC) number dependent, even at small values where viscous effects were anticipated to be negligible. The wave frequency corresponding to peak response is downshifted relative to that of a semi-enclosed basin (Cummins et al., ibid.). This is likely related to the formation of leading edge vortices (of a size dependent on wavenumber) which constrict flow into the cavity, and are not captured by techniques which are based on the assumption of irrotational flow. An improved understanding of system damping and loss mechanisms will facilitate the improved design of WECs and a broad range of marine structures, including coastal defences.

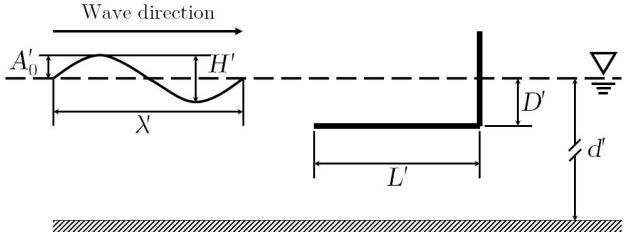

Figure 1: Schematic of a semi-enclosed, rectangular, surface-piercing cavity. D' denotes the submergence depth, L' is the length of the horizontal plate, and d' is the water depth. The incident, monochromatic wave is of height H', amplitude A_0' and wavelength λ'

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References

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