Leveraging 2:1 Parametric Resonance in a Notional Wave Energy Harvester

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Abstract. In ocean engineering applications, parametric resonance is normally detrimental for both the stability of large structures and energy extraction efficiency, so the vast majority of effort in the literature is towards preventing and reducing it. Conversely, this paper purposely introduces a 2:1 parametric resonance into a pitching wave energy harvester to inherently increase the energy absorption capabilities. Such a change in perspective is enabled by the use of a computationally efficient nonlinear hydrodynamic model, that is able to articulate such a parametric instability in a design-oriented simulation framework. The introduced 2:1 instability is found to be promising, since a significant amplification is obtained in the 2:1 region, where the oscillation amplitude is similar or even higher than in the 1:1 region.

Introduction

Wave energy harvesters (WEHs) are devices that respond to the external wave excitation force, typically with an oscillation motion. WEHs are required to improve their performance to become economically competitive. Efforts to this objective include design optimization and real-time control strategies; however, the underlying linear models, normally used due to computational convenience, are unrepresentative when large motions occur. In addition, the use of linear models causes blindness to instability, which is then discovered only after the preliminary design; consequently, effort is just invested towards after-corrections or live-limitation [1]. However, having a representative and fast numerical model may enable to incorporate such instabilities already at the early stages of design. With this perspective, this paper proposes to embed parametric resonance into WEHs, making it an enabling rather than a detrimental factor: a 2:1 resonance condition is defined by design into a heaving-pitching device, assuming energy extraction in the rotation DoF. Parametric resonance is articulated via a computationally efficient nonlinear Froude-Krylov (NLFK) force model [2]. The claim, herein demonstrated, is that parametric resonance can expand the operational bandwidth of the WEH.

Results and discussion

Figure 1 clearly shows the region of 2:1 parametric resonance (around $T_w = \frac{1}{2}T_5$), where there is a sharp increase of the pitching motion; the amplitude also bends towards larger periods as the wave height increases: such a bending behaviour contributes to enlarge the operational bandwidth of the response. It is also possible to appreciate a nonlinear coupling with heave, which shows a clear decrease as the pitching angle increases; this is usually detrimental for WEH that exploit heaving for the extraction, while is beneficial for WEH working on the pitching DoF. Conversely, in the 1:1 parametric resonance region, the coupling causes a significant increase in the heave motion, which drains energy from the pitching DoF.

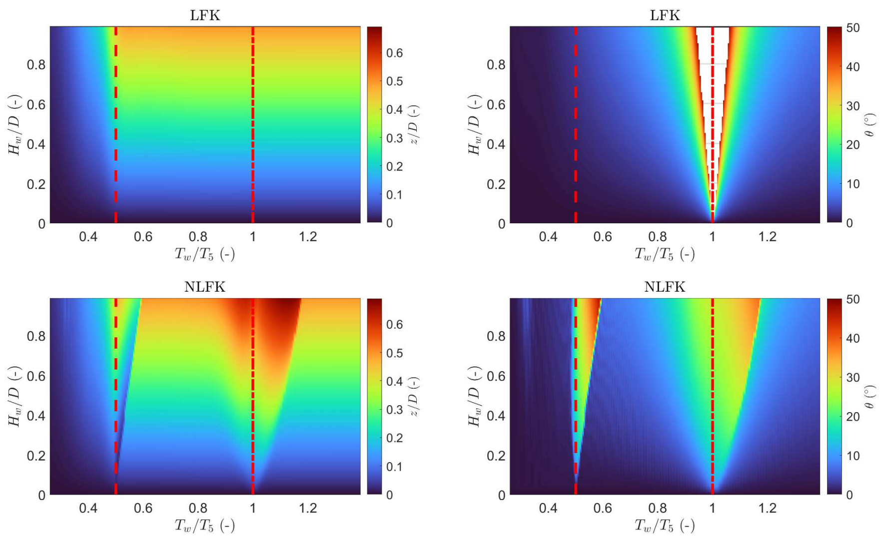

Figure 1: Amplitude of response for heave (left) and pitch (right), according to the linear (top) and nonlienar (bottom) models. The dash-dot and dashed red lines highlight one or half of the pitching natural, respectively. The white region indicates capsizing.

References

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