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Wave-Assisted Flapping Foil Propulsion: Flow Physics and Scaling Laws From Fluid-Structure Interaction Simulations

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Abstract : Wave-assisted propulsion (WAP) systems convert wave energy into thrust using elastically mounted hydrofoils. We employ sharp-interface immersed boundary simulations to examine the effect of two key parameters on the flow physics, the fluid-structure interaction, as well as thrust performance of these systems - the stiffness of the torsional spring and the location of the rotational center. The variation in spring stiffness leads to different amplitude of pitch motion, phase difference with respect to heaving motion and thrust coefficient and we show the utility of 'maps' of energy exchange between the flow and the hydrofoil system, as a way to understand and predict this behavior. The Force Partitioning Method (FPM) is used to decompose the pressure forces into individual components and understand the mechanism behind increase in thrust. Next, a scaling law is presented for the thrust coefficient generated by heaving and pitching foil. The parameters within the scaling law are calculated based on direct-numerical simulations based parametric study utilized to generate the energy maps. The predictions of the proposed scaling law are then compared with those of a similar model from the literature, showing a noticeable improvement in the prediction of the thrust coefficient.

Keywords : propulsion, flapping foils, hydrodynamics, wave power
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