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Optimization of a Small-Scale, N-Pendulum, Wave Energy Converter for Drifter Applications based on OrcaFlex Simulation

Regina Flix[1], Matias Carandell[1] and Montserrat Carbonell[1]

[1] *SARTI research group, Universitat Politècnica de Catalunya (matias.carandell@upc.edu),*

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I. ABSTRACT

Lagrangian Drifters are small oceanic instrumentation devices that provide oceanographic surface data for use in climate research, oil spill tracking and rescue operations. These autonomous passive floating devices are low-cost, versatile and easily deployable. Drifter deployments can last for years and cover large oceanic regions, so autonomy is one of the main challenges related to their design. To reduce maintenance costs for battery replacement, several energy harvesting (EH) sources are being explored such as the kinetic oscillatory movement of the waves [1]-[2].

Several studies report the parametric pendulum as a wave energy converter (WEC) system to harvest energy from the sea surface [3]. The main concept is that by exciting the pendulum's pivot point with the vertical oscillation of the waves (z(t) in Fig. 1) and using the specific constructive parameters, complete rotations can be obtained ($\dot{\theta}$ in Fig. 1). However, this is not possible for all the combinations of excitation parameters. To obtain parametric oscillation in a pendulum WEC resulting in complete rotations, at least a pendulum's natural frequency of twice the excitation frequency is required. This leads to pendulum lengths of hundreds of meters, which is not realistic for drifter applications. To mitigate this issue, two solutions have been suggested. First, a N-pendulum is proposed in [4] which it can achieve low natural frequencies by adding multiple masses (m_i) distributed around an array of pendulum arms (l_i). This allows to keep the size of the device small. Second, the concept of reduced gravity is proposed in [5]. By tilting the vertical axis of the pendulum (α in Fig. 1), the effect of the gravity is reduced according to the inclination of the pendulum's axis.

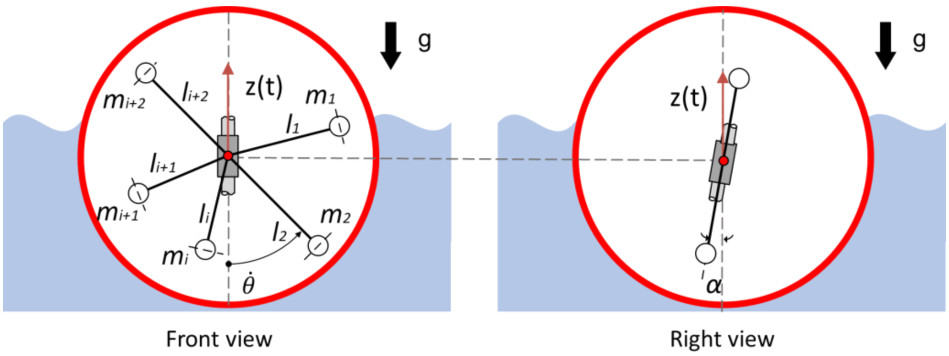

Fig. 1. N-pendulum Wave Energy Converter embedded on an oceanic drifter with the plane of the arms titled α from the vertical.

The objective of this work was to optimize the WEC concept by using OrcaFlex dynamic simulations. An oceanic drifter as the one shown in Fig. 1 was modelled with an embedded N-pendulum with 4 arms placed on a plane tilted α from the vertical. By tuning α, the relative rotation $\dot{\theta}$ between the drifter and the pendulum arm was optimized under wave excitation. Table 1 reports the drifter, pendulum and environmental parameters used for this work.

Environmental parameters		Drifter parameters		Pendulum parameters	
Depth	20 m	Diameter	0.2 m	$m_{1,2,4}$	0.032 kg
Water density	1027 kg/m^3	Total mass	3.5 kg	m_3	0.029 kg
Temperature	17º	Center of mass*	0.05 m	$l_{1,2,4}$	0.02 m
Wave height	5.1 m	Horizontal inertia	0.0095 kg·m^2	l_3	0.01 m
Wave period	10 s	Vertical inertia	0.0065 kg·m^2	α	Variable

Table 1. Environmental, Drifter and pendulum parameters used in OrcaFlex. *Distance taken from the center of the drifter.

Fig. 2 shows the accumulated θ between the pendulum swing and the drifter in a 180 seconds simulation with a δt of 20 ms for different α inclinations. The accumulated θ gives an idea of how many turns the N-pendulum has made during the simulated period. The environmental conditions were maintained fixed for all simulations, where m_3 and l_3 differ from the other pendulum's lengths and masses.

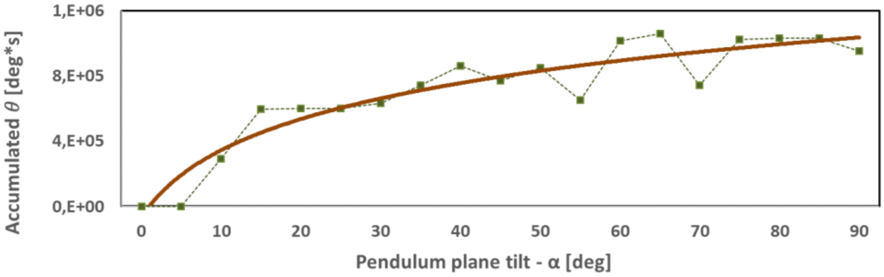

Fig. 2. Accumulated θ in a 180 seconds simulation for different α inclinations. The dashed green line represents the simulated data and the solid brown line is a logarithmic trendline.

Observing the results, an increase in α influences the rotation of the pendulum relative to the drifter positively. In fact, for small alphas (pendulum plane orientated vertically) no appreciable rotation is detected, and for large alphas (pendulum plane orientated horizontally), the rotation achieved during 180 seconds of simulation reaches 34 complete turns.

II. AKNOWLEDGEMENT

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