Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)

Hydrodynamic characteristics of a wind turbine monopile foundation integrated with an oscillating water column wave energy device

Zhigang SHAN, Mengxia SONG, Jiapeng PAN, Baolong ZHANG, Miaojun SUN, Fang HE

Cite this as: Zhigang SHAN, Mengxia SONG, Jiapeng PAN, Baolong ZHANG, Miaojun SUN, Fang HE, 2025. Hydrodynamic characteristics of a wind turbine monopile foundation integrated with an oscillating water column wave energy device. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 26(6):499-511. https://doi.org/10.1631/jzus.A2400045

PowerChina HuaDong Engineering Co., Ltd & Zhejiang University & Zhejiang Provincial Energy Group Co., Ltd.

An OWC-integrated monopile foundation

■Offshore monopile foundations are commonly used but are subject to large wave forces in deep-sea environments. Integration of oscillating water column (OWC) devices aims to reduce wave loads and capture additional energy.

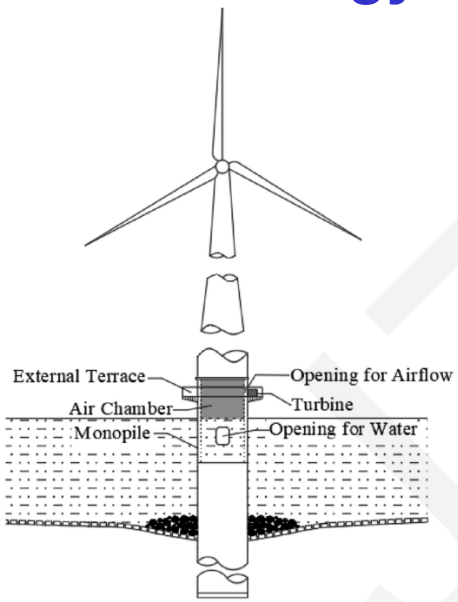


Fig. 1. Concept of An OWC-integrated monopile foundation. Reprinted from (Yanni Li, 2022), Copyright 2022, with permission from Elsevier

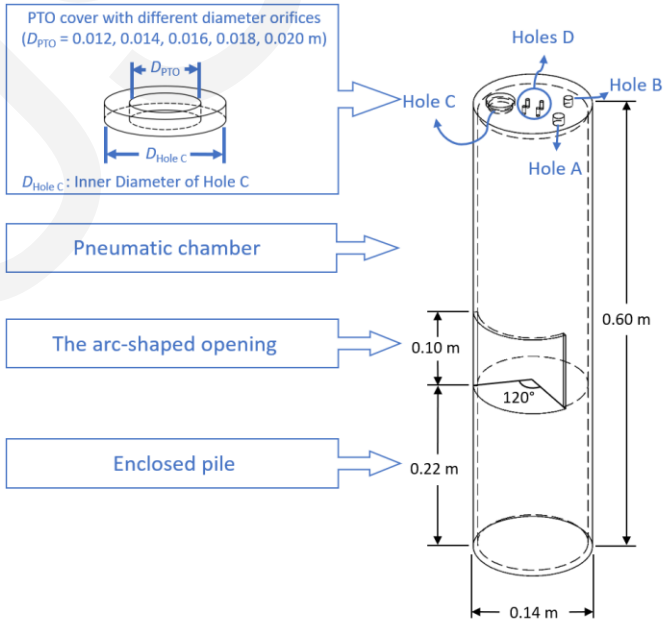


Fig. 2. Geometric details of the laboratory-scale OWC integrated monopile foundation model

Objectives

■To assess and understand load-reduction characteristics on OWC monopiles.

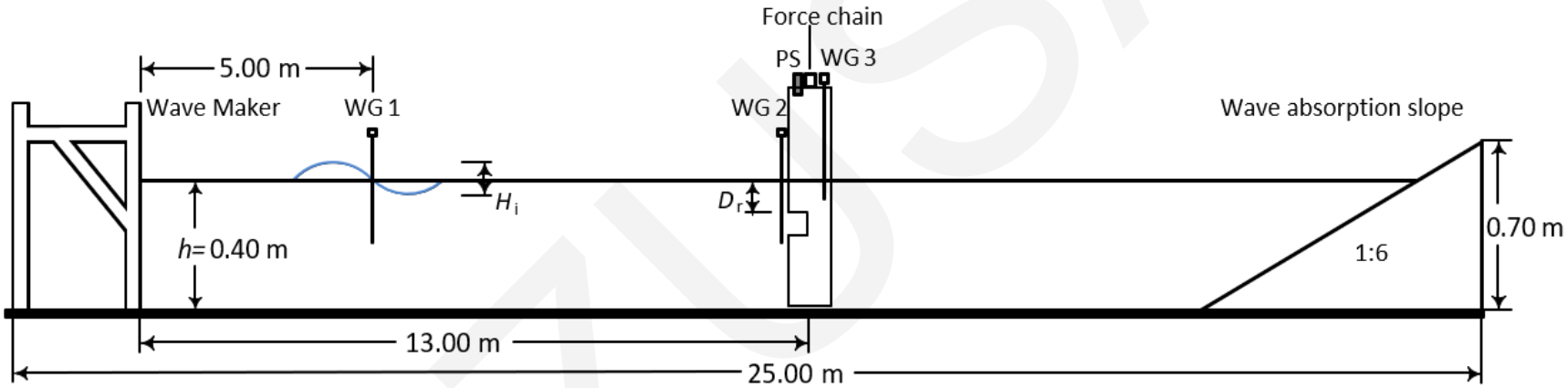


Fig. 3. Schematic diagram of the experimental setup

In this study, the water depth h was kept at 0.40 m for all test conditions, and so the draft of the OWC chamber D_r was fixed at 0.06 m. The wave period T was varied from 0.70 s to 1.60 s at an interval of 0.10 s, and the target incident wave height H_i was varied from 0.03 m to 0.06 m at an interval of 0.01 m.

Hydrodynamic characteristics

Water Surface Oscillation and Air Pressure Fluctuation

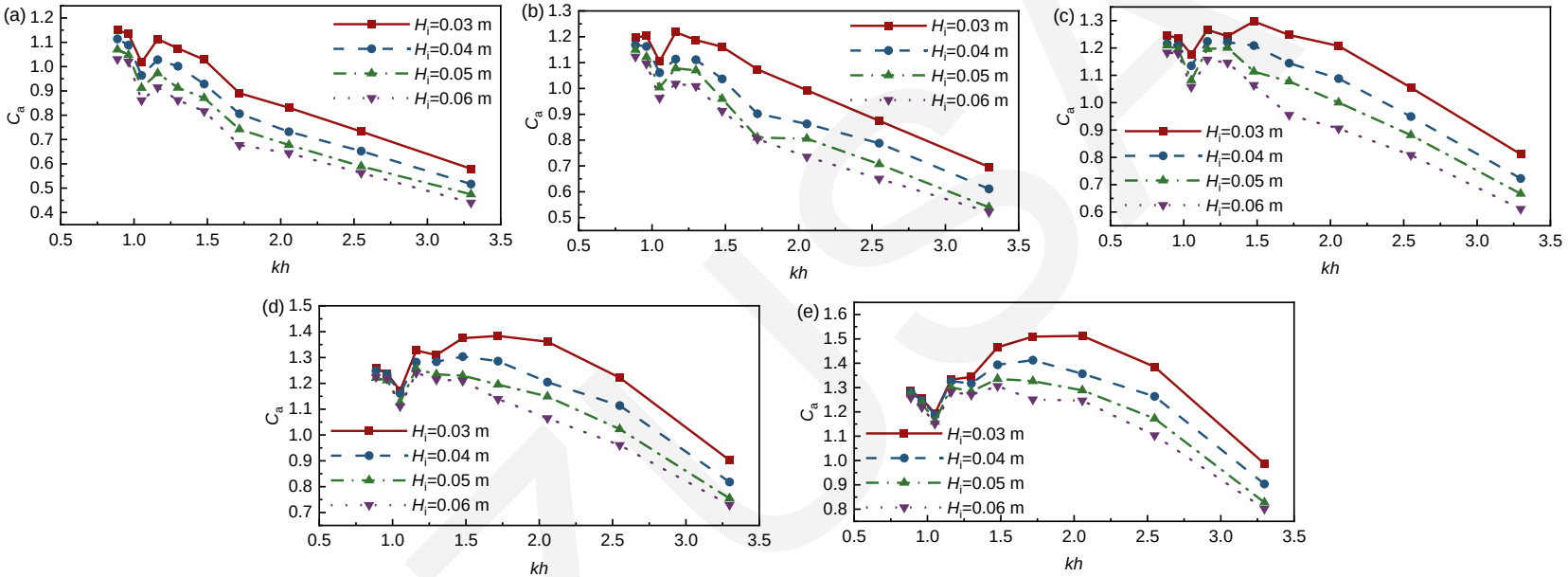


Fig. 4. Variation of in-chamber water surface oscillation coefficient C_a versus kh for different values of H_i with: (a) e=0.85%; (b) e=1.16%; (c) e=1.51%; (d) e=1.92%; (e) e=2.37%

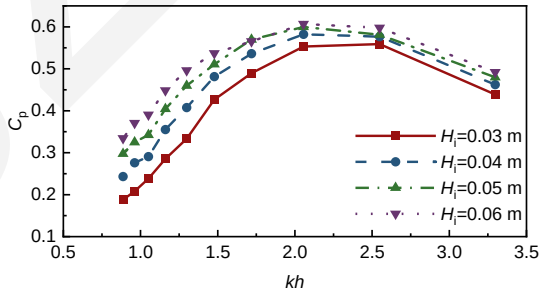


Fig. 5. Variation of the air pressure coefficient C_p versus kh for different values of H_i with e=1.51%

Hydrodynamic characteristics

■Wave Energy Extraction Power and Efficiency

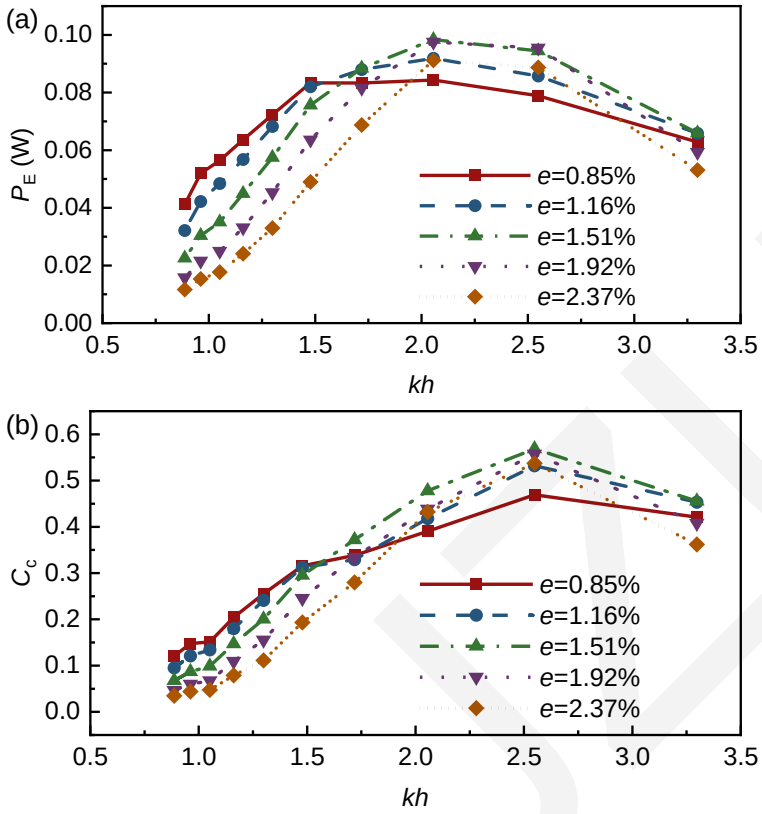


Fig. 6. Variation of (a) the pneumatic power P_E and (b) the capture width ratio C_c versus *kh* for different values of *e* with H_i=0.04 m

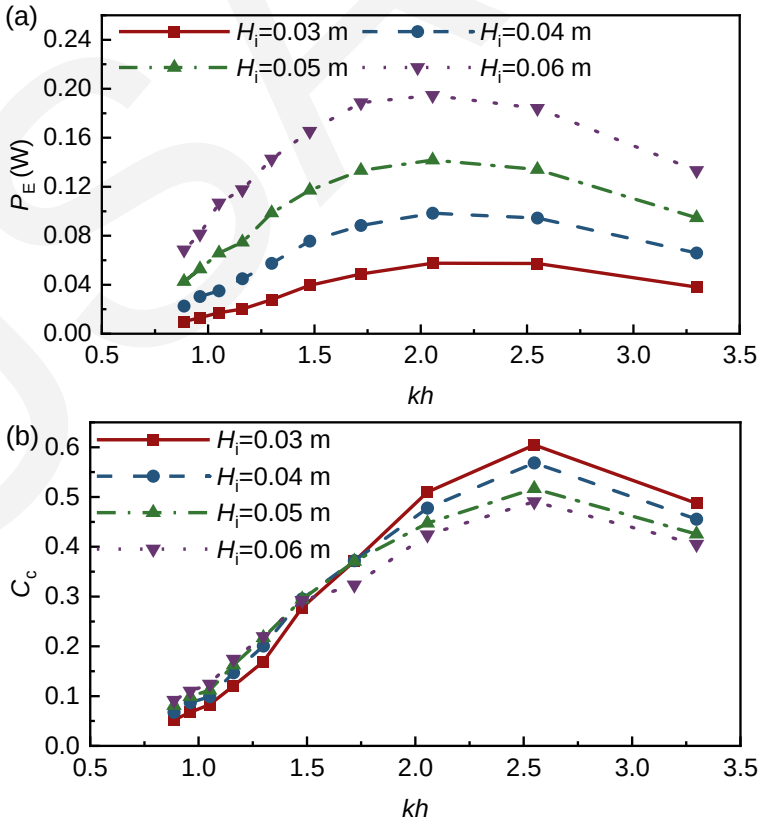


Fig. 7. Variation of (a) the pneumatic power P_E and (b) the capture width ratio C_c versus *kh* for different values of H_i with *e*=1.51%

Hydrodynamic characteristics

Wave Load Reduction Results

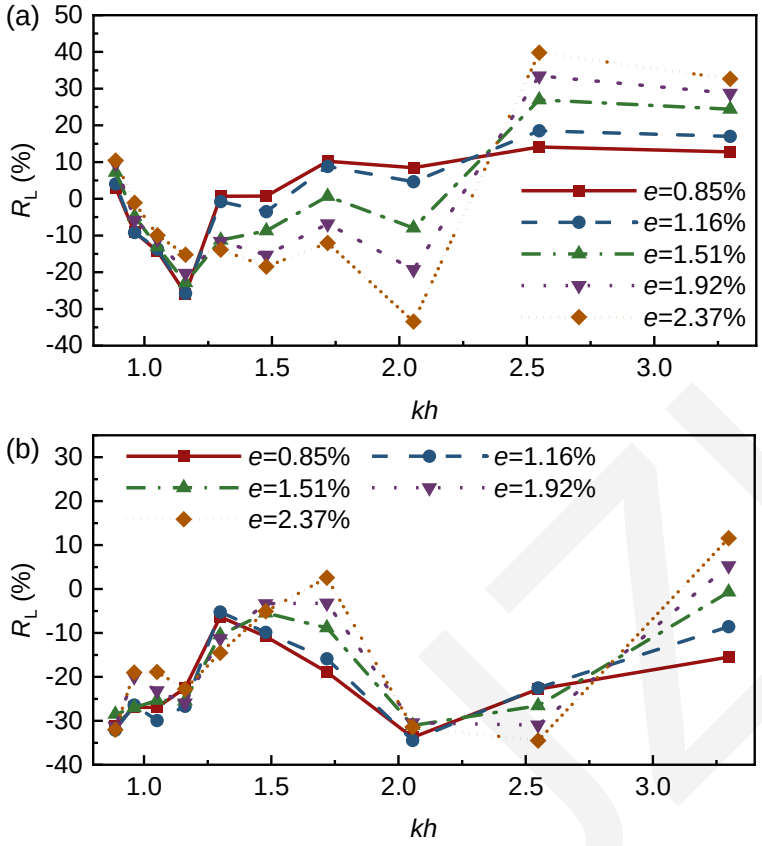


Fig. 8. Variation of the ratio of load reduction R_L versus *kh* for different values of e with H_i=0.04 m in (a) the positive direction and (b) the negative direction

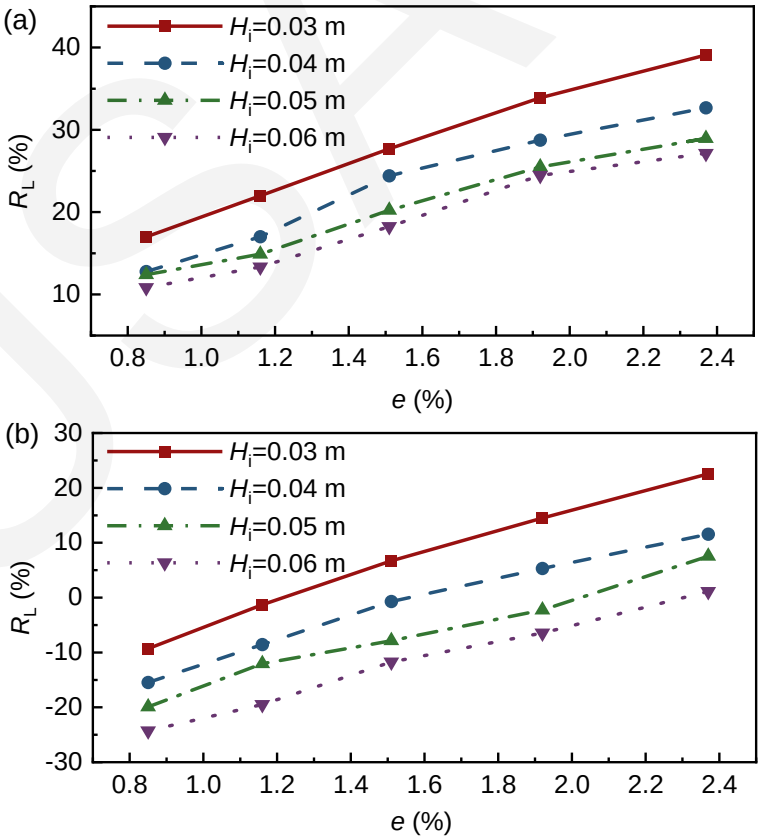


Fig. 9. Variation of the ratio of load reduction R_L versus *e* for different values of H_i with *kh*=3.30 in (a) the positive di-rection and (b) the negative direction

Conclusions

- **Hydrodynamic characteristics and wave energy efficiency:** The in-chamber water surface oscillation coefficient (C_a) and pneumatic power (P_E) are influenced by incident wave height and frequency, with higher opening ratios shifting peak frequencies to higher wave frequencies due to quadratic damping effects.
- **Load reduction in the positive direction:** OWC monopiles reduce positive wave loads at high wave frequencies, with smaller C_a and larger P_E providing better load reduction.
- **Effect of opening ratio on load reduction:** Large opening ratios cause load surges at medium wave frequencies, so medium ratios (e.g., 1.16% or 1.51%) are optimal for load reduction.
- **Optimal opening ratio:** An opening ratio of approximately 1.51% maximizes both wave energy capture and load reduction, offering strong performance across low- to high-frequency sea states.
- **Future research:** Further studies on structural strength using finite element methods and wave angle effects could deepen the understanding of OWC monopiles' performance.