Hydrodynamic forces on near-bed underwater datacenter

Xiaoyuan Hu[1], South China University of Technology, 202210192505@mail.scut.edu.cn
Yunfei Teng[1], South China University of Technology, tengyunfei@scut.edu.cn
Liang Cheng[1,3], South China University of Technology, liang.cheng@uwa.edu.cn
Feifei Tong[2], Southern Cross University Gold Coast Campus, Australia, Feifei.tong@outlook.com
Hongwei An[3], School of Engineering, The University of Western Australia, hongwei.an@uwa.edu.cn
Scott Draper[3], School of Engineering, The University of Western Australia, scott.draper@uwa.edu.cn

Abstracts

Compare with the flow past a sphere and finite-length cylinders, flow around a short cylinder with hemisphere ends has not been studied extensively. As a transition variant of sphere and finite-length cylinder, it is ubiquitous in engineering, e.g. submarine-like shape[1] and underwater datacenter (UDC)[2, 3]. There are few works focusing on hydrodynamic forces on a near-bed short cylinder with hemisphere ends, despite of its wide range of engineering applications.

The concept of underwater datacentre (UDC) was conceived by Microsoft 2014. The UDC commissioned by Microsoft 2014 was comprised of a pod with a shape identical to a short cylinder with hemisphere ends that was used to house computer servers. The pod was cooled using ambient water in the ocean. Traditional land-based datacentres consume significant amount of energy on cooling, normally up to 40% of the total energy consumption of the datacentre [3]. The concept of underwater datacentres has gained momentum recently. One of the companies in China, namely the Highlanders, planned to install 10000 data pods from 2021 to 2025 in China.

Hydrodynamic forces acting on the datacentre pods are key inputs for the stability design of underwater datacentres. There have not been any published data on hydrodynamic forces on pod structures installed above the seabed. To bridge the knowledge gap, the present study conducted physical experiments to investigate hydrodynamic forces on a short cylinder with hemisphere ends, subject to steady currents and waves that are perpendicular to the axis of the cylinder. The tests were conducted using the O-tube facility at The University of Western Australia. The Reynolds number ($Re = DU_c/\nu$) covered in the study ranged from 15000 to 150000 under steady current conditions. The Re and Keulegan-Carpenter number($\mathrm{KC} = U_m T_w/D$) were ranging from 7500 to 37500 and 6.7 to 66.7 respectively under wave conditions. All the tests mentioned above were conducted over the gap ratio (e/D) ranging from 0.1 to 2.0, where e is the gap between the cylinder and the plane boundary. The test results on hydrodynamic forces were presented with interpretations of physics involved in the flow.

Some of the test results are provided below. Figure 1 shows the variations of drag coefficient C_D with Re under the conditions of L/D = 3 and 9 and e/D = 2, together with relevant published data in the literature[4, 6]. It is seen that the present test results for the case of L/D=9 agree well with the results reported by Wieselsberger (1922) with L/D = 5, suggesting the influences of e/D and L/D on CD at e/D ≥ 2 and L/D ≥ 5 are week. The sudden drop of C_D with Re observed at around Re = 105 is likely induced by the boundary layer transition to turbulence on the cylinder surface, similar to the phenomenon known as drag crisis for in infinitely long cylinder. Figure 2 shows the variations of maximum horizontal (C_{Hmax}) and vertical force (C_{Lmax}) coefficients with velocity ratio of U_c/U_w for the case with e/D = 0.1 and KC = 10, together with the published force coefficients by DNV RP F109 (2021) for an infinitely long cylinder[7]. A general observation is that both C_{Hmax} and C_{Lmax} are smaller than those of infinitely long cylinder, demonstrating potential benefits of the tests conducted in the present study.

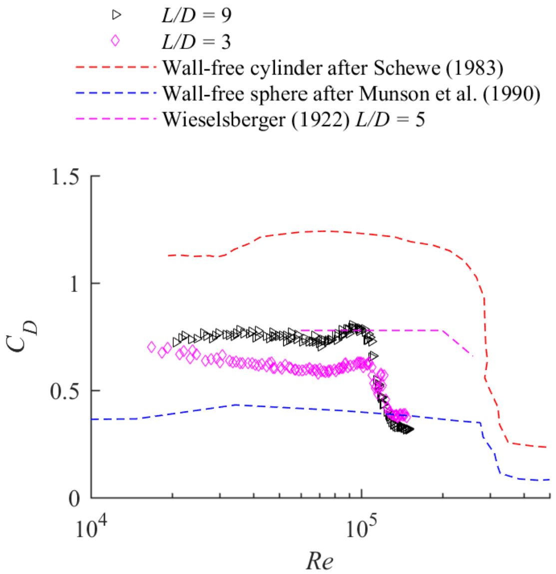

Figure 1 The results of drag forces coefficients in steady flow when e/D=2

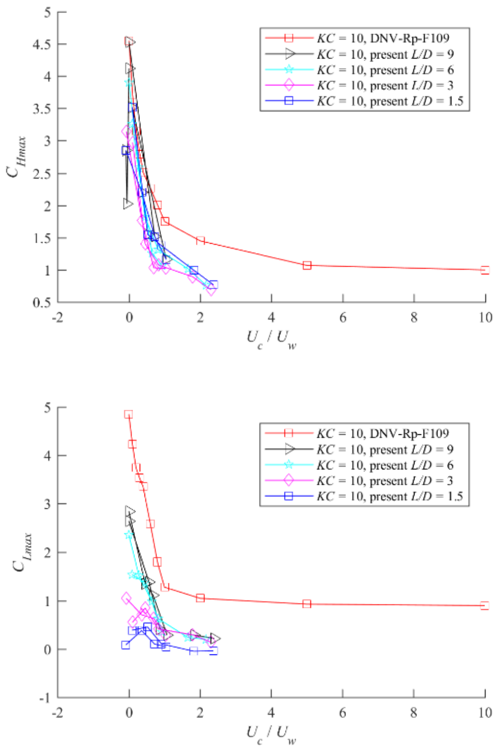

Figure 2 The results of hydrodynamic forces in combine flow when e/D=0.1

Key word: Hydrodynamic forces; Underwater datacentre; Near-bed

REFERENCES

[1] A. Acrivos, C.F. Delale (2008): Report on the IUTAM Symposium on Recent Advances in Multiphase Flows: Numerical and Experimental (11-14 June 2007, Istanbul, Turkey), Physics of Fluids, vol. 20, pp. 040501.

[2] T. Sutherland, G. Bopp (2023): The Pacific futures of subsea data centers, New Media & Society, vol. 25, pp. 345-360.

[3] Z.-H. Hu, Y.-X. Zheng, Y.-G. Wang (2022): Packing computing servers into the vessel of an underwater data center considering cooling efficiency, Applied Energy, vol.314, pp. 118986.

[4] J.A. Schetz, A.E. Fuhs (1999): Fundamentals of fluid mechanics, John Wiley & Sons.

[5] G. Schewe (1983): On the force fluctuations acting on a circular cylinder in crossflow from subcritical up to transcritical Reynolds numbers, Journal of Fluid Mechanics, vol: 133, pp. 265-285.

[6] Wieselsberger, C. (1922). On the drag of circular cylinders. Physikalishce Zeitschrift, vol. 23, pp. 219-224.

[7] D.N. Veritas, DNV-RP-F109 (2021)： on-bottom stability design of submarine pipelines, Det Norske Veritas, Norway.