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Hydrodynamics of a Free-Surface Piercing Porous Cylindrical Body

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ABSTRACT

In the present paper the hydrodynamic analysis of a floating, free-surface piercing, porous cylindrical body with vertical axis of symmetry is presented. Linear potential theory is assumed, and the associated diffraction and radiation problems are solved in the frequency domain. Analytical representations of the velocity potential are derived through the idealization of the flow field around the body using ring shaped fluid regions. The condition on the porous boundary is defined by applying the Darcy's law, whereas the fluid velocity and its derivatives are matched at the common boundaries of adjacent fluid domains by enforcing appropriate continuity conditions. The theoretical hydrodynamic approach is supplemented by numerous results comparing the hydrodynamic forces and free-surface elevation at a porous cylindrical body with the corresponding ones on an impermeable solid. The presented results demonstrate that a porous surface can reduce the hydrodynamic loads on the body enhancing its survivability on severe wave conditions.

KEY WORDS: Porous cylindrical body, Darcy's law, Hydrodynamics, Wave diffraction, Radiation

INTRODUCTION

In the recent decades, much effort has been made on wave interaction with submerged, bottom mounted or floating surface-piercing marine structures. Examples are floating airports, semi-submersible platforms, and wave power energy conversion systems. However, these structures are often struggled to commercialize due to the harsh offshore environmental conditions at the installation locations and the severe exciting wave loads. Therefore, research has especially been focused on optimising the structure to avoid significant hydrodynamic impact. Structures with porous portion are coming to the fore since they can reduce the influence of wave-body interaction through the pores on the body surface when compared with impermeable surfaces. Breakwaters, piers, docks, and sea-cage culture constitute typical examples of porous maritime structures.

There has been a great deal of effort directed towards quantifying wave interactions with marine porous structures. Chwang (1983) and Chwang and Li (1983) examined the use of porous plates as wave makers, whereas Wang and Ren (1994) studied the wave interactions with a concentric porous cylinder system, rigidly fixed on the seabed. Williams et al., (2000) investigated water wave interactions with a floating porous cylinder embodying a permeable side surface and impermeable top and bottom. The interaction of waves with arrays of bottom-mounted porous circular cylinders was also studied by Williams and Li, (2000) and Silva et al. (2003). Sankarbabu et al., (2007) considered an array of dual porous; sea bottom fixed; circular cylinders encompassing an outer porous surface and an impermeable coaxial internal cylindrical body and investigated the effect of wave and structural parameters on the bodies' hydrodynamics. Bao et al., (2009) examined the wave forces acting on a submerged porous circular cylinder, determining the exciting hydrodynamic forces by solving the corresponding diffraction and motion radiation problems, whereas Zhao et al., (2011) presented a theoretical and experimental study on a porous cylinder exposed to the waves' action and established an empirical relation between a porosity parameter and an opening ratio of the porous materials. Moreover, Mandal et al., (2013) presented a hydroelastic analysis of gravity wave interactions with concentric porous and flexible cylindrical bodies in which the inner body is rigid and the outer porous and flexible. Park and Koo, (2015) introduced an optimal ratio of the porous portion to the impermeable portion in order to design an effective array of partial-porous circular cylinders with minimal hydrodynamic impact.

Apart from porous cylindrical bodies also permeable compound cylinders either fixed on the seabed or semi submerged have been examined (Teng et al., 2001; Ning et al., 2017). In the latter studies the three-dimensional wave diffraction problem was solved based on the method of separation of variables and eigen-function expansion technique. Recently, Sankar and Bora, (2019, 2020a, b) examined the