International Journal of Offshore and Polar Engineering (ISSN 1053-5381)
Copyright © by The International Society of Offshore and Polar Engineers
Vol. 17, No. 1, March 2007, pp. 39–46

Development of Floating Body with High Performance in Wave Reflection

Masashi Kashiwagi*, Hirofumi Yamada and Makoto Yasunaga
Research Institute for Applied Mechanics, Kyushu University, Fukuoka, Japan

Tomohiro Tsuji
SRI Hybrid Limited, Kobe, Japan

A theoretical study is made first of the transmission and reflection waves past 2-dimensional, general, antisymmetric floating bodies which are oscillating in response to regular incident waves. As a result, the reciprocity theorem for the transmission and reflection coefficients and the wave-energy splitting theorem for the symmetric and antisymmetric wave components are derived for a general case of the motions of an antisymmetric body being free. Next, in order to develop floating piers with high performance in wave reflection, numerical computations and corresponding experiments are conducted with emphasis placed on the effects of horizontal fins attached to the original body of the rectangular shape. Depending on the number and location of the fins, there exist 1 or 2 frequencies at which zero wave transmission can be realized. With this fact, it is suggested that the transmission wave can be small over the frequency range of our interest by optimizing the number, size and location of horizontal fins attached to a rectangular-shaped main body.

INTRODUCTION

There is a practical demand for floating breakwaters or piers (hereafter described generically as breakwaters) with high performance in the wave reflection to be developed and installed near the mouth of a marina to protect yachts or other small vessels from waves coming from the open sea or generated by a high-speed boat running in proximity. From a viewpoint of preservation of water by exchanging with fresh water, floating-type breakwaters may be preferable. In fact, there have been many studies so far for the development of floating breakwaters using various ideas, and most of them were moored by slack chains anchored to the sea bottom. However, in this study, it is required that the water depth is relatively shallow, and that floating breakwaters to be developed must not move horizontally to avoid collision with vessels in the marina; that is, the movement of floating breakwaters may be restricted to heave by a number of vertical piles mounted to the sea bottom. In addition, the section shape of a body is required to be relatively simple for easy construction.

Under these circumstances, experiments in a wave channel and numerical computations based on the potential-flow theory have been conducted for a variety of 2-D models with a rectangular-shaped model used as the original one. To enhance performance in wave reflection, small horizontal fins are attached to the right and/or left part of the bottom and/or sidewall of the original body, and the performance is tested by changing systematically the number, length and position of the fins.

In connection with antisymmetric bodies (a body with only one fin attached to the right or left lower bottom), a theoretical study is made of transmission and reflection waves past 2-D, general, antisymmetric bodies oscillating freely in response to incident waves. Based on Green's theorem applied to the 2 different velocity potentials, very useful relations are found. One of these relations is the so-called reciprocity property that both of the transmission and reflection coefficients for an antisymmetric body are independent of the incoming direction of incident waves; this property is valid irrespective of whether the body motions are fixed or free to oscillate in waves. The other is the wave-energy splitting theorem: The energy of the symmetric (antisymmetric) wave component when the incident wave is coming from the right is equal to that of the antisymmetric (symmetric) wave component when the incident wave is coming from the left.

Numerical computations indicate that, depending on the number and location of the horizontal fins, there exist 1 or 2 frequencies at which zero wave transmission is realized, and these frequencies are different from the so-called waveless frequency at which the wave-exciting force in heave becomes zero. Although the degree of agreement between numerical computations and corresponding experiments is not very good because of viscous effects, particularly around the heave resonance, experimental results seem to support the findings by this paper's theoretical and numerical studies.

REFLECTION AND TRANSMISSION WAVES

Under the assumption that the fluid is incompressible and inviscid with irrotational motion, we introduce the velocity potential and consider the flow around a floating body in regular waves. The wave-induced motion of a body and associated fluid motion are assumed to be linear in the incident-wave amplitude and harmonic in time with circular frequency ω of the incident wave. In what follows, all oscillatory quantities will be expressed in complex form, with the time dependence $e^{i\omega t}$ understood.

In order to treat the problem in general, we consider an antisymmetric body; in this case, depending on the incoming direction of the incident wave, the flow field around a body may be different. Accordingly, as shown in Fig. 1, let us first consider the case where an incident wave is coming from the positive x-axis,

---

*ISOPE Member.

Received March 1, 2006; revised manuscript received by the editors October 30, 2006. The original version (prior to the final revised manuscript) was presented at the 16th International Offshore and Polar Engineering Conference (ISOPE-2006), San Francisco, May 28-June 2, 2006.

KEY WORDS: Wave reflection and transmission, reciprocity theorem, wave-energy splitting theorem, antisymmetric body, perfect reflection, waveless frequency.