Ocean Engineering 147 (2018) 447–457

Contents lists available at ScienceDirect

Ocean Engineering

journal homepage: www.elsevier.com/locate/oceaneng

Side wall effects on ship model testing in a towing tank

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ARTICLE INFO

Keywords:
Side wall effects
Rankine source method
Ship model testing
Shallow water
Forward speed

ABSTRACT

Due to the existence of the side walls in a towing tank, the measured hydrodynamic forces would present some discrepancies compared to the open sea results. This phenomenon is referred to as the side wall effect. The objective of the present study is to investigate the side wall effects on ship model testing in a towing tank. The method used in the present study involves a 3D panel method based on the Rankine type Green function. Both the steady and unsteady problems were investigated numerically. The numerical results were validated against ship model test results. After the validations, a large scale computations were performed to investigate the parameters which could determine the side wall effects. Two diagrams of side wall effects (one in calm water and the other one in waves), were obtained which showed whether the side wall effect was less than the permissible error to be included in the measured values.

1. Introduction

A ship model towing tank always has a limited width. Due to the existence of the side walls of the towing tank, the measured hydrodynamic forces would present some discrepancies compared to the open water results. This phenomenon is referred to as the side wall effect. There are many factors which determine the side wall effects. These factors include ship geometry, width (w) and depth (h) of the tank and forward speed of the ship model. In seakeeping tests, the oscillating frequency is another critical parameter which must be taken into consideration. For a certain combination of the above parameters, the measurements from the tests could differ significantly from the open sea results. The object of the present work is to find the relation between the side wall effects and the parameters which determine the side wall effects. According to the purpose of the ship model test in a towing tank, the side wall may affect the measurements in wave-making problems (in calm water) and seakeeping problems (in waves).

The side wall effects on model testing in calm water is not very obvious and therefore it is usually neglected in ship model tests. In calm water, the side wall effects can be simply estimated from Kelvin wave pattern, as shown in Fig. 1. The waves produced in the bow are reflected by the side walls, and these reflected waves will strike the ship if the tank width (w) is very small. The minimum distance w_m can be estimated as

$$w_m = L \tan\theta \approx 0.36L \tag{1}$$

where L is the length of the ship model. It indicates that if the width of the tank is larger than 0.36L, the side wall effects can be neglected in ship model tests in calm water with infinite water depth. It should be pointed out that this minimum distance w_m will be modified by the near field local waves produced by a 3D ship. Therefore, w_m is slightly larger than the estimated value from Eq. (1). However, it will not overturn the conclusion that w_m is much smaller than ship length L. In practice, the width of most of the towing tanks is larger than w_m. Therefore, the side wall effects are neglected in wave-making problems in deep water, and the studies on side wall effects on calm water model tests are very rare. But ships advancing in a channel has been widely studied (Beck et al., 1975; Mei and Choi, 1987; Norrbin, 1974; Tuck, 1978). Theoretically, these two problems are very similar. The difference is that in a towing tank, the ship model is usually fixed in the centre line of the tank (as shown in Fig. 1). There is no force (or moment) components in y direction. Whilst for a ship manoeuvring in a canal or channel, it is very difficult to guarantee the ship is always advancing along the centre line of the canal. Therefore, there is a lateral force, as well as a yaw moment acting on the ship (Yuan and Incecik, 2016). More importantly, the side wall effects are often accompanied by shallow water effects. In shallow

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https://doi.org/10.1016/j.oceaneng.2017.10.042
Received 3 October 2016; Received in revised form 12 October 2017; Accepted 19 October 2017

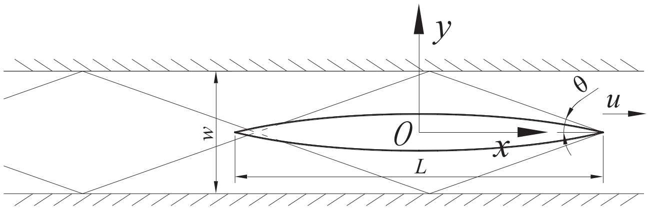

Fig. 1. A sample ship advancing in a towing tank, where w is width of the tank, L is the length of the ship, u is the speed of the model and θ is the semi-wedge angle of the waves produced by the ship. In calm water, the semi-wedge angle $\theta = \sin^{-1}(1/3) \approx 19.47°$.

Table 1
Main dimensions of Wigley III hull.

Length, L (m)	3
Breadth, B (m)	0.3
Draught, D (m)	0.1875
Displacement, V (m^3)	0.078
Centre of rotation above base, KR (m)	0.1875
Centre of gravity above base, KG (m)	0.17
Radius of inertia for pitch, k_{yy} (m)	0.75

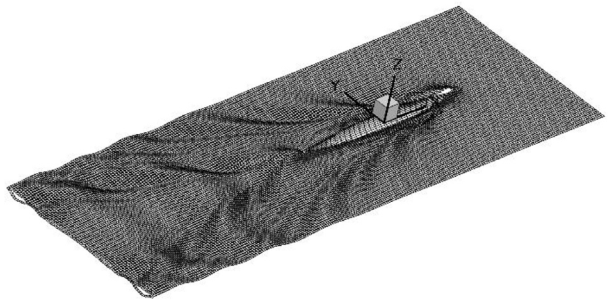

Fig. 2. The coordinate system and panel distribution on the computational domain of a Wigley III hull advancing in open calm water. There are 9900 panels distributed on the half computational domain: 300 on the body surface and 9600 on the free surface. The computational domain is truncated at L upstream and $2L$ downstream. The figure also shows the waves produced by Wigley hull at $F_n = 0.3$, where $F_n = u/\sqrt{gL}$ is the Froude number.

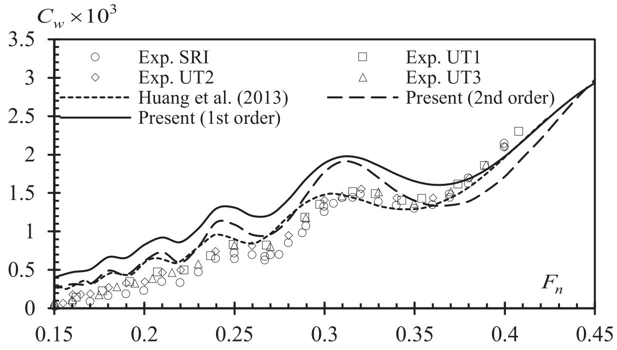

Fig. 3. Wave-making resistance coefficient of a Wigley hull. The experiments are conducted by Ship Research Institution (SRI), University of Tokyo (UT).

water, the water depth Froude number F_h ($F_h = u/\sqrt{gh}$, where u is the forward speed and g is the gravity acceleration) becomes a critical parameter which determines the feature of the wave-making resistance. It was found that in a shallow channel, the wave-making resistance experienced a sudden drop at the critical speed (Kirsch, 1966; Newman and Poole, 1962). Doctors (2015) proposed a formula to estimate this drop and found that the wave-making resistance was less for greater values of the tank width or the water depth.

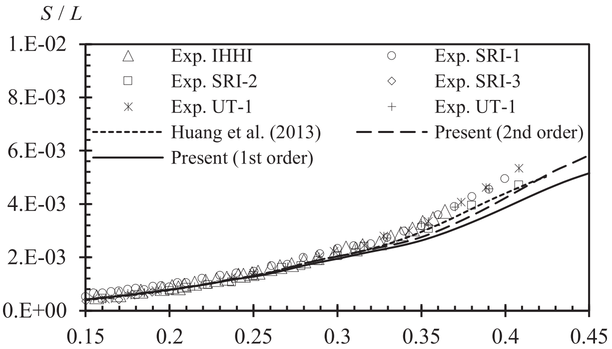

Fig. 4. Sinkage of a Wigley hull. IHHI indicates the experiments conducted by Ishikawajim-Harima Heavy Industries Co., Ltd.

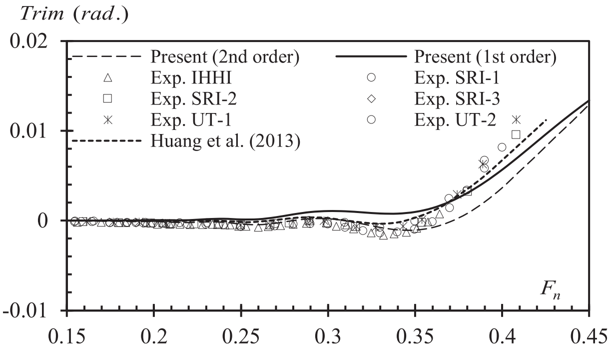

Fig. 5. Trim of a Wigley hull.

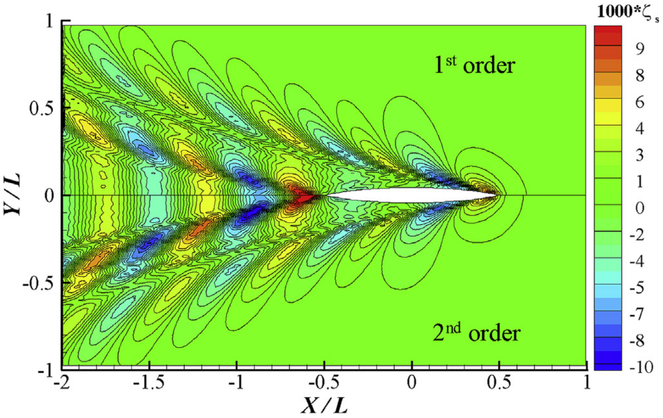

Fig. 6. Steady wave pattern produced by a Wigley hull in open and deep water at $F_n = 0.3$.

The side wall effects on ship model testing in waves are more complicated than those in calm water due to the factor of oscillating frequency (ω). In order to investigate the side wall effects on ship model testing in waves, another critical parameter τ ($\tau = \omega_e u/g$, ω_e is the encounter frequency) must be introduced. Due to the oscillating and translating properties, there are three individual wave systems as the parameter $\tau < 0.25$ (Becker, 1958; Noblesse and Hendrix, 1992; Yuan et al., 2015b). Correspondingly, the semi-wedge angles are not constant anymore, which is different from Kelvin waves. They are determined by parameter τ. Besides, the semi-wedges angle of the waves produced by an oscillating source are generally larger than Kelvin wedge. Therefore, the side wall effects have to be taken into consideration during the model test in waves in the towing tank. Kashiwagi and Ohkusu (1989, 1991) used the asymptotic wave contour to estimate the side-wall effect. They also