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Experimental study on the hydrodynamic forces induced by a twin-propeller ferry during berthing

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Abstract

The paper presents the experimental study on the influence of wall effect on the hydrodynamic forces induced by the propellers and thrusters of a ferry during the berthing. The program of the model tests was developed for the twin-propeller, twin-rudder, man-manned model of a car–passenger ferry in 1:16 scale, equipped with two bow thrusters. The different combinations of the operational settings of bow thrusters and propellers operating in the push–pull mode allowed to observe and quantify the variation of the hydrodynamic forces due to the changes of the water depth to draft ratios and distances to the quay. The results of model tests are introduced and discussed in the paper. The difference between the measured total hydrodynamic force and superposition of the component forces induced by the propellers and thrusters has been investigated. According to the structure of the generally accepted modular manoeuvring model, the proposition of the weight factors for the component forces comprising the interaction effects has been introduced and discussed.

Keywords: Twin propeller; Twin-rudder ferry; Berthing; Unberthing; Wall effect; Model tests; Modular manoeuvring model

1. Introduction

The decreasing manoeuvring space and increasing traffic have a big impact on the risk of damage to vessels and port facilities. Because the main safety options: training of seamen, implementation of navigational aids and planning of harbour operations are based on the simulation of ship motion, the modelling of ship motions at slow speed in the constrained space is now essential to enhance safety. The investigations on the modelling of the berthing forces aim at the improvement of efficiency and increase of the vessels' turn around speed in ports.

Because of a complex turbulent flow generated around the ship, a general mathematical model that aims to describe the ship motions close to the quay wall is difficult to formulate with respect to both the methods based on CFD and model tests. Due to this fact there are few experimental results of self-berthing available (Shin and Lee, 2004; Qadvlieg and Toxopeus, 1998; Yoo et al., 2006).

The modular manoeuvring models that allow for the superposition of the forces generated on the hull while accounting for extreme interactions always need a tuning usually based on the heuristic methods. However, the heuristic methods based on the opinions of experienced pilots and masters help to bring the simulation reasonably close to reality for the training purposes; the better accuracy is expected when the applications related to ship operation are considered. The open water model tests presented in the paper, carried out using the stationary model to investigate the forces generated by propulsion and steering devices, allowed to perform the quantitative analysis of the phenomena dependent on the fluid flow induced by the working propellers and thrusters.

2. Model tests

The open water experiments were carried out using a large man-manned model of a car–passenger ferry in 1:16 scale. The specially designed experimental test setup shown in Fig. 1 was constructed on the shore of the Silm lake at the Ship Handling Research and Training Centre of the

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Fig. 1. Model of the car–passenger ferry and experimental test setup.

Foundation for Safety of Navigation and Environment Protection in Ilawa—Kamionka, Poland. The influence of several operational parameters on the variation of hydrodynamic forces was investigated. The program of model tests consisted of different settings of the propellers operating in push–pull mode in combination with the different rudder angles and settings of the bow thrusters, different depth to draft ratios and model distances to the quay wall. The main assumptions regarding the classification and hierarchization of the parameters influencing the interaction forces had followed from the engineering study based on the previously published results (Abramowicz-Gerigk, 2006a; Shin and Lee, 2004; Qadvlieg and Toxopeus, 1998).

2.1. Model and experimental test setup

The large man-manned model in 1:16 scale was adopted to the stationary tests to allow the measurements of the hydrodynamic forces generated on the hull only by the propellers, rudders and bow thrusters (Abramowicz-Gerigk, 2006b).

The main particulars of the car–passenger ferry model are presented in Table 1. The model presented in Figs. 1 and 2 was equipped with two, four blades, controllable pitch propellers of the inward direction of revolution, two rudders and two bow tunnel thrusters. The quay model was a tight vertical wall. The water depth was adjusted by the movable horizontal flat plate. The dimensions of the experimental test setup were as follows: 12 m length, 5 m width and 1.25 m of the maximum adjustable water depth. The model was stationary in the horizontal plane and free to the pitch, heave and roll motions. The position of model, relative to the wall, was fixed using the bow and stern pantographs (Fig. 1). The setup of the propellers' thrust, bow thrusters and rudder angles was done using the on-board controls. The RPM and pitch of the propellers for the settings of the on-board engine telegraphs were measured by the on-board meters. The rudder angles were measured by the on-board meters as well. The measuring system of the bow and stern transverse and longitudinal forces consisted of two (bow and stern) tensometer-type dynamometers AMTI (Advanced Mechanical Technology, Inc.) MC3-100. The signals from the dynamometers were amplified using the AMTI amplifiers and sent to A/D converter in the computer. The data collection software (VBasic) had been developed for data collection and processing. The total sway force and yawing moment were calculated on the basis of the measurements.

Table 1
Main particulars of the car–passenger ferry model

Length overall (m)	10.98
Length between perpendicular (m)	9.64
Breadth (m)	1.78
Draft (m)	0.42
Displacement (m)	4.89
Block coefficient (–)	0.687
Scale	1:16

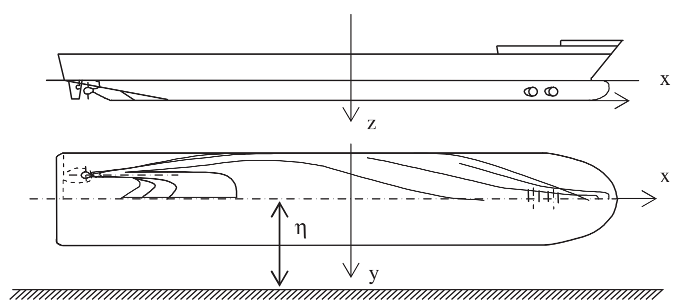

Fig. 2. Coordinate system.

2.2. Results of experiment

The results of berthing and unberthing experiments are presented in the form of non-dimensional sway force and yawing moment plotted as the functions of non-dimensional distance b (1) between the hull centreline and the quay wall for the water depth to draft ratios $h/T = 1.2$ and 3:

$$b = \frac{\eta}{B}, \qquad (1)$$