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EXPERIMENTAL ANALYSIS OF THE EFFECTIVENESS OF SHIP PROPULSION DEVICES

ABSTRACT

The paper presents the study on the effectiveness of ship propulsion devices based on model tests conducted in the open water experimental set up. The influence of the water depth to draft ratio and distance from the vertical tight wall on the hydrodynamic forces generated by the propellers on the ship hull was investigated. The interaction effects observed for the twin propeller ship in bollard pull condition were compared with the effects induced by single propeller vessels available in literature and discussed with respect to the mathematical modelling of hydrodynamic forces generated on the hull by ship propulsion devices.

Keywords:
ship propulsion, modelling, hydrodynamic forces.

INTRODUCTION

Ship motion simulation is widely used in design, operation and training of the personnel. Modelling of ship motion used for simulation should be reasonably realistic. The accuracy of mathematical models is the most important in the development of operational procedures and safety studies. The modular manoeuvring models preferably used for simulation purposes allow for the superposition of the forces generated on the hull. The generally accepted practice in the development of modular force models for the ship manoeuvring in confined waters is to consider the interaction effects in form of the correction coefficients or the additional hydrodynamic forces acting on the hull.

The results of the series of experiments conducted at the open water experimental set-up in the lake Slim in Ilawa, Poland, in the Research and Training Centre of Foundation for Safety and Environment Protection allowed to study the interaction effects and the hydrodynamic forces, induced by propellers working in different modes, on the hull of a stationary model in confined waters. Comparison of the results obtained for the twin propeller twin rudder ship with published results of single propeller ships, allowed to formulate further conclusions with respect to modelling of ship — wall interaction force due to working propellers.

EXPERIMENTAL PROGRAM

The experimental program was developed for a twin propeller twin rudder ferry model, whose main parameters are presented in table 1. The tests were conducted in the experimental setup consisted of the vertical tight wall and the adjustable bottom allowing the change of the water depth. The large man manned model in 1:16 scale was adopted to the stationary tests. The model presented in fig. 1 [1] was equipped with two, four blades, controllable pitch propellers of the inward direction of revolution. The model was stationary in the horizontal plane and free to the pitch, heave and roll motions.

Table 1. Main particulars of the car — passenger ferry model

Main particulars	
Length over all	10.98 [m]
Length between perpendiculars	9.64 [m]
Breadth	1.78 [m]
Draft	0.42 [m]
Displacement	4.89 [m3]
Block coefficient	0.687
Scale	1:16

The position of model, relative to the wall was fixed using the bow and stern pantographs (fig. 1). The setup of the propellers thrust 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 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 (Visual Basic) had been developed for data collection and processing. The total surge, sway forces and yawing moment were calculated on the basis of the measurements [ocean].

Fig. 1. Experimental test setup, bow pantograph

Two water depth to draft ratios h/T =3 and h/T = 1.2 were tested. For each h/T several distances b (1) between the vessels centreline and wall were assumed.

$$b = \frac{\eta}{B}, \tag{1}$$

where: η — the distance between the wall and model centreline (fig. 2);
B — the model breadth.

The non-dimensional surge (2), sway force (3) and yawing moment (4) are made non-dimensional and based on the length between perpendiculars and draft [2].

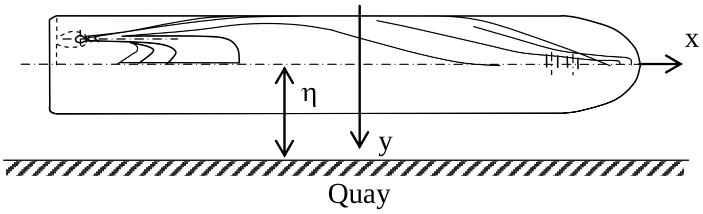

Fig. 2. Coordinate system

$$Fx' = \frac{Fx}{0.5\rho g L^2 T}; \tag{2}$$

$$Fy' = \frac{Fy}{0.5\rho g L^2 T}; \tag{3}$$

$$Mz' = \frac{Mz}{0.5\rho g L^3 T}, \tag{4}$$

where: Fx, Fy, Mz — the measured forces and moment;
ρ — the water density;
g — the acceleration of gravity;
L — the model length between perpendiculars;
T — the model draft.

The propellers were operated both in the push or pull modes to generate the longitudinal forward or astern force. The measurements were used for the qualitative and quantitative analysis of the interaction effects and forces generated on the hull.

RESULTS OF THE EXPERIMENTS

Efficiency of ship propellers in confined waters is strongly dependent on the flow field generated around the ship. The main parameters influencing the interaction effects are propellers rates, water depth to ship draft ratio and distance to the lateral restrictions such as banks and or quay walls.

Forward and backward propeller action in deep water conditions

Results of measurements for h/T = 3 are presented in figures 3, 4 and 5. The longitudinal surge force is dependent on the ship distance from the wall. The biggest interaction effects are observed for Slow Ahead and Slow Astern propellers rates.

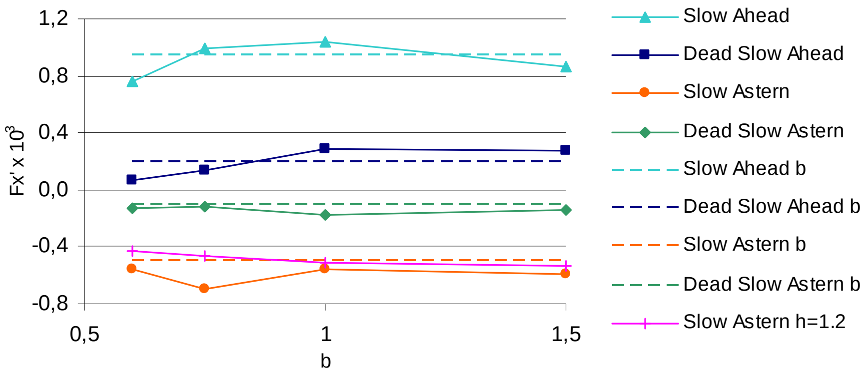

Fig. 3. Longitudinal force induced by propellers as a function of ship-berth distance compared to longitudinal force induced in unrestricted waters in bollard-pull condition, water depth to draft ratio h/T = 3

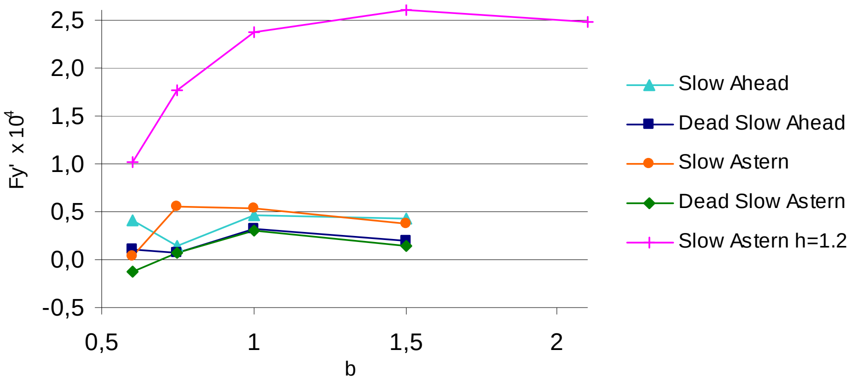

Fig. 4. Lateral force due to ship — berth interaction induced by propellers as a function of ship-berth distance for several propeller rates and water depth to draft ratio h/T = 3

Lateral force generated due to the proximity of the tight wall has the greatest values for the small distances and higher propeller rates. Slow Astern measurements are presented in figure 2 to compare the results obtained in shallow water.

Yawing moment induced during the backward action of the propellers changes its values from zero to stern attraction values due to the suction effect of the flow between the ship side and the wall. The moment induced in shallow water conditions has changed from the bow attraction at the distances up to the half of the ship breadth to the stern attraction at the bigger distances.

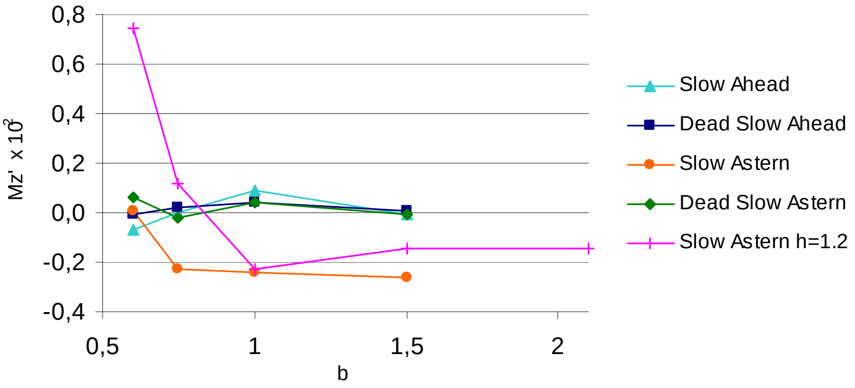

Fig. 5. Yawing moment due to ship — berth interaction induced by propellers as a function of ship-berth distance for several propeller rates and water depth to draft ratio h/T = 3

Forward and backward propeller action in shallow water conditions

Results of measurements for h/T = 1.2 are presented in figures 6, 7 and 8. The observed interaction effects are much stronger then in deep water conditions however the character of interaction is not similar.

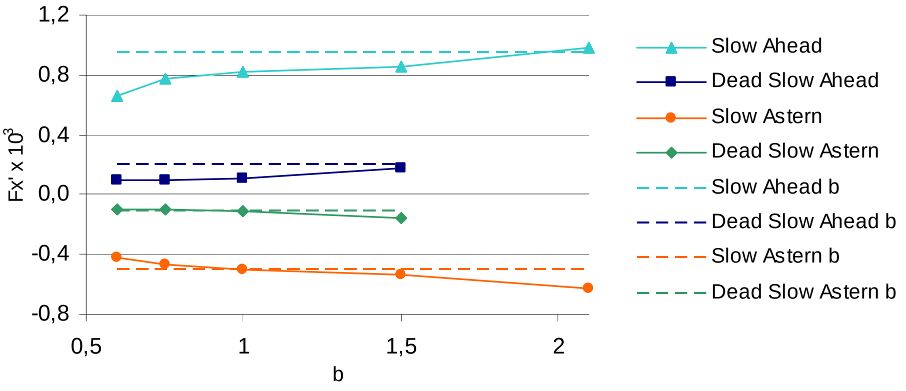

Fig. 6. Longitudinal force induced by propellers as a function of ship-berth distance compared to longitudinal force induced in unrestricted waters in bollard-pull condition, water depth to draft ratio h/T = 1.2

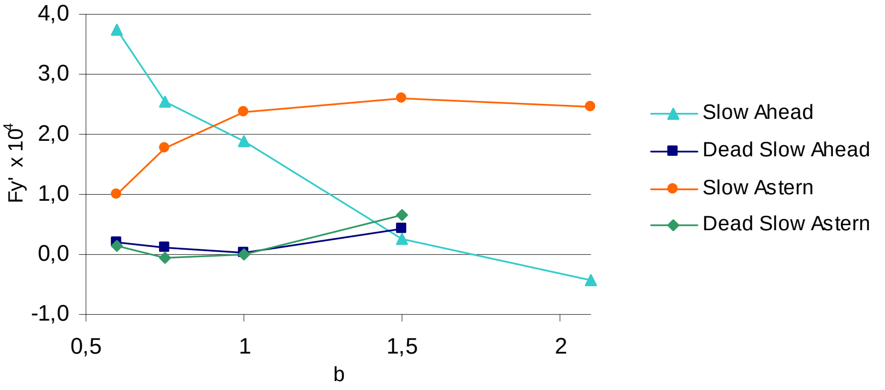

Fig. 7. Lateral force due to ship — berth interaction induced by propellers as a function of ship-berth distance for several propeller rates and water depth to draft ratio h/T = 1.2

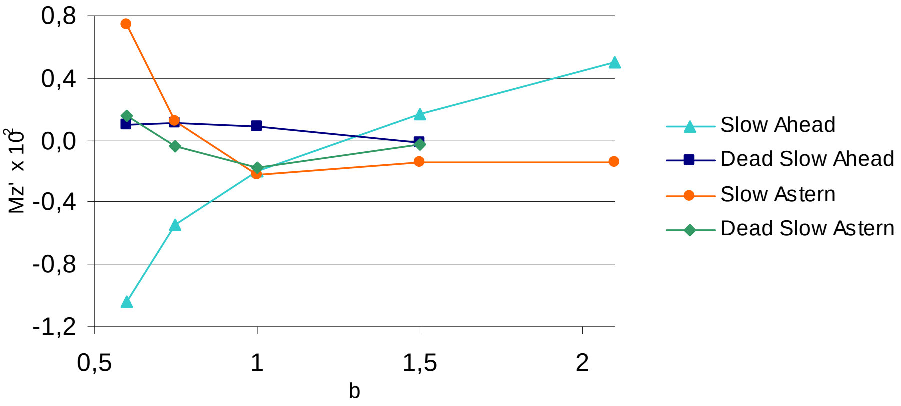

Fig. 8. Yawing moment due to ship — berth interaction induced by propellers as a function of ship-berth distance for several propeller rates and water depth to draft ratio h/T = 1.2

In figure 9 the influence of water depth on the longitudinal surge force generated on hull is presented. The observed difference for Slow Ahead propeller rates is about 60% for the distance of half of the ship breadth.

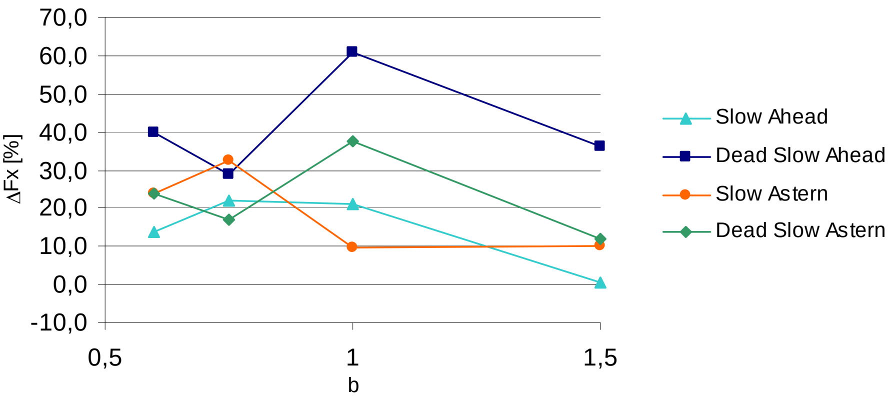

Fig. 9. Longitudinal force decrease due to shallow water effect by propellers as a function of ship-berth distance compared to longitudinal force induced in unrestricted waters in bollard-pull condition, water depth to draft ratio h/T = 1.2

The presented study allows for the comparison with investigations carried out for single propeller ships [3].

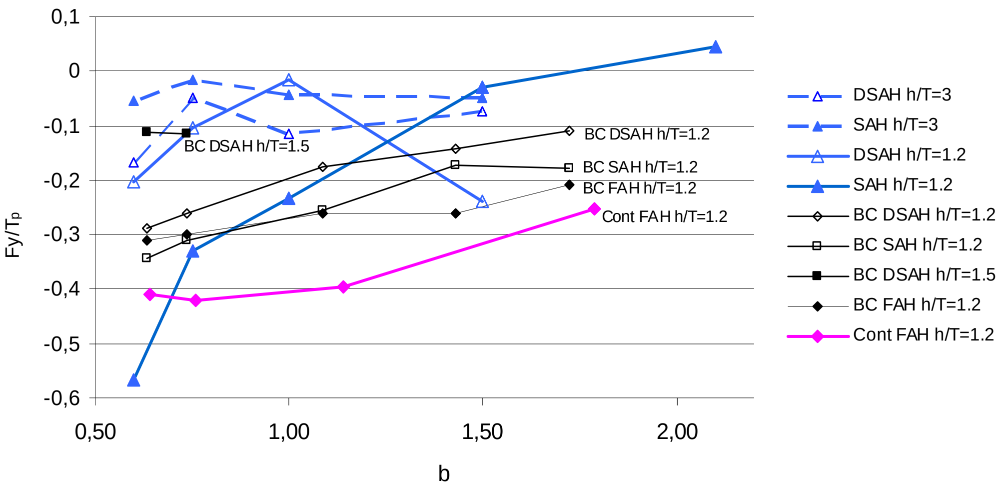

Fig. 10. Lateral force due to ship — berth interaction induced by propellers as a function of ship-berth distance for the twin propeller ferry, bulc carrier (BC) and container vessel (Cont), for several propeller rates and water depth to draft ratios h/T = 3 and h/T = 1.2

The character of changes of the interaction effects is different in dependence of several parameters. The development of the general model for interactions is possible only by the application of sub models developed for particular ranges of influencing parameters.

CONCLUSIONS

Due to the complex flow around the vessel induced by the propulsion devices the strong changes of their effectiveness in the berth proximity the interaction force is dependent on the distance to the berth and water depth to draft ratio. The interaction forces are also sensitive to the scale effect therefore they can not be implemented in the force model without further corrections. The usually used heuristic methods based on the experience of pilots and ship masters allow to bring the simulation closer to reality.

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REFERENCES

[1] Abramowicz-Gerigk T., Experimental study on the hydrodynamic forces induced by a twin-propeller ferry during berthing, Ocean Engineering, doi:10.1016/j.oceaneng.2007.10.009, Elsevier 2007.

[2] Yoo W-J., Yoo B. Y., Rhee K. P., An experimental study on the maneuvering characteristics of a twin propeller/twin rudder ship during berthing and unberthing, Ships and Offshore Structures, 2006, Vol. 1, issue 3.

[3] Vantorre M., Delefortrie G., Eloot K., Laforce E., Experimental Investigations of Ship-Bank Interaction Forces, International Conference MARSIM '2003, Kanazawa 2003.

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