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Study on Critical-uncontrollable Hydrodynamic Interaction between Ships

Yanmin Xu[a,b,c], *Zaojian Zou*[b], *Mingjun Liu*[a], *Kamlesh S. Varyani*[c]
[a]Navigation College, Wuhan University of Technology, Wuhan, China
[b]School of Naval Architecture, Ocean and Civil Engineering (NAOCE), Shanghai Jiao Tong University, Shanghai, China
[c]Department of Naval Architecture and Marine Engineering (NA-ME), Universities of Glasgow and Strathclyde, Glasgow, UK

ABSTRACT

In order to ensure navigation safety in confined waters, especially in pier waters, the conception of Critical-uncontrollable Hydrodynamic Interaction (CHI) between ships was put forward. Based on the slender theory, the maneuverability theory and generic equations for hydrodynamic interaction between ships were combined to analyze the phenomenon of CHI. Ship maneuverability model was utilized to calculate rudder force/moment and lateral force/moment induced by hull, and new generic equations were utilized to calculate hydrodynamic interaction forces/moment between ships respectively. The results verified the objective existence of Critical-uncontrollable Hydrodynamic Interaction Zone (CIZ) under which the ship cannot provide sufficient force/moment to maintain ship under control. The magnitude of CIZ was analyzed according to changes of ratio of water depth by draft, Spacing between the centerlines of the ships, length overall, ship speed etc. respectively. Finally, generic equations for forecasting of CIZ were put forward.

KEY WORDS: Critical-uncontrollable hydrodynamic interaction; critical-uncontrollable hydrodynamic interaction; generic equations; ship-ship interaction; collision avoidance; navigation safety in pier waters;

INTRODUCTION

Close proximity maneuvering of ships in port area or in other congested waters can easily result in dangerous and unexpected emergency conditions. It is important that interaction effect is taken into account in simulation calculations. Therefore, the hydrodynamic interaction effects which are amplified in close encounters in congested waters should be properly understood. The sway force and the consequential yaw moment provided by the rudder should maintain the ship under full control. However, it is not always possible and this may not be available under some typical situation. Because the ship is subject to an attraction force towards another ship and at the same time is subjected to a "bow-in" turning moment, an unconstrained ship would tend to head into the adjacent ships or fixed objects. This causes a destabilizing influence on a ship operating in congested waters, and can lead to a situation, under which safe navigation is impossible. As for ship-ship interaction, there are many researchers who did great contribution on the subject. Silverstein (1957) first developed a linearized theory of the interaction of ships. In addition to some earlier experiments, Newton (1960) and Mizuno (1961) investigated by experiments interaction effects during overtaking maneuvers with two ship models in deep water. To obtain the accurate interacting forces and moments, Chung (1964) investigated by experiments interaction effects between two ships on parallel courses with more data points which revealed slight differences from Newton (1960) and Mizuno (1961). Müller (1967) studied both overtaking and meeting of ships in a narrow canal. Remery (1974) the interaction forces on a moored vessel due to the passage of another ship. Dand (1981) carried out overtaking and head-on encounter tests between two ship models on parallel courses. Comprehensive test series with ship models of both equal and different length in overtaking and encountering maneuvers are described by Vantorre *et al*. (2001). Other authors have developed numerical methods to calculate interaction forces theoretically, including Tuck and Newman (1974), Kijima (1985, 1987), Kaplan and Sankaranarayanan (1987). Brix (1993) presents a method to estimate the forces and moments acting on a ship during overtaking. Varyani *et al*. (1999) present empirical formulae for predicting the peaks of the lateral force and the yaw moment during encounter maneuvers. The above research is essentially dealing with either one-ship or two-ship interaction problems. Varyani *et al* (1997, 2003) obtained interactive forces between multiple ships in restricted waters for different ship configurations. In this paper, the MMG maneuverability model was utilized to calculate rudder force/moment and lateral force/moment induced by hull, meanwhile, the transient sway force and yaw moment induced by a passing ship are obtained with generic model.

MATHEMATICAL MODELING

The co-ordinates systems (x_i, y_i, z_i) are fixed to the ships (Fig. 1). Navigation status of ships navigating in congested waters will be influenced not only by the forces/moments acting on hull (Y_H), propeller (Y_P) and rudder (Y_R), but also by the hydrodynamic