Influence of Hydrodynamic Derivatives on Ship Manoeuvring Prediction and Application of SQCM to Ship Hull Forces

ファーリ, アクバ, アユブ

出版情報：Kyushu University, 2021, 博士（工学）, 課程博士
バージョン：
権利関係：

（様式２）

氏　　名　：　ファーリ アクバ アユブ
Fakhri Akbar Ayub

論 文 名　：　Influence of Hydrodynamic Derivatives on Ship Manoeuvring Prediction and Application of SQCM to Ship Hull Forces（船舶の操縦運動推定に及ぼす流体力微係数の影響ならびに船体流体力に対する SQCM の適用）

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論　文　内　容　の　要　旨

Good manoeuvring capability of a ship is important for marine safety and protection of marine environment. It is crucial that a ship has a good manoeuvrability and can be controlled safely whether the ship is operated at open water or restricted water. For this reasons, the International Maritime Organization (IMO) has approved the regulations for manoeuvring performance of ships. In particular, the IMO defined ship manoeuvrability as essential characteristics of ships to change or maintain their course and speed.

To confirm that the ship satisfies the IMO manoeuvring standards, sea trials must be performed for newly-built ships. However, it is almost impossible to conduct the sea trial under the ideal weather conditions specified by the IMO manoeuvring standards. Therefore, prediction of manoeuvring performance based on simulations is often used.

It is important to predict the performance indices of ship manoeuvrability such as advance and tactical diameter in turning motion, the first and the second overshoot angles for zigzag manoeuvres, and so on at the design stage. The accuracy of predicted manoeuvring motions mainly depends on the quality of hydrodynamic coefficients included in mathematical models of hydrodynamic forces acting on a ship. Especially, lateral force and yawing moment acting on a ship hull have great influence on manoeuvring motions.

Two kinds of mathematical models for lateral force and yawing moment acting on a hull are often used. One is a quadratic model which expresses nonlinear terms of hydrodynamic forces by quadratic polynomials on drift angle (or non-dimensional sway velocity) and non-dimensional yaw rate. The other is a cubic model based on cubic polynomials. It is well known that linear hydrodynamic derivatives based on the cubic model and the quadratic model show different values even if the same dataset of measured hydrodynamic forces are used to drive the derivatives due to the difference of fitting characteristics between the two models. However, the influence of the difference between both models on simulated manoeuvring motions has not been investigated deeply so far.

The hydrodynamic derivatives are generally derived by analyzing hydrodynamic forces measured by conducting captive model tests in a model basin using a model ship. However, measurements of the hydrodynamic forces in the same conditions are not repeated in general, because it consumes long time to carry out the measurement even for one condition. Therefore, measurement error included in the measured results is directly reflected to the values of hydrodynamic derivatives. It means that simulated manoeuvring motion is also affected by the measurement error through the hydrodynamic derivatives. Then, it should be necessary to understand the influence of the measurement error on the hydrodynamic derivatives and simulation results to evaluate ship manoeuvrability properly.

As mentioned above, hydrodynamic derivatives which are good in quality must be used to achieve accurate prediction results. Therefore, the author investigated applicability of the SQCM (Source and Quasi Continuous vortex lattice Method) which is one of panel methods to hydrodynamic forces acting on a ship hull theoretically.

The aim of this study is to clarify the difference between the characteristics of the quadratic and cubic models for hydrodynamic forces acting on a ship and to investigate the sensitivity of simulated ship manoeuvring motion to hydrodynamic derivatives including the influence of measurement error. Furthermore, applicability of the SQCM for the prediction of hull forces is investigated introducing two kinds of vortex models with the consideration of the deformation of free vortices.

This thesis consists of six chapters.

Chapter 1 introduces a general overview of this study including brief review of manoeuvring prediction methods, hydrodynamic derivatives, and so on. A literature review is presented associated with mathematical models of hydrodynamic forces acting on a hull and sensitivity analysis related to ship manoeuvring motion. The objectives and expected outcome of this study as well as a brief layout of this thesis are also presented.

Chapter 2 starts by presenting equations of motion for ship manoeuvring motions. Mathematical models of hydrodynamic forces which are necessary to simulate ship manoeuvring motions are described in this chapter. The differences between a cubic model and a quadratic model of hydrodynamic forces are evaluated by focusing on course stability index.

The sensitivity of simulated ship manoeuvring motions using hydrodynamic derivatives to measurement error included in measured lateral force and yawing moment is investigated in Chapter 3. Furthermore, the difference of the sensitivity between hydrodynamic derivatives based on a cubic model and a quadratic model is discussed.

To calculate lateral force and yawing moment acting on a ship hull representing the shape of the hull accurately, the SQCM is introduced in Chapter 4. To represent flow field around the hull appropriately, vortex models considering the deformation of free vortices are also introduced.

To investigate the applicability of the SQCM, Chapter 5 presents the results of the SQCM application to the Wigley hull and real hulls such as KCS and KVLCC2. The results of hydrodynamic forces obtained from the SQCM are compared with the experimental data. Pressure distribution for each ship is also presented in this chapter.

Finally, the conclusions of this research and recommendation for future work are shown in Chapter 6.