学位論文の要旨（論文の内容の要旨）
Summary of the Dissertation (Summary of Dissertation Contents)

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Dissertation Title: Maneuverability of a Container Ship under Various Loading Conditions
論　文　題　目 (様々な載荷状態におけるコンテナ船の操縦性能に関する研究)

A container ship navigates under various loading conditions in the daily voyage. Although the trim and draft effects on the resistance and propulsive performances are of concern, more research is required on their effects on the maneuverability. They are important for the ship control and safe navigation. This study aims to determine those effects on the container ship's maneuverability by conducting free-running tests to measure the maneuvering motions and captive model tests to clarify the hydrodynamic forces. Each test was under five loading conditions and comparative analysis was performed. CFD was conducted to explain the mechanism of the change of the course stability and the simulation-based study was also presented to study the maneuvering motion and course-keeping performance under wind disturbance. The details of this study are as follows.

KCS container ship was the subject ship which has 3600 TEU loading capacity. In this study, the model ship with the scale ratio is 1/75.24 was used for the experiment. The five types of loading conditions were studied, i.e., full-load draft/even keel (EK), shallow draft/even keel (S-EK), deep draft/even keel (D-EK), full-load draft/bow trim (TB) and full-load draft/stern trim (TS). They were designed as not-significant different loading conditions, which may have been commonly experienced by container ships due to the different volume and arrangement of containers in daily voyages.

First, in order to discuss the effect on maneuvering performance, free-running model tests were conducted. The turning and zig-zag tests were conducted under every loading condition. As one of main results, I found that the turning diameter becomes smaller (i.e., turning ability improves) with an increasing draft or trim by bow. The smaller turning diameter cause a larger OSA during zig-zag maneuvers. It indicates lower yaw-checking ability and course stability. These changes occur even if the change in the loading condition is not necessarily drastic.

Next, captive model tests were performed to understand the differences in hydrodynamic characteristics among different loading conditions. Several kinds of tests were performed, such as rudder force test to find out the rudder force characteristics, oblique towing test and circular motion test to find out the hull force characteristics. Through the eigenvalue analysis based on the linear derivatives of the hull hydrodynamic force and moment, the course stability, which is an important performance to maintain the course stably, was discussed. As one of main results, the course stability of the ship deteriorates with an increasing draft. A major factor was that the acting point of the sway force in the sway motion moved close to the bow. Regarding the trim-series, the course stability decreased in the trim order by the stern, even keel, and trim by the bow when the displacement was kept constant. In this study, OpenFOAM, which was an open-source code of CFD (Computational Fluid Dynamic), was used for the analysis of the course stability. The hydrodynamic surge force, sway force, and yaw moment acting on the hull were calculated. Since the calculated hydrodynamic forces and identified derivatives could capture the tendency of the experimental data, the CFD results were validated. The visualization of the flow field around the hull and the pressure field on the hull surface were used to consider the mechanism for the changes in the course stability according to the loading conditions. For example, the effect of the draft is related to the large positive pressure by an incident fluid at the bow on the face-side and the large negative pressure by the smooth accelerated flow around the fore shoulder of the hull on the backside. The latter was affected by the flow disturbance caused by the bulb. It depends on its submergence depth, i.e., the draft of the ship.

Besides, the maneuvering mathematical model of the subject ship was established in the framework of the MMG-model. A series of hydrodynamic force coefficients used in the model were identified by the captive model test results. The simulation results were compared to the free-running model test results. Evidently, the simulation results captured the difference in trajectories due to the difference in draft and trim observed in the

experimental results. Thus, I confirmed the validity of the maneuvering mathematical model of the subject ship and the present simulation method has enough accuracy in practice. The maneuvering motions in the real scale were continuously conducted. Every model-scale dimension including the loading conditions was converted to the real-scale one, and the roll-motion characteristics were update for the real-scale ship. Because the roll-motion characteristics became more realistic through the realistic design of the container arrangement, there were some difference in the maneuverability from the model ship one. As one of conclusions, when the draft is deeper, or when the bow trim is attached to the ship, the controllability may deteriorate to the extent that the overshoot angle increases. The ship operator should be aware that the maneuverability of large container ship changes significantly due to the loading condition changes.

Finally, the loading conditions and wind effects on the course-keeping performance of the subject ship were investigated. The windage section on the upper deck was designed under five loading conditions which had various draft and trim combinations, and the wind forces and moments acting on the ship were estimated. Based on the developed mathematical model, the course-keeping performance under wind disturbance was investigated by the simulation. The check helm angle under wind conditions, which is defined as the rudder angle required to maintain the specified course without deviation, was significantly different among the loading conditions. Meanwhile, the difference in the hull drift angle and roll angle in the equilibrium state was relatively small among them. Among the trim-series conditions, the trim by bow required a larger check helm angle, while the trim by stern had a smaller angle. This is related to the essential course stability determined by the hydrodynamic water forces acting on the hull under each loading condition. A shallow-draft ship requires a significantly small check helm angle. This is because of the small windage area as well as the better course stability.

Through this study, the maneuverability of the containership under various loading conditions has been investigated comprehensively.