論　　文　　の　　要　　旨（Abstract）

題目：Study on Maneuvering of a Large Tanker in Still Water and Adverse Weather Conditions
（平水中および荒天下中における大型タンカーの操縦性能に関する研究）

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Ship maneuverability has a significantly important role in navigation safety point of view. In order to ensure this important role, a ship must certainly have good maneuver during the initial design process before the ship is built. Likewise, a ship should be maneuvered safely without harming the effectiveness of operating costs. Particularly, a Very Large Crude Carrier (VLCC) with a large size sails not only in still waters or inland waterways but also frequently in various sea states with uncertain environmental conditions. These conditions make a VLCC potentially get a serious accident at sea. Therefore, a VLCC must have a good course stability, and it can be well maneuvered and controlled even in stormy weather under any loading conditions. Furthermore, a VLCC also must be efficient that is proven by low fuel consumption to reduce CO_2 emissions as regulated under IMO regulation with respect to the Energy Efficiency Design Index (EEDI). A small main engine output is one of the alternative options to the above constraint. However, an excessive reduction in the engine output will adversely result in a potentially unexpected unsafe situation wherein a helmsman may not be able to maneuver the ship well in adverse weather conditions. As consequences to the engine output reduction, a large-diameter and low-revolution propeller and an energy efficiency device are employed. A high lift rudder has been selected in this research work as an effective way that aims to improve the ship maneuverability since it becomes worse under reduced-engine output.

In this study, the maneuvering performance of a VLCC tanker in both still water and adverse weather conditions is investigated by using a Maneuvering Modeling Group (MMG) model including wind and waves. A free running model test using a VLCC model (KVLCC2) was carried out to evaluate the maneuvering simulation method in waves. Next, maneuvering of a VLCC is investigated in two loading conditions of a full-load condition (DF) and normal ballast load condition (NB) to assess the effect of load conditions. Furthermore, to achieve an energy efficiency of a VLCC in DF, the investigation involved a situation where the engine output of a VLCC was significantly reduced owing to advances in energy-saving technology. A VLCC with 30% reduced EEDI (Step3) is planned for the conventional VLCC (Step0) by the adoption of energy efficiency devices, a large-diameter and low-revolution propeller, etc. Subsequently, to improve the maneuverability of a VLCC in Step3, a high lift rudder (HL rudder) with a fishtail section and end plates was newly designed to increase the rudder force under a restriction that minimizes the increase in rudder resistance. Tank tests were performed by using a scaled ship model with a HL rudder to capture propulsive performance and rudder force characteristics of the ship with a HL rudder.

Through the research presented in this thesis, it was confirmed that the loading conditions significantly influence the ship maneuverability. The steady-state sailing condition in adverse weather conditions is quite different between DF and NB: the absolute value of the check helm becomes small in NB, but the hull drift angle becomes large. The relative drift direction of the ship in turning to the wave direction is 20°–30° in NB and DF with a rudder angle 35° and almost constant for any wind (wave) directions. The drifting displacement in turning under NB becomes larger than that under DF at the same environmental condition. Advance A_D and tactical diameter D_T become significantly small with an increasing Beaufort scale in head wind and waves when approaching, although A_D and D_T are almost constant in following wind and waves. In beam wind and waves, the tendency depends on the plus and minus of the rudder angle. In zig-zag maneuvers, the first and second overshoot angles (OSAs) in head wind and waves become smaller than those in still water (SW), and those in following wind and waves are almost the same or become larger than those in SW. In the case of 10/10 zig-zag maneuvers of a ship in beam wind and waves, the first OSA increases compared with the value in SW, because the effective rudder angle decreases, and the second OSA decreases, because of the effective rudder angle increases. This tendency becomes opposite for $-10/-10$ zig-zag maneuvers. The effective rudder angle changes owing to the order of magnitude of the check helm in adverse weather conditions. These tendencies with respect to OSAs are the same in between DF and NB, although DF is more significant. However, the situation where the VLCC uncontrollable in DF did not occur. Since the reduction 30% EEDI was applied to a VLCC in Step3, it was observed that Step3 satisfied IMO maneuvering criteria in the still water condition. However, the maneuverability of Step3 was worse than that of Step0 since the rudder force was reduced owing to the low propeller load, which resulted from the small engine output. Additionally, the steady-state sailing performance of Step3 in adverse weather conditions, such as check helm, hull drift angle, and speed drop, generally worsened when compared with those of Step0. Furthermore, course changing ability also deteriorated in the case of Step3. However, the difference between the trajectories of Step0 and Step3 reduced with respect to the large Beaufort scale since the difference in the rudder force became less noticeable owing to the presence of large external lateral forces caused by strong winds and waves. The improvement of step3 was performed by attaching a HL rudder. The results indicated that the designed HL rudder increased the effective rudder force by approximately 10% when compared to a conventional mariner rudder (MN rudder). And the HL rudder presented in this study is useful in improving maneuverability while maintaining almost the same level as the propulsive performance of a ship with a mariner rudder.