(2) Environmental impact evaluation of LNG carriers

In the international maritime industry, which has implemented measures to reduce GHG emissions, the evaluation of ships' GHG emissions is an urgent challenge. Since the international evaluation system for the environmental impact during ship operation started in 2023, in the industry's efforts toward carbon neutrality, visualization of ships' actual fuel efficiency for evaluation is gathering much attention.

The CII (Carbon Intensity Indicator), which serves as an evaluation index for LNG carriers, can be expressed by the following equation.

$$\text{CII} = \frac{\text{CO}_2 \text{ emissions [g]}}{\text{Deadweight (DWT) [MT]} \times \text{Actual navigation distance [NM]}}$$

MT：Metric Ton
NM：Nautical Mile

A carbon intensity rating of A to E is determined according to the attained CII. If a ship has a low carbon intensity rating, the shipowner must create an improvement plan for the ship and obtain approval from the authority. In addition, because the International Maritime Organization (IMO), which established this system, encourages parties in the maritime industry, including the main supervising agency and port authorities, to reward ships that have high carbon intensity ratings, it has become important in relation to ship operations to monitor the attained CIIs and to improve carbon intensity ratings.

In addition, companies in the international maritime industry have established the Sea Cargo Charter for cargo owners and maritime companies to evaluate and announce how well operating ships are meeting the IMO's GHG emissions reduction goal, and they have established the Poseidon Principles for financial institutions' ship loan portfolios. Therefore, evaluation of GHG emissions from ship operations can be considered a maritime-industry-wide challenge.

3 Problem-solving processes using SOPass

(1) Efforts to boost the transportation efficiency of LNG carriers

We have developed BOG-Navigation, which is a function that contributes to improving the efficiency of marine transportation of LNG, by combining the optimal route calculation technology and the operation data analysis technology we have created through past system development, operational insights from the construction of LNG carriers, our thermodynamic evaluation technology, and more.

(i) Prediction of ship motion and LNG state

SOPass can predict the amount of increase in the ship resistance and the swing of the ship as a result of changes in marine climate conditions based on the vessel performance model constructed using design data during ship construction. As shown in **Fig. 2**, the system can predict the amount of increase in the resistance according to the cycle and direction of waves to which the ship is subjected at a given vessel speed, using the vessel

Fig. 2 Amount of increase in resistance in irregular waves at a certain vessel speed

performance model to predict the amount of increase in the resistance due to waves. In addition, the system can calculate the shaft output, number of propeller revolutions, vessel speed, and fuel consumption required for ship propulsion by predicting the wind resistance against the ship, wave-making resistance, viscosity resistance, and other factors. It can also predict the motion of the ship in waves and wind, such as rolling and pitching.

Furthermore, the system can predict the states of the cargo tank as well as the liquid and vapor inside the cargo tank based on the cargo tank heat transfer model constructed with consideration given to structural factors such as the hull, tank, and piping. Moreover, it can predict the pressure in the cargo tank and the amount, temperature, and composition of LNG, which changes from hour to hour in response to the ambient air temperature, sea temperature, and heat intrusion, such as solar radiation. **Fig. 3** shows the calculation result of the solar radiation impact using a heat transfer model constructed using the design data of an LNG carrier that we built. The amount of NBOG and SBOG generated in the cargo tank as well as the equator temperature for Moss tanks and the LNG temperature at each liquid level for membrane tanks can also be predicted.

By making it possible to predict the ship motion and