Fuel saving method based on statistical analysis for high-speed small boat

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1. Introduction

Frictional resistance accounts for most of the resistance that the hull receives from the water. For example, in a large ship such as a VLCC, about 90% of the hull resistance is the frictional resistance. In such a large displacement vessel, the power required for propulsion is roughly proportional to the cube of the ship speed. For this reason, slow steaming basically has a great effect for fuel consumption saving. On the other hand, in small ships that goes at relatively high speed, wave-making resistance is one of the main resistance components. The wave-making resistance also increases with the ship speed, but it is also known that the bow waves and the stern waves interfere with each other. Due to this physical phenomenon, the wave-making resistance does not increase monotonically. As a result, an increase in ship speed causes a phenomenon in which resistance not only increases (hump) but also decreases or does not increase more than expected (hollow). It is thought that the expected fuel consumption can be expressed as an approximation curve derived based on multiple data of measured ship speed and fuel consumption. Generally, this approximate curve is a fuel consumption trend that ship operators have no choice but to accept. Hence if the fuel consumption is less than that trend, it can be judged that the fuel efficiency is better than they expect. Fig.1 shows the fuel consumption trends based on observed data. These trends vary from voyage to voyage depending on the load weight, trim balance, environmental conditions, and the state of the hull fouling. Therefore, it is not adequate to use a specified fuel consumption trend, which means the prepared trend needs to be determined in every voyage. However, in actual operation, it is not practical to calculate the fuel consumption trends based on the multiple measured data for each voyage. It is desirable to estimate a fuel consumption trend with a few measured data which can be observed on board.

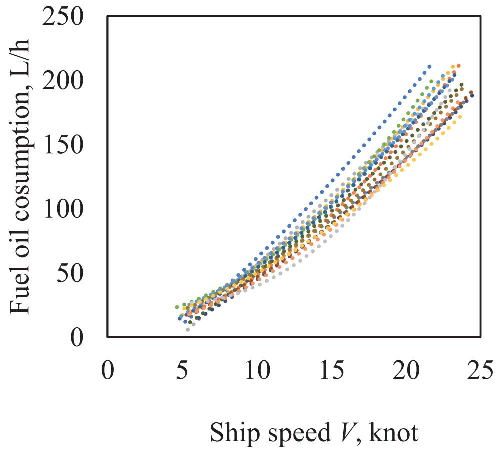

Fig.1 Observed Fuel oil consumption Trend

In order to approach the issue, this paper proposed a method for determining the Expected Fuel oil consumption Trend (EFT) using statistical methods and a few observed data during the voyage.

2. Experiment

This research project had been conducted on the 19.8-meter-long, 19-ton fishery research vessel "Hojo" belonging to Fisheries Technology Center of Kanagawa Prefecture. The experimental voyages were taken place 16 times from October 2022 to March 2024. In the experiment, the engine speed was stepped up by 50 rpm in the range of about 450 rpm to 1950 rpm. Ship speed V, engine speed N, and fuel oil consumption FOC were measured for more than 60 seconds at each engine speed.

3. Derivation method of EFT

To determine EFT with as little observation data as possible, it is necessary to reduce the number of parameters to be calculated. From the measured data of Fig.1, this paper assumes that the FET could be expressed as a following simple equation.

$$FOC = aV^2 + b \tag{1}$$

Multivariate analysis of the relationship among FOC, V and N was conducted. As a result, a strong correlation was found between fuel efficiency at maximum ship speed E_{f-max} and a. (Fig. 2)

$$a = pE_{f-max} + q \tag{2}$$

$$E_{f-max} = \frac{V_{f-max}}{FOC_{f-max}} \tag{3}$$

V_{f-max} : Maximum ship speed [knot]

E_{f-max} : Fuel efficiency at V_{f-max} [mile/L]

FOC_{f-max} : FOC at V_{f-max} [L/h]

p : Slope of a linear function

q : Intercept of a linear function

Substituting (2) and (3) into equation (1), the intercept b is derived.

$$b = FOC_{f-max} - \left(p\frac{V_{f-max}}{FOC_{f-max}} + q\right){V_{f-max}}^2 \tag{4}$$

p and q are known from statistical data shown in Fig.2, V_{f-max} and FOC_{f-max} can be measured onboard.

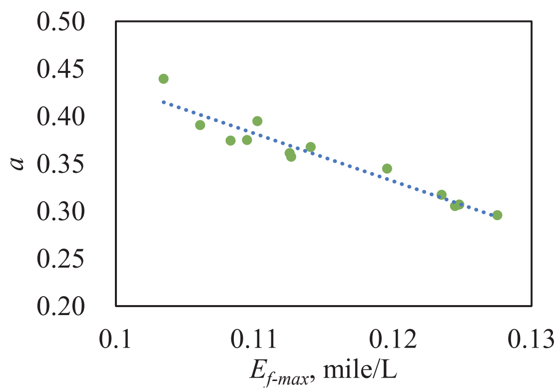

Fig.2 Correlation between E_{f-max} and a

4. Evaluation

In order to verify the proposed method, three data group which are not used for the multivariate analysis are preserved. Fig.3 shows an example to use them for determining EFT with measured data. It may say that EFT determined by the proposed way fits those measured data to some extent.

EFT is not line based on these measured data, however the coefficient of determination was applied to evaluate the degree of agreement with the measured values. (Table 1) Based on the values of the coefficient of determination, the proposed method earned high score. On the other hand, looking at Fig.3 in detail, EFT has some difference from those observed data. One of the reasons is that EFT is regarded as the simplified equation (1). It is necessary to be considered various aspects including equation model of FOC for achieving EFT with a few measured data.

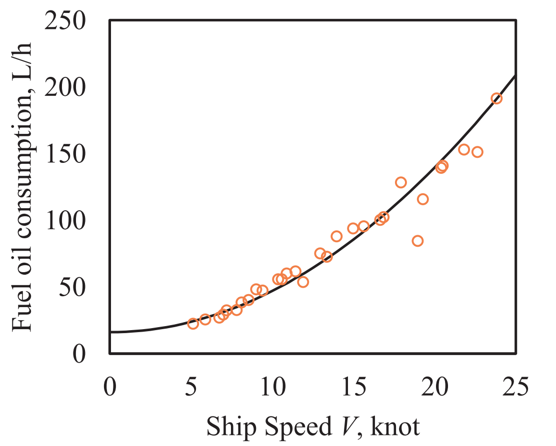

Fig.3 Measured data and EFT

Table 1 Verification results

	Day1	Day2	Day3
Coefficient of determination	0.9859	0.9560	0.9422