Analysis of Biofouling Influence on Hull and Propeller Based on Observed Ship Data

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1. INTRODUCTION

Biofouling increases the resistance of hull and propeller, which results in the required power increases at constant speed[1)2)]. This paper shows influence of biofouling on propulsion performance by analyzing the observed long-term data for last decade.

2. OBSERVED DATA

The data was observed since 2011 to 2020 on ship A. Ship A is about 50 meters long and mainly navigates in Tokyo Bay. Ship A has a middle-speed diesel engine of about 1,000kW and 4 blade controllable pitch propeller (CPP). The observed data including ship speed, shaft horsepower (SHP), shaft speed, propeller blade angle, rudder angle, heading course, true wind speed and true wind direction are observed every second and recorded on the shore data server through the network.

3. ROTATONAL HORSEPOWER

3. 1 Definition of RHP

To observe the influence of the propeller fouling, this paper focuses on SHP in a specific condition that CPP does not provide any thrust force to push the hull. The propeller requires the power to some extent for keeping its constant speed even if its blade angle θ is neutral. This dissipated power is defined as Rotational horsepower (RHP) in this paper.

$$RHP = SHP_{(\theta=\mathrm{Neutral})} \tag{1}$$

3. 2 Measuring RHP

Before starting its navigation, the propeller is usually driven at neutral angle for a few minutes. RHP is the averaged value of SHP as following conditions are satisfied: CPP angle is in between -2.5deg and -1.0deg, rudder angle is under ±1.0deg and shaft speed is over 290 min^{-1}. The value of RHP is determined in each voyage and recorded as a representative value.

3. 3 Trend of RHP

Ship A used to go to the dock every summer season and to have a service for removing the fouling from its hull and the propeller. Fig. 1 shows the RHP variation after leaving a dock each year. RHP increases 30-50% over times after leaving dock every year. It can be seen that RHP is increased in the period of 0-60 days and 300-360 days after the dock which coincide with the summer season. It is natural to think that the hull gets the biofouling faster when the water temperature is high. Therefore, one may say that RHP has a relation with the fouling.

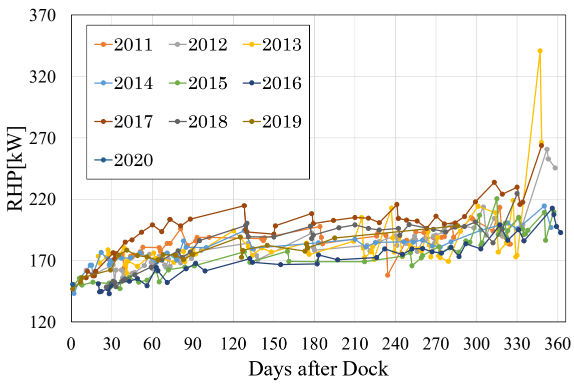

Fig. 1 RHP trend

4. RELATION BETWEEN RHP AND SHP

4. 1 Filtering and extracting data

In order to clarify the relation between RHP and the fouling, the big data acquired in long term observation was analyzed. It is necessary to remove variations of data which were caused by the environment condition and the navigation state[3)]. Several filters were developed to extract data at steady state. From the viewpoint of statistics, moving average and coefficient value evaluation were implemented. Additionally, the following filters were used.

(1) For variations caused by sea condition

Wind and waves lead to increase ship resistance. To eliminate the data recorded in rough seas condition, Beaufort scale was calculated from observed wind speed. The data set with under BF3 or less (wind speed 5.5m/s or less) was extracted.

(2) For influence of blade angle

In order to investigate variation of SHP at constant driving condition, the data was extracted in three conditions that the blade angle is 9.3deg, 13.4deg and 17.3deg, because ship A often navigates in these conditions.

4. 2 SHP and RHP

Fig. 2 shows the relationship between RHP and SHP extracted from the big data with the filters. To make the trends of RHP clear, only median values in each voyage are indicated. As is clear from Fig. 2, RHP and SHP have linear relations. Large SHP is required to maintain the propeller speed constant as RHP is large. If deterioration of hull performance is neglected, the increase of SHP can be attributed to the fouling. Hence, one may conclude that RHP is an indicator of the fouling.

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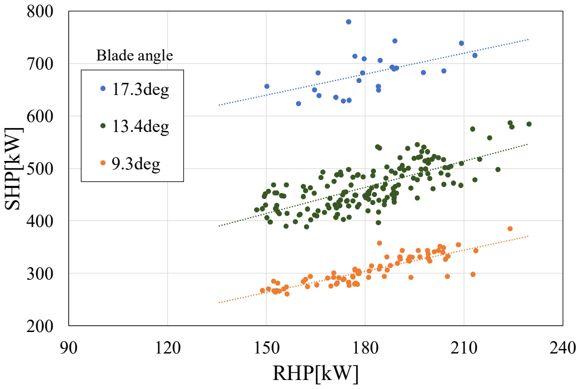

Fig. 2 RHP and SHP of CPP

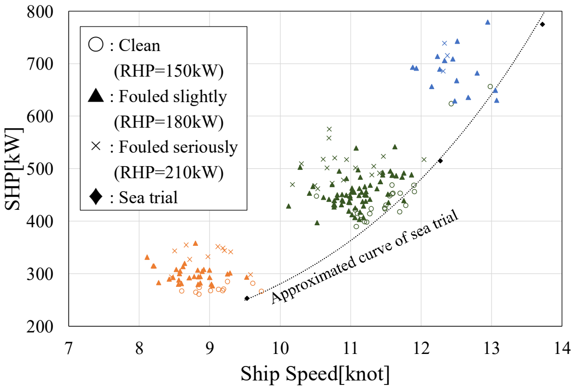

Fig. 3 Performance degradation by fouling

5. BIOFOULING INFLUENCE

5. 1 Influence on ship speed

Fig. 3 shows the relation between the ship speed and required SHP to drive the propeller. As shown in Fig. 1, RHP is around 150kW immediately after the dock. Dotted data are classified into clean, slightly fouled, seriously fouled condition by using the value of RHP. Comparing these data to the approximated curve which was obtained in the sea trial of ship A, the biofouling influences not only increase of power but also decrease of ship speed. To assess only the influence of the power, it is necessary to compare the value of SHP at constant speed between clean and fouled conditions. Performance curves of each fouling condition were estimated with the Ordinary Least Square method (OLS). The regression model between the ship speed and SHP is suggested by ITTC[4)] as follows:

$$SHP = aV^n + b \tag{2}$$

where, *a, b, n*: coefficients of regression, *V*: ship speed.

It is considered that SHP equals to RHP at *V*=0knot. Thus, RHP can be substituted as the intercept *b* for Eq. (2). Table 1 shows coefficients of regression models. Fig.4 shows estimated performance curve of three fouling conditions. It is obvious that SHP is increased in the seriously fouled condition, although the variation is lager than other conditions because the number of samples is small.

Table 1 Regression models

Condition	Samples	a	b	n	R^2
Clean	34	0.041	150	3.628	0.944
Fouled slightly	113	0.053	180	3.564	0.882
Fouled seriously	31	0.020	210	4.001	0.839

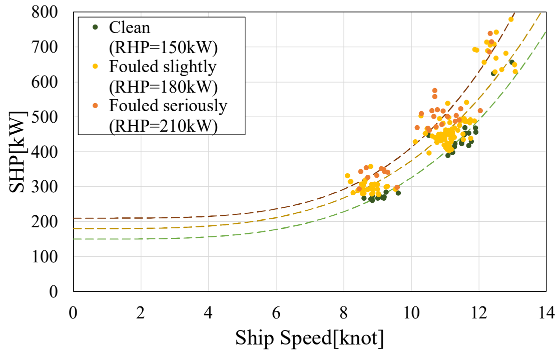

Fig. 4 Estimated performance curve

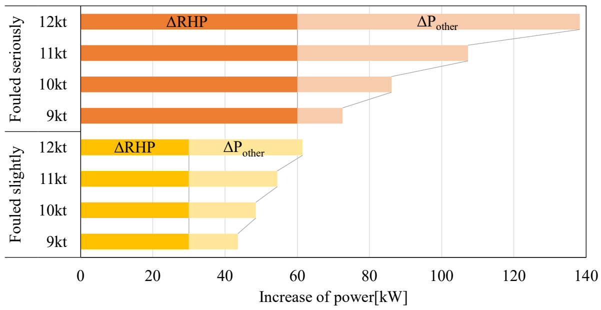

Fig. 5 Breakdown of SHP

5. 2 Power increase ratio by propeller fouling

To focus on the increase of the power, ΔSHP and ΔRHP were defined. These are calculated by subtracting the power at the clean condition from the observed values. ΔSHP have to include ΔRHP. Additionally, other power (ΔP_{other}) is included in ΔSHP.

$$\Delta SHP = \Delta RHP + \Delta P_{other} \tag{3}$$

Fig. 5 shows the breakdown of ΔRHP and ΔP_{other} with respect to ΔSHP. ΔSHP increases as fouling progression and speed increase. ΔRHP is occupied over 50% of ΔSHP under 11kt conditions. It is natural to assume that ΔRHP is caused by the fouling of propeller. Hence it can be said that from the Figure, ΔP_{other} is mainly derived from the fouling on the hull. Therefore, the influence of propeller fouling has more serious impact on propulsion performance than the hull fouling in these conditions of ship A.

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