A study of factors influencing fuel efficiency for high speed small boat

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1. Introduction

It is well known that hull fouling increases hull resistance and seriously affects fuel consumption as well as reducing ship speed.[1][2] Fouling due to biological deposition begins with the formation of a slime layer composed of bacteria and algae on the hull surface.[3] After that, barnacles, bryozoans, and other waterborne wandering organisms can also attach to the hull surface. These factors increase the roughness of the hull surface. As a result, the hull frictional resistance increases, which leads to an increase in fuel consumption. IMO reports that the growth of a slime layer makes fuel consumption worse by as much as 10-20%.[4] Most of these studies were based on investigations of displacement-type vessels. However, we have not seen any studies on small boats, such as fishing boats, that can go in semi-sliding or sliding states. In this study, the influence of hull fouling was investigated using observed data from a 19-ton fisheries research boat “Ho-jo”.

2. Observed data

In this study, engine speed, fuel consumption, ship speed, and boat inclination were measured. The engine speed was measured by using a laser reflective sensor installed at the end of the main propulsion shaft. An ultrasonic flow meter was installed in the fuel line to measure the fuel consumption. The same sensor was installed on the return oil line. The difference between these two values was treated as the fuel consumption. The ship speed was calculated based on GPS position data obtained from a smartphone. A gyro sensor was installed to measure the inclination of the boat in the pitching direction.

All measured data were recorded every second. The data were averaged over 50 seconds. This is regarded as a steady-state condition for the analysis.

3. Measuring Results and Discussion

The boat had periodic maintenance checks on the dock in February. The fouling on the hull was removed, and the hull was coated with antifouling paint. Figure 1 shows the hull surface when lifted in the dock. The entire hull was covered with a layer of slime, and barnacles were observed near the propeller boss. To obtain a clearer picture of the impact of hull fouling on the propulsive performance of the boat, this paper compared the data obtained immediately before the boat entered the dock and immediately after the boat left the dock.

Fig. 1 Hull fouling

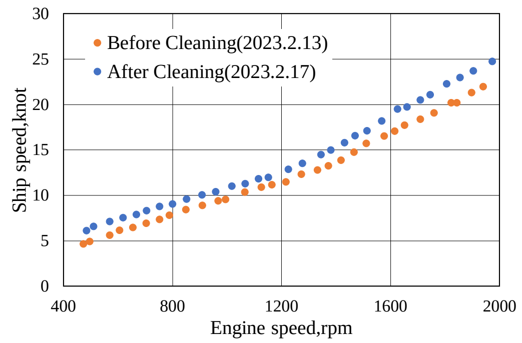

Fig. 2 Engine speed and ship speed before and after dock

Figure 2 shows the relationship between ship speed and engine speed before and after the dock. Even if the engine speeds are the same, there is a large difference between them. The maximum ship speed decreased by nearly 3knots. The slope changes when the ship speed is approximately 12knots, but the relationship between ship speed and engine speed is linear for both before and after the dock. From the figure, it is clear that hull fouling is one of the factors that uniformly reduces ship speed. On an average, a 12.2% reduction in speed was observed across the entire speed range.

A decrease in ship speed also affects fuel efficiency [miles/L] (see figure 3). As this figure clearly shows, fouling deteriorates fuel efficiency. An average degradation of 16.2% was observed over the entire speed range of the ship. As mentioned earlier, ship propulsion performance is severely affected even though the hull is only thinly covered by the slime layer.

This influence was remarkable in the low-speed range. This fuel efficiency decreased by 23.1% in the low- speed range below 10knots due to biofouling, while it deteriorated by 10.9% in the speed range above 10knots. To determine the mechanism, the ship speed and hull tilt angle were investigated (see figure 4). The hull tilts as its speed increases, because the bow is lifted gradually. This effect may reduce the underwater area above 10knots, which mitigates the increase in hull resistance. Consequently, the deterioration of the fuel efficiency in the high-speed range was limited, although hull fouling increased the surface roughness.

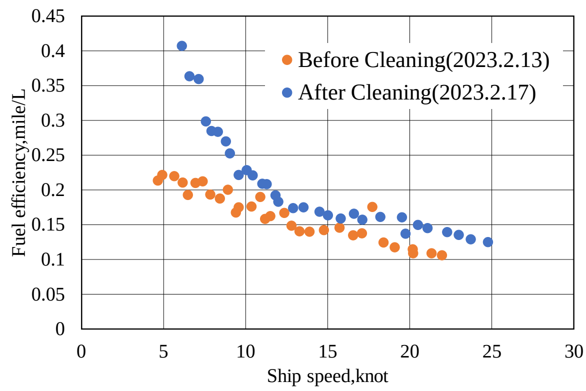

Fig.3 Ship speed and fuel efficiency before and after dock

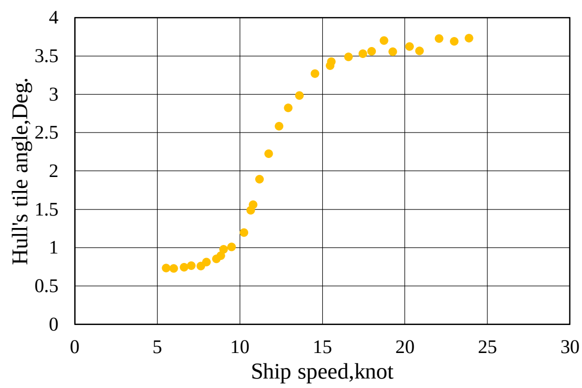

Fig.4 Ship speed and ship's inclination

Reference

[1] M. P. Schultz, “Economic impact of biofouling on a naval surface ship,” Biofouling, vol. 27, no. 1, pp. 87–98, 2011.

[2] M. P. Schultz, “Effects of coating roughness and biofouling on ship resistance and powering,” Biofouling, vol. 23, no. 5, pp. 331–341, 2007.

[3] USDPA, “Underwater ship husbandry discharges,” 2011, EPA 800-R-11-004.

[4] “Preliminary results: Impact of ships’ biofouling on greenhouse gas emissions”, Glofouling Partnerships Project, IMO, Nov. 2021.