Fuel Saving Effects on Slow Steaming and its Limitation for Small Boat

Tokyo University of Maritime Science and Technology 〇Kazunori Hiraga, Hiroyasu Kifune, Masataka Kawana
Fisheries Technology Center Sagami Bay Experiment Station Of Kanagawa Prefectural Government
Tatsuo Nishimura,Yuya Kagami,Isao Shimada, Hikaru Hasegawa

1. Introduction

In a ship, it is known that the frictional resistance R due to seawater increases in proportion to the square of the ship's speed v. The effective output EHP required to propel the ship can be estimated by the hull frictional resistance R and the ship's speed v. It can be expressed by the following equation (1).

$$EHP = cRv = cv^3 \quad (1)$$

c is an arbitrary constant.

Effective power increases in proportion to the cube of the ship speed approximately. In general, fuel consumption is assumed to be roughly proportional to EHP. Figure 1 shows an example of observed fuel consumption of a small boat. As the ship speed increases, the FOC becomes very large. Under the same operating conditions for the same distance, navigation at a slower speed increases the voyage time but reduces the fuel consumption. Therefore, slow steaming is well known as an effective way to reduce fuel oil consumption. It has been more common concept and conducted to save fuel regardless of vessel size. This study investigates the effects of slow steaming on small, high-speed vessels.

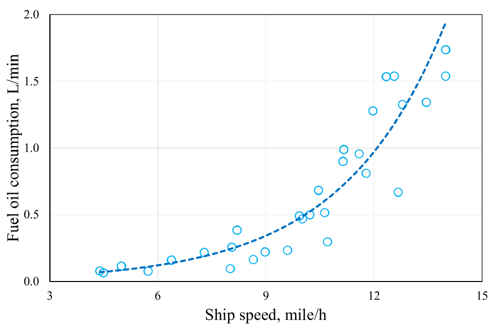

Figure 1 Ship Speed and FOC

2.wave making resistance

Wave making resistance, increases roughly in proportion to the square of the ship speed like frictional resistance. However, it is known that the waves created by the bow and stern sections interfere with each other. Due to this phenomenon, wave-making resistance does not increase uniformly with an increase in ship speed. From the naval architects view, it is predicted that the wave making resistance increase and decrease periodically in accordance with the ship speed. (See Figure 2.) The state in which wave-making resistance increases is called as hump, and the opposite is defined as hollow. Since the resistance is greater in hump conditions, engine power to maintain ship speed is also greater. Therefore, fuel consumption also increases. On the other hand, if the vessel can maintain a hollow condition instead of a hump, it is thought that a fuel-efficient navigation can be achieved. Because hump and hollow are important phenomena that affect fuel consumption, they are discussed under certain conditions, such as tank tests, when planning high-speed vessels. The equation for wave-making resistance that describes the occurrence of hump and hollow is expressed as follows

$$R_w = \frac{1}{4}\rho g(a_F^2 + a_A^2 + 2a_F\, a_A \cos\frac{1}{F_n^2}) \quad (2)$$

,where $\rho[kg/m^3]$: sea water density

$g[m/s^2]$: the acceleration of gravity

$a_F[m]$: amplitude of fore wave

$a_A[m]$: amplitude of aft wave

$F_n[-]$: the Froude number

$U[m/s]$: ship speed $L[m]$:total length.

$$F_n = \frac{U}{\sqrt{gL}}$$

As the third term in equation (2) indicates, wave-making resistance has a component that varies periodically with respect to the Froude number. Figure 2 shows an image of the hump and hollow that occur on the hull of a high-speed ship. the speed range in which the hump and hollow appear can be calculated by $\cos(1/F_n^2)$. When the value is $\cos(1/F_n^2)$ = 1,the resistance of wave making will be "hump" and the resistance of wave making will increase significantly. On the other hand, it is expected to be "hollow" and the resistance of wave making will decrease when the value is $\cos(1/F_n^2)$ = -1. The phenomenon called "last hump" appears when F_n = 0.79, and no periodic change occurs when $F_n \geq 0.79$.

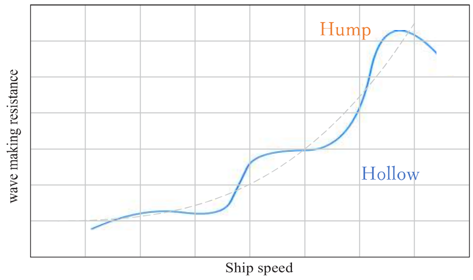

Figure 2　Image of Hump and Hollow in Ship Speed

3.Navigation data

Fuel consumption was measured on the "Hojo" belonging to Fishery Technology Center of Kanagawa Prefectural Government. In placing the flow meter, the return oil from the main engine was considered. At the same time, the main engine speed and ship speed were also recorded. Figure 3 illustrates the fuel efficiency [mile/L] versus ship speed. It shows a tendency for the propulsion efficiency to decrease as the ship speed increases. This trend is attributed to the increase in frictional resistance.

On the other hand, it is seen that the fuel efficiency is not uniformly decreasing. This is not just a variation of observed data because all plots wave calculated by using averaged the data for 30sec. In other words, it shows some kind of characteristics in the resistance. Consequently, it is considered that the ship resistance including the wave making resistance became high when the efficiency is low. For example, as Figure 3 shows, from the perspective of fuel consumption, the speed range around 18.5knots should be avoided. It is better to slow down to about 16knots for fuel saving, or conversely, to increase speed to around 21.5knots for fuel-efficient high-speed navigation. This suggests that it is inappropriate to simply slow down and navigate without taking hump and hollow into account for small high speed vessels. Figure 4, It is thought that the hump or a similar phenomenon of the hump can be seen around 18knots. Fuel oil consumption raised by 18% when the engine speed was changed from 1600 rpm to 1700 rpm although ship speed became faster by only 0.1 knot, If ship operator can choose the navigation state properly, unnecessary fuel consumption may be reduced.

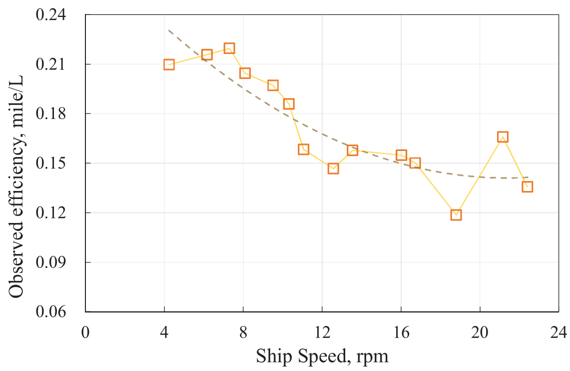

Figure 3 Ship speed and propulsion efficiency [mile/L]

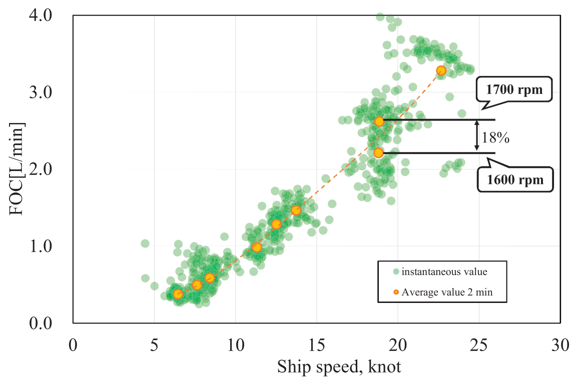

Figure 4 Ship speed and fuel consumption