SIMULATION STUDY OF THE SHIP'S LOSS OF SPEED WHILE MANEUVERING

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Abstract
The problem of determining the influence of weather conditions on the loss of speed of the vessel during maneuvering is the crucial problem for ship's operation. More accurate introduction of the loss of speed of the vessel will increase the safety of navigation and the quality of maritime transportation. Analysis of the existing methods of calculations of loss of speed of vessel shows that they allow calculating the required values of speed loss, but can be used only under certain conditions that are mutually exclusive. The results of an experimental investigation on the flow resistance around ship's hull during maneuvering based on loss of speed may be referred to an external hydrodynamic task. Experiments were conducted performing the zigzag maneuver using a vessel motion simulator under various weather conditions. The laws of speed loss were obtained in a form of longitudinal friction coefficients depending on weather conditions for their practical use and consideration when maneuvering in congested waters.

Keywords: loss of the vessel's speed, longitudinal friction coefficients, maneuver "zigzag", maneuvering, weather conditions influence.

INTRODUCTION

The research shows that the existing methods for calculating the loss of speed due to the influence of wind and wave resistance on the hull, can be used only for at constant values of the wind angle, rolling and ruder angle.

There are formulas for calculating the ship's loss of speed which take into account ship's speed, current, loss of speed during a single turn, wave length and height [2, 3, 4, 5]

However, the methods of calculating the loss of speed of the vessel during maneuvering do not take into account the effect of weather conditions on the hull, thus not meeting the needs of the driver in calculating the loss of speed of the vessel.

The problem of determining the influence of weather conditions on the loss of speed of the vessel during maneuvering is posed.

Loss of speed referres to an external hydrodynamic task, as the vessel is an object being flown round by water under various angles while maneuvering.

To determine the conformity of loss of speed of the ship depending on weather conditions, a representative series of experiments was made to determine the influence of weather conditions on the ship, during the "zigzag" maneuver, as a theoretical model of maneuvering.

Two ship models were selected, which were used to perform six zigzag maneuver experiments using the ship motion simulator.

During each experiment, periodic logging of such parameters of the vessel's movement as course, speed over ground (SOG), rudder angle and relative wind course angle was performed.

The obtained data were analyzed and compared. Based on the results of each experiment, a graph of the dependence of the speed of the vessel on time was constructed, for graphical analysis and determination of ways to find patterns of the process of loss of speed of the vessel during maneuvering depending on weather conditions.

EXPOSITION

Two different ship models were used for experiments: VLCC and Cape Size bulker.

During the experiment, a "zigzag" maneuver was performed with the rudder angle set at 15 degrees.

Each ship performed three experiments with different weather conditions: one, three and five points on the Beaufort scale (BS).

The course angle of wind and rolling is zero at the initial time of all experiments. After the start of the maneuver, the course angle changed alternately to port and starboard.

The initial velocity V_0 for first vessel is 12.5 knots and 10,3 knots for second vessel.

Every 10 seconds, the vessel's course and speed (SOG) as a function of time were recorded.

Six experiments were performed and a following data was obtained.

Loss of speed in relation to time is represented for first vessel in table 1.

Table 1. *Loss of speed of first vessel*.

Time, min	***SOG***		
	Beaufort scale 1	***Beaufort scale 3***	***Beaufort scale 5***
0	12,5	12,5	12,5
0.5	12	12,1	12
1.0	11,5	11,3	11,4
1.5	11,2	11,2	10,6
2.0	11	10,7	10,7
2.5	10,6	10,3	10,3
3.0	10,1	9,7	9,5
3.5	9,8	9,7	8,8
4.0	9,9	9,9	8,9
4.5	9,8	9,8	9,1
5.0	9,5	9,5	9,1
5.5	9,2	8,9	8,8
6.0	9,3	9	8,5
6.5	9,5	9,3	8,5
7.0	9,4	9,2	8,8
7.5	9	8,9	8,9
8.0	9,1	9,1	8,5
8.5	9,3	9,2	8,3
9.0	9,3	9,4	8,8
9.5	9,2	9,5	8,7

The obtained data can be represented as a graph (Fig. 1)

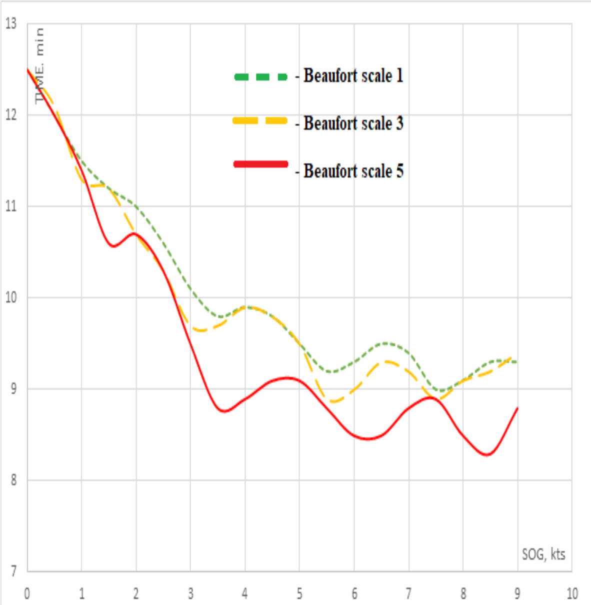

Fig. 1. *Loss of speed of first vessel*

Loss of speed in relation to time for second vessel is represented in Fig. 2.

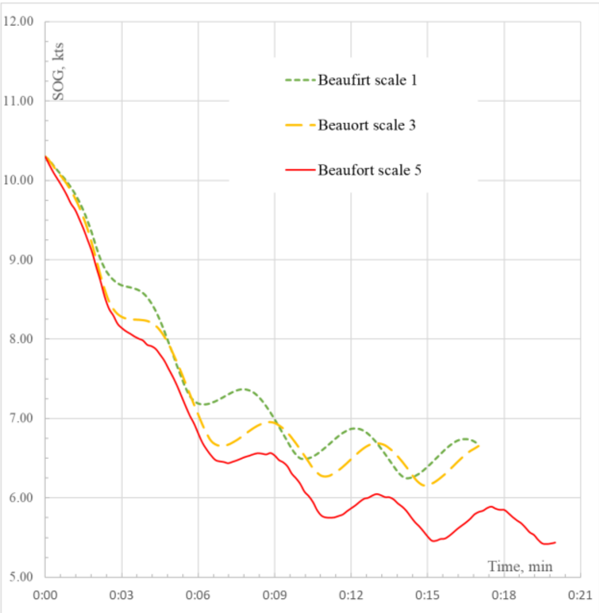

Fig. 2. *Loss of speed of second vessel*

Comparing both graphs it was found that the process of loss of speed of the both vessels during the "zigzag" maneuver can be divided into two periods.

During the first period, the speed of the vessel decreases intensely and evenly. However, after reaching a certain point, the speed begins to increase and decrease in a wavy way, so to determine the nature of the loss of speed, it was decided to use the first period of the maneuver.

Having obtained the dependences of the speed of the vessel on time during the first period, the loss of speed, in each case was put in accordance with a certain function of the speed of the vessel on time.

Comparing the obtained functions, we can conclude that when the wind speed and wave height increase during the zigzag maneuver, the angular velocity decreases and the maneuver slows down, but due to the impact on the hull of the wind-wave resistance and longitudinal hydrodynamic friction [1], the vessel speed decreases by a larger amount. Therefore, considering the problem of speed loss depending on weather conditions, taking into account this process when maneuvering, it is necessary to take into account not only the magnitude of the speed loss but also the nature of this process.

The obtained formulas (Formulas 1,2,3,4,5,6) for calculating the speed drop depending on weather conditions reflect the nature of the speed drop and take into account both the magnitude and time of the speed drop.

$$V(t) = V_0 - 0{,}78 \times t \qquad (1)$$

Where: t – moment of time in minutes;

V_0 - initial ship's speed in knots.

$$V(t) = V_0 - 0{,}87 \times t \qquad (2)$$
$$V(t) = V_0 - 0{,}98 \times t \qquad (3)$$
$$V(t) = V_0 - 0{,}51 \times t \qquad (4)$$
$$V(t) = V_0 - 0{,}54 \times t \qquad (5)$$
$$V(t) = V_0 - 0{,}58 \times t \qquad (6)$$

From formula (1), which was obtained during the experiment on the first ship, for weather conditions corresponding to Beuafort scae one, loss in speed when performing the maneuver "zigzag" can be assigned a coefficient of k_{11} = -0.78.

Similarly, from formulas (2) and (3) we obtain the coefficients k_{13} = -0.87 and k_{15} =-0.98, under weather conditions three and five points, respectively.

As a result of experiments using the model of the second vessel, similar to the previous ones, are assigned coefficients k_{21} = -0.51, k_{23} = -0.54 and k_{25} = -0.58.

Significant differences between the coefficients can be explained by the fact that for each vessel has it's unique maneuvering characteristics , but the nature of the loss of speed is similar (Fig.3).

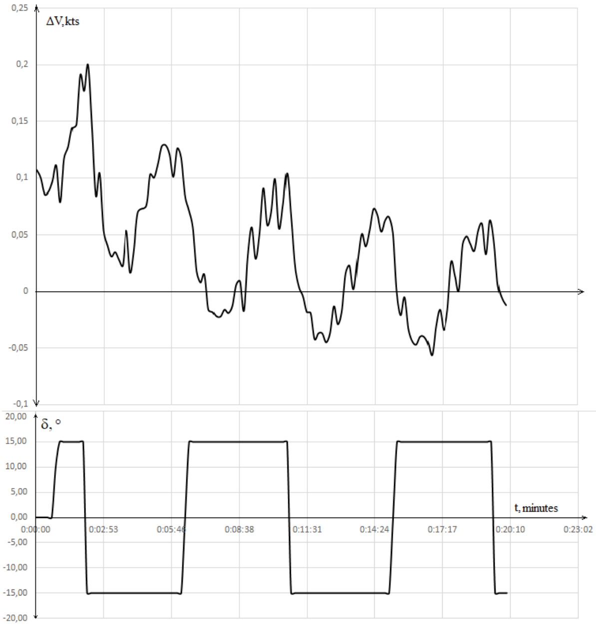

Fig.3. *Relation between value of loss of speed and rudder angle in time*

According to the results of the experiments, we have six linear functions (1) - (6) of the speed drop during maneuvering depending on weather conditions. Bringing them together into one formula (7), we get:

$$V(t) = V_0 - k \times t \qquad (7)$$

Where: V_0 - initial ship's speed in knots;

k – longitudinal friction coefficients;

t – moment of time in minutes;

The obtained formula represents the loss of ship's speed. When using this method of calculating speed loss in practice, having obtained from the coefficients for a particular vessel, depending on weather condition. For the deck officer on watch (DOOW), when calculating the loss of speed while maneuvering, there is no need to rely on intuition and subjective assessment of the situation.

As can be seen from the experiment, the values of the coefficients differ depending on the vessel. However, having received as a result of observations the coefficients for a particular vessel and substituting them into the obtained expression of the speed-time dependence, a clear idea of the magnitude of the speed loss and its nature will be obtained.

After analyzing the data obtained, we can conclude that with increasing wind speed and wave height during the maneuver "zigzag" angular velocity (rate of turn) decreases and the maneuver slows down. Normaly this leads to a smaller loss of speed, but due to the impact on the hull of the wind-wave resistance, the vessel speed decreases by a larger amount namely:

- for a vessel №1 - 21% for calm weather , 22% for 3 BS and 30% for 5 BS;
- for a vessel №2 - 30% for 1 BS, 35% for 3 BS and 37% for 5 BS.

Therefore, considering the problem of speed loss depending on weather conditions, taking into account this process when maneuvering, it is necessary to take into account not only the magnitude of the speed loss but also the nature of this process.

A more accurate forecast and calculation of all speed losses when planning a voyage will allow the DOOW to avoid delays during voyage, and the shipowner to avoid additional costs associated with these delays.

CONCLUSIONS

According to the analysis of the existing literature, modern methods of calculating wind-wave loss of speed of ships and maneuvering speed allow calculating the required values of speed loss, but can be used only under certain conditions that are mutually exclusive.

Research shows that the existing methods for calculating the loss of speed due to the influence of wind and wave resistance on the ship's hull, can be used only with constant values of the wind angle and rolling. Furthermore, the methods of calculating the loss of speed of the vessel during maneuvering do not take into account the effect of weather conditions on the hull, thus not corresponding the needs of the DOOW in calculating the loss of speed of the vessel.

Two ship models were selected, for performing six zigzag maneuver experiments were on the ship motion simulator under different weather conditions. Wind speeds and waves increased from one to five Beaufort scale with each experiment.

Having obtained the dependences of the speed of the vessel on time during the first period, the loss of speed, in each case was put in accordance with a certain function of the speed of the vessel on time.

The obtained formulas for calculating the speed drop depending on weather conditions reflect the nature of the speed drop and take into account both the magnitude and time of the speed drop.

With the help of the obtained functions, the corresponding longitudinal friction coefficients depending on weather conditions were obtained.

Substituting the obtained coefficients into the obtained expression of the speed-time relationship, a clear idea of the magnitude of the speed loss and its nature will be obtained.

REFERENCE

[1] Vorobiev Y. Hydrodynamics of a vessel in a limited fairway Y.Sparrow. - St. Petersburg: Shipbuilding, 1992. - 224 p.

[2] Pershits R. Shiphandling and maneuvering of the vessel / Pershits R. - L .:Shipbuilding, 1983. - 272 p.

[3] Demin S. Approximate analytical definition of circulation elements

[4] Maltsev A. Maneuvering of ships taking into account discrepancies / Maltsev A -Odessa: Marine Training Center, 2002. - 208 p.

[5] Demin S. Questions of Shiphandling of sea going vessels / Demin S - M .:Reklaminformburo MMF, 1975. - 75 p.