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THE PROBLEM OF NOT DRIVEN PROPELLERS IN MULTI-SCREW SHIPS PROPULSION ARRANGEMENTS

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Abstract

Power requirement for ship's movement depends on their size (water displacement) and sailing speed. The problem is especially important for fast ships, because the speed of movement is generating significant high power requirement, while limited displacement, diminishing a drag quantity from one hand, is a reason of limited draft and consequently limited capacity of a hull from the other. Above facts have strong influence at a number, type, power and size of main engines and propellers. Fast ships are designed for reaching maximum speed, but majority of exploitation time, are cruising at lower speed, called partial speed. That exploitation profile requires stopping of some engines or braking of propellers. Not driven propellers are dragged behind the hull, and work at a turbine mode, giving a torque at a propulsion shaft and creates a negative thrust what means the additional drag. The additional drag of not driven propellers must be calculated during the propulsion design stage, and analysis of speed value during different variants of the ship's movement . Torque values and thrusts can be evaluated basing on the universal hydrodynamic characteristics of propellers. the method and example of calculation of the drag created by free-rotating and stopped propellers of the exemplary propulsion set are presented in the paper.

Keywords: *fast ships, ships screw propellers, multi-screw propulsion arrangements*

Introduction

Because of power requirements for fast ships propulsion and low draft of a ship, what is the reason limited diameter of selected propeller, propulsion arrangement of ships like that are multi-engine and multi-propeller type [3, 4, 6].

Fast ships have specific exploitation profile. They are designed for maximum speed but mostly move with significantly lower velocity, called partial speed. It is a reason of needs of stopping of some of the engines or propellers. Not driven propellers are dragged behind the hull, and work at a turbine mode, giving a torque on a propulsion shaft and creates a negative thrust, what means the additional drag [2, 3, 8]. The additional drag of not driven propellers must be calculated during the propulsion design stage, and analysis of speed value during different variants of the ship's movement.

Also the torque generated by the propeller is transmitted at the shaft and when oversteps the value of resistance of bearings, is causing rotation of movable elements with the rotational speed of significant value. In order to prevent of the engine or reduction gear seizure, special brakes are mounted at propulsion shafts. Calculation of the necessary braking torque is necessary for ensuring proper functioning of the brake and preventing before shaft's movement. Two kinds of propeller's work in turbine mode are existing: "free-rotating propeller" and "stopped propeller". Torques and thrusts appearing at the propeller within defined zones of work can be easily evaluated using the universal hydrodynamic characteristics of propellers [2, 3, 8].

1. The universal hydrodynamic characteristics of propellers

The hydrodynamic characteristics are related to the case when the ship's movement is "ahead" and rotational speed of the propeller is positive, speed of travel is positive, than the coefficient of feed J=vp/Dn is also positive. For this case, the coefficient of drag KT and the coefficient of torque KQ are positive.

At the ship, during its exploitation, situations when coefficients of feed, thrust or torque are negative, occurs very often. For example, it can be the ship's deceleration during ahead and astern movement, and towing of the not driven propeller.

Presented cases of not typical working modes of the propeller are pointing that for clear evaluation of the ship propulsion behaviour, necessary is the knowledge about propeller's performance in whole exploitation zone. That was the reason of elaborating of universal hydrodynamic characteristics of free propellers [2, 3, 8]. Example of such characteristic is given in fig. 1. The universal hydrodynamic characteristics of propellers are used for evaluation of the ship manoeuvring properties as reversing characteristics and can serve for evaluation of the drag of free rotating, not working propellers of the multi-screw propulsion arrangements.

2. The drag of not driven free rotating, and stopped propellers

Dealing with multi-screw marine propulsion arrangements, one copes very often with situation when one or several screws are not driven, what means that the engines are not transmitting the torque to the shafts. In that case, the propellers are dragged by moving ship. Not driven propeller can be stopped by special brake mounted at the shaft or, when is not stopped, free rotate transmitting the torque from propeller to the engine.

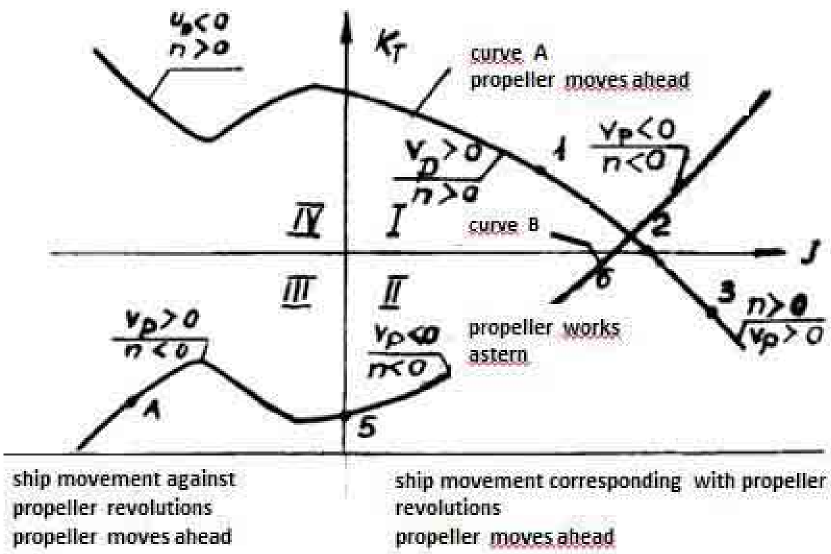

Fig.1. Universal hydrodynamic propeller characteristics for H/D=idem

In this case, the propeller works like water turbine and drives the stopped engine by the propeller shaft.

Dragged stopped propeller

When the propeller does not work, is dragged and does not rotate, the friction torque of the shaft is higher than propeller's torque within its turbine mode zone. During ship's movement ahead, vp>0 and stopped propeller n=0, coefficient of feed J=vp/Dn is going to infinity. For that reason, the hydrodynamic characteristic of propellers of cases when $n \rightarrow 0$, i.e. when $J \rightarrow \infty$. It was done in such a way that at abscissa axis, the feed coefficient has been replaced by its inverse $J_0=1/J = D_n/v_p$. Then, in the case of stopped propeller, J0 is placed in the centre of the coordinates.

Examples of universal hydrodynamic characteristics of the propeller in coordinates K'_T and K'_Q are presented in [2, 3, 8]. For evaluation of the drag or torque of the stopped propeller one must on the diagram $K'_T - f(J_0)$, at centre of coordinates (J_0=0), for adequate feed coefficient H_1/D, to define coefficients of trust and torque. Then negative thrust of the stopped propeller is:

$$R_{st} = T' = K_T' v^2_p D^2, \quad (1)$$

$$Q_{st} = K_Q' \rho v_p^2 D^3. \quad (2)$$

Dragged free-rotating propeller

During ship's movement, when propeller's torque in the range of turbine work, is higher than the friction torque of the shaft, it begins to rotate. Revolutionary speed is the result of relation between the torque of shaft and propeller's friction and the torque created by the propeller. During calculation of resistance of the free-rotating propeller, value of its rotational speed is unknown. For that reason, it is necessary to estimate the friction torque of the shaft and subsequently the coefficient of the friction torque balanced by torque of the propeller working in turbine mode, i.e. driving the shaft.

$$Qtlw = Qso, \quad (3)$$

$$Qso = KQ' \rho vp2D3. \quad (4)$$

As the value of propeller's rotational speed is unknown, one assumes $n = v_p/DJ$, and $K_Q' = K_Q/J$.

$$Q = KQ' \rho vp2D3. \quad (5)$$

3. Calculation of the drag of free rotating and stopped propellers

Examples of calculation of the drag of not engaged propellers were conducted for marine propulsion arrangement with three propellers, the propeller has three fixed blades, with pitch value $H_1/D = 1.175$, diameter D = 1.15 m, blades area coefficient $S_0/S = 1.1$. The main engine torque is 25 kNm. Seawater density is assumed ρ= 1026 kg/m^3 at t = 15ºC.

For stopped propeller (v_p=0, J_0=0) the thrust coefficient is K_T= 0.32 and the torque coefficient is K_Q = 0.057.

For free rotating propeller very important is defining of the shaft line friction torque. Friction torque of the shaft line is the function of its rotational speed and length. The longer shaft needs bigger number of support bearings glands and shaft's efficiency goes down. One can assume the relations for evaluation of the friction torque:

$$Q_{tlw} = \left(a + b\frac{n_x}{n} \right) Q, \quad (6)$$

$$Q_{tlw} = cQ\left(\frac{n_x}{n} \right)^{\frac{1}{2}}, \quad (7)$$

when:

$a = \frac{1}{2}c; b = \frac{2}{3}c; c = 0.02 - 0.05$ (lower values for shorter shafts),

$c = 1 - \eta_{iw}$,

Q – Main Engine nominal torque,

n_x – nominal rotational speed of the shaft.

Given relations can be used when revolutionary speeds of free rotating shafts are known a posterior.

In Fig. 2 are presented calculated values of the drag of not engaged propellers, free rotating and stopped, depending on sailing speed.

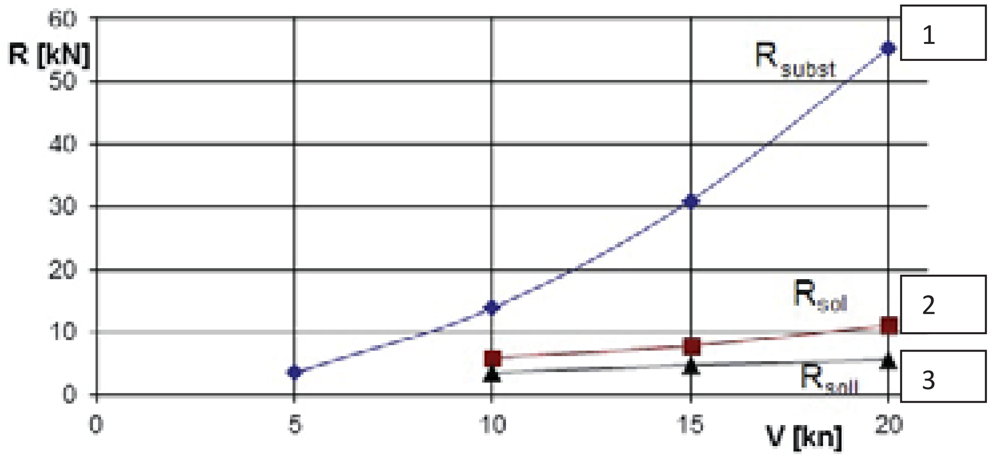

Fig. 2. Resistance of dragged propellers, 1- stopped, 2 – free rotating – 1st approximation, 3 – free rotating 2nd approximation (known rotational speed of the propeller)

4. Conclusions

Correctness of undertaken methodology of calculation of the drag not engaged propellers, free rotating and sopped has been proven on experimental way with using real ship. During the experiment was found, that rotational speed of not engaged shaft driven by propeller in the scope of turbine mode, was close to idle speed of main engine.

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