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RESEARCH ARTICLE

A method for testing small shipmodels

Zoltán Benedek

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Abstract

In a small tank there are possibilities for testing only small models (length of 1-2 m). They are engaged to measure the resistance of the ship, but self propulsion tests cannot be performed because the dimensions of the propeller are too small. This paper proposes a method for determining the mutual influence of ship body and propeller without using propeller model behind the ship body. On the towing carriage there is mounted a pump. The inlet end of the pipe is behind the investigated ship model at the place of its propeller, and has the same diameter as the propeller. This propeller simulator gives possibility to calculate the thrust of the propeller according to the momentum theory of propeller.

Keywords

Wake fraction · thrust deduction fraction · ship model experiment tank

Zoltán Benedek

Department of Aeroplans and Ships, BME, H-1111 Budapest Sztoczek u. 6., Hungary

e-mail: benedek@rht.bme.hu

1 Introduction

For the usual design method of the propulsion of a ship it is necessary to know the resistance of the ship and the mutual influence of the ship body and the propeller. Owing to the complicated nature of the problems connected with the resistance and propulsion of ships, it is convenient to have model experiments. For this purpose there are about 150 ship model experiment tanks all over the world. The dimensions of their basins: lengths are about 160-300 m, breadths about 10-20 m and depths about 5-10 m. In these tanks there are investigated models of lengths about 10-20 m.

There are small tanks too, usually associated with teaching and research establishments. Dimensions of these tanks are length of 20-50 m and breadth of 1-5 m . In these small tanks ít is possible to test only small models (length of 1-2 m). They are engaged in measuring the resistance of the ship, but self propulsion tests cannot be performed because the dimensions of the propeller are too small. The Reynold's numbers of the blade elements are smaller than the critical value. Therefore they are not suitable for investigations of the mutual influence of ship bodies and propellers [1].

2 Purpose of testing

To take into consideration the mutual influence of ship body and propeller is used the wake fraction and the thrust deduction fraction are used. The effective wake fraction defined by Taylor is [2]

$$w = \frac{v - v_A}{v}$$

where

- v is the ship speed at the propulsion tests of the ship model (in self propelled condition)
- v_A is the advance velocity of the propeller, which in a homogeneous field would enable the propeller to create a thrust equal to the necessary thrust in self propelled condition of the ship (propeller advance speed in open water condition, when the propeller is tested without ship model).

The thrust deduction fraction is

$$t = \frac{T - R}{T}$$

where
- T is the thrust of the propeller in self propelled condition,
- R is the resistance in towing condition (ship without any acting propeller),
  both at the same ship speed.

These values are determined only by the following model experiments:

Towing experiment (ship without propeller) for determining the resistance of the ship. (Measured: $R = f(v)$).

Self propulsion tests (ship with propeller) to determine the necessary thrust, wich is different from the resistance owing to mutual influence of shipbody and propeller. (Measured: $T = f(v)$).

Propeller in open water condition (without ship). (Measured $T = f(v_A)$).

3 Method of testing

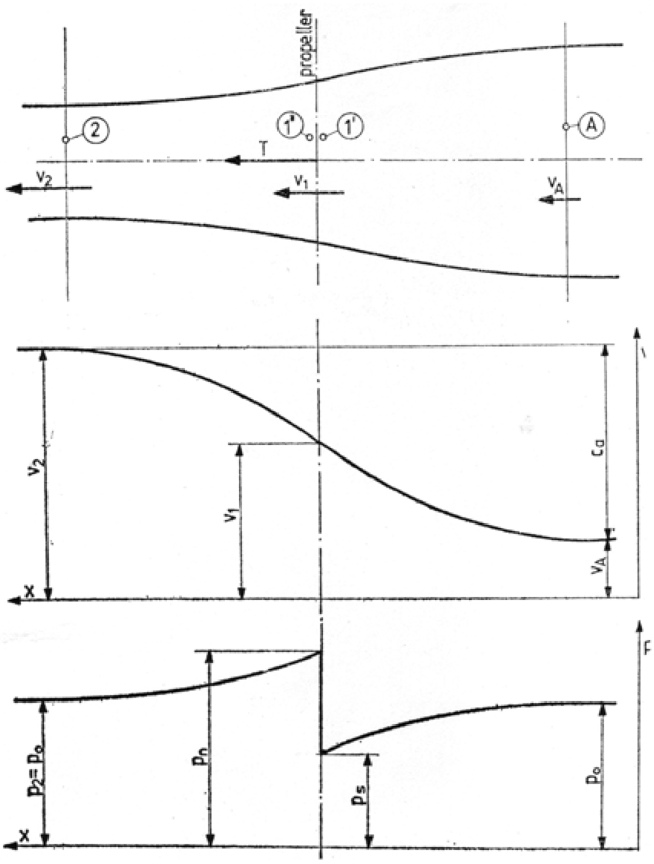

Fig. 1. Propeller in open water condition [3]

The thrust in open water condition according to the momentum theory of propeller:

$$T = \rho A v_1 \left(v_2 - v_A\right)$$

because of $v_1 = \frac{v_2 + v_A}{2}$

therefore

$$T = \rho A 2 v_1 (v_1 - v_A) \tag{1}$$

It means that the thrust coefficient

$$c_T = \frac{T}{\rho . A . v_1^2} = 2 - 2\frac{v_A}{v_1}$$

is only the function of the velocity ratio. This equation is valid only for perfect fluid. The real function

$$c_T = f(\frac{v_1}{v_A})$$

is determinable by the open water tests of model propeller.

The Bernoulli equation written between an undisturbed point and before the propeller:

$$\frac{p_O}{\rho} + \frac{v_A^2}{2} = \frac{p_1}{\rho} + \frac{v_1^2}{2}$$

According to this

$$v_A = \sqrt{v_1^2 - 2.\frac{p_O - p_1}{\rho}}$$

and the thrust of propeller

$$T = 2\rho A v_1 \left(v_1 - \sqrt{v_1^2 - 2\frac{p_0 - p_1}{\rho}}\right) \tag{2}$$

At the testing of small models the propeller is substituted by the mouth of a pipe. The pipe is connected to a pump mounted on the towing carriage.

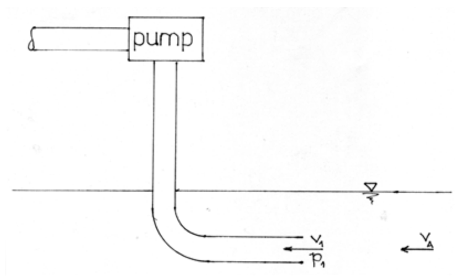

Fig. 2. Propeller simulator

During the *open water test* of this „propeller" the advance velocity of the carriage (v_A), the pressure of water at the inlet end of the pipe (p_1) and the quantity of water passing trough pipe to calculate the velocity (v_1) are measured.

These measured values give possibility to calculate the thrust according to Eq. (2).

In this way we can determine the curve of

$$c_T = f(\frac{v_1}{v_A})$$

At the self propulsion test the mouth of the pipe is mounted behind the investigated ship model at the place of its propeller. The ship model is towed by the carriage with the velocity v (corresponding to the velocity of ship).

Measured is the quantity of water passing through the pipe, the v_1 velocity of the water at the place of propeller can be calculated. From this velocity and the measured pressure of the water at the inlet end of the pipe it is possible to calculate the thrust of the propeller (T_p) according to the Eq. (2).

$$T_p = \rho A v_1^2 .(1 - \sqrt{\frac{2.\Delta p}{\rho . v_1^2}})$$

For measuring the necessary thrust of the ship model, it is connected to the carriage by a dynamometer to measure the resistance of the ship model in this self propelled condition (T_s).

During the test we change the quantity of water passing through the pipe, till the calculated and measured value of thrust are equal $(T_p = T_s = T)$.

According to the calculated value of the thrust coefficient

$$c_T = \frac{T}{\rho . A . v_1^2}$$

we can read the value of velocity ratio $\frac{v_1}{v_A}$ from the results of the open water tests.

With a towing experiment (ship model without propeller) we can determine the R resistance of the ship at v velocity.

In this way the necessary values of v, v_A, R and T are determined.

4 Conclusion

The proposed method gives possibility to determine the necessary values to calculate the effective wake and the thrust deduction fraction, i.e. the mutual influence of shipbody and propeller by testing of small model. Of course this method is not able to substitute the usual testing of bigger models, this is suitable only for qualitative investigations [4].

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