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COMPUTATION OF MAIN DIMENSIONS AND FORM COEFFICIENTS IN INITIAL SHIP DESIGN

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ABSTRACT

In order to reduce CO_2 emissions aboard the ship, the IMO strategy imposes the decrease of the Energy Efficiency Design Index (EEDI). The generation and multi-criteria optimization of the body lines plan represent an important solution for EEDI reduction. In this context, the selection and checking of the ship's main dimensions and form coefficients in the initial design stage will contribute to obtaining satisfactory hydrodynamic performance. This paper deals with some statistical relations used to calculate the main dimensions and form coefficients in the initial ship design stage. It also describes the new PHP-Ship Dimensions computer codes, developed in the Research Centre of the Faculty of Naval Architecture of "Dunarea de Jos" University of Galati. On the basis of this numerical instrument, the checking of the displacement equation may be performed. The students will use the computer program in order to increase their knowledge related to initial ship design activities.

Keywords: main dimensions, form coefficients, initial ship design.

1. INTRODUCTION

The generation and multi-criteria optimization of a body lines plan is a complex and iterative ship design process, based on a theoretical and experimental approach. In accordance with the IMO strategy for the increase of energetic efficiency in ships [1], it is recommendable to calculate the Energy Efficiency Design Index (EEDI) for all new ships starting from the 1st of January 2013. The 10% decrease of the EEDI as compared to the current values is imposed for new ships to be built between 2015-2019. The reduction of ship resistance, required power and fuel consumption will determine the decrease of CO_2 emissions aboard ships, in order to meet the EEDI criteria. As a consequence, the body lines design process observes a special methodology.

The first step regards the selection of the main particulars and form coefficients, in order to achieve satisfactory hydrodynamic performance. The initial design software platforms are used to make preliminary estimations of the ship resistance, powering and manoeuvring abilities. The second step refers to the numerical optimization of body lines. By means of CFD instruments, the free surface flow around the hull and hydrodynamic performance may be analysed. In order to validate the numerical solution, experimental model tests must be performed in the final step of the methodology.

The present paper is dedicated to the initial ship design process. A preliminary hydrodynamics platform (PHP) was developed in the Research Centre of the Faculty of Naval Architecture in order to estimate the ship resistance, powering and manoeuvring performances, on the basis of the main dimensions and form coefficients of the ship. The aim of this paper is to describe a method of checking the ship's main dimensions and form coefficients (based on statistical relations) and also, the new PHP-Ship Dimensions computer code which was developed and integrated into the PHP software platform in the Faculty of Naval Architecture. The specific relations used to compute the main dimensions of the ship are shown in following chapter.

2. MAIN DIMENSIONS OF THE SHIP

The selection or checking of the ship's main dimensions may be made by means of statistical data and empirical formulas ([2], [3], [4]). The ship length is one of the most important dimensions, being related to the ship resistance and powering requirements. The length may be determined as a function of displacement Δ and ship speed *v*. According to Gallin, the length between perpendiculars is calculated by the following relation

$$L_{pp} = c \cdot \left(\frac{v}{v+2} \right)^2 \cdot \nabla^{1/3} \qquad (1)$$

where ∇ is the volumetric displacement and the coefficient *c* has the following values:

- 7.17 for single propeller ships with v=11-16.5 Kn;
- 7.32 for ships with twin propellers and v=15.5-18.5 Kn;
- 7.93 for passenger ships with v>20 Kn.

Jager proposed the following relations

$$\sqrt{L_{pp}} = \sqrt[3]{p+q} + \sqrt[3]{p-q}$$
$$p = b \cdot v \cdot \sqrt[3]{\Delta} \qquad (2)$$
$$q = b \cdot (v^2 - 2 \cdot \sqrt[3]{\Delta})^{1/2} \cdot \sqrt[3]{\Delta}$$

where the coefficient *b* is equal to:

- 1 for fast passenger ships;
- 5/6 for cargo ships, bulk carriers and tankers;
- 3/4 for coaster ships;
- 2/3 for trawlers and tugs.

Noghid introduced the relation

$$L_{pp} = 2.3 \cdot \sqrt[3]{v \cdot \Delta} \qquad (3)$$

and Posdunine recommended the expression

$$L_{pp} = 7.2 \cdot \frac{v}{v+4} \cdot \nabla^{1/3} \qquad (4)$$

The ship breadth *B* may be determined as a function of the length between perpendiculars. The following formulas may be used in the initial design stage:

- Arkenbout and Schokker

$$B_{\min} = \frac{1}{9} \cdot L_{pp} + 3{,}66 \qquad (5)$$

- Watson

$$B = \frac{1}{9} \cdot L_{pp} + 4{,}27 \qquad (6)$$

- Sanderson, for cargo and passenger ships

$$B = \frac{L_{pp} + 41.7 \pm 5}{9.3} \qquad (7)$$

- Bendford, for cargo ships

$$B = \frac{L_{pp} + 35.5 \pm 16}{9} \qquad (8)$$

In order to estimate the mean draught *T* and the depth *D*, the breadth-draught or length-depth relations proposed by Watson can typically be used in the initial ship design.

The main dimensions ratios L_{pp}/B and B/T influence the ship resistance, manoeuvring, course keeping and transverse stability performances. Moreover, the ratio L_{pp}/D influences the longitudinal structural resistance of the ship, and the ratio D/T is connected to the buoyancy reserve of the ship.

On the basis of the relations mentioned above or similar ones, the main dimensions of the ship and specific ratios may be determined in the initial design stage. Furthemore, if the main dimensions have pre-established values, these relations may be used to check the concordance with statistical data.

The following chapter is dedicated to the presentation of specific formulas used to compute the form coefficients (block coefficient, water plane area coefficient, midship section coefficient) in the initial design stage.

3. FORM COEFFICIENTS

Statistical or empirical expressions may be used to determine the form coefficients in the initial ship design ([2], [3], [4], [5]). The block coefficient C_B may be computed by means of the following relations:

- Asik, for the Froude number F_n=0.25-0.30

$$C_B = \frac{0.16 \pm 0.01}{Fn} \tag{9}$$

- Ayre, for F_n=0.15-0.30

$$C_B = 1.05 - 1.68 \cdot Fn \tag{10}$$

$$C_B = 1.08 - 0.536 \cdot \frac{v}{\sqrt{L_{pp}}} \tag{11}$$

- Alexander

$$C_B = 1.01 - 0.5 \cdot \frac{v}{\sqrt{L_{pp}}} \tag{12}$$

- Dawson and Silverleaf

$$C_B = 1.214 - 0.714 \cdot \frac{v}{\sqrt{L_{pp}}} \tag{13}$$

The waterplane area coefficient C_w may be determined by the following formula

- Lyndbladom

$$C_W = 0.98 \cdot \sqrt{C_B} \pm 0.06 \tag{14}$$

- Bronikov

$$C_W = C_B + 0.12 \tag{15}$$

- Parsons, for tankers and bulk carriers

$$C_W = \frac{C_B}{0.471 + 0.551 \cdot C_B} \tag{16}$$

- Gallin

$$C_W = (1 + 2 \cdot C_B)/3 \tag{17}$$

The midship section coefficient C_M may be estimated by means of the following specific relations:

- Noghid

$$C_M = 0.786 + 0.267 \cdot C_B \tag{18}$$

- Jeleazkov

$$C_M = 1.012 \cdot C_B^{\,1/12} \pm 0{,}005 \tag{19}$$

- Parsons

$$C_M = 0.977 + 0.085 \cdot (C_B - 0.6) \tag{20}$$

On the basis of the form coefficients previously mentioned, the prismatic coefficients (longitudinal and vertical) may be determined. The displacement equation must also be verified

$$\Delta = \rho \nabla = \rho \cdot C_B \cdot L_{pp} \cdot B \cdot T \tag{21}$$

where ρ is the water density.

4. PHP-SHIP DIMENSIONS COMPUTER CODE

The PHP-Ship Dimensions computer code was developed to check the main dimensions and form coefficients in initial ship design. The flow chart of the code is shown in Fig. 1.

The input data module comprises the type of ship, deadweight (or number of containers / passengers), ship speed and autonomy. The prototype ship data must be transposed by means of linear scale coefficients.

On the basis of the computation module, the main dimensions and form coefficients are checked, and the displacement equation must be verified. In case these do not check out, the linear scale coefficients must be modified. The output data module yields the corresponding results.

The PHP-Ship Dimensions computer code was included into the PHP software platform, a complex initial design instrument, and may be used in teaching applications at the Preliminary Ship Design Numerical Laboratory and in research activities developed at the Faculty of Naval Architecture .

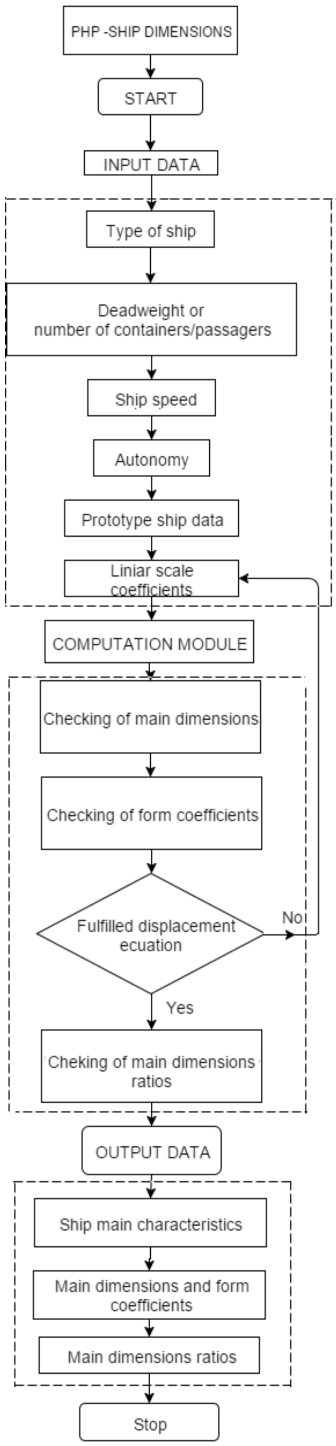

Fig.1. PHP-Ship Dimensions flow chart

5. CONCLUDING REMARKS

The IMO strategy related to the new ships imposes the decrease of the EEDI, in order to reduce CO_2 emissions aboard ships.

In this context, the generation and multi-criteria optimization of a body lines plan is an important solution.

In the initial design stage, the selection and checking of the main dimensions and form coefficients contribute to achieving satisfactory hydrodynamic performance.

Hence, a computer code was developed in the Research Centre of the Faculty of Naval Architecture of "Dunarea de Jos" University of Galati, in order to determine the main dimensions and form coefficients of the designed ship, and to check the displacement equation.

On the basis of this numerical instrument, the students have the possibility to increase their knowledge related to the initial ship design activities.

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