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ESTIMATING THE MAIN DIMENSIONS OF THE SHIP'S HULL

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Abstract

Preliminary ship owner's assumptions for new ship consist of deadweight, speed-shipping line and others. Taking it as a base, in early stage of design one has to select propulsion type. This goal needs definition of principal dimensions of a vessel, which are the base for further calculations of hull's resistance and evaluation of necessary power of main engine to fulfil shipping requirements. Selection of main dimensions of vessel is limited by rules regarding buoyancy, stability, hull strength, manoeuvring capability, and limitations related to seaways or harbours characteristic. In this article is presented the methodology of calculation of principal parameters of a vessel, necessary for calculation of displacement in relation to vessel's type, volumetric coefficients, Froude number, and others values affecting ship's dimensions. It is about midship section coefficient, waterline coefficient, prismatic coefficient. Those values are necessary for calculation of hull resistance. In the article, are presented major constraints for designing of new vessels coming from ship-owner assumptions such as seafaring limitations. In the table is presented comparison of results of calculations above-mentioned values of three type of vessels representing same displacement. There are also presented different calculation methods of transverse midship section coefficient and wet area coefficient, for 3 types of vessels (container vessel, bulk carrier and tanker with displacement of 120000 t.

Keywords: *seagoing ships, hull coefficient, hull dimensions parameters*

1. Introduction

Main dimensions and other definitions following parameters are used in calculation procedure of the ship resistance:

Lpp – length between perpendiculars [m],
B – the waterline breadth of the hull [m],
T – the draught amidships [m],
∇ – the volumetric displacement of the hull [m^3],
Δ – the mass displacement of the hull [t],
S – the wetted surface of the hull [m^2],
V – the sailing speed [m/s],
Fn – Froude number,
C_B – block coefficient,
C_D – mass coefficient,
C_M – midship section coefficien,
C_p – prismatic coefficient,
$L/\sqrt[3]{D}$ – slenderness ratio.

The procedure of ship design has iterative character. Such way of approach is unavoidable because of the fact, that all requirements concerning a new construction can be expressed by analytic relations. It can be previously elaborated criterions of application of main dimensions coefficients of specified ship's type, block coefficients or mass coefficients for all ship or partly mass of equipment etc. Because of above, during designing process, at subsequent stages, is necessary to carry out control calculations as well as verification of obtained results. Results of approximation are used for correction of basic parameters obtained in previous steps and for specification of taken assumptions. Rules of subsequent approximations are implemented at all stages of preliminary.

Another attribute of a task of determination of general technical parameters of designed ship is fact that beside determined by ship-owner values such as speed, cargo capacity, shipping range, several random parameters must be considered. Those parameters come from experience background or Classification Societies rules [4].

The fact, that random parameters are included in initial equations, makes ambiguity of solutions of a task of basic parameters assumptions for new construction. It makes possible variety of fulfilling basic requirements posed by ship-owner. Ships designed according to different but possible variants may vary in main dimensions, block and mass coefficients, displacement or power.

Any change of one amongst numerous parameters with keeping others unchanged; generally improve one group of parameters but parallel results with deteriorating others. For example, expansion of the relation of beam to draft B/T is resulting with growing initial stability, what is desirable from safety of shipping. From the other hand during sailing through rough sea, the rise of stability decrease hulls behaviour at swells and, in consequence decrease of effectiveness of transportation because loss of speed.

In ship owner assumptions, load capacity (TEU) for container vessels and dead weight (DWT) for other classes, and the sailing speed are given. Those values have strong impact at necessary power of the first estimate that the naval architect makes is to estimate the lightweight of the new ship.

2. Definition of displacement of ship Δ

Deadweight is the weight of a ship carries. It can be made up of oil fuel, fresh water, stores, lubricating oil, water ballast, crew, cargo and passengers.

Displacement is the volume of water displaced by submerged part of the hull ∇ [m^3]. In addition, expression mass displacement is used $\Delta = \nabla\rho_{fw}$.

Mass coefficient C_D links the deadweight with the displacement. C_D will depend on the ship type being considered. $C_D = DWT/\Delta$.

Step by step, all parameters and any other important subject related to the planning of our power plant will be calculated, so that at the end of this project the complete and correctly design of it will be provided.

Considering ship mass one has: mass displacement Δ = DWT + mass of hull.

Considering container ships, important is to find a relation between number of TEU and dead weight DWT. In Fig. 1, above-mentioned relation referring to certain class of container vessels is presented.

Relations enable to define ships dead weight in domain of container vessel load capacity, and capacity expressed in mass units as a function of ship's dead weight. Mass of cargo and provisions is a part of whole ship mass.

We can suppose, that being a reduction of the weight of the crew, stores, fresh water, food, oil or load totally illogical and out of order, the main reason for this decrease of the deadweight during the time is the possibility of a fuel amount reduction.

Another scope of project is to show the importance of using a proper propulsion system in a ship as described. This will result in a better employment of the general resources of the ship, what means a reduction of consumption in fuel oil, lubrication oil, etc. and a more efficient maintenance. To have a general view of the designed ship, we will show the most important data, as main dimensions of the hull, block and mass coefficient, deadweight or Froude number, in following points of this project.

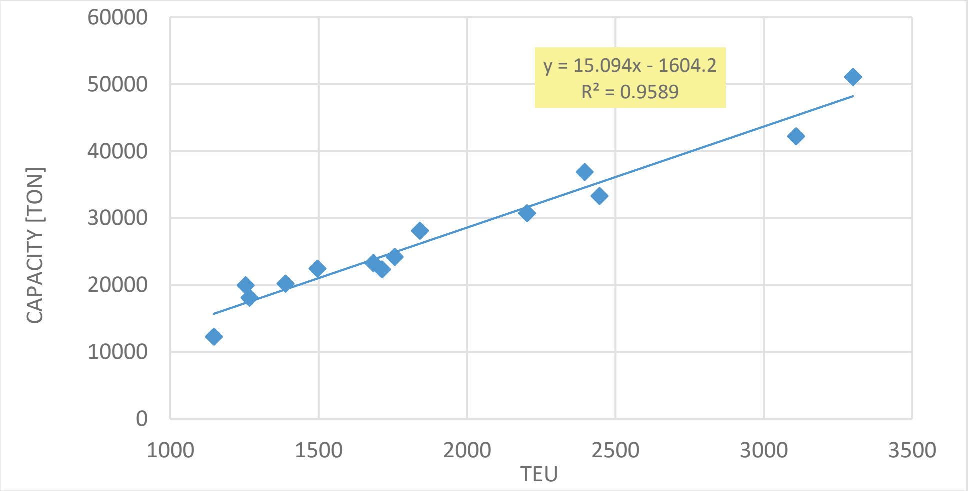

Fig. 1. Load capacity of a container ship in domain of TEU

3. Hull Dimensions parameters' calculations

The first and essential step before beginning with the calculations to design our power plant is to estimate the main dimensions of the hull of our vessel.

In order to achieve this we will estimate the main dimensions of the hull of vessels in design employing the values of the comparison ships' tables above.

For practical implementation, the obtained values should be optimized by additional calculation loops, if necessary.

A proper development of a detailed table, which contains the most important data of very similar ships to ours, is the first and one of the most important steps to estimate the main dimensions of the hull of our vessel.

From all the values of our comparison ships' tables, we will take the Froude number and the block and mass coefficient as constants, for beginning our calculations.

Doing selection of principal dimensions of a vessel, especially length between perpendiculars ranges of Froude numbers when local minima of wave resistance occur, must be omitted. The minima can be observed in range 0.27 and 0.36 [7]. This is very important for fast ships like passenger ships or container vessels, for which typical Froude number is placed in range of first local minimum. For typical cargo vessels like tankers or bulk carriers, the Froude number is below 0.2, when problem of wave resistance does not occur [3].

3.1. Calculation of the Block and Mass Coefficient (CB)

That coefficient, basing on database elaborated with support the knowledge about contemporary ships, is defined by different formulas, corresponding to different classes of vessels. Formula C_B given by C. D. Barras [1] relates to Froude number, and it is assumed that those are limit values for different classes of vessels.

$$C_B = 1.20\text{-}2.378\ Fn. \qquad (1)$$

In Tab. 1 are presented typical relations of block and mass coefficient and Froude number [1]. One has to notice that for contemporary vessels. Also taking container vessels as an example is clear that Block Coefficient is below recommended limit value 0.65 [7].

Table 2 consist of recommended values of coefficients describing main dimensions of three types of ships. The values of that coefficients are results coming from condition of ensuring proper parameters of the movement, strength of a hull, stability requirements and rules of classification societies.

Tab. 1. Recommended Froude's numbers and block and mass coefficient

	Fn	C_B	C_D
Container ship	0.262	0.58	0.6
Bulk carrier	0.21	0.7	0.7-0.85
Oil tankers	0.16	0.82	0.7-0.85

Tab. 2. Recommended values of coefficients describing main dimensions of a ship [1]

	Fn	C_D	L/B	$L/\sqrt[3]{D}$	C_B	B/T	L/H	B/H	T/H
Cargo ship	0.16-0.17	0.65-0.75	6-7	5.5-6.5	0.7-0.85	2-2.5	12-13	1.9	0.7-0.8
Oil tankers	0.16	0.79-0.85	5.5-6.5	5.5-6.5	0.7-0.86	2-5	12-13	~1.9	0.7-0.8
Container	0.23-0.26	~ 0.6	5.5-6.5	6.5-8.5	< 0.65	2.3-3.6	12-13	~1.7	0.7-0.8

3.2. Calculation of the slender coefficient $L/\nabla^{1/3}$

The slender coefficient describes the relation between the submerged ship's volume and its length. One of the suggested formulas to estimate this coefficient is this one $L/\nabla^{1/3}$. For typical cargo vessels it takes value between 4 and 6, and for fast vessels, i.e. container and passenger ships from 6 to 7.5 [2].

3.3. Calculation of the Hull Dimensions parameters: L, B, T

Evaluation of main dimensions of typical hulls of cargo vessels was carried out basing at list of similar ships considered classes, i.e. container ships, bulk carriers and tankers characterized by similar displacement around 120 000 tons. In Tab. 3 are presented obtained ranges of main dimensions, elaborated at a database encompassing 35 ships.

As result of analysis of similar ships, 3 hypothetical modes having the same displacement 120,000 t were created. For these, were done calculations of main dimensions according to above-mentioned method; and subsequently they were calculated block coefficients, which are necessary for subsequent calculations of hull's resistance and finally required power of propulsion. In Tab. 4 are presented values of hull's coefficients related to three types of vessels with displacement of 120,000 t.

Tab. 3. Range of dimensional coefficients of similar ships

	Lpp/B	Loa/H	B/T	B/H	$Lpp/\sqrt[3]{D}$	C_B	Fn	C_D
Container	7.04-7.45	12.4-13.6	2.94-3.5	1.65-1.75	6.0-6.5	0.57-0.66	0.23-0.24	0.66-0.76
Bulk carrier	5.58-6.9	11.2-11.7	2.2-2.97	1.6-2.2	4.66-5.03	0.79-0.90	0.16-0.17	0.69-0.88
Oil tankers	5.5-6.5	12-13	2.3-3.6	1.7-1.9	5.5-6.5	0.6-0.69	0.16	0.76-0.85

Tab. 4. Assumed values of characteristic coefficients of similar ships

	Fn	D [m^3]	Lpp·B·T [m]	H [m]	C_B	C_D
Container	0.24	120,000	317·43.4·13.23	25.22	0.63	0.7
Bulk carrier	0.16	120,000	237·40·14.4	21	0.86	0.84
Oil tankers	0.17	120,000	237·41·13.4	21.3	0.9	0.8

3.4. Calculation of the Midship Section Coefficient (C_M)

$$C_M = A_M/BT, \tag{2}$$

where:
A_M – midship section area.

During the last years, some formulas to calculate the midship section coefficient were developed. All these equations are based on the experience of existing hull forms.

This coefficient describes the relation between the midship section (until a determined waterline) and the area of a rectangle, which sides are the draft and the breath of the ship.

Next, we will expose four of the most frequently used formulas to calculate our C_M according to [8] and calculations their values for 3 considered vessels with displacement 120,000 t. All calculations were based on equations of Benford, Schneekluth and Bertram, Jensen and Nogid:

– Benford: $C_M = 0.977 + 0.085 \cdot (C_B - 0.6)$,
– Schneekluth and Bertram: $C_M = 1.006 - 0.0056 \cdot C_B^{-3.56}$,
– Jensen: $C_M = [1 + (1 - C_B)^{3.5}]^{-1}$,
– Nogid: $C_M = 0.928 + 0.080 \cdot C_B$.

Results of calculations of Midship Section Coefficient by 4 methods and Waterplane Coefficient by method of Schneekluth are presented in Tab. 5.

Tab. 5. Values of Midship Section Coefficient and Waterplane Coefficient for three types of vessels with displacement 120,000 t

	Benford	Schneekluth and Bertram	Jensen	Nogid	Schneekluth $C_{WP} = (1+2 \cdot C_B)/3$
Container	0.9855	0.986	0.985	0.984	0.8
Bulk carrier	0.997	0.996	0.998	0.995	0.89
Oil tankers	0.994	0.988	0.996	0.992	0.87

Presented results of calculations of block coefficient (by different method show) choice of method does not affect significantly its value.

Calculation of the Waterplane Coefficient (C_{WP}):

$$C_{WP} = A_{wp}/LB, \tag{3}$$

The water plane coefficient plays a very important role in the stability and resistance of the ship. It is described as the relation between the area by a determined waterline and that from a rectangle which sides are the length over all and the breath of the vessel (for the same determined waterline).

There are many formulas to estimate this coefficient depending on the form of the ship's stern.

In our case, we will use the Schneekluth's equation valid for average stern forms [8]:

$$C_{WP} = \frac{(1 + 2 \cdot C_B)}{3}, \tag{4}$$

Calculated values of Waterplane Coefficient for three types of ships are presented in Tab. 5.

3.5. Calculation of the longitudinal Prismatic Coefficient (C_P)

$$C_P = \nabla / A_m L, \tag{5}$$

The longitudinal prismatic coefficient describes the distribution of volume along the hull form

Knowing the midship and block coefficients of ship, we can obtain the C_P using the following equation: C_B = CMCP.

Values of coefficients mentioned above are necessary during calculations of shape coefficient or wet area coefficient, which are subsequently used for resistance and power calculations. Due to fact that midship section coefficients for considered vessels, especially for tankers and bulk carriers, are taking values close to 1, in first approximation is possible to assume that longitudinal prismatic coefficient and block coefficient are equal.

4. Summary

Prediction of propulsion power necessary for movement of designed ship is one of most important tasks at beginning stage of design process. That power can be estimated basin at data related to main constructional dimensions of a hull. For that reason, in the article is presented method of selection of main dimensions basing at list of similar constructions, with constraints due to required buoyancy, stability heavy sea durability, and performance, strength of a hull etc. In the article are given relations necessary for defining proper coefficients describing shape of a hull and necessary for estimation of resistance in way of regression. It concerns such method as Holtrop- -Mennen, Keller, Harvald [5, 6]. Analysis of calculations was done for three types of hulls with similar displacement.

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