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DETERMINATION OF MAIN DIMENSIONS AND ESTIMATION OF PROPULSION POWER OF A SHIP

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Abstract

TEU number, which is the container ships' crucial designing factor, directly influences the main hull dimensions such as displacement ∇, length L, breadth B, draught T, their combinations and block coefficient C_B. The main dimensions have a great impact on developing the ships resistant performance. Thus, it is really fundamental to establish the correct dimensions of the hull during the design and ship building process. Estimating the shape of the ship's hull, that comprises its main dimensions, is one of the basic tasks as part of the preliminary design stage. The most significant decisions determining ships performance, its duration and building costs are made at the beginning of the preliminary stage, when the costs are relatively low.

It is important to limit the total ship resistance, for instance, by lowering the wave ship resistance as much as possible, especially when the operational speed and TEU number carried by one vessel is increasing. That resistance depends on the operational speed expressed by Froude number.

The resistance criteria and the existing hull dimensions limits, resulting from ships route, must be taken into consideration bearing in mind safety conditions such as ships stability and seaworthiness, when the main ships dimensions are being determined. In the paper are presented general rules for calculations of ship's hull principle dimensions and total power of engines of container ship 1300TEU and 18 kn at preliminary stage of design process.

Keywords: *ship propulsion, Marine Power Plant, data base, ship' dimensions*

Introduction

Evaluation of propulsion power, aimed on achieving of assumed contract parameters of ships movement, is a main goal of preliminary design stage.

For proper evaluation of ship's resistance and finally calculation of power of a main engine, basic dimensional data are necessary. Dimensional values and related to that characteristic coefficients are limited by vary constraints, including propulsion, buoyancy, stability and hull strength limits. For proper definition of main ship's dimensions is selection of coefficients of hull shape and dimensional criteria according to ship owner requirements i.e. deadweight (DWT) or cargo capacity (TEU), and sea keeping. In the paper are analysed dimensional constraints due to shipping region, diminishing of wave making and skin friction resistance or application of Froude number, ships dimensional coefficients (C_B, L/B, B/T, L/H) and coefficients expressing relations between capacity and displacement.

1. Selection of main dimensions of a ship

Analysis of main dimensions of designed ship were carried out on basis of data base created basing on information about constructions finished in a near past within similar time period, alike capacity or deadweight, speed or dedication (range, shipping zone, ice class etc.)

The more similar units are close to each other in respect to design requirements, the better accuracy of main dimensions, propulsion power and propulsion characteristics calculation can be achieved during preliminary design phase. Methodology of estimation of main dimensions was presented basing on data included in [3-5].

In Tab. 1. are presented main dimensions and characteristic coefficients of similar ships.

Tab. 1. Main dimensions and characteristic coefficients of similar ships

No Vessel	TEU	v [kn]	Total Power [kW]	Loa [m]	Loa/ Lbp	Δ[t]	∇[m3]	DWT [t]	C_B	Fn	Lbp/B	B/T	DWT/Δ
1	1334	19	12200	165	1.07	27072	26283	20275	0.62	0.25	6.11	2.5	0.75
2	1253	18	10640	163.67	1.06	28495	27800	21569	0.61	0.24	5.43	2.76	0.76
3	1388	17	9540	167.24	1.06	24280	23687	20270	0.61	0.22	6.31	2.54	0.83
4	1346	18	11300	174.02	1.06	32570	31775	28422	0.61	0.23	5.76	2.53	0.87
5	1228	19	13560	151.26	1.06	22215	21673	18196	0.61	0.26	5.68	2.53	0.82
6	1300	19	11130	153.22	1.04	25000	24272	20406	0.61	0.22	6.23	2.54	0.82
7	1300	21	17760	161.35	1.07	25054	24324	16921	0.61	0.25	6.05	2.78	0.68
8	1388	19	12180	167.03	1.05	25690	25064	20100	0.61	0.25	6.31	2.5	0.78
9	1216	19	12180	158.7	1.05	23370	22800	15312	0.61	0.28	5.9	2.5	0.65
10	1334	19	12180	165	1.07	27072	26283	20255	0.62	0.25	6.11	2.5	0.75
11	1202	18	11300	178.54	1.07	38930	37982	26868	0.61	0.23	5.41	2.76	0.69
12	1338	17	11130	167.19	1.06	42157	41128	20140	0.61	0.22	6.31	2.54	0.48
13	1388	18	11130	167.24	1.06	27200	26408	20140	0.64	0.24	6.31	2.54	0.74
14	1174	19	13320	153.6	1.08	24540	23942	17250	0.61	0.26	5.61	2.5	0.70
15	1384	20	16200	175.04	1.07	30453	29710	22338	0.61	0.26	6.19	2.52	0.73
16	1262	18	13530	170	1.06	23320	22641	20461	0.57	0.23	6.47	2.61	0.88
17	1388	17	9540	167.24	1.08	25723	25096	20100	0.61	0.22	6.31	2.54	0.78

2. Analysis of the comparisonships values

2.1. Determination of displacement of a ship

Moreover, for container ship, one has to know the relation between container capacity TEU and deadweight DWT. Standard mass of one container is 14 t/TEU. Good results are given by statistic elaboration of data from significant ships list. In Fig. 1 is presented function DWT = f (TEU) for container vessel 1300TEU.

Conclusion coming from presented approximation is that for 1300 TEU unit, deadweight should be around 20000 DWT. It is value slightly higher than one for similar ship with equal number of assumed quantity of carried containers. It can be result of similar ship specificity. However, statistics calculations do not include such specificity. Sometimes, in ship's specification, value of displacement is not given. In literature [6, 7], for different class of ships, relations between deadweight and displacement are presented. For example, relation DWT/Δ of container vessels is around 0.8.

2.2. Determination of ship's length

For assumed preliminary values i.e. 1300 TEU and speed of 18kn, taking under consideration recommended Froude number 0.24, estimated length between perpendiculars should be 152 m. The adopted Froude number value is mean value of similar ships, according to recommendation for minimizing of wave resistance [1, 2, 6]. That value oversteps the range of first minimum of wave resistance coefficient, coming from interference of bow and stern waves generated by ship's movement. Estimation of ship's length based on recommended Fn and regressive analyses for similar ships, results with close values (Fig. 2).

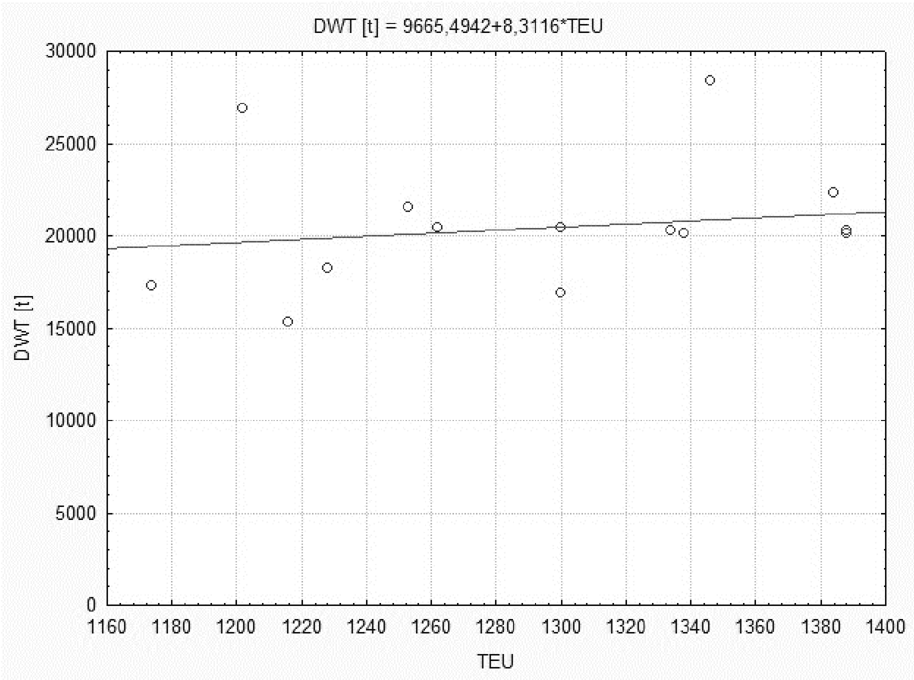

Fig. 1. Deadweight [t] –Number of TEU relation of the selected similar vessels

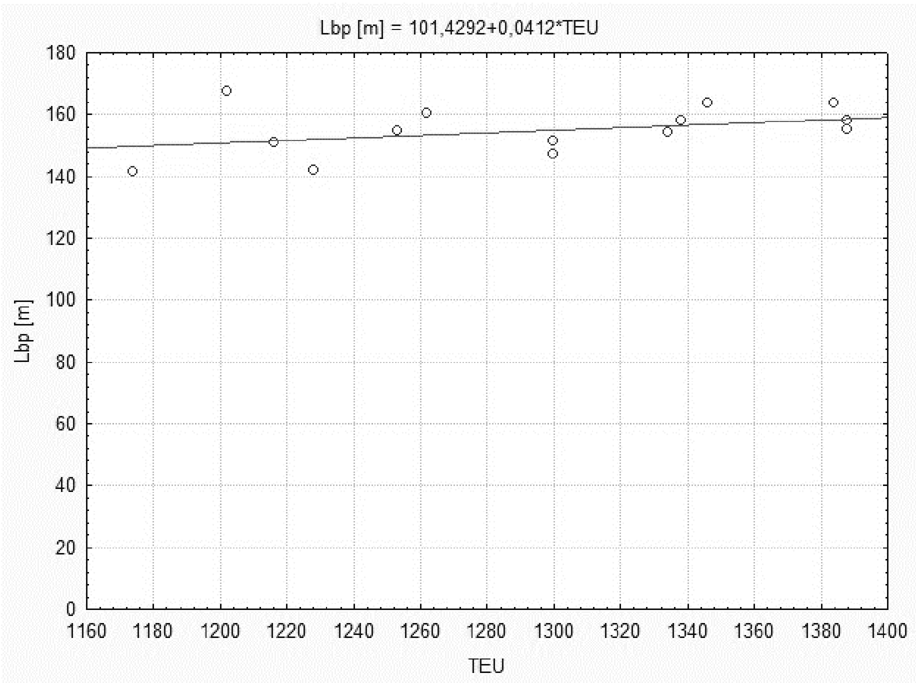

Fig. 2. Length between perpendiculars [m] – Number of TEU relation of the selected similar vessels

2.3. Determination of block coefficient

The block coefficient is the value of high importance, affecting ship's resistance and subsequently required propulsion power. According to [6, 7] for container vessels shall be lower than 0.65. From analyses of similar ships list, conclusion is coming that for container vessels with assumed cargo capacity, block coefficient shall be 0.61. That coefficient attached together all main dimensions of the vessel, and its value affects generally ships resistance. Having known ship's length and block coefficient, other dimensions can be calculated, with assumption that dimensional coefficients will fulfil proper criteria.

2.4. Determination of hull's width

Hull's width of container vessels is straight related to number of containers carried on the deck and their dimensions. Of course, distance between containers due to mounting devices must be considered. From other hand, width of the hull affects ships strength and stability. In Fig. 3 is presented relation between Lbp/B as function of TEU.

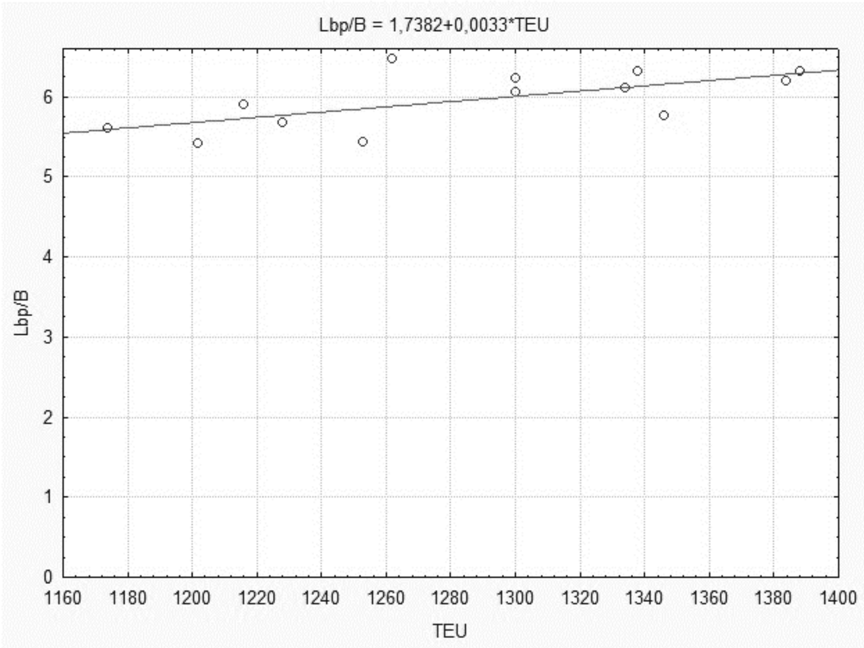

Fig. 3. Lbp/B [ratio] – Number of TEU relation of the selected similar vessels

Figure 3 shows the relation between the length between perpendiculars and the breath of the comparison ships. As expected, the increase of the length between perpendiculars of a ship involves the growth of its breath. Length to breadth relation coefficient L/B depends on type and destination of a vessel. For container ships, it takes value amongst 5.5 to 6.5. [3, 6].

It is not necessary to comment that relation between any other length of the ship (e.g. length over all) and its breath is exactly as direct as the mentioned before between the length between perpendiculars and the breath of a container vessel. For assumed number of containers above relation is 6, thus ships width should be 25.33.

2.5. Other main dimensions of a ship

Correlation between coefficients L/B and B/T enables defining of impact of specified dimensions at ships, length.

Coefficient B/T has impact at transverse stability of a vessel. Increasing of breadth will result with better stability, but higher resistance of a hull and requirement for higher propulsion power. Relation B/T for different classes of ships takes value from range 2-5. For fast vessels like container ships, which have slim shape of hull, B/T coefficient takes values from 2.3 to 3.6 but most often is equal to 3. One has to notice that container vessel's breadth depends on container unit dimensions and number of loading rows at a deck. Basing on list of significant ships, hull's breadth for container vessels the relation is B = L/10 + (7.5 + 10).

Conclusion coming from similar ships list is that coefficient B/T shall be around 2.52, what the value placed within recommended ranges is presented in literature [6, 7]. In first iteration, one can assume that for taken relations between main dimensions, draught of the vessel should be T =10.05.

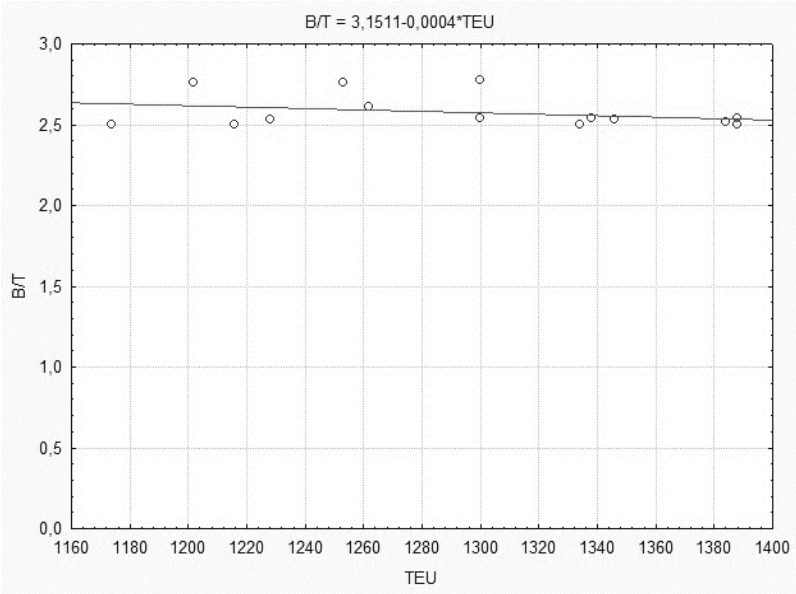

Fig. 4. B/T ratio - Number of TEU relation of the selected similar vessels

Dimensions determined according to that way must fulfil relation $\mathbf{C_B} = \nabla/LBT$ and additional criteria such as free board criteria or hull's strength L/H.

Because of hull strength requirements, crucial relation is coefficient L/H, where His the board's height. For cargo vessels, general assumption of L/H is 12-13.

Next important criteria of stability are coefficient B/H. For fast ships, like container vessels, limit value is placed between 1.7- 1.9 [6].

Considering free board criterion, important is coefficient T/H, which for cargo vessels is around 0.7-0.8 [6]. Coming out from hull's strength criteria (L/H), board height shall be 12.7 m. Whereas stability criterion (B/H) forcing board's height 13.3 m. Crucial is free board criterion, which will match to requirements when board height is between 12.56 and 14.36 m, thus is in accordance to dimensions undertaken due to strength and stability criteria. Comparison of calculation results and sample ship data is presented in Tab. 2.

Tab. 2. Comparison of calculation results and sample ship data

Parameter	Selected value v=18kn	Sample ship I v=19kn	Sample shipII v=18kn
TEU number	1300	1300	1253
deadweight	20500	20406	21569
displacement	24212	25000	27808
Loa	153.2	152	163.47
B	23.6	25.33	28.5
T	9.73	10.05	10.33
H	13.5	13.33	13.4

From presented data, conclusion is coming that taken dimensional parameters are fulfilling required criteria and calculated dimensions are close to sample ships dimensions. It is the evidence of propriety of undertaken methodology implemented for definition of main dimensions of the ship, at early stage of propulsion design, necessary for calculations of ship's resistance. Sample ship I, having lower smaller displacement presents bigger deadweight. It can be caused by assumed different requirements concerning shipping area or additional reinforcement of the hull.

3. Implementation of database for determination of ship's propulsion power

Selected main dimensions allow evaluation of necessary power for ships propulsion, with utilization of computational methods or model tests [1, 2, 6, 7]. At preliminary designed stage, power estimation in way of regressive analyses is also permitted. In Fig. 5, it is presented relation between effective power of container vessel with defined cargo capacity at level of 1300 TEU and ship's speed.

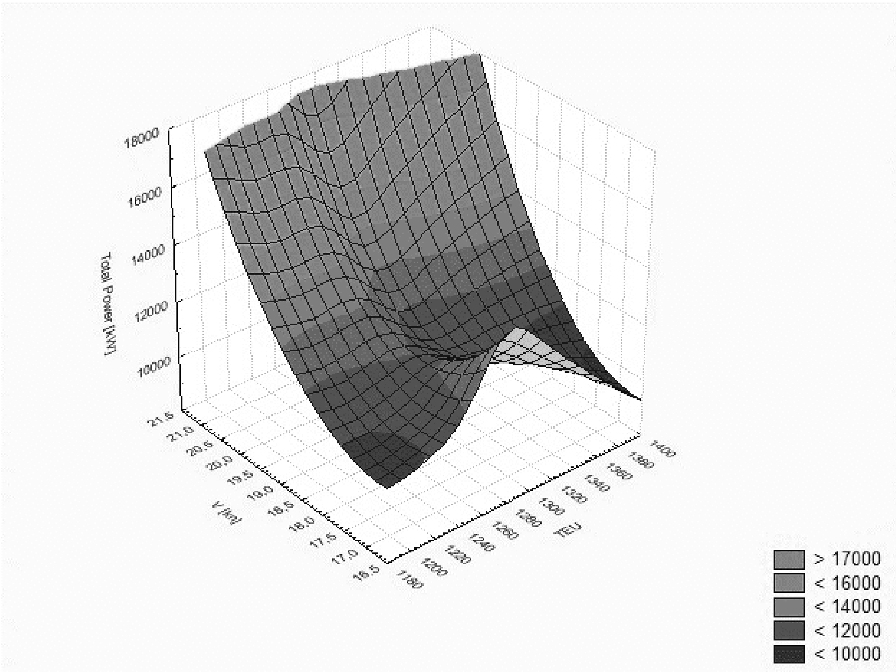

Fig. 5. Power of propulsion – Number of TEU and speed relation of the selected similar vessels

Final conclusions

Presented methodology of main dimensions estimation within assumed values of criteria of propulsion (Fn), strength (L/H), stability (B/H), and free board (T/H) allows proper selection. That methodology can be implemented at preliminary stage of propulsion design, when required data, coming from research tank tests are not available. Such method is also useful for propulsion power calculations in way of regressive analysis.

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