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UTILISATION OF DATA BASE IN PRELIMINARY DESIGN OF MARINE POWER PLANT

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Abstract

The paper presents general rules of utilization of database, called „significant ships list," for preliminary design of ship's propulsion and configuration of power plant. Knowledge collected in the database is related to new buildings classified according to type, displacement, shipping class etc. It encompass general dimensions, characteristics of mobility ,propulsion's power and type of main engines and propulsors, electric power plant, boilers and main mechanisms of a power plant. In the paper is presented method of utilization of the significant ships list during design of a container ship with capacity of 1300 TEU and speed of 18 knots. The first step of propulsion and main engine's selection is determination of main dimensions, i.e. displacement, length, draft and breadth. That dimensions cannot be selected random way, due to hull's mobility, stability and durability constraints. The list of significant ships consisted of 30 units, and amongst them, 17 were selected and analyzed. Others were rejected because of significant difference from mean values what could be due to different class of the ships.

Keywords: *ships propulsion, Marine Power Plant, database, ship's general dimensions*

1. Comparison of ships

Preliminary chose of propulsion and Power plant's design affects subsequent designing phases. Very important is influence of proper selection of hull's dimensions and propulsion configuration at costs of design and construction of the ship. Proper conduction of preliminary design is crucial for next stages quality. Design process is carried on spiral way, what means that every next step is developing and improvement of solutions undertaken before [1].

That is a cause of necessity of exact realization of design assumptions and proper selection of preliminary configuration of the propulsion and the power plant. Correction of errors in preliminary phase is not expensive, while detection and correction of errors in construction phase results with significant increase of final product price.

Good effect can be achieved when designing is based on existing similar ships knowledge database. It encompasses general data about ship's load, capacity (TEU), displacement, basic dimensions, block coefficient, Froude Number, dimensional coefficients, speed, power, configuration of propulsion plant, electric power plant, boilers etc.

Credibility of that list depends on fundamental assumptions used for its construction. It is going on to include ships constructed in similar time period, according to undertaken capacity, for example TEU for container ships, the same class, for example bulk carriers, tankers, Ro-Ro ships, and similar shipping area (for example ice class requirement). Above requirements are coming from necessity of fulfilling stipulations given by classification societies such as free board, ice class, hull strength, displacement and shipping area limitations.

1.1. Characteristics of main dimensions of a ship

The tables present the most important characteristics for each of the 17 selected comparison vessels. The main objective of these tables is to make a first impression of the constructive trends followed, during the last years, in the building of container vessels similar to ours.

All below presented values are real and as the bibliography of this project mentions, they were obtained from the databases of the ship owners and principally from the online database of the *Germanischer Lloyd* Register.

There were 17 container ship´s selected, with very similar characteristics to our vessel. Preliminary analyses covered around 30 ships. Some of them were rejected because of unreliable data, deviating from others, not typical propulsion or different class with impact at hull's mass [2].

For making this selection, we have based on two important parameters for our ship's design. Our chosen ships should be, first of all, only container vessels and not multipurpose ships or any other type of carrier and, second, the number of TEU containers should not be higher or smaller as a 10% of the desired quantity of TEU for our container vessel (1300 TEU). That means all our selected ships have a capacity between 1174 and 1388 TEU. Tab. 1 presents general dimensions of the ship, i.e. number of carried 20 feet container equivalent units, ship's speed v, length overall – Loa and between perpendiculars – Lbp, breadth – B, draft – T and hull's height – H, mass displacement – Δ [t], volumetric displacement – ∇ [m^3], load – DWT.

Furthermore, in the table are placed values of significant coefficients for a hull and propulsion designing. It is related to Froude number – $Fn=v/(gL)^{1/2}$, Block coefficient – $C_B=\nabla/LBT$ and relation between burden mass to overall mass of the ship DWT/Δ.

Tab. 1. Main data of the hull parameters for chosen vessels

Vessel	TEU	v [kn]	Loa [m]	Lbp [m]	B [m]	T [m]	H [m]	Δ [t]	∇ [m^3]	DWT [t]	C_B	Fn	DWT/Δ
1	1334	19	165	154.46	25.3	10.11	13.51	27072	26283	20275	0.62	0.25	0.75
2	1253	18	163.67	154.8	28.5	10.33	15.8	28495	27800	21569	-	0.24	0.76
3	1388	17	167.24	157.85	25	9.84	13.4	24280	23687	20270	-	0.22	0.83
4	1346	18	174.02	163.62	28.4	11.21	15.45	32570	31775	28422	-	0.23	0.87
5	1228	19	151.26	142.12	25	10	-	22215	21673	18196	-	0.26	082
6	1300	19	153.22	146.99	23.6	9.73	13.5	25000	24272	20406	-	0.22	0.82
7	1300	21	161.35	151.35	25	9.9	13.9	25054	24324	16921	-	0.25	0.68
8	1388	19	167.03	157.85	25	9.84	13.4	25690	25064	20100	-	0.25	0.78
9	1216	19	158.7	151.07	25.6	9.2	-	23370	22800	15312	-	0.28	0.65
10	1334	19	165	154.46	25.3	10.11	13.5	27072	26283	20255	0.62	0.25	0.75
11	1202	18	178.54	167.59	31	11.25	16	38930	37982	26868	-	0.23	0.69
12	1338	17	167.19	157.85	25	9.84	13.4	42157	41128	20140	-	0.22	0.48
13	1388	18	167.24	157.85	25	9.84	13.4	27200	26408	20140	0.64	0.24	0.74
14	1174	19	153.6	141.59	25.3	10.1	13.5	24540	23942	17250	-	0.26	0.70
15	1384	20	175.04	163.96	26.5	10.5	-	30453	29710	22338	-	0.26	0.73
16	1262	18	170	160.55	24.8	9.5	14.2	23320	22641	20461	0.57	0.23	0.88
17	1388	17	167.24	155.22	25	9.84	13.4	25723	25096	20100	-	0.22	0.78
Arithmetic Mean	1307	18.53	165.02	155.25	25.8	10.07	14.03	26836	26181	20531	0.61	0.24	0.76

Values highlighted in the Tab. 1 were not presented straight in the similar ships' description, but were obtained, on indirect way, from other data and relations presented in those descriptions.
Some of required data cannot be found in published specifications of the ships. It is mainly about displacement and the block coefficient. That data are necessary for determination of general dimensions of designed hull, mainly for drag calculation [3].

Mentioned data can be approximated in way of taking published data of similar units or recommended coefficients. It refers to displacement, mean relation load – mass displacement, and block coefficient [4, 5].

1.2. Characteristics of main propulsion of the ship

Main propulsion of the ship consists of main engines, propulsors, and eventually reduction gears. In considered container ships class, basic form of propulsion is low speed marine diesel engines and fixed pitch propeller. Propulsion with medium speed engines and reduction gears can be spotted but very rare, and are not to be analysed. In Tab. 2 are presented characteristics of main engines of analysed container ships.

Tab. 2. Particulars of the main engines of chosen vessels

MAIN ENGINE				
No. of Vessel	Total Power [kW]	Rpm [min^{-1}]	No. Of Cylinder	Diameter/ Stroke [mm]
1	12180	109	6	620/2150
2	10640	130	7	700/1250
3	9540	127	6	580/1700
4	11300	106	5	800/1950
5	13560	105	6	600/2400
6	11130	127	7	580/1700
7	17760	113	8	620/2150
8	12180	109	6	620/2150
9	12180	109	6	620/2150
10	12180	109	6	620/2150
11	11300	106	5	800/1950
12	11130	127	7	580/1700
13	11130	127	7	580/1700
14	13320	113	6	620/2150
15	16200	107	7	700/2268
16	13530	105	6	600/2292
17	9540	127	6	580/1700

1.3. Characteristics of ship's electric power plant

Electrical energy is necessary for driving of auxiliary machines and powering of main engine's feeding and steering systems, also for other machines placed in machine room and deck equipment, navigation and communication systems, galley equipment etc. [4].

Required amount of energy is determined by following factors:

- type and size of a ship and type of cargo,
- crew and passenger number,
- shipping zone (climate) and season of shipping,
- type and power of main engine and type of fuel,
- level of ship's automatization and electrification,
- typical, specified for certain unit, condition of load.

Every ship can be at different exploitation condition what results with various requirements for electrical energy (steaming at sea, harbour mooring, anchoring, manoeuvres, or distress situation). Rules of Classification Societies requires, besides of main generator sets, installation of emergency generator with power equal to one of main generators. That is the reason of various configurations of electric power plants even for the same levels of electric power requirements.

On board of modern ships, three different solutions of electric generators driver can be spotted:
- independent electric generators set i.e. generators driven by piston engines or gas turbines,
- recuperation turbo – generators (generators driven by steam turbines, feeding from utilisation (recuperation) boilers),
- Shaft generators (generators mounted on shafts or driven from reduction gear's output).

In Tab. 3 are presented configurations of electric power plants of significant ships.

Tab. 3. List of similar ships– electric power plants

No. of Vessel	Characteristics of the plant	Shaft generators	Main Generators	Emergency Generator
1	440 / 220 V with 3413 kVA	1x 1250 kVA	3x 675 kVA	1x 138 kVA
2	440 / 220 V with 2963 kVA	-	3x 956 kVA	1x 95 kVA
3	450 / 220 V with 3563 kVA	1x 1000 kVA	3x 800 kVA	1x 163 kVA
4	440 / 220 V with 3350 kVA	-	2x 1200 kVA 1x 863 kVA	1x 87 kVA
5	450 / 220 V with 3925 kVA	-	3x 1200 kVA	1x 325 kVA
6	1x450 / 220 V with 1417 kVA 1x440 / 220 V with 3390 kVA	1x 1250 kVA	3x 1130 kVA	1x 167 kVA
7	440 / 220 V with 4095 kVA	-	3x 1313 kVA	1x 156 kVA
8	450 / 220 V with 3413 kVA	1x 1250 kVA	3x 675 kVA	1x 138 kVA
9	1x450 / 220 V with 2163 kVA 1x425 / 220 V with 1150 kVA	1x 1150 kVA	3x 675 kVA	1x 138 kVA
10	440 / 220 V with 3313 kVA	1x 1150 kVA	3x 675 kVA	1x 138 kVA
11	440 / 220 V with 5927 kVA	1x 2400 kVA	2x 1140 kVA	1x 107 kVA
12	440 / 220 V with 4075 kVA	1x 1035 kVA	3x 955 kVA	1x 175 kVA
13	1x450 / 220 V with 4565 kVA 1x440 / 220 V with 175 kVA	1x 1250 kVA	3x 1105 kVA	1x 175 kVA
14	440 / 220 V with 3000 kVA	-	3x 954 kVA	1x 138 kVA
15	440 / 220 V with 3545 kVA	-	2x 1030 kVA 1x 1360 kVA	1x 125 kVA
16	440 / 220 V with 4699 kVA	-	3x 1499 kVA	1x 202 kVA
17	450 / 220 V with 3563 kVA	1x 1000 kVA	3x 800 kVA	1x 163 kVA

1.4. Characteristic of auxiliary boilers

On board of ships powered by diesel engines, steam is a heating medium. General use of steam is for:
- heating of fuel in fuel systems,
- stand – by engines' worm up temperature sustainment,
- heating of fuel and lubrication oil before centrifugal separators,
- for bilge water purificators,
- as working medium for steam turbine generators, feeding pumps or condenser ejectors,
- for fire fighting systems,
- for heating of chest boxes and storm lids,
- for drying and heating of cargo.

Identification of heat energy requirement is not easy, because it depends of various random conditions. For ships powered by low speed engines, feed by HFO (heavy fuel oil), it depends on fuel type, which needs preheating in transportation and preparation phase. Moreover, heat requirement depends on:
- type and size of a ship and kind of cargo,
- crew and passenger number,
- shipping Line climate zone, season or time of day.

For ships dedicated for long range trips, are implemented steam boilers with fuel oil burners, and recuperation boilers heated by exhaust gases coming from main engines.

The general idea is that recuperation boiler works during steaming at sea and burner boiler works when ship is mooring at a harbour. Both boilers are functionally connected. Most common working medium is water, but also thermal oil can be spotted. In Tab. 4 are presented configurations of boilers for considered ships.

Tab. 4. Main data of the chosen for comparison vessels– boilers

No. of Vessel	**Boiler Type**, oil fired	**Max. working Pressure [bar]**	**Heating Surface [m]**	**Boiler Type exh. gas heated**	**Max. working Pressure [bar]**	**Heating Surface [m^2]**
1	Steam	9	24.0	Steam	9	237
2	Steam	9.5	35	Steam	9.5	174
3	Steam	9	30	Steam	13	276
4	Steam	11	68	Steam	11	290
5	Steam	9	19	Steam	9	349
6	Steam	9	30	Steam	9	198
7	Steam	7	30	Steam	7	219
8	Steam	9	24.0	Steam	9	278
9	Steam	9	24.0	Steam	9	278
10	Steam	9	24.0	Steam	9	278
11	Steam	9	24.0	Steam	9	248
12	Thermal oil	10	55	Thermal oil	10	123
13	Steam	9	30	Steam	9	198
14	Steam	10	42	Steam	10	314
15	Steam	9	48	Steam	10	317.8
16	Steam	9	45	Steam	9	310
17	Steam	9	30	Steam	13	207

2. Summary

In next few phrases, we will comment, in a short way, the most important points undertaken as preliminary factors for design procedure. As Classification Society, we have decided to choose *Germanischer Lloyd* (GL), because it gives easy access to the information registered in its database. All our comparisons vessels were register and classify by the same Classification Society, which was GL.

From the 17 selected sample ships, six of them have a service speed of 18 knots and eight of them sail with 18 knots.

It means that 70% of our comparison ships are sailing with almost the same service speed (18-19 kn), with only one knot of difference. Because of that we have chosen, for our vessel in design, a minimum service speed of 18 knots. We can estimate that, at the end, our service speed will be around 17-19 kn.

About the propeller implemented for the propulsion of considered container carriers, we have to comment that all of them are equipped with single screw.

All comparison ships have low speed marine diesel engines as main propulsion. Power is varying from 9.5 to 15 MW and revolutionary speed span is from 105 to 135 rpm (due to different service speed).

In 100% of the cases, the transmission is directly on propeller shaft.

As far as the electrical installation is concerned, we have to say that almost all the comparison ships use the electric plant current of 440 / 230 V with power of 3671 kVA.

General tendency for generator sets is to install three units the same type and the same power (15 ships from 17 selected). Shaft generators are very common (10 ships from 17) and power is between 1100 to 1250 kVA.

Emergency generators power is between 138 and 170 kVA (only four cases with lower power can be spotted)

Most common working medium for boilers (regardless burner or recuperation system) is water, but also thermal oil must be considered.

References

[1] Barrass, C. B., *Ship Design and Performance for Masters and Mates*, Elsevier, 2004.
[2] Charchalis, A., Kreft, J., M*ain dimensions of the container vessels,* Journal of Powertrain and Transport, 2009.
[3] Charchalis, A., D*imensional constraints in ship design,* Journal of Powertrain and Transport, 2013.
[4] Charchalis, A., Kreft, J., *Main dimensions selection methodology of the container vessels in the preliminary stage*, IMAM, Stambul 2010.
[5] Molland, A. F., *the Maritime Engineering Reference Book*, Elsevier, 2008.
[6] Schneekluth, H., Bertram, V., *Ship design for efficiency and economy*, Butterworth Heinemann, Oxford 1998.