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The use analysis of regression for preliminary determine the parameters of the design – exploitation of motor yachts

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Abstract

The economic crisis initiated in 2007, has caused disturbance and a fairly a sharp drop the yachting industry in the country. Many of foreign companies could not bear at all the crisis and were forced to close or were absorbed by other companies in the sector. Since 2010, is observed the at first slow, and currently the dynamic growth of produced boats for various purposes also on the Polish market for Polish customers. The upward trend of the sector will need adequately trained engineers (specialists) - designers, constructors, technologists, etc.

Deficiencies literature regarding (approaches) design guidelines on recreational boats, bowed the author to develop one of the methods determine the basic dimensional parameters and design of motor yachts at the initial stage, right away selected the technical assumptions.

Based on the gathered database of built yachts developed regression that allow the initial design stage to determine the basic dimensions, namely: L_{OA}, B, H, T and the design parameters, i.e. D, SP, C_B yacht. This allows start the next project stage, which is the creation the first concept yacht along with his shape, bodylines and estimate construction costs.

Introduction

The economic crisis initiated in 2007, has caused disturbance and a fairly a sharp drop the yachting industry in the country. Many of foreign companies could not bear at all the crisis and were forced to close or were absorbed by other companies in the sector.

Due to the strong interest recreational yachts, form several years is observed produced an increase in yachts for various purposes also on the Polish market for Polish customers, although today most domestic production (almost 90%) is exported to Western Europe, Scandinavia, USA, Russia.

Should mention that Poland is the european leader in the production of especially small units (motor yachts and sailing).

According to the data source [1] potential Polish yacht industry is the production of 22,000 yachts per year. In the manufacture motor boats up to 9.0 m Poland takes second place right after the United States. The largest Polish shipyards i.e. Galeon, Delphia Yachts, Balt Yacht, etc. produce about 60% of the total annual production. Therefore, there is a need to increase the number of specialists (engineers) in the design and construction of yachts and also pay attention to the main design parameters of these units and their influence on comfort, performance and costs of construction and exploitation.

In contrast to design of transport vessels, a crucial role in the design of particular units of recreation and tourism play a prominent role, such as beauty solid body, its streamline, stylish and unique figure, with a comfortable often very comfortably equipped interior, with less attention paid to its technical parameters, such as displacement, the maximum capacity and the speed with minimal fuel consumption – which are the basic parameters of the transport ship.

The first step in designing spiral design is –after selected preliminary assumptions – to determine the basic dimensions of the designed unit with its first architectural concept. Design assumptions selected by a potential owner of a motor yacht can be varied, the most important and necessary for the designer preliminary information may include:

- Type of yacht and its destiny;
- Area navigation;
- Classification society;
- Crew limit;
- Operating (cruiser) speed, maximum speed;
- Limitations for the dimensional parameters, such as: maximum length, the maximum draft or displacement of unit, etc.;
- Equipment units;
- Route Shipping and limitations of the waterway and road restrictions in road transport;
- Material of the hull;
- Maximum costs.

In case of lack of experience or lack of reliable technical data of an exemplary standard yacht is not easy to properly assess the main dimensions of the newly-designed units, maintaining the appropriate balance dimensional, which in turn have an impact on exploitation properties the yacht.

For the purposes of determining a first approximation, the main design parameters of the motor yachts used a statistical method involving the use of dependence developed using regression analysis of the collected statistical data on the relationship between its various parameters. Results of analyzes are presented later in this article.

Characteristics of the database of motor yachts

Motor yachts that combines the comfort, elegance and high speeds, are characterized by a slender hull, water line looks elongated.

Characteristic feature rounded shape of the whole body yacht (Fig. 1). The main purpose of this group of individuals is tourism and recreation on inland waterways, seas and estuaries and bays.

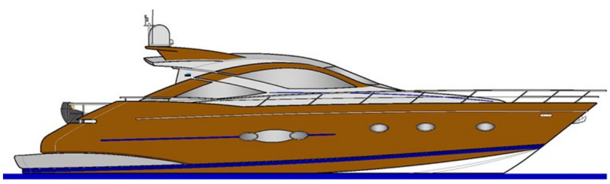

Fig. 1. Profile motor yacht – 2010 VULCANO 60' – example [2]

Motor yachts subject article, have the following main technical parameters:

Length of overall: L_{OA} = 10.0÷24.0 m;
Length of hull: L_H = 9.5÷22.9 m;
Displacement: D = 5.5÷77.0 t;
Cruise speed: v = 19.0÷32.0 kn;
Maximum speed: v_{max} = 22.0÷42.5 kn;
Main drive power: MCR = 170÷1400 HP;
Crew: n_c = 8÷18 persons.

Database yachts consists of 40 cases of yachts, with hulls pre-planing / planing with sharp and bend shapes, adapted for cruise planing, driven (in most cases) by a stationary engine. Exemplary technical and operational characteristics that were used in the regression analysis are shown in table 1. For reasons of limitation, table 1 contains only a part of the analyzed cases yachts.

According to the database hulls of yachts have the following operational parameters [3, 4]:

- block coefficient:

$$C_B = \frac{V}{L \cdot B \cdot T} = 0.16 \div 0.36 \tag{1}$$

This parameter influences the slenderness of the hull shape and the displacement of the watercraft

- Number Froude'a:

$$Fr = \frac{v}{\sqrt{L \cdot g}} 0.67 \div 1.45 \tag{2}$$

This parameter enables the selection of the key parameters for a type of watercraft.

- Relative speed:

$$\frac{v}{\sqrt{L}} = 2.11 \div 4.56 \tag{3}$$

The parametr of relative speed allows the selection of the main parameters for a specific type of watercraft.

- Froude'a number relative to displacement:

$$Fr_D = 0{,}165 \frac{v}{D^{1/6}} = 0.81 \div 1.80 \tag{4}$$

This parameter defines the scope of the occurrence of "velocity ability to float" yacht, i.e. a floating buoyancy or planing, etc.

- Slenderness of ratio:

$$\frac{L_H}{D^{1/3}} = 5.14 \div 6.48 \tag{5}$$

This parameter affects the size of the resistance and achieved the speed of the watercraft.

Above parameters, especially their scope (range) values allows to assess the exploitation properties of unit, including for example, what type of buoyancy is the yacht between the size and shape of the hull and the speed and power of the engine.

Table 1. Database – principal dimensions and design parameters of motor yacht [5, 6]

No.	Yachts	L_{OA} [m]	L_H [m]	B [m]	T [m]	H_{under} [m]	D [t]	D_{LS} [t]	DWT [t]	C_B [–]	$V_{cruis.}$ [kn]	V_{max} [kn]	Fuel [l]	Water [l]	Crew [persons]	PB [HP]	Fr [–]	$L_H/D^{1/3}$ [–]	$v/L_H^{1/2}$ [–]	Fr_D [–]
1	Ferretti 690	21.07	20.54	5.53	1.70	5.48	48.20	42.20	6.72	0.244	30.0	33.0	3700	990	18	1268	1.086	5.644	3.402	1.334
2	Ferretti 750	22.75	21.65	5.70	1.85	6.72	59.00	49.80	8.50	0.252	27.0	30.0	5000	990	20	1120	0.952	5.561	2.983	1.161
3	Ferretti 650	19.67	18.37	5.25	1.50		41.20	34.80	8.50	0.278	27.0	30.5	3700	530	18	1015	1.034	5.319	3.238	1.232
4	Ferretti 570	17.42	17.02	4.96	1.53		31.85	26.50	8.50	0.241	25.0	29.5	3100	710	18	800	0.994	5.369	3.115	1.191
5	Rodman 41 Crucero	13.67	11.98	4.20	0.85	4.50	12.40	10.90	1.50	0.283	30.0	32.5	1300	420	12	430	1.422	5.176	4.455	1.672
6	Neptunus 41 Sport	13.02	12.40	3.78	0.98	2.80	9.10	8.20	0.90	0.193	27.0	30.0	750	300	12	260	1.258	5.939	3.941	1.585
7	Fairline Phantom 50	15.80	15.24	4.50	1.25	5.16	21.60	19.50	2.10	0.246	30.0	32.3	1980	486	14	675	1.261	5.472	3.950	1.525
8	Fairline Targa 52	16.22	15.73	4.27	1.09	4.82	15.00	13.00	2.00	0.200	32.3	35.6	1820	455	10	700	1.336	6.378	4.186	1.744
9	Gobbi 425SC	13.70	12.00	4.07	1.05	3.96	8.76	7.80	0.96	0.167	30.0	34.3	780	312	14	285	1.421	5.821	4.451	1.772
10	Azimut 68S	21.17	20.65	5.31	1.62	4.48	32.43	27.50	4.93	0.178		37.6	3200	950	12	1066		6.475		
11	Azimut AZ55	17.50	16.80	4.75	1.23	6.12	26.00	21.00	5.00	0.258	29.0	32.0	2520	640	12	660	1.161	5.671	3.637	1.429
12	Azimut 68 EVO	21.60	21.08	5.40	1.45		41.40			0.245	31.0	34.0	4800	1200		1360	1.108	6.094	3.470	1.414
13	Azimut 58	17.88	17.59	4.95	1.37		25.00			0.204	28.0	32.0	2800	650		800	1.096	6.016	3.432	1.389
14	Sea Ray Sundancer 455	13.87	12.65	4.22	1.02	3.07	11.90	10.50	1.40	0.213	27.4	30.7	1268	379	15	350	1.264	5.541	3.960	1.538
15	Fleming 75	24.69	22.86	6.53	1.58	8.08	77.00	65.50	11.50	0.319	19.6	22.3	11365	1909	12	1400	0.673	5.373	2.107	0.806
16	Sabreline 36 Sedan	12.34	10.97	3.81	1.02	3.81	9.30	8.00	1.30	0.213		30.0	1136	379	10	370		5.216		
17	Sea Ray 680 Sun Sport	21.46	19.81	5.64	1.45		38.00	34.00	4.00	0.229		33.0	3785	757	18	1400		5.892		
18	Azimut 62	19.70	19.22	5.05	1.38	5.47	32.00	28.00	4.00	0.233	30.2	31.0	3400	1000	16	900	1.130	6.054	3.541	1.437
19	Cranchi Mediterranee 50	15.30	15.01	4.33	0.95			14.30				36.6	1600	500	14	480				
20	Marex 330 Scandinavia	10.26	9.50	3.31	1.00	3.16	6.30	5.40	0.90	0.195		42.7	670	350	10	285		5.144		
21	Princess v39	12.98	11.99	3.81	1.02	3.10	9.10	6.44	2.67	0.191		38.0	650	332	12	330		5.743		
22	Princess	18.77	18.47	4.88	1.35	6.12	29.30	26.00	3.30	0.235	28.0	30.9	3000	755	12	800	1.069	5.991	3.349	1.352
23	Atlantis 50	16.90	14.34	4.30	1.27			20.92			28.0	32.0	1700	420		442			3.801	
24	Sealine 42/5	12.90	12.90	4.21	0.99	4.34	13.60	11.80	1.80	0.247	29.9	32.1	1410	630	12	480	1.366	5.404	4.279	1.641
25	Rodman 56	17.40	16.94	4.88	1.10	4.90		19.50			28.5	32.7	2800	700	16	700	1.136		3.559	
26	Storebro 475 Commander	14.20	12.73	4.25	1.00	4.10	14.90	13.00	1.90	0.269	31.2	34.5	1560	600	12	480	1.435	5.173	4.495	1.687
27	Delphis Ten	10.11	10.00	3.37	0.95	2.47	5.40	4.50	0.90	0.165	20.2	30.7	827	259	6	170		5.700		
28	Carven 506	15.72	15.03	4.67	1.37	6.35	22.20	20.00	2.20	0.225	20.2	22.4	1931	598	15	450	0.8551	5.348	2.678	1.022
29	Azimut 68	21.60	21.00	5.50	1.65	5.28	39.00	34.00	5.00	0.200	25.6	29.4	4800	1200	16	1050	0.917	6.192	2.871	1.179
30	Dufour ACM Exellence	11.75	11.48	3.78	0.90	4.47	7.40	6.20	1.20	0.185	24.5	27.2	1000	350	10	230	1.187	5.891	3.717	1.488
31	Bavaria 330	10.30	10.00	3.40	0.91	3.20	7.20	5.80	1.40	0.227	22.4	37.6	650	130		260	1.162	5.179	3.641	1.367

According to [3] at a relative velocity greater than 1.2 can achieve hydrodynamic pressure at the bottom of the balancing part or all of the weight of the boat. However, according to the formula Froude number and referred to the displacement $Fr_D \leq 1$ – the unit is able to buoyancy and $Fr_D \geq 5$ – the unit is capable of a full planing.

Functions of regression to determine the dimensions and design parameters of a motor yacht

Regression analysis is one of the most frequently used of statistical models – allows to estimate the relation between variables and prediction of one variable based on the knowledge of its values correlated with other variables. The overall objective of regression analysis is to investigate relations between several independent variables with the dependent variable.

In developing the relations between the main parameters of motor yachts from table 1, were sought solutions in various forms functions, mostly non-linear functions. Among the examined as a primary function, i.e. logarithmic, quadratic, exponential, the best power function has proved to be:

$$y(x) = a \cdot x^b \qquad (6)$$

The results of analyzes are shown in graphic form successively in figures 2–9 each of the graphs of the function which has the best mileage replicated tested parameters and the value of the correlation coefficient r.

Developed functions of regression presented in graphic form can be used to determine the dimensions of the main newly designed motor yacht in the preliminary design phase and then be examined basic equation of buoyancy – a binding dimensions of a yacht with his masses:

$$L \cdot B \cdot T \cdot C_B \cdot \rho \cdot g = PS + \sum P_{\text{(storages)}} + \sum P_{\text{(other)}} \qquad (7)$$

Regression analysis started from the foundation of one of the dimensional parameters, namely: the length of the hull L_H. Other dimensional parameters and mass parameters can be calculated in the order according to the sequence shown figures 2 to 9.

After the initial determined of dimensions to be checked whether the ratio of main dimensions namely: L/B, B/T and H/T are within the average ranges for similar yachts.

In order to achieve advantageous technical-exploation parameters of small units characterized with high speed ratio to the length, should accordingly be shaped hull in topsides and underwater part, to reduce resistance in the water and of wind pressure during cruising with the required speed.

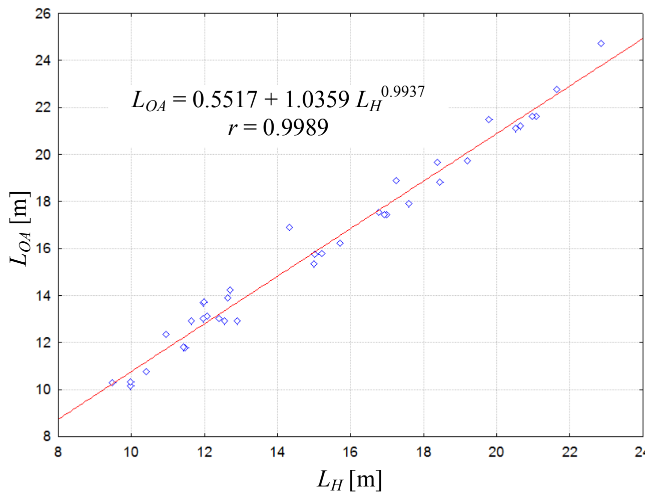

Fig. 2. Length overall L_{OA} depending on length of the hull L_H

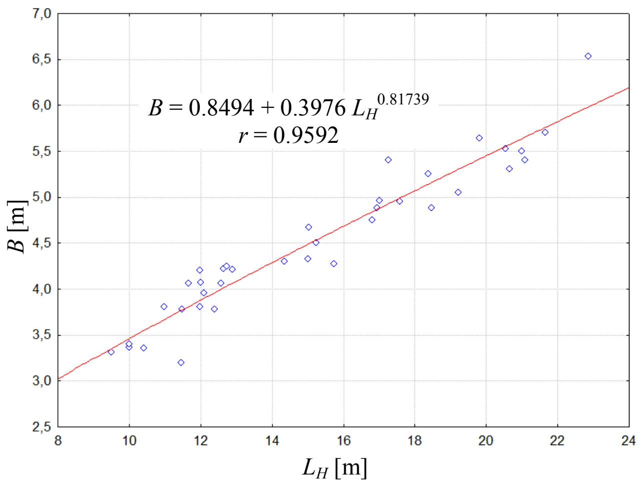

Fig. 3. Breadth B depending on length of the hull L_H

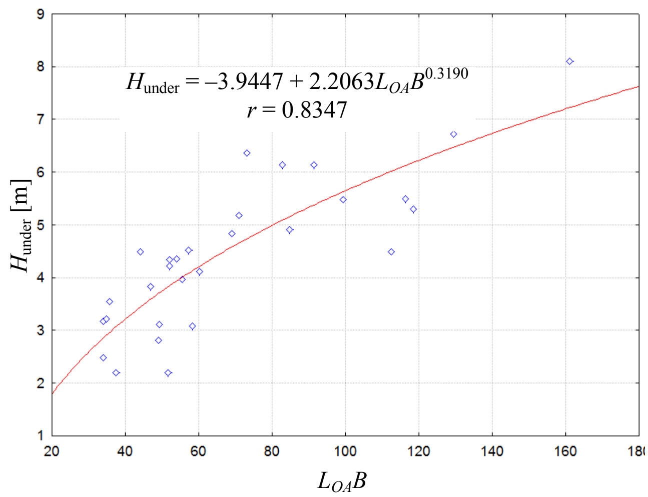

Fig. 4. Height of topside H_{under} depending on the surface of the deck $L_{OA}B$

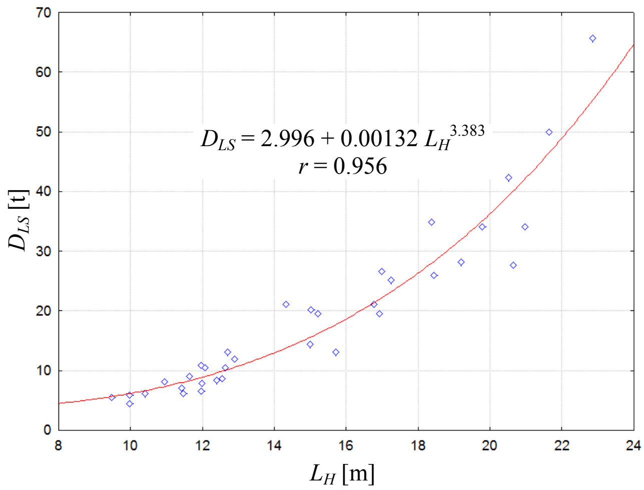

Fig. 5. Displacement of the light ship D_{LS} depending on length of the hull L_H

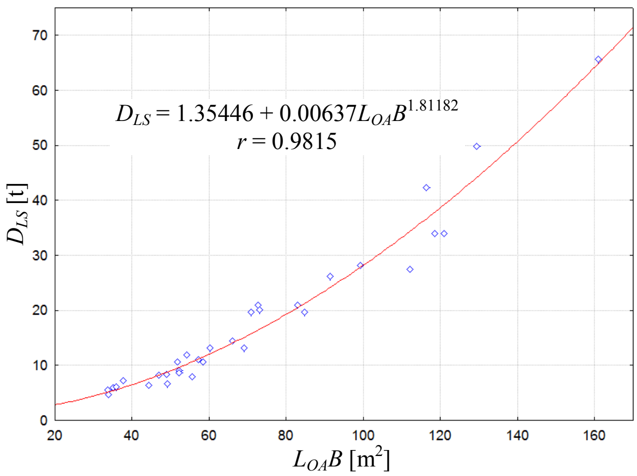

Fig. 6. Displacement of the light ship D_{LS} depending on the surface of the deck $L_{OA}B$

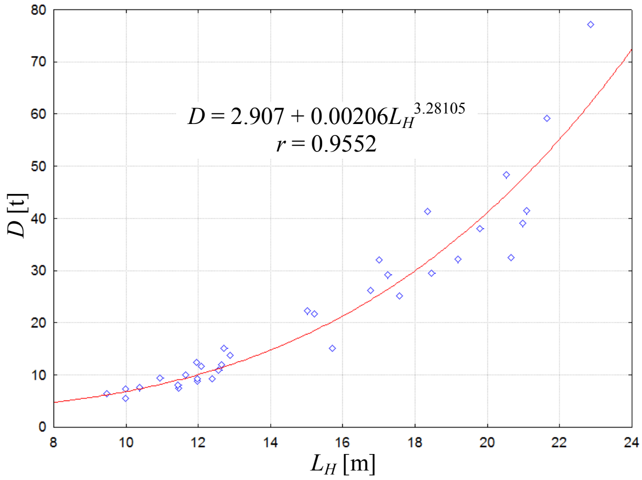

Fig. 7. Full displacement D depending on length of the hull L_H

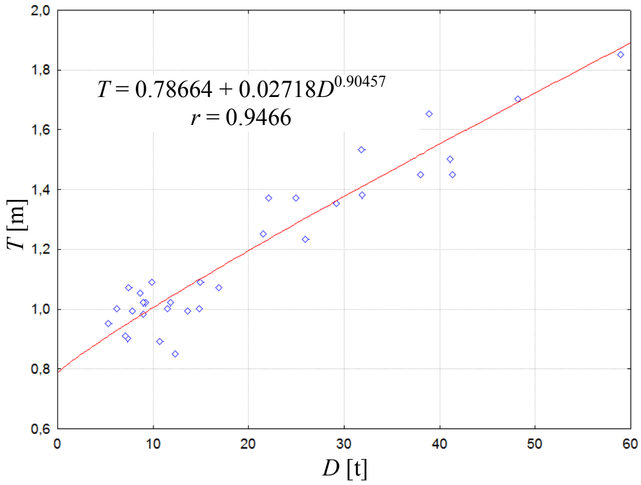

Fig. 8. Draft T depending on the full displacement $D_{całk}$

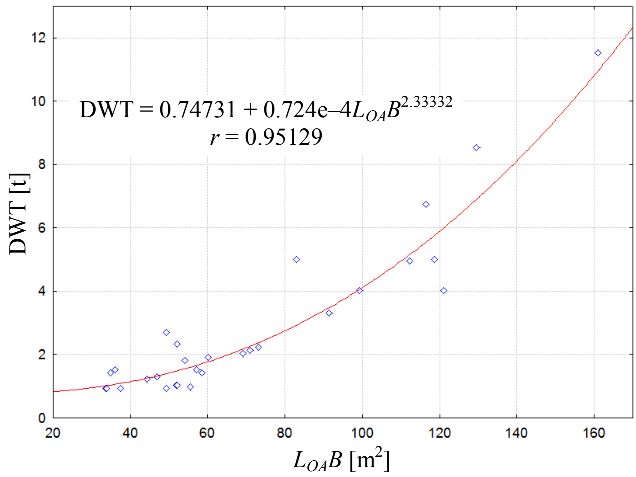

Fig. 9. Deadweight DWT depending on the surface of the deck $L_{OA}B$

Conclusions

1. Due to the upward trend and importance of yacht industry in Poland, is need to develop a general theory, principles of design and construction recreational boats with particular emphasis on motor yachts.

   To meet the demands of the domestic market and not only from 2012 there is the opportunity to improve knowledge in the design and construction of recreational vessels and sport (daily study and postgraduate studies) in the Chair of Ocean Engineering and Marine Systems Design in the Faculty of Maritime Technology in the West Pomeranian University of Technology in Szczecin.
2. The proposed in the article methodology exploited statistical and developed function of regression can be used to determine the size of the yacht (the well-known design assumptions) at the initial stage.
3. Presents the main parameters of design and exploitation and their value range for the analyzed group of yachts, which allows to assess the exploitation properties, i.e. type of buoyancy, size of resistance and speed, etc.

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