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Electric Propulsion Applied for Research Vessel

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Abstract. In the present work a research boat or specifically for geography was developed where the electric propulsion was chosen, for the reason that advantages of electric propulsion in this type of vessel. The dimension the power necessary to propulsion the ship is necessary to account the wholly weight of the ship and her navigation velocity. In this work the weight of the every part of the ship were considerate, as: electric equipment, mechanic equipment, hull structure, and crane, etc. Then the preliminary design of the hydrographic boat was developed where a group of the three engineers was constituted for realize this work.

Keys words

Ship Design, Electric Power, Hull Form, Efficiency Calculation, Electric Propulsion.

1. Introduction

Geo technical research vessels, oceanographic vessels, and fishing research vessels have in common very strict underwater noise requirements, typically several decades dB below normal levels for other applications. This has traditionally been achieved by use of direct propulsion with DC motors, special considerations for filtering and reduction of vibrations and torque variations. By use of modern frequency converters and filtering techniques, AC motors have become feasible for such high demanding applications as well, and are now taken into use in recent ship designs [1].

At present, electric propulsion is applied in ships supply vessels. There is also a significant on-going research and evaluation of using electric propulsion in new vessel designs for existing and new application areas. As propose here.

2. Hydrographic Boat as the start point for the Project

This working boat will be used for investigation tasks. It will collect information like wind, wave, and topography and so on its operation zone is in the North Sea and channels. Besides of data measure equipments, this boat should satisfy those specific data: Travel in 6 days without reload (fuel and water); Carry 5 persons (crew and specialists); Sonar in the front; Maps and navigation equipment; Kitchen with table for six persons; Shower and toilet; Speed: 11 knobs; Carry 1 crane which will be used to loading/unloading equipment from the boat.

3. Bibliographic revision

In this work was studied many researchers and studies realized to show and give solution for more divers problem in navigability in first one we can shown the work of Alf Kåre Ådnanes[1] , where is find the technology apply to diesel electric propulsion. CHISTOPOULOS & LATORRE [3] developed a design procedure of this type of propeller, applying it, years later, the development of a helix called semi-Kaplan, with changes in the distributions of ropes and steps with these propellers show that the new design procedure introduced an improvement about 10% of the propulsive efficiency of boats, comparing fuel consumption and average speeds. PADOVEZI [9] notes that the literature on inland waterway is mainly concerned with testing the models in tanks and evidence that are not found references to present complete results of tests on propulsion scale mainly train. PHILIPPE RIGO and ENRICO RIZZUTO [10, 11] wrote the paper "Analysis and Design of Ship Structure", in according to the author the organization and framework of this book are based in two books 'Ship Design" and "Construction and Principles of Naval Architecture'. Nóbrega in his Post doctorate Report in Naval Architecture realized in Anast/ULG, Liège – Belgian [7] developed the complete project over geographic ship design, also, the same author was published in the icrepq´12 the work about the solar boat where developed the work over structural analisys of small ship powered with solar energy [8].

Optimization is treated in Ship structural design. J. MARCHAL [6] wrote the book Ship Theory who is divided in three volumes, the first "The Static", this book give all the theory relative to stability of the ship, in the most divers situations, take in consideration stability of floating bodies, influence of geometry of the floating body over the centre of carene position, metacenter and others. In the second volume “The dynamic”, that author describe about: Launch ship, stop the vessel, maneuverability study and others. Finally in the third volume “Propulsion” in this volume is described about: propeller, standardization, blades, engine and other.

The main dimension of the ship was chosen by following the rules and by the others ships already existing. The general arrangement was done by following the upper requests and the existing rules for these navigation areas. It could be divided into 2 floors. In the lowest part is used for tanks (gray, fresh and black water tank). Dimension for each tank is listed on the table below. In the fore part of the first floor, we arranged the space for kitchen and bathroom area. In the aft part is the fuel tanks and engine room.

4. General Arrangement

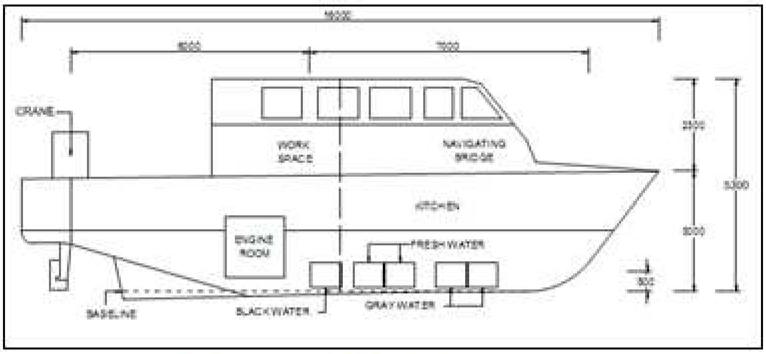

Fig. 1. General arrangement on side view

At this moment, we did not decide which type of engine will used. So the dimensions of engine room still are an unknown. But we decided should use two engine instead of one. Fuel tank is also divided into 2 tanks. Each one is 2000x750x500 (mm). These tanks can contain 1500 l of fuel which satisfy for requirement of 6 days travel without reload. The second flood is used for working space (hydrographic survey), navigating bridge, and free deck for crane working zone.

Table I. - The main dimension of the ship

Vessel Characteristic	Value
Length	16 m
Width	5 m
Draft	1.4 m
Displacement	38.64 T
Engine Power	? Kw
Personas	5
Endurance	6 Days

Table II. - Water tanks dimensions

	Black water tank	Fresh water tank (x2)	Gray water tank (x2)
Length (mm)	900	1200	1200
Height (mm)	750	750	750
Width (mm)	600	600	600

In the aft body part of ship, there is loading/unloading equipment for sensors. Working space is enough for 4 crews with their devices (laptop, data collector, etc.)

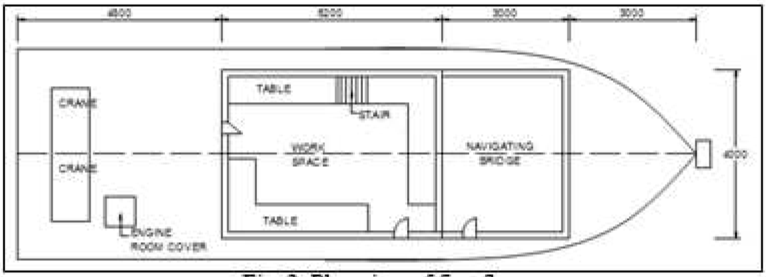

Fig. 2. Plan view of first floor

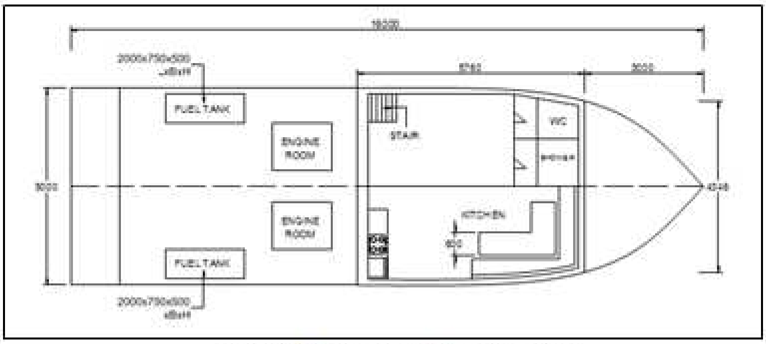

Fig. 3. Plan view of the second floor

5. Weight Assessment

The weight estimate was conducted in three phases. First the hull steel weight was determined by calculating the center of gravity and mass of each structural member and plate in the hull on a frame-by-frame basis using scantling calculation and Workshop program. The detail weight and calculation is tape in the Juraci Nóbrega post doctorate report presented in Liège University Belgian [7]. This final result is shown on the table below.

Table III. - Hull form mass

Total weight of hull form (Tones) Without superstructure (Tones)	VCG (m)	LCG (m)	TCG (m)
20.06	7.202	2.313	0
Total weight of hull form (Tones) With superstructure (Tones)	VCG (m)	LCG (m)	TCG (m)
24	8	1.4	0

Table IV. - Deadweight of the ship

Deadweight of the ship (Tones)	VCG (m)	LCG (m)	TCG (m)
38,64	7.018	1.42	0.89

From the steel weight estimate, it was then possible to calculate the overall weight of the vessel by adding the masses of the various components at their respective centers of gravity.

Where

- VCG is the vertical gravity center
- LCG is the longitudinal gravity center
- TCG is the transversal gravity center

Hull form design - The hull form design base on main parameters which satisfy the general arrangement using:

- Length: 16m
- Weight: 4m
- Draft: 1.3m – 1.5m

The hull form was developed in Maxsurf program. The drawing was started by using a horizontal surface after that was added an other two vertical surfaces. In below picture is the final drawing.

6. Hull Form Design and Hull Form Parameters

A. Hull form parameters

The Maxsurf was used to also calculate hull form parameters, and even estimate draft of the hull.

However the scantling of the super structure and also the building part of the ship have not included in the weight. So the draft was used for reference purpose only. In the definition of hull geometry there are certain coefficients which will later prove of value as guides to the fatness or slimness of the hull.

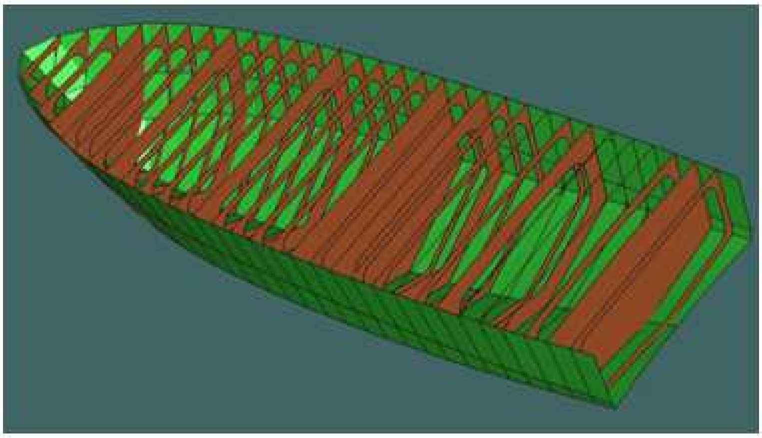

Fig. 4. Workshop drawing of the structure

The coefficient of fineness of waterplane, C_{WP}, is the ratio of the area of the waterplane to the area of its circumscribing rectangle. It varies from about 0.07 for ships with unusually fine ends to about 0.90 for ships with much parallel middle body.

$$C_{WP} = \frac{A_W}{L_{WL} B} \quad (1)$$

The midship section coefficient, CM, is the ratio of the midship section area to the area of a rectangle whose sides are equal to the draft and the width extreme amidship. Its value usually exceeds 0.85 for ships other then yachts.

$$C_M = \frac{A_M}{BT} \quad (2)$$

The block coefficient, CB, is the ratio of the volume of displacement to the volume of rectangular block whose side is equal to the width extreme, the mean draft and the length perpendiculars.

$$C_B = \frac{\nabla}{BTL_{PP}} \quad (3)$$

Table V. - Hull form parameters

Displacement	38,64	tons
Volume	53.155	m^3
Waterplane area	59.309	m^2
Cp	0.724	
Cb	0.458	
Cm	0.683	
Cwp	0.849	

7. Structural Design

The structural design is very important for find the total power required for a ship. The weight of the ship structure depend these calculations. In this work the cross section scantling was made in according ***Bureau Veritas*** rules.

A. Shell Plate Thickness:

The minimum net plate thickness of the bottom was obtained as:
The minimum plate thickness:

- bottom plate……….................………... 6 mm;
- side plate…………................…………..... 6 mm;
- deck plate………................…………... 5 mm;
- keel plate ……………................……... 7 mm;
- watertight bulkhead plate…................... 13 mm;
- platform in engine room………….…… 13 mm;

B. Minim Mid-ship Section Modulus for the Elements:

The space between stiffeners is equal whit (s = 500 mm) for this type of ship. The maximum space between frames is five times stiffeners spacing (S = 2500 mm).On the bottom it is one centre girder and on the deck the same. On the side will not be centre girder because it is used when the high of the side is more then three meters.

C. The minimum modulus [cm^3] value for the structure is:

- bottom centre girder……......................212 cm^3;
- deck centre girder…………………..…. 118,3 cm^3;
- bottom frame……………………..…. 127,4 cm^3;
- side frame ……………………………... 21 cm^3;
- deck frame …………..…………….....… 63 cm^3;
- bottom stiffeners ……………….….....…7,8 cm^3;
- side stiffeners……………………..….....5.4 cm^3;
- deck stiffeners……………………...…..4,9 cm^3.

D. The section area [cm^2] value for the structure is:

- bottom centre girder.......…..................5,6 cm^3;
- deck centre girder……………………...….3,2 cm^3;
- bottom frame…………………...……….5,6 cm^3;
- side frame ……………...………………0,8 cm^3;
- deck frame ………………………....….2,8 cm^3;
- bottom stiffeners ………………...…….0,3 cm^3;

- side stiffeners……………………..……...0,2 cm^3;
- deck stiffeners……………….......……..0,2 cm^3.

After calculate the section modulus was took a standard profile with a modulus value higher than the value obtained from calculation. Profile from standard table which are in ***Bureau Veritas*** rules are bulb profile and for calculation was changed the bulb profile in "T" profile. Then was added too the "T" profile the plate which is 50 % from the distance between stiffeners and 80% from the frame spacing. If the value of modulus obtained for this profile is higher than the first than is good if not was chose another bulb profile and was repeated the calculation.

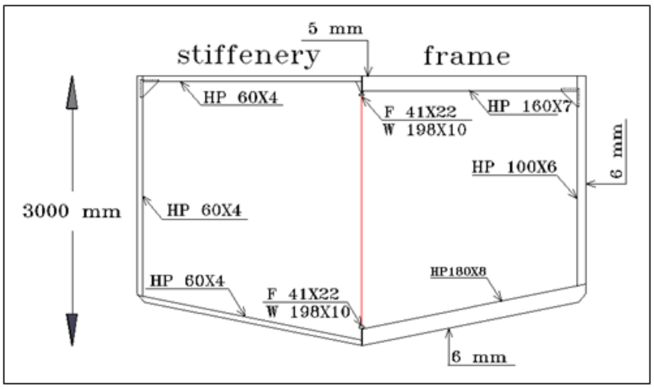

Fig. 5. Final dimension drawn boat

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E. Power Ship Calculation

Any propulsion system interacts with the ship hull. The general definition:

“Power = force X speed”, Yields the effective power:

$P_E = R_T.V_S$ (4)

R_T is the total calm-water resistance of the ship excluding resistance of appendages related to the propulsive organs. Sometimes the rudder is also excluded and treated as part of the propulsion system.
Can define a power formed by the propeller thrust and the speed of advance of the propeller, the so-called thrust power:

$P_T = T.V_A$ (5)

The thrust T measured in a propulsion test is higher than the resistance R_T measured in a resistance test (without propeller).
The brake power, P_B, is the power measured at the crank–shaft coupling by means of a mechanical, hydraulic, or electrical brake. It is determined by a shop test and is calculated by the formula:

$P_B = 2\pi \cdot Q \cdot n$ (KW) (6)

Where:
Q = brake torque, kN-m
n = revolutions per sec.
The shaft power, P_S, is the power transmitted through the shaft:

$P_S = P_B \cdot \eta_G$ (7)

,

Where: η_G is the gearing efficiency.
Through the bearing efficiency η_B and the stern tube efficiency η_S, we arrive at the delivered power:

Which is the power available to the propeller for the propulsion of the ship.

$P_D = P_B \cdot \eta_S \cdot \eta_B \cdot \eta_G$ (8)

The power we need for a speed given was calculate with Hydromax program. The result is in below table. The is used Holtrop method.

Tab. VI. - The power we need for a speed given

No	Speed (kts)	Holtrop power (KW)
38	10.17	99.5
39	10.45	112.72
40	10.72	126.5
41	11	140.84

8. Propeller’s geometry

Diameter of the propeller can be obtained by following the steeps. With the data [NÓBREGA, 2010]

$P_D = P \cdot A \cdot S \cdot \eta_r = 460 \cdot 0{,}9 \cdot 0{,}97 \cdot 1{,}0 = 401{,}6hp$ (9)

- resistance…...24,9 KN ;
- power…………………..………….…141 KW ;
- sea margin A= 0,9

- shaft S = 0,97
- relative rotative efficiency, η_r = 1,0

9. Hull efficience

$$\eta_h = \frac{1-t}{1-w} = \frac{1-0.1}{1-0.3} = 1{,}3 \quad (10)$$

Table VII. - Characteristics boat Power and coefficient

speed (kn)	8.0	9.0	10.0	11.0
power PE (kW)	33.8	54.7	86.8	140.8
power PE (HP)	45.9	74.3	117.8	191.1
VA =V(1-W) (kn)	5.6	6.3	7	7.7
for N equal	100	110	120	130.0
$B_p = \frac{N\sqrt{P_D}}{V_A}$	27	22	19	16
$\sqrt{B_p}$	5.2	4.7	4.3	4.0

Table VIII. - Characteristics boat Power and diameter boat

η_o	0.8	0.73	0.67	0.63
P/D	0.84	0.76	0.7	0.66
δ	67	61	56	52
$P_{TE} = P_D \cdot \eta_h \cdot \eta_O$ (HP)	417.6	381.1	349.8	328.9
D (m)	0.8	0,7	0.6	0.4

10. Conclusion

Then in this study developed we find the 141 kW to move the ship with 11 knots of velocity. The total weight can see in the table III. In this project of this boat were calculated: Power necessary to move the boat plus the energy electric necessary to supply the electric load. To dimension the necessary energy to supply the boat propulsion was necessary to account the wholly weight of the ship and her navigation velocity. For the total weight of the hull structure plus superstructure was computed the weight of the: frames, beams, plates, pillar, etc. These calculations were showed in this article e much more that this can be found in the post doctorate report from CAPES/ANAST-ULG [15]. Finally is important show that this power that was find in this study can be used to chose the primary energy: diesel, solar panel; battery bank, or other.

In this study was proposed find the total power necessary to empowering the ship. This article was developed in collaboration with ANAST/ULg – Be, during the course of Naval Architecture as prerequisites for Master Degree Program. .

η_o - open-water propeller efficiency
P/D- pitch ratio
P_{TE} - thrust hors power
D – Diameter.

Fig. 6. Simple example of the propeller used in electric propulsion

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