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DESIGNING PROPELLER OF MINISUBMARINE 22 M BY USING STANDARD SERIES DATA

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ABSTRACT

Mini submarine with 22 meters in length , hull diameter of 3 meters and 130 ton in displacement is very common operated for shallow water. The choice of propeller as a propulsion of minisubmarine is the important role in the designing of minisubmarine 22 m. The powering calculation specially resistance calculation of minisubmarine is carried out by using the Viginia Technology (VT) method and submarine sister for getting similar data. Based on the result of powering calculation, designing propeller was to be done by using the B-series Propeller The choice of the blade area ratio, pitch diamater ratio number of blade , rpm and diamater of propeller depend on the required thrust and the the available power. It's found that the propller B7-85 with PDRA 0.9 and the number of blade 7 is suitable for the propulsion of minisubmarine 22 m.

KEYWORDS: *minisubmarine, powering,design, propeller, suitable*

I. INTRODUCTION

In the initial ship design stage, it is necessary to predict the performance of the considered propeller. For this purpose the commonly preferred open water is the Wageningen B screw propeller series. The experimental data of this series were firstly reported by Troost [1]. Later some corrections were made on the series by taking the scale effects into account. The results of the study are presented by van Lammeren et.al. [2]. Great information of the Wageningen propeller series is also published by G Kuiper [3] A detailed regression analysis was made for the performance characteristics obtained from the Wageningen B propeller series by Oosterveld and van Oossanen [4]. They presented the open water propeller characteristics of the Wageningen B series for the Reynolds number at 2 x 10^6 as polynomial functions. The variable parameters relating these series are the propeller blade number (Z), the blade area ratio (A_E/A_0), and the pitch ratio (P/D).

In this paper, a practical design approach for designing propulsion for mini submarine is presented by using the Wageningen B series propellers for a case where the delivered power (P_D), the advance speed (V_A) and the revolution number (n) is known. A set of propellers suitable for a wide loading range is developed by the use of open water diagram polynomials representing the open water diagrams of the Wageningen B propeller series. The Wageningen B propeller series is a general purpose series. This series is expressed with open water diagrams obtained from model tests where the K_T-K_Q-J curves are showed for propellers with constant blade number (Z) and constant blade area ratio (A_E/A_0) but variable pitch ratios (P/D). Because the open water experiments are made in fresh water, this must be considered in the design calculations. The Wageningen B series propellers are extensively used for the design and analysis of fixed pitch propellers.

II. MATERIALS AND METHODS

The main dimension of minisubmarine 22 M presented as bellow

Length	:	22.0 m
Pressure hull diameter	:	3.0 m
Displacement	:	133 ton
Wetted Surface area (fully submerged)	:	130.6 m^2

And the shape (Lines Plan) of minisubmarine 22 m is presented in Figure 1.

If the required thrust of minisubmarine and the main engine are known, the propeller design is carried out as follows. Firstly, the torque requirement curve K_Q-J obtained according to Equation (8) is drawn over the Wageningen B open water diagram. The intersection points of this curve which express the torque requirement of the propeller and the K_Q curves of different P/D values on the open water diagram describe the possible design solutions. The optimum efficiency curve is obtained by drawing vertical lines from the intersection points to the efficiency curves. And the maximum point of this curve, which represents the most efficient propeller among the different solutions satisfying the requirements, is read-off. Later the J, P/D, K_T, K_Q and η_o values of the optimum propeller are read-off.

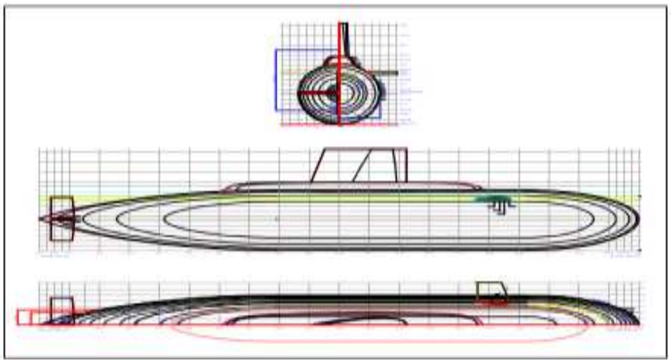
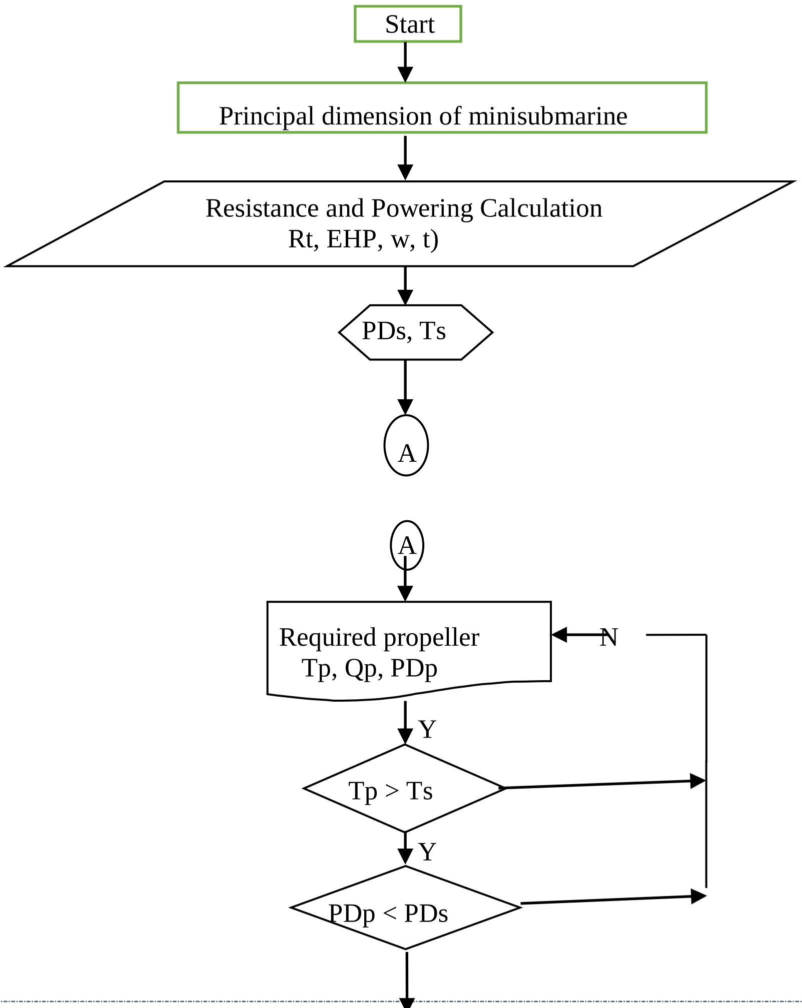


Fig.1. Lines Plan of minisubmarine 22 m

A computer code based on polynomials and open water diagram of the Wageningen B series are used in the applications of the design method. In the designing propeller of mini submarine 22 m, it follows the flowchart presented in Figure 2



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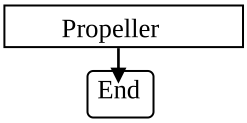

Fig. 2. Flow diagram of design propeller

Resistance and Effective Horsepower

The resistance calculations of Submerged bare hull were performed by using a modified Gilmer and Johnson method and called as the VT method. The viscous resistance is found using a modified Gilmer and Johnson form factor and an ITTC coefficient of friction which uses a 30% correction factor for sails and appendages. The total bare hull resistance is the sum of viscous resistance, correlation allowance and wavemaking resistance (when submarine near the water surface). The Effective Horsepower (EHP) was determined over a range of speeds by using this resistance calculation.

According to Alemayehu D, et all [5], the total resistance and effective horse power of submarine can be calculated as follow :

Total resistance

$$R_{Ti} = R_{vi} + R_{Ai} \qquad (1)$$

Where

$$R_{vi} = 0.5 * \rho * (V_i)^2 * S * C_{Fi} \qquad (2)$$

And

$$R_{Ai} = 0.5 * \rho * (V_i)^2 * S * C_A \qquad (3)$$

Effective Horse power :

$$EHP = 1.3 * R_{Ti} + V_i \qquad (4)$$

By using equation (1) through (4) the resistance and Effective Horse Power of the minisubmarine 22 m are calculated and presented in Table 1 and Table 2 respectively. The total resistance of minisubmarine 22 m at 8 knot is 4.807 kN and ilustrated in Figure 2. The Effective horse power at this speed is 49.997 kW . Both are ilustrated in Figure 3

Table 1. Total Resistance calculation of Minisubmarine

i	Vi	CA	R_{Ai}	Form fact	Rn	CF	R_{vi}	R_{Ti}
1	0	0.0006	0	1.683525	0	0	0	0
2	0.5144	0.0006	10.6265	1.683525	9672479	0.003017	89.96961	100.5961
3	1.0288	0.0006	42.506	1.683525	19344957	0.002684	320.0606	362.5666
4	1.5432	0.0006	95.63849	1.683525	29017436	0.002513	674.4569	770.0954
5	2.0576	0.0006	170.024	1.683525	38689915	0.002402	1146.013	1316.037
6	2.572	0.0006	265.6625	1.683525	48362393	0.002321	1730.112	1995.774
7	3.0864	0.0006	382.554	1.683525	58034872	0.002258	2423.379	2805.933
8	3.6008	0.0006	520.6985	1.683525	67707350	0.002206	3223.177	3743.875
9	4.1152	0.0006	680.096	1.683525	77379829	0.002163	4127.353	4807.449
10	4.6296	0.0006	860.7464	1.683525	87052308	0.002126	5134.097	5994.844
11	5.144	0.0006	1062.65	1.683525	96724786	0.002093	6241.852	7304.502

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Table 2. Total Resistance and Effective Horse Power over speed range

V_I (knt)	R_{ti}	EHP
0	0	0
1	0.100596	0.130775
2	0.362567	0.942673
3	0.770095	3.003372
4	1.316037	6.843393
5	1.995774	12.97253
6	2.805933	21.88627
7	3.743875	34.06926
8	4.807449	49.99747
9	5.994844	70.13967
10	7.304502	94.95853

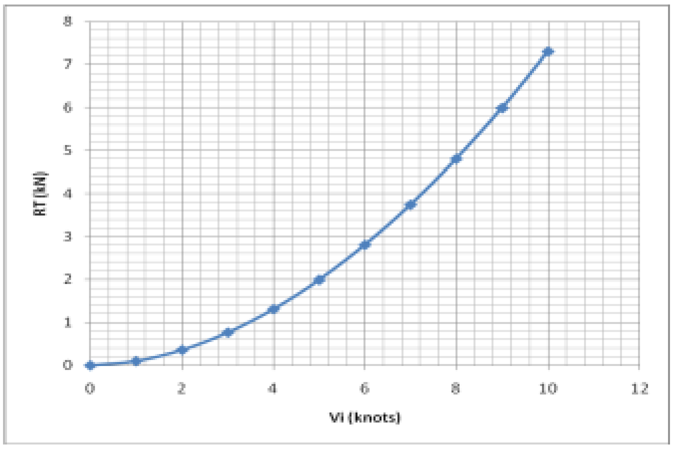

Fig. 2. Total Resistance according to VT method

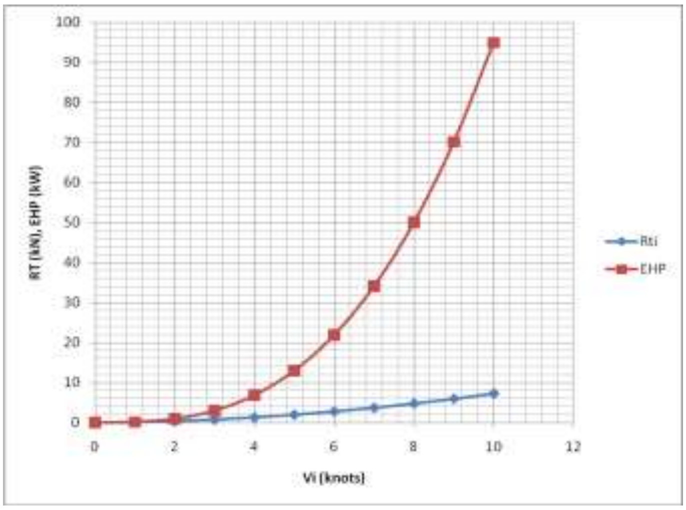

Fig. 3. Powering calculation according to VT method

III. RESULTS AND DISCUSSION

Initial design variable requirements of the propeller are the delivered power (P_D), the advance speed (V_A), the number of propeller revolutions (n), the blade number (Z) and the blade area ratio (A_E/A_0) are known and the pitch ratio (P/D), the diameter (D) and the performance characteristics (J, K_T, K_Q, η_o) are investigated among probable solutions. All of variables are defined as

$$J = \frac{V_a}{n*D} \quad (5)$$

$$K_t = \frac{T}{\rho * n^2 * D^4} \quad (6)$$

$$K_q = \frac{Q}{\rho * n^2 * D^5} \quad (7)$$

$$P_{Dp} = 2*\pi*Q*n \quad (8)$$

The required Thrust for moving forward can be calculated by the emperical formulas as stated bellow

$$w = 1 - 0.371 - 1.7151*\left(\frac{\frac{D_P}{D}}{\sqrt{C_{WS}\frac{LOA}{D}}}\right) \quad (9)$$

Where

$$C_{WS} = \frac{S}{\pi * L_{OA} * D}$$

if w >0.2, used w = 0.205

$$t = 1 - 0.632 - 1.3766*\left(\frac{\frac{D_P}{D}}{\sqrt{C_{WS} * \frac{L_{OA}}{D}}}\right) \quad (10)$$

if t<0.17, used t=0.17

$$V_A = Vi*(1-w) \quad (11)$$

$$T = \frac{R_T}{(1-t)} \quad (12)$$

$$\eta_H = \frac{1-t}{1-w} \quad (13)$$

$$THP = \frac{EHP}{\eta_H} \quad (14)$$

Based on the formula that mentioned in equation (9) through (10) above, wake fraction and thrust deduction fraction of minisubmarine 22 m respectively are 0.205 and 0.15. The required thrust and THP for minisubmarine moving forward 8 knots can be calculated by using equation (12) and (14). And it's found that the required thrust is 5.656 kN and THP is 46.762 kW.

The diameter of propeller should be 0.4 – 0.6 of the diamater pressure hull and the RPM of the propeller is 200 rpm (minisubmarine). This value is very common in the operation of mini submarine propeller. Propeller with 7 blades was used. Table 3 shows the different in blade area ratio affected on the efficiency of propeller B7. Based on it, the propeller with blade area ratio 0.85 has a highest value in efficiency.

Table.3. Propeller characteristic of mini submarine 22 m

A_E/A_0	J	K_T	$10K_Q$	η_o	P/D
0.55	0.650	0.1714	0.2817	0.6296	0.90
0.55	0.650	0.2006	0.3320	0.6216	0.95
0.70	0.650	0.1703	0.2760	0.6387	0.90
0.70	0.650	0.2006	0.3278	0.6053	0.95
0.85	0.650	0.1684	0.2730	0.6386	0.90
0.85	0.650	0.1993	0.3258	0.6331	0.95

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The chosen propeller for minisubmarine 22 m is

Diameter	:	1.2 m
Number of blade (Z)	:	7
Blade are ratio (A_E/A_O)	:	0.85
PDRA	:	0.9

Figure 4 shows the open water diagram of B7-85 and the drawing of propeller B7-85 was presented in Figure 5 .

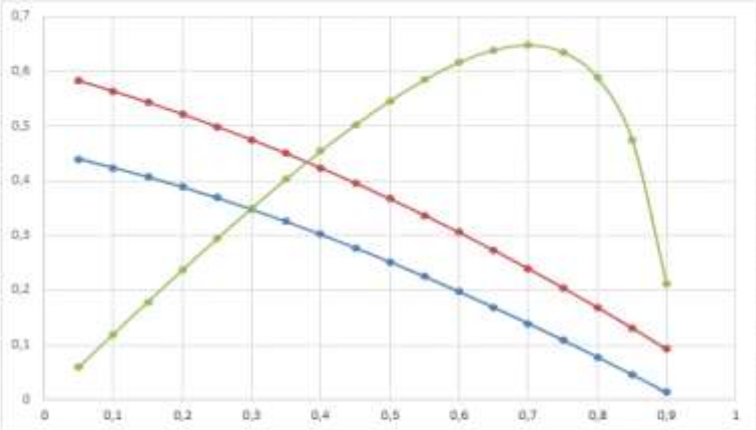

Fig. 4. Open water characteristic of minisubmarine 22 m

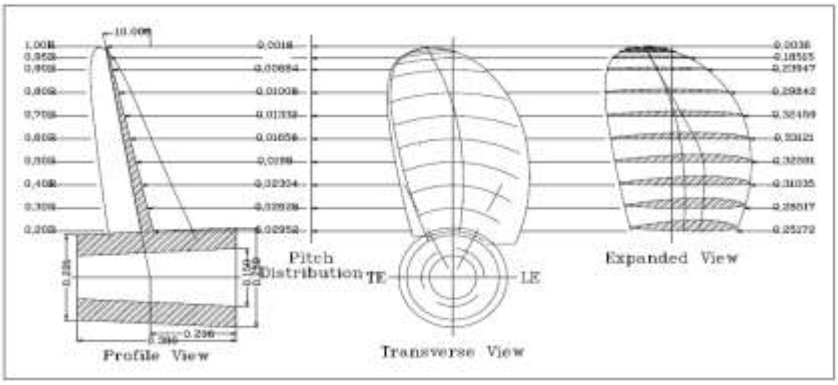

Fig.*5. Propeller B7-85 for Minisubmarine 22m*

IV. CONCLUSION

Chosing a type of propeller as a propulsion for mini submarine, the required thrust and the available power of main engine are absolutely to be known. For minisubmarine 22 m, the series data of Troost (Wageningen B-series) is recomended as one of propeller type that could be used as a propulsion of minisubmarine

V. ACKNOWLEDGEMENTS

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