Design Propeller Of Fast Missile Boat 60 M By Using Gawn Series

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Abstract. The 60m Fast Missile Boat (FMB 60m) with a full load displacement of 467T draft 2.6m uses a 3900Kw engine and a maximum speed of 28 knots. In this research, it will be designed using the Gawn series. Choice of the Gawn series is because Gawn has a P / D of 0.4 - 2.0 and a maximum KT of 1.1. Powering calculations, performed using the MARIN DESPPC method. Based on the calculation results, the KTR and Jdesign value will be obtained, then all Gawn series propellers that meet the required engine power will be calculated. From the calculation of thrust requirements and the availability of engine power, the Gawn series propeller is suitable for the propulsion of 60m fast missile boat.

1. Introduction
The Indonesian sea has 2 (two) different characters, the western region which is integrated with the Asian continent has shallow seas (<200m) and the eastern region which is integrated with the Australian continent has a deep-sea (> 200m). The western region with its shallow sea characteristics and thousands of islands is suitable for fast missile boats with a length overall 60m and a displacement of 500GT. This paper focuses on the design of the 60m Fast Missile Boat propeller using the Gawn series propeller application. The choice of the Gawn series propeller as the 60meter fast patrol missile boat propulsor was due to:
   a. The Gawn Series was chosen because it is widely used for high-speed ship propellers [1] [2][3][4][5][6][7][8]
   b. Has a larger pitch and blade area ratio[9][10].

   Fast Missile Boat is a multi-role ship, namely as a warship, patrol boat, and search and rescue ship. The most important factor in the design of a fast missile boat is speed. This is what distinguishes fast missile boats from cargo or passenger ships. Speed is a very important factor when functioning as a combat ship. At times as a patrol boat speed is also required in direct pursuit while on patrol.

   This paper will discuss the 60m Fast Missile Boat which is applied using a propeller - Gawn series. The design is done using the open water test model diagram [10]. The author designed whether the Gawn Series propeller could be used as propulsion by the initial design required on the 60meter Fast Missile Boat.

2. Propeller Calculation Method
The research object is the 60-meter Fast Missile Boat with the following technical data in table 1 and picture in Figure 1.
Table 1. Specification 60-meter Fast Missile Boat.

| Specifications          | Value | Unit   |
|-------------------------|-------|--------|
| Design speed            | 28    | knots  |
| LOA                     | 59.5  | meter  |
| Length on waterline     | 54    | meter  |
| LBP                     | 53.71 | meter  |
| Length                  | 7.23  | meter  |
| Displacement            | 467   | Ton    |
| Block coefficient       | 0.391 |        |
| RPM Engine              | 600   | 1/Min  |

Environmental conditions:

| Specification          | Value | Unit   |
|------------------------|-------|--------|
| Temperature            | 30    | m3     |
| Viscosity              | 1025  | kg/m2  |
| Kinematic viscosity    | 8.43E-07 | m2/s |

Figure 1. Fast Missile Boat 60m (https://pal.co.id/publikasi/artikel).

The power requirements (engine) of the fast patrol boat are designed to use 2 (two) main engines with specifications in table 2.

Table 2. Engine Specifications.

| Specifications       | Value | Unit |
|----------------------|-------|------|
| Power shaft(Ps)      | 2x3900| KW   |
|                      | 500-700| Rpm  |
| Gearbox efficiency   | 97    | %    |
| Sea margin           | 15    | %    |

Sea margin worldwide 15%, the maximum engine power with sea margin is 6630 KW. The efficiency of the gearbox is 97%, then the PE (Engine Power installed). Fast Missile Boat is assumed to be a heavy-duty engine so that the MCR operation is capable of up to 100% Engine load. So that the existing Power Engine is 6431 KW. The calculation of the maximum diameter of the propeller is obtained from the stern design of the ship and the calculation of the empty load so that the maximum diameter of the propeller is 1.8m. The results of testing the MARIN DESPCC software are for the ideal trial condition (no current, wind and, waves). Therefore, it is necessary to add an Allowance Sea Margin to overcome the loss of speed due to waves during the sea trial.
3. Methodology
The calculation begins by entering the ship data including LoA, LwL, B, D, T, J\text{design}. With DESPCC software, the required Thrust value (T_{\text{requirement}}) will be obtained. By getting the T_{R} value, the K_{T} value can be found. Then using the Gawn series will be able to determine the K_{TP} that meets the conditions K_{TP} > K_{TR}. After obtaining the K_{TP} value, it can be seen the value of Q, PD, and the efficiency of the propeller. The research methodology can be seen in the following flow chart Figure 2.

Figure 2. Research Flowchart.

4. Result and Discussion
The 60m Fast Missile Boat resistance is calculated using the MARIN DESPCC software. The calculation is carried out at full load at 2.57m with a speed variation between 20 to 30 knots. The results of resistance testing with the MARIN DESPCC software are in table 3.

| VS [knots] | R-TOT [kN] | THRUST [kN] | W [-] | T [-] | ETA-H [-] | ETA-R [-] | ETA-0 [-] | ETA-D [-] |
|-------------|-------------|--------------|-------|-------|-----------|-----------|-----------|-----------|
| 20.00       | 163.0       | 186.7        | 0.053 | 0.127 | 0.922     | 0.968     | 0.546     | 0.487     |
| 20.50       | 174.7       | 200.1        | 0.053 | 0.127 | 0.922     | 0.968     | 0.546     | 0.487     |
| 21.00       | 186.4       | 213.5        | 0.053 | 0.127 | 0.922     | 0.968     | 0.546     | 0.487     |
| 21.50       | 198.1       | 226.9        | 0.053 | 0.127 | 0.922     | 0.968     | 0.546     | 0.487     |
| 22.00       | 209.7       | 240.2        | 0.053 | 0.127 | 0.922     | 0.968     | 0.546     | 0.487     |
| 22.50       | 221.3       | 253.5        | 0.053 | 0.127 | 0.922     | 0.968     | 0.545     | 0.486     |
| 23.00       | 232.9       | 266.8        | 0.053 | 0.127 | 0.922     | 0.968     | 0.545     | 0.486     |
| 23.50       | 244.5       | 280.0        | 0.053 | 0.127 | 0.922     | 0.968     | 0.545     | 0.486     |
The propeller performance can be expressed in terms of four non-dimensional parameters:

a. Advance ratio, \( J \).
b. Thrust coefficient, \( K_T \).
c. Torque coefficient, \( K_Q \).
d. Open water efficiency, \( \eta \).

\[
J_D = \frac{(1 - w) V_S}{nD^2} \\
K_T = \frac{T}{\rho n^2 D^4} \\
K_Q = \frac{Q}{\rho N^2 D^5} \\
\eta = \frac{1}{2\pi} \frac{K_T J_S}{K_Q}
\]

From the calculation results at a speed of 28 knots, the effective \( w \) value is 0.052 so that the \( J_{Design} \) value is obtained:

\[
J_D = \frac{(1 - 0.052) \times 14.4044}{10 \times 1.8} \\
J_D = 0.758
\]

Base on table 2 Thrust propeller (\( T_p \)) value required for Full Load load on 2.6m at 28 knot is 372.4 KN, then the appropriate propeller will be selected by getting the required Thrust Coefficient (\( K_{TR} \)) value first.

\[
T_p = K_{TR} \times \rho \times \pi^2 \times D^4
\]

\[
T_p : 372.4 \text{ KN} \\
\rho : 1025 \text{ Kg/m}^3 \\
n : 600 \text{ Rpm} = 10 \text{ Rps} \\
D : 1.8 \text{ m}
\]

The \( K_T \) value is 0.346 at \( J = 0.758 \)
The calculation of propeller performance using the open water test experiment method. The gawn propeller series presented by Gawn consists of a series of 37 (3) three-leaf propellers covering a wide range of pitch ratios from 0.4 to 2.0 and blade area ratios from 0.2 to 1.1. When testing the open water test using a propeller model each has a diameter of 503mm (20in.), so that the resulting scale effect due to the small model can be eliminated.[10]. Each type of propeller has a uniform face section pitch, segmental blade section, a constant blade thickness ratio of 0.060, and a boss diameter of 0.2D. The outline blade is elliptical with an inner and outer knot of 0.1R and a blade tip, respectively. The entire series was tested in towing tank No. 2 in A.E.W. Haslar is in the slip range from zero to 100 percent: to achieve this the propeller rotation speed is in the range of 250 to 500rpm. No destructive cavitation characteristics are given for this series. Fast boats that cannot be filled with the B series are recommended to use the Gawn series because they have a higher P / D value, namely 0.6-2. This research only uses the open water test diagram of the experimental results. In table 2 counter curves on pitch ratio inclusive are by experiment. Other counters are derived in Table 4.

Table 4. Gawn Series by experiment [10].

| BAR | P/D by experiment |
|-----|-------------------|
| 0.2 | 0.4-1.0           |
| 0.35| 0.4-1.2           |
| 0.5 | 0.4-2.0           |
| 0.65| 0.4-2.0           |
| 0.8 | 0.8-1.6           |
| 0.95| 1.0-1.6           |
| 1.1 | 0.8-1.4           |

Based on the KT value of 0.346 at J = 0.758 and by using the open water test diagram [10], several Gawn series blades can be selected in table 5.

Table 5. Available Gawn Series Types.

| BAR | P/D | KT | KQ | EFF % | PD KW | PE KW |
|-----|-----|----|----|-------|-------|-------|
| 0.5 | 1.6 | 0.39| 0.09| 52.3  | 10947 | 11275 |
| 0.5 | 1.8 | 0.469| 0.12| 47.17 | 14596 | 15034 |
| 0.5 | 2   | 0.53| 0.146| 43.82 | 17758 | 18291 |
| 0.65| 1.6 | 0.442| 0.103| 51.87 | 12510 | 12885 |
| 0.65| 1.8 | 0.528| 0.136| 46.96 | 16507 | 17002 |
| 0.65| 2   | 0.589| 0.173| 41.09 | 21042 | 21674 |
| 0.8 | 1.4 | 0.377| 0.08| 56.65 | 9768  | 10061 |
| 0.8 | 1.6 | 0.47| 0.114| 49.85 | 13842 | 14257 |
| 0.95| 1.4 | 0.4 | 0.091| 52.81 | 11121 | 11454 |
| 0.95| 1.6 | 0.521| 0.132| 47.53 | 16092 | 16575 |
| 1.1 | 1.4 | 0.45| 0.106| 51.38 | 12858 | 13243 |

From Table 5, it is found that the thrust that meets there are 12 types, and BAR 0.8 with P / D 1.4 is the most efficient with a propeller efficiency value of 56.65% and PD 9768 KW. Assuming a sea margin of 15%[12] and the Fast Missile Boat uses a heavy improper formatting-duty engine so that it can be loaded with a full load and the efficiency of the gearbox is 0.3 so the PE or engine power needed is 10.061 KW.
5. Conclusion

From tables 4 and 5 it can be concluded that the Gawn series propeller can be used as a 60m fast patrol boat propulsion using BAR 0.8 on PDRA 1.4 with PE or the required engine power is 10,061 KW. From these data, considering that the efficiency is very low, less than 0.6, it is advisable not to use the Gawn series propeller as a 60m fast missile boat propulsion. However, it should be noted that the propeller efficiency is very low <0.6%, so it is necessary to consider the use of other series that are more efficient than the Gawn series.

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