International Journal of Engineering &Technology, 8 (4) (2019) 611-618

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper



Analysis of installation of ducted propeller (kort nozzle) on cargo ship after maintenance

Romie Oktovianus Bura[1]*, I Nengah Putra Apriyanto[1], Arica Dwi Susanto[2]

[1]Indonesia Defense UniversitySentul, Sukahati, Citeureup, Bogor, West Java, Indonesia 16810
[2]Indonesian Naval Technology College, STTAL.Bumimoro-Morokrembangan, Surabaya 60187, Indonesia
**Corresponding author E-mail: romiebura@idu.ac.id*

Abstract

The country of Indonesia is a country of export and import of international trade goods. A cargo ship is a type of ship that carries cargo from one port to another. To meet the needs of international trade must carry out various patterns of ship maintenance by carrying out maintenance. The problem is that conventional propellers are currently installed, at high rotations there can be cavitation of air bubbles around the propeller which decreases propeller efficiency. To improve the conditions above, a Ducted Propeller was installed. From the matching calculations that have been done, the propeller that suits the needs of the ship is a Ka 3.65 type using a ducted propeller. By using a Ka 3.65 type propeller. The power needed is 2239.99 kW the efficiency that can be achieved is 55%, sfoc 214 g / kW, and the speed of the ship will be 16.09 knots at 100% rotation of the propeller, and at 85% the power needed 1375.84 kW, sfoc 214 g / kW, speed reaches 9.88 knots. The difference in speed between conventional blades with type B 4.55 with type Ka 3.65 that uses a cort nozzle is 16.09 knots-13.05 knots = 3.04 knots. Or you can experience a speed increase of (3.04 / 13.05) x100 = 23.29.

Keywords: *Ship Resistance; Power Boats; Propeller; Ship Propulsion; Engine Propeller Matching; Cargo Ship.*

1. Introduction

The country of Indonesia is a country of export and import of international trade goods. A cargo ship is a type of ship that carries cargo from one port to another. Thousands of ships of this type traverse the world's oceans and oceans each year - containing goods of international trade (Susanto.et.al., 2017).

To meet these needs the ship owner or owner must carry out various patterns of ship maintenance, one of which is by carrying out maintenance. In carrying out maintenance, in addition to replacing the appropriate main engine, it must also replace the right propulsion system so that optimal results are obtained according to the cargo ship's mission.

This paper have any literature to support the research about it, for example paper with title An Approximate Method For Calculation of Mean Statistical Value of Ship Service Speed on a Given Shipping Line, Useful in Preliminary Design Stage (Żelazny, 2015). Analysis of The Propulsion System Toward The Speed Reduction of Vessels Type PC-43 (Arica Dwi Susanto A. O., 2017). Experimental Investigation on Stern-Boat Deployment System and Operability For Korean Coast Guard Ship (Chun.et.al., 2013). Performance of VLCC Ship with Podded Propulsion System and Rudder (Amin, 2014). Study of Water Jet Propulsion System Design For Fast Patrol Boat (FPB-60) (U.B.P, 2018). Introduction to Naval Architecture (Tupper E. , 1975). Basic Ship Theory (Tupper K. R., 2001). Practical Ship Design (Watson, 1998). Ship Resistance and Propulsion : Practical Estimation of Ship Propulsive Power (Anthony F. Molland, 2011). Practical Ship Hydrodynamics (Bertram V. , 2000). Type of Ship Trim Analysis on Fuel Consumption with a Certain Load and Draft (I Nengah Putra A. D., 2017). Effect of Fluid Density on Ship Hull Resistance and Powering (Samson, 2015). Ship Design and Contruction(D'arcalengelo, 1969). Resistance Propulsion and Steering of Ship (WPA Van Lamerren, 1984). Predictive Analysis of Bare-Hull Resistance of a 25,000 Dwt Tanker Vessel (Adumene, 2015). Comparative Analysis Result of Towing Tank And Numerical Calculations With Harvald Guldammer Method (I Nengah Putra A. D., 2017). Predicting The Time And Cost of Fireboat Construction Using Earned Value Method (EVM) (I Nengah Putra Apriyanto, 2019). Resistance and Propulsion of Ships (Harvald, 1992). Hydrodynamic of Ship Propellers (Andersen, 1994). Ship Design for Efficiency and Economy (Bertram H. S., 1998). Design of Propulsion Systems for High-Speed Craft (Bartee, 1975).Determination of Critical Pattern of 60 Meter Ship Construction Project Using Precedence Diagram Method (PDM)(Siswo Hadi Sumantri, 2019). A Method of Calculation of Ship Resistance on Calm Water Useful at Preliminary Stages of Ship Design (Zelazny, 2014). Numerical Calculation Analysis of Lift and Bow Thruster Design of Class LCAC Hovercraft (Sutikno Wahyu Hidayat, 2018). Increase of Ship Fuel Consumption Due to the Added Resistance in Waves (Degiuli.et.al., 2017). An Inventigation Into The Resistance Components of Converting a Traditional Monohull Fishing Vessel Into Catamaran Form (Samuel, 2015). Simulation of a Free Surface Flow over a Container Vessel Using CFD (Atreyapurapu.et.al, 2014). Empirical Prediction of Resistance of Fishing Vessels (Kleppesto, 2015). The Optimization of Multipurpose Building Development on Project Scheduling Using Precedence Diagram Method (PDM) (Arica Dwi Susanto, 2018). Designing Constraints in Evaluation of Ship Propulsion Power

Copyright ©RomieOktovianus Bura et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

(Charchalis, 2013). Coefficients of Propeller-hull Interaction in Propulsion System of Inland Waterway Vessels with Stern Tunnels (Tabaczek, 2014). The Selection of Fast Patrol Boat (FPB) Propeller Ship to Optimize Machine Usage of MTU 16V 595 TE 70l Using HarvaldGuldhamer Method and Engine Propeller Matching (EPM) (Arica Dwi Susanto I. N., 2019). Cost optimization of marine fuels consumption as important factor of control ship's sulfur and nitrogen oxides emissions (Kowalski, 2013). Numerical Investigation of the Influence of Water Depth on Ship Resistance (Premchand, 2015). The Wageningen Propeller Series (Kuiper, 1992). Principles of Naval Architecture Second Revision (Lewis, 1988). Marine Propulsion (Sladky, 1976).

The basic function as a cargo ship that requires ships to be able to carry out leaning in shallow water (beaching) is very risky to have a direct impact on the propeller because it is not protected.Based on the initial hypothesis the efficiency of conventional propeller propulsion is relatively low compared to ducted propeller. Conventional propellers are currently installed, at high rotations there can be cavitations of air bubbles around the propeller which decreases propeller efficiency. As an alternative to improve the conditions above, a Ducted Propeller was installed (Gerr, 2001).

This Paper is organized as follows. Section 2 review about the basic ship theory. Section 3 givesresult anddiscussion of research. Finally, in section 4 present conclusion of this paper.

2. Research methodology

2.1. Technical concept

Analysis of the calculation of the propulsion system (engines that have been installed on the ship to find out the power that is continued to calculate the cort nozzle), is carried out on the propulsion system installed on the freighter, the data used in calculations using data from the freighter, does not discuss the problem of the budget required, analysis of strength, structure and materials and their support systems, matching is done using data engine envelope mockups, a technical review of the construction and stability of the ship as a whole is not discussed in detail, the characteristics of the ship are considered not to experience very large changes.

2.2. Propulsion system of the ship

The ship propulsion system, which is the exact matching between prime mover (diesel engine, gas turbine, steam turbine) and propeller from ship (Herdzik, 2013). Matching completion is not only seen from the engine or propeller point of view, but both are an integrated problem. In FIG. 1 there is provided a definition of the variables in terms of power, torque, and velocity.

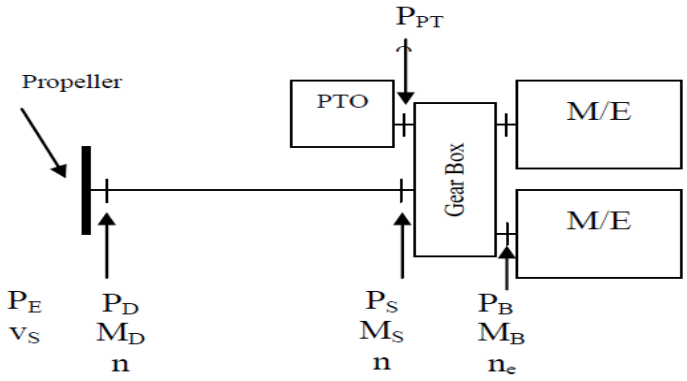


Fig.1: Variable Related with Matching Problems.

2.3. Ship resistance

The ship's resistance (R) at a certain velocity is the fluid force acting opposite the movement of the vessel. The resistance will be the same as the fluid force component working parallel to the axis of the ship's movement.

The required power (effective power) to drive the ship in water or to draw the vessel at speed Vs is:

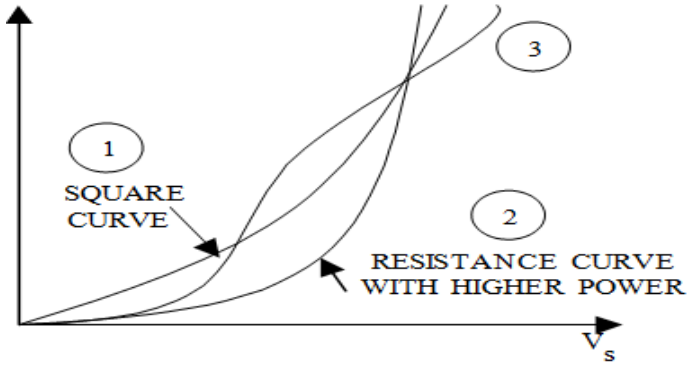


Fig.2: Resistance-Speed Curve.

Notes:

1) Quadratic relationship of Fn = 0,1-0,2
2) High speed ship

3) Type planningcraft, swath ship

This is true only for relatively low velocity ships with froude number of (Fn = 0,1-0,2) and depends on the hull shape(Harrington, 1992). For high speed vessels, ship resistance is no longer a quadratic relationship of speed or with the rank of more than two.

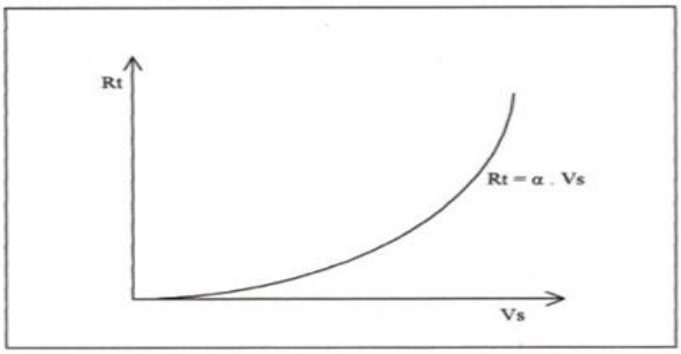


Fig.3: The Relationship between Total Resistance and Speed of the Ship.

2.4. Displacement

Displacement is the weight of liquid displaced by the hull under the water surface. When the vessel floats in the balance state/motionless then the downward pressure equal to the pressure of the liquid to the hull. Thus the overall weight of the vessel and its contents at that time equal to the weight of liquid displaced by the hull immersed in a liquid in which the vessel is located (Anthony F. Molland, 2011).
Displacement : Lwl x B x T x CB x density of sea water (ton)

2.5. Volume displacement

The volume of liquid displaced by the hull under the surfacewater where the ship is located (Anthony F. Molland, 2011).
Volume displacement: LWL x B x T x CB

2.6. Selection of the main engine

In the selection of the main engine, it is necessary to calculate the need of power engine. There are several indicators that need to be sought in order toobtain the desired results, those are effective horse power (EHP), thrust horse power (THP), delivery horse power (DHP), shaft horse power (SHP) dan brake horse power (BHP) (Anthony F. Molland, 2011):

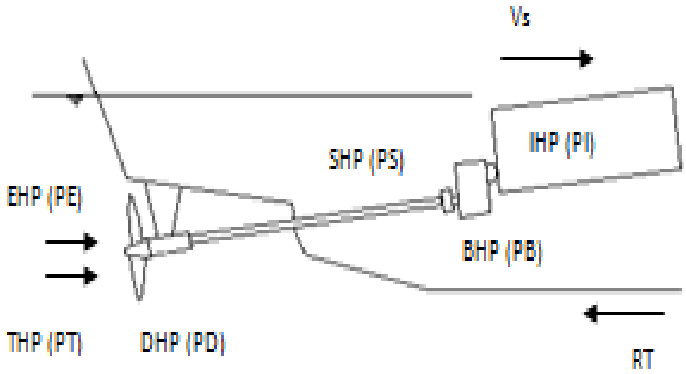


Fig.4: Ship Propulsion System.

2.7. Propeller

In propeller selection, there are some characteristics that must be considered and will be the main consideration, namely: propeller type, propeller diameter, pitch ratio and the number of propeller propeller blade.
The propeller type selection with the most optimal level of efficiency, can be found using the Bp-δ diagram.
The steps in propeller selection is as follows:

a) Bp Calculation

$$Bp = \frac{Np \times \sqrt{P_d}}{Va^{5/2}} \quad (1)$$

Cut off the Bp with optimum line propeller of efficiency.
(P/D)o and δo value interpretation
Do value determination

$$Do = \frac{\delta o \times Va}{Np} \quad (2)$$

Determination of Db value (behind the hull. For ship using Single Screw DB = 0,95 . Do and Double Screw DB=0,97 . Do
δB Calculation

$$\delta_B = \frac{D_B \times Np}{Va} \quad (3)$$

Cut off the initial Bp with δB. This condition was already in behind the hull.
(P/D)B and Efficiency Interpretation

2.8. Engine propeller matching

The matching process between the propulsion engine and the propeller is an essential process for obtaining optimal conversion between fuel and thrust under operating conditions which ensures the working safety of the propulsion and propeller motors. Matching process is not only done from the side of the motor only or from the side of the propeller, but must be handled as a whole. The matching process is basically based on power characteristics vs rpm or torque vs rpm of diesel engines and propellers.

2.9. Method of research

The following is the structure to be designed in this paper:

a) Calculation of Power and Resistance of ships based on Sv. A A. Haavard with the Holtrop method Foran M.V.40 software program (Guldhammer, 1974).
b) Propeller matching engine data on the installed system (conventional propeller)
c) Ducted Propeller Planning based on: Open water test data Ducted Propeller profile with a combination of Ka-series Type propeller published by Wageningen.
d) The resulting performance:

- KT, KQ, J efficiency
- Power vs Rpm
- Main engine operational point (Engine Propeller Matching)

3. Result and discussion

Data: L = 82.50 m, B = 11.11 m, T = 2.64 m, Dprop = 2000 mm, Gear Box Ratio = 4.206: 1, Cb = 0.7642, Max Power = 1195 KW, Ñ = 1849, 179 m, D = 1895.409 tons, Fn = 0.251, Rn = 495.07 x 106, P = 1.025 tons/m ^{3}

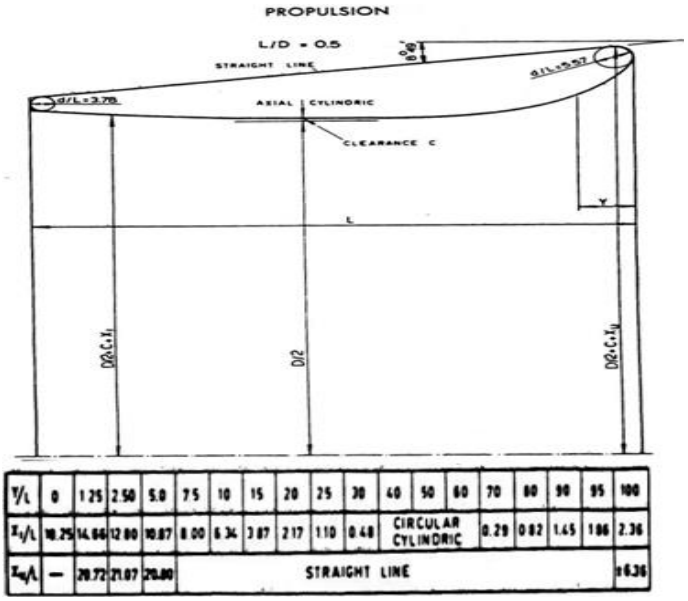


Fig.5: Profile and Geometry of NACA 7415 Propeller Nozzle Type 19a with 2000 MmPropeller Diameter.

Table 1: Circular Cilinder and Straight Line

Y/L	X1/L	XU/L
12.5	103	-
25	147	297
50	120	211
75	101	200
100	80	
150	63.4	
250	30.7	
300	21.7	
400		STRAIGHT LINE
500	CIRCULAR CILINDER	
600		
700	2.9	

800	8.2					
900	14.5					
950	19.6					
1000	23.6			164		

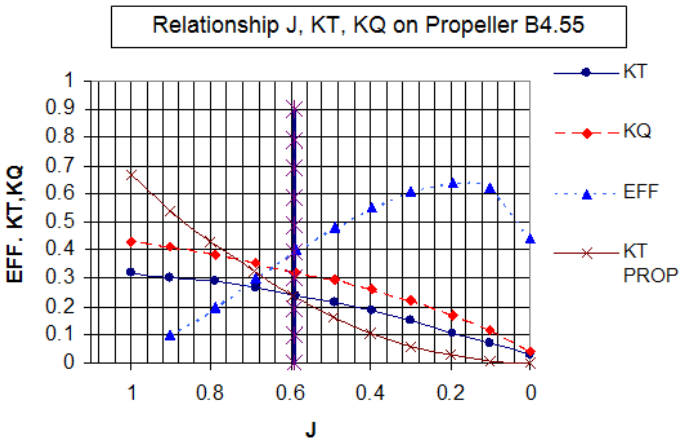


Fig.6: Open Water Test B 4.55.

Table 2: Calculation of Power Needs for Propeller Type B 4.55

%n	n(rpm)	n(rps)	n3	PD	PB MCR	PB(MCR)%
33.43	100	1.667	46.296	71.15	73.34	3.07
36.78	110	1.833	61.620	94.71	111.42	4.66
40.12	120	2.000	80.000	122.96	144.65	6.05
43.46	130	2.167	101.713	156.33	183.91	7.70
46.81	140	2.333	127.037	195.25	229.70	9.61
50.15	150	2.500	156.250	240.15	282.53	11.82
53.49	160	2.667	189.630	291.45	342.88	14.35
56.84	170	2.833	227.454	349.58	411.27	17.21
60.18	180	3.000	270.000	414.97	488.21	20.43
63.52	190	3.167	317.546	488.05	574.18	24.02
66.87	200	3.333	370.370	569.24	669.69	28.02
70.21	210	3.500	428.750	658.96	775.25	32.44
73.55	220	3.667	492.963	757.66	891.36	37.30
76.90	230	3.833	563.287	865.74	1018.52	42.62
80.24	240	4.000	640.000	983.64	1157.23	48.42
83.58	250	4.167	723.380	1111.79	1307.99	54.73
86.93	260	4.333	813.704	1250.62	1471.31	61.56
90.27	270	4.500	911.250	1400.54	1647.69	68.94
93.61	280	4.667	1.016.296	1561.99	1837.63	76.89
96.96	290	4.833	1.129.120	1735.39	2041.64	85.42
100.00	299.10	4.985	1.238.817	1903.99	2239.99	93.72
110.00	329.01	5.484	1.648.866	2534.21	2981.42	124.75

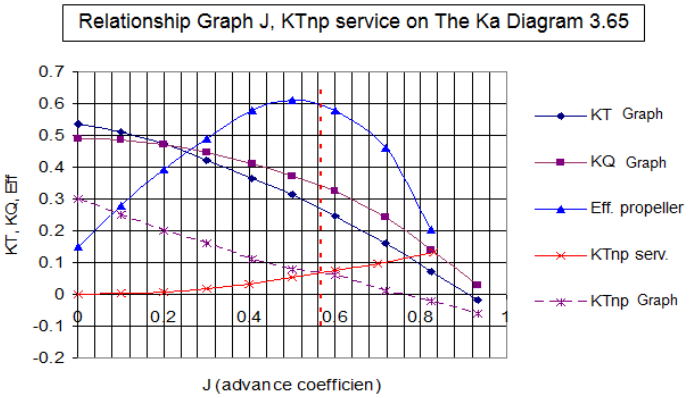


Fig.7: Open Water Test Ka 3.65.

Table 3: Calculation of Power Needs for Ka Type Propeller 3.65

%n	N(rpm)	N(rps)	n3	PD	PBMCR	PB(MCR)%
33.43	100	1.667	46.296	75.60	77.92	3.26
36.78	110	1.833	61.620	100.63	118.38	4.95
40.12	120	2.000	80.000	130.64	153.69	6.43
43.46	130	2.167	10.171	166.10	195.41	8.18
46.81	140	2.333	127.037	207.45	244.06	10.21
50.15	150	2.500	156.250	255.16	300.18	12.56
53.49	160	2.667	189.630	309.67	364.31	15.24
56.84	170	2.833	227.454	371.43	436.98	18.28
60.18	180	3.000	270.000	440.91	518.72	21.70

63.52	190	3.167	317.546	518.55	610.06	25.53
66.87	200	3.333	370.370	604.82	711.55	29.77
70.21	210	3.500	428.750	700.15	823.70	34.46
73.55	220	3.667	492.963	805.01	947.07	39.63
76.90	230	3.833	563.287	919.85	1082.17	45.28
80.24	240	4.000	640.000	1045.12	1229.55	51.45
83.58	250	4.167	723.380	1181.28	1389.74	58.15
86.93	260	4.333	813.704	1328.78	1563.27	65.41
90.27	270	4.500	911.250	1488.07	1750.67	73.25
93.61	280	4.667	1.016.296	1659.61	1952.49	81.69
96.96	290	4.833	1.129.120	1843.85	2169.24	90.76
100.00	299.10	4.985	1.238.817	2022.99	2379.99	99.58
110.00	329.01	5.484	1.648.866	2692.60	3167.76	132.54

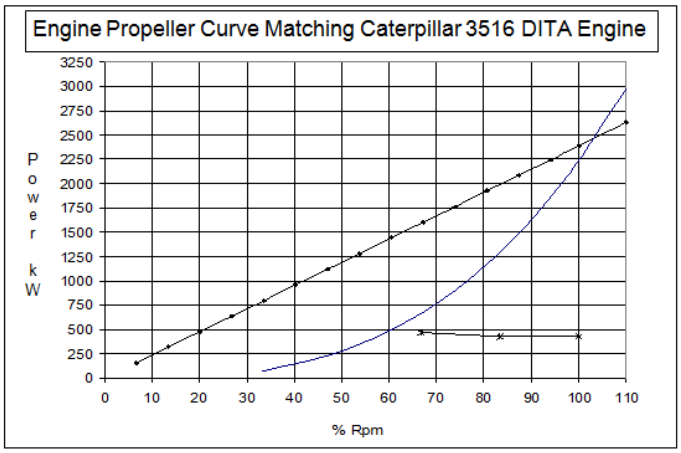


Fig.8: Engine Propeller for Type Propeller B 4.55.

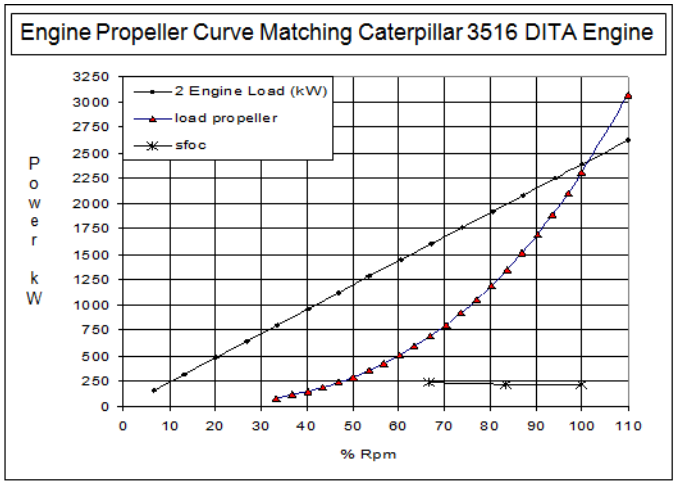


Fig.9: Engine Propeller for Propeller Type Ka 3.65.

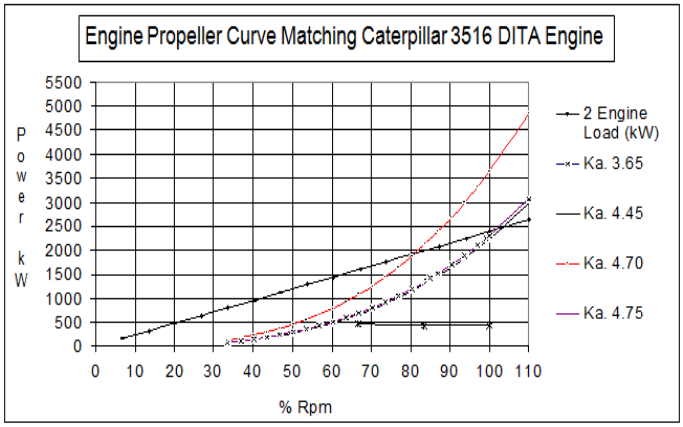


Fig.10: Comparative Graph of Matching Propeller Type Ka 3.65, Ka 4.45, Ka 4.70, Ka 4.75.

Ka 4.70 was not selected because its characteristics were above the engine characteristics, Ka 4.45 & Ka 5.75 curves were not chosen because there was still too much power wasted at the 100% rpm point, Ka 3.65 curve was chosen because the operational point was closest to optimal when plotted on the Caterpilar 3516 DITA engine load curve.

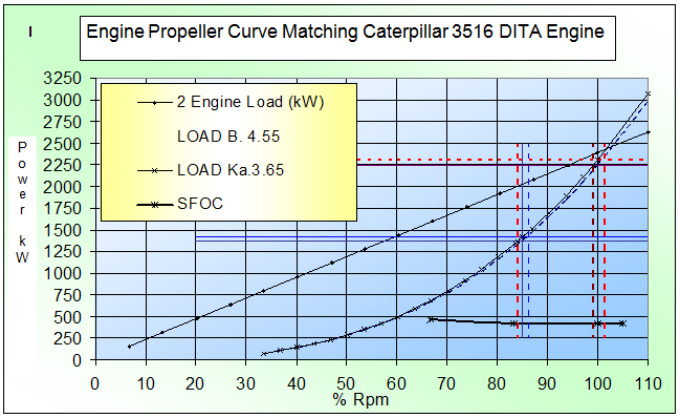


Fig.11: Comparative Graph of The Need For Conventional Propeller Power (B 4.55) With Ducted Propeller (Ka 3.65).

The load curve B 4.55 is below the load curve of Ka 3.65, at 100% rpm and 85% rpm we can compare the power usage, efficiency and speed obtained by each propeller.

Table 4: Operational Point Propeller Type B 4.55 And Type Ka 3.65

Item	Propeller type Ka 3.65		Propeller type B 4.55	
	Rpm 100%	Rpm 85%	Rpm 100%	Rpm 85%
Power (kW)	2239.99	1375.84	2239.99	1418.83
Efficiency	59	-	57	-
Sfoc g/kWh	214	214	214	214
Vs (knots)	16.09	9.88	13.05	8.017
Rpm	299.103	254.25	299.103	254.25

Table 5: Propeller Ka 3.65 Diameter 2000 mm Geometry Kort

Item	Propeller type B 4.55 is operated at Ka 3.65 propeller operating point		Propeller type Ka 3.65 is operated at B 4.55 propeller operating point	
	Rpm 100%	Rpm 85%	Rpm 100%	Rpm 85%
Power (kW)	2239.99	1375.84	2309.99	1418.83
Efficiency	-	-	-	-
Sfoc g/kWh	214	214	214	214
Vs (knots)	12.65	7.77	16.59	9.11
Rpm	302.84	257.22	296.111	251.24

4. Conclusion

Naca 7415 type 19a nozzle for cargo ship: Nozzle length: L = 1000 mm, Nozle thickness S = 150 mm, Nozle diameter: DNOZ = 2070 mm, D1 = 37.8 mm, D2 = 55.7 mm, Clearance: α = 8 ° 49 ’

Table 6: Circular Cilinder and Straight Line

f = 35 Y/L	X1/L	XU/L
12.5	103	-
25	147	297
50	120	211
75	101	200
100	80	
150	63.4	
250	30.7	
300	21.7	
400		
500	CIRCULAR CILINDER	STRAIGHT LINE
600		
700	2.9	
800	8.2	
900	14.5	
950	19.6	
1000	23.6	164

From the matching calculations that have been done, the propeller that suits the needs of the ship is a Ka 3.65 type using a ducted propeller. By using a Ka-type propeller 3.65 The power needed is 2239.99 kW the efficiency that can be achieved is 55%, sfoc 214 g / kW, and the speed of the ship will be 16.09 knots at 100% rotation of the propeller, and at 85% the power needed 1375.84 kW, sfoc 214 g / kW, the speed reaches 9.88 knots.The difference in speed between a conventional blade with a type B 4.55 with a Ka type of 3.65 that uses a cort nozzle is 16.09 knots - 13.05 knots = 3.04 knots. Or you can experience an increase in speed of (3.04 / 13.05) x100 = 23.29%.

Acknowledgements

This research had been Supported by Indonesia Defense University and Indonesia Naval Technology College (STTAL).

References

[1] Adumene, N. S. (2015). Predictive Analysis of Bare-Hull Resistance of a 25,000 Dwt Tanker Vessel. *International Journal of Engineering and Technology* , 194-198.
[2] Amin, J. K. (2014). Performance of VLCC Ship with Podded Propulsion System and Rudder. *International Society of Ocean, Mechanical and Aerospace Scientists and Engineers* , 1-7.
[3] Andersen, J. P. (1994). *Hydrodynamic of Ship Propeller.* Cambridge: Elsevier.
[4] Anthony F. Molland, S. R. (2011). *Ship Resistance and Propulsion.* United Stated of America: Practical Estimation of Ship Propulsive Power.https://doi.org/10.1017/CBO9780511974113.
[5] Arica Dwi Susanto, A. A. (2018). The Optimization of Multipurpose Building Development on Project Scheduling Using Precedence Diagram Method (PDM). *Asro Journal-STTAL, 9* (1), 1-7.
[6] Arica Dwi Susanto, A. O. (2017). Analysis of The Propulsion System Toward The Speed Reduction of Vessels Type PC-43. *International Journal of Engineering Research and Applications (IJERA), 7* (4), 08-15.https://doi.org/10.9790/9622-0704060815.
[7] Arica Dwi Susanto, I. N. (2019). The Selection of Fast Patrol Boat (FPB) Propeller Ship to Optimize Machine Usage of MTU 16V 595 TE 70l Using Harvald Guldhamer Method and Engine Propeller Matching (EPM). *Journal of Engineering Science & Technology Review, 12* (4), 202-208.https://doi.org/10.25103/jestr.124.25.
[8] Atreyapurapu.et.al, K. (2014). Simulation of a Free Surface Flow over a Container Vessel Using CFD. *International Journal of Engineering Trends and Technology* , 334-339.https://doi.org/10.14445/22315381/IJETT-V18P269.
[9] Bartee, D. L. (1975). Design of Propulsion Systems for Hidh-Speed Craft. *The Society of Naval Architects and Marine Engineers* , 1-17.
[10] Bertram, H. S. (1998). *Ship Design for Efficiency and Economy.* Great Britain: Butterworth-Heinemann.
[11] Bertram, V. (2000). *Practical Ship Hydrodynamic.* Inggris: Great Britain.
[12] Charchalis, A. (2013). Designing Constraints in Evaluation of Ship Propulsion Power. *Journal of KONES Powertrain and transport* , 1-6.https://doi.org/10.5604/12314005.1135307.
[13] Chun.et.al., H. H. (2013). Experimental investigation on stern-boat deployment system and operability for Korean coast guard ship. *International Journal Naval Architecture Ocean Engineering* , 488-503.https://doi.org/10.2478/IJNAOE-2013-0113.
[14] D'arcalengelo, A. M. (1969). *Ship Design and Contruction.* Michigan: Professor of Naval Architecture and Marine Engineering University of Machigan.
[15] Degiuli.et.al., N. (2017). Increase of Ship Fuel Consumption Due to the Added Resistance in Waves. *Journal of Sustainable Development of Energy, Water and Environment Systems* , 1-14.https://doi.org/10.13044/j.sdewes.d5.0129.
[16] Gerr, D. (2001). *Propeller Handbook.* (J. E. Oppenheim, Penyunt.) United Stated: International Marine.
[17] Guldhammer, H. E. (1974). *Ship Resistance.* Copenhagen: Akademisk Forlag.
[18] Harrington, R. L. (1992). *Marine Engineering* (Revised, Subsequent ed.). (Revised, Penyunt.) Jersey City, United States: The Society of Naval Architects and Marine Engineers .
[19] Harvald, S. A. (1992). *Resistance and Propulsion of Ships.* New York: John Wiley and Sons.
[20] Herdzik, J. (2013). Problems of propulsion systems and main engines choice for offshore support vessels. *Scientific Journals Zeszyty Naukowe, 2* (1733-8670), 45-50.
[21] I Nengah Putra Apriyanto, R. O. (2019). Predicting The Time And Cost of Fireboat Construction Using Earned Value Method (EVM). *Engineering and Technology Quarterly Reviews, 2* (2), 114-125.
[22] I Nengah Putra, A. D. (2017). Comparative Analysis Result of Towing Tank And Numerical Calculations With Harvald Guldammer Method. *International Journal of Applied Engineering Research, 12* (21), 637-645.
[23] I Nengah Putra, A. D. (2017). Type of Ship Trim Analysis on Fuel Consumption with a Certain Load and Draft. *International Journal of Applied Engineering Research, 12* (21), 10756-10780.
[24] Kleppesto, K. (2015). Empirical Prediction of Resistance of Fishing Vessels. *NTNU Trondheim Norwegion University of Science And Technology* , 1-87.
[25] Kowalski, A. (2013). Cost optimization of marine fuels consumption as important factor of control ship's sulfur and nitrogen oxides emissions. *Scientific Journals* , 94-99.
[26] Kuiper, G. (1992). *The Wageningen Propeller Series.* Netherland: MARIN.
[27] Lewis, E. V. (1988). *Principles of Naval Architecture Second Revision.* New Jersey: The Society of Naval Architecs and Marine Engineers.
[28] Premchand, P. K. (2015). Numerical Investigation of the Influence of Water Depth on Ship Resistance . *International Journal of Computer Applications* , 1-8.
[29] Samson, D. I. (2015). Effect of Fluid Density On Ship Hull Resistance and Powering. *International Journal of Engineering Research and General Science* , 615-630.
[30] Samuel, M. I. (2015). An Inventigation Into The Resistance Components of Converting a Traditional Monohull Fishing Vessel Into Catamaran Form. *International Journal of Technology* , 1-10.https://doi.org/10.14716/ijtech.v6i3.940.
[31] Siswo Hadi Sumantri, S. T. (2019). Determination of Critical Pattern of 60 Meter Ship Construction Project Using Precedence Diagram Method (PDM). *International Journal of Civil Engineering and Technology (IJCIET), 10* (10), 124-140.
[32] Sladky, J. (1976). *Marine Propulsion.* New York: The Winter Annual Meeting of The American Society of Marine Engineers.
[33] Sutikno Wahyu Hidayat, A. O. (2018). Numerical Calculation Analysis of Lift and Bow Thruster Design of Class LCAC Hovercraft. *International Journal of Recent Engineering Science (IJRES), 5* (5), 1-8.
[34] Tabaczek, J. K. (2014). Coefficients of Propeller-hull Interaction in Propulsion System of Inland Waterway Vessels with Stern Tunnels. *International Journal on Marine Navigation and Safety of Sea Transportation* , 1-8.https://doi.org/10.12716/1001.08.03.08.
[35] Tupper, E. (1975). *Introduction to Naval Architecture.* Inggris: Great Britain.
[36] Tupper, K. R. (2001). *Basic Ship Theory.* Inggris: Great Britain.
[37] U.B.P, A. D. (2018). Study of Water Jet Propulsion System Design For Fast Patrol Boat (FPB-60). *International Journal of Academic and Applied Research (IJAAR), 2* (7), 1-7.
[38] Watson, D. G. (1998). *Practical Ship Design.* Netherlands: Elsevier Science Ltd.
[39] WPA Van Lamerren, T. L. (1984). *Resistance Propulsion and Steering of Ship.* Holland: Harleem Holland.
[40] Zelazny, K. (2014). A Method of Calculation of Ship Resistance on Calm Water Useful at Preliminary Stages of Ship Design. *Scientific Journal Maritime University of Szuczecin* , 125-130.
[41] Żelazny, K. (2015). An Approximate Method For Calculation of Mean Statistical Value of Ship Service Speed On a Given Shipping Line , Useful In Preliminary Design Stage. *Polish Maritime Research* , 28-35.https://doi.org/10.1515/pomr-2015-0005.