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Repowering On KMP Trimas Ellisa To Obtain The Optimal Propulsion System

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Abstract – The working optimization of this ship is also closely related to the driving factor of the working ships, commonly referred to in the shipping world as a ship propulsion system. The propulsion system explains how the depat ships move well under existing shipping conditions in order to meet existing needs. KMP. TRIMAS ELLISA is one of the passenger ships that serve inter-island passenger transportation. Based on Ministry of Transportation Regulation 104 year 2017 states that Ferry Transportation Ship is a Crossing Motor Vessel (KMP) which is a mechanically powered water vehicle, serves as a moving bridge to transport passengers and vehicles along with their cargo that goes in and out through different ramps, has double bottom construction and has at least 2 (two) main engines. Based on its regulation, KMP. TRIMAS ELLISA must be repowered by replacing it with a double machine. Changes in the propulsion system using twin screw resulted in a change in propulsion size dimension to 2.68 m. This change to support main engine that is already available. The larger the diameter of the propeller the greater the efficiency, so also if the greater the ratio of the discus (blade area ratio) propeller efficiency will increase as well.

Keywords – repowering, ship, regulation, twin screw, optimization, propulsion

I. Introduction

he vessel is a vehicle carrying passengers and goods on the river and sea. Centuries of ships are used by humans to wade through rivers or oceans. The materials used for the manufacture of ships in the past using wood, bamboo then used the metal materials such as iron / steel because of the human need for a strong ship. The greater the need for power, the ship is made in large sizes

Initially, the ship used the paddle as its propulsion, then the wind with the sail, until sometime the Industrial revolution came a new way of driving with steam engines and diesel and nuclear engines.

All types of vessels are currently experiencing continuous development to meet the needs, including the needs in the distribution of goods and mass transportation. Mass sea transport called cruise ship used to navigate between the oceans. the ship is experiencing a significant development, from the form that can load passengers in large numbers, complete facilities, to the ship's machinery system. This is to optimize ship work. The working optimization of this ship is also closely related to the driving factor of the working ships, commonly referred to in the shipping world as a ship propulsion system. The propulsion system explains how the depat ships move well under existing shipping conditions in order to meet existing needs.

The capability of such a large capacity side, allowing customers to use sea transport services to reach places in coastal areas that are difficult to reach by land and air vehicles. In addition, Passengers with private vehicles and congenital lots will prefer sea transport, because it has a large capacity.

KMP. TRIMAS ELLISA is one of the passenger ships that serve inter-island passenger transportation. Based on Ministry of Transportation Regulation 104 year 2017 states that Ferry Transportation Ship is a Crossing Motor Vessel (KMP) which is a mechanically powered water vehicle, serves as a moving bridge to transport passengers and vehicles along with their cargo that goes in and out through different ramps, has double bottom construction and has at least 2 (two) main engines. Based on Permen Kemenhub 104 Tahun 2017, KMP KMP. TRIMAS ELLISA must be repowered by replacing it with a double machine.

Passenger ships are boats used for passenger transport. To improve the efficiency or serve the needs of a wider passenger ship can be a Ro-Ro boat, or for scheduled short rides in the form of ferry boats.

In Indonesia, the company that operates passenger ship is PT. Indonesian National Shipping, known as PELNI, while Ro-Ro passenger and vehicles are operated by PT ASDP, PT Dharma Lautan Utama, PT Jembatan Madura, PT. Prima Eksekutif and various other shipping companies. The type of vessel that will be used as the study of ship propulsion system design at this time is KMP. TRIMAS ELLISA is one type of passenger ship that serves the transportation services between the islands.

On a global scale, the passanger ship has been built and operational. One example is KMP. TRIMAS ELLISA which will be used as study material of designing main engine repowering and ship propulsion system. This ship has been registered in BKI Class. KMP. TRIMAS ELLISA is showing in Figure 1 has the following ship dimensions:

Lenght Overall	: 61.50 meter
Length	: 57.06 meter
Breth	: 12.70 meter
Heigh	: 4.40 meter
Draf	: 3.50 meter

Figure 1 Existing condition KMP. TRIMAS ELLISA

II. METHODS

A. *Ship Resistance*

When an object moves on the free surface area of a fluid, the variations in the pressure around the body will produce waves on the surface of the fluid. The force required to sustain the occurrence of such waves, called resistance. Ship resistance is a very complex function depending on the variable form of the hull, displacement and speed. Some of the main components of ship resistance are:

- Friction Resistance
- Pressure Resistance
- Wave Resistance
- Residual Resistance
- Air Resistance

The ship's resistance is a fluid force working on the ship's body in such a way that it works against the movement of the ship. Ship resistance is defined as:

$$R = ½.C.\rho.\ V^2.S \tag{1}$$

Where,

C = coefficient of resistance,

V = speed of ship,

ρ = density of sea water, and

S = wetted surface area of ship.

Total resistance can be decomposed into a number of components of the resistance caused by various causes and interact with each other on the ship.

For official shipping conditions there should be additional allowances depending on the sea margin. The price of the allowance factor can be given in the percentage of total prisoners from the trial shipping conditions. For the main line, the percentage of additional leeway (p) for service delivery conditions may be provided as follows:

- The North Atlantic cruise to the east, for summer 15% and winter 20%
- North Atlantic shipping lines, for summer 20% and winter 30%
- Pacific cruise shuttles, 15-30%
- South Atlantic and Australian shipping lines, 12-18%
- East Asia shipping line, 10-20%

When a vessel makes an official voyage, the total resistance of the formula becomes

$$R = ½.C.\rho.\ V^2.S\ .\ (1+P) \tag{2}$$

Where;

C = coefficient of resistance,

V = speed of ship,

ρ = density of sea water, and

S = wetted surface area of ship.

P = additional leisure conditions

In this case, KMP. TRIMAS ELLISA which is the subject of propulsion system designer at this time has Semarang-Batulicin line. the total resistance calculation can be assumed to have an additional concession of 15%.

B. Propulsion System of Ship

A ship built of course to be able to operate at sea. In its operations at sea the vessel has a service speed (Vs), and the ship must have the ability to maintain the speed of service according to its planning. This requires that a ship has a propulsion system to address the overall resistance (total resistance) that occurs in order to meet the standard speed of service.

In the ship propulsion system generally has three main components, as shows figure 2 :

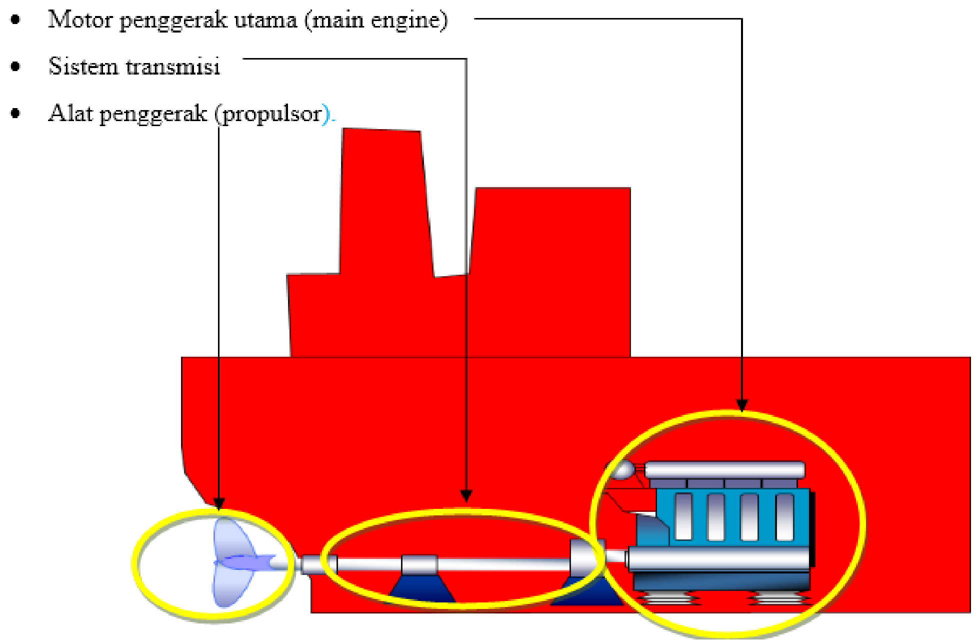

Figure 2 Propulsion System of Ship

The three components of the ship's propulsion system can not be reviewed separately, and all three are interconnected with each other. If in this ship propulsion system there is one component that is not successfully operate or there is a mistake in operation, there will be several possibilities:

1. Not achieving the planned speed of service,

2. Fuel oil consumption is not efficient,

3. The economic decline of the vessel,

4. Effect of vibration level that occurs on the body of the ship

C. Determination of Main Engine Ship

Analyze the power used is the variable speed of the ship. So that obtained some power needed to fit with that required. Then do the selection of power engine in accordance with the expected.

The steps - steps determine the main engine power is as follows:

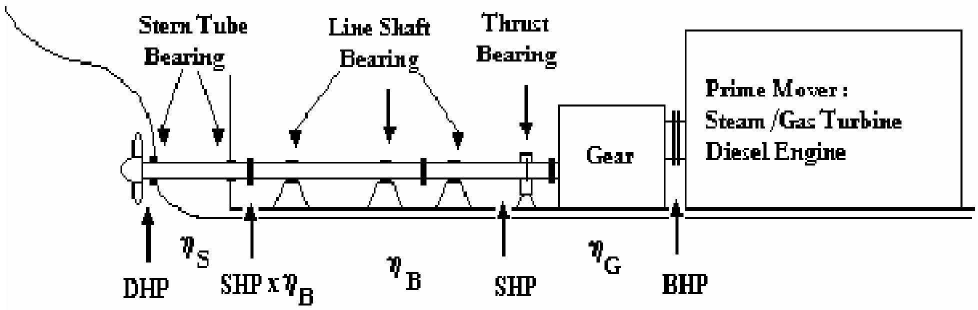

Figure 3 Axis System

1. Calculation of Effective Horse Power (EHP)

Effective Power or EHP is the power required to drive a ship in water or to attract a vessel with velocity. Calculation of ship effective power (EHP) according to Harvard book, Resistance & Propulsion of Ship, 6.2.1 p. 135 as follows:

EHP = RTservice x Vservice (3)

2. Calculation of Delivery Horse Power (DHP)

DHP Is the power absorbed by the propeller of the system of power or power delivered by the shaft system to propeller to be converted into thrust

DHP = EHP/Pc (4)

Where;

Pc = ηH x ηrr x ηo (5)

a. Efficiency of Hull

(ηH) ηH =(1 - t)/ (1 - w) (6)

Where ;w is wake friction, wake friction is the comparison between the speed of the ship and the speed of water leading to the propeller. Using the formula given by Taylor (Resistance, Propulsion and Steering of Ships, Van Lammeren, p. 178).

The equation looking for the value of w is as follows:

w = (0.5 x Cbwl) - 0.05 (7)

t = Thrust Deduction Factor, t value can be sought from the value of w which is known that t = k.w, where k value between 0.7-0.9 and taken value k = 0.8 according to the book Harvald.

b. Efficiency of Relative Rotation (ηrr)

The value of ηrr for ships with single screw type propeller ranges from 1.02 ~ 1.05 (Principal of Naval Architecture p. 152) on propeller plan and propeller shaft tunnel is taken value: 1.02 ~ 1.05

c. Efficiency of Propulsion (ηo)

Open water efficiency is efficiency of the propeller at the time of open water test, the value between 40-70%.

3. Calculation of Thrust Power Propeller (THP)

THP Is the amount of power generated by the work of the propeller to push the ship's body.

THP = EHP / ηH (8)

4. Calculation of Shaft Horse Power (SHP)

For Ship that have engine rooms located at the rear will experience losses of 2%, whereas on ship which engine rooms are in the midship area the vessels experience losses of 3%. (Principal of Naval Architecture p. 131). In this planning, the engine room is located at the back, so the losses that occur only 2%

$$SHP = DHP/\eta s\eta b \quad (9)$$

Where :

ηsηb = shaft transmission efficiency. reduce 2% ~ 3% for engine room is located at back

5. Calculation Power Main Engine

a. BHPscr

The power of the ship's engine during service continuous rating conditions. Since the rotation obtained from the engine is 500 rpm, it needs a gearbox / reduction gear, so ηG = 0.98

$$BHPscr = SHP/\eta G \quad (10)$$

b. BHPmcr

The power of the ship's engine when the condition is maximum continuous rating (factory output power). Its value ranges from 80 ~ 85% of HP_{SCR}

$$BHPmcr = HPscr/ 0.85 \quad (11)$$

D. Propulsion System Planning

The ship propulsion system consists of axle system and propeller. Planning the propulsion system is planned according to the new power engine using the general calculation. After planned how many dimensions and specifications of the propulsion system, new construction planning is done in accordance with the propulsion system and the new main engine

III. Result and Discussion

A. Calculation of Ship Resistance

In the calculation to find the ship resistance used some of the main dimension of the ship, calcution formula, tables and diagrams.

a. Calculation of Volume Displacement

$$\blacktriangledown = Lwl \times B \times T \times Cb$$
$$= 58.40 \times 11.20 \times 3.50 \times 0.651$$
$$= 1408.14\ m^3$$

b. Calculation of Froude Number

$$Fn = v / (g \times Lwl)^{0,5}$$
$$= 7{,}46 / (9.8 \times 58.40)^{0,5}$$
$$= 0.31$$

c. Calculation of Reynold Number

$$Rn = (v \times Lwl) / Vk,$$

where; Vk is viscoucity kinematic coefficient

$$= 1.188 \times 10^{-6}$$

$Rn = (7.46 \times 58.40) / 1.18 \times 10^{-6}$

$= 3.67 \times 10^{8}$

d. Calculation of Wetted Surface Area is used formula as follows ;

S = 1.025 x Lpp x (Cb x B + 1,7T)

= 1.025 x 58.40 x (0.561x11.20+1.7x3.5)

$= 737.81\ m^{2}$

e. Calculation of Friction Resistance according to ITTC -78 :

$CF = 0.075 / (\text{Log } Rn - 2)^{2}$

$= 0.075 / (\text{Log } 3{,}67 \times 10^{8} - 2)^{2}$

$= 1.618.10^{-3}$

In this case there is no additional correction of the ship hull which includes blade of steering, keel bilga, propeller boss, and propeller shaft, because the additional wet surface of the vessel hull is relatively small, thus it can be ignored.

f. The calculation of C_R or the remaining vessel resistance can be determined through the Guldhammer - Harvald diagram with the result being as follows:

$C_R = L / (\blacktriangledown^{1/3}) = 58{,}40\ (1408.14)^{1/3}$

$= 5.21$

From these results we interpolate the Guldhammer diagram and Harvald obtained:

$L/V^{1/3} = 5$ $CR = 1.15 \times 10^{-3}$

$L/V^{1/3} = 5.5$ $CR = 0.94 \times 10^{-3}$

With the interpolation formula obtained:

$Y - Y_1\ (X_2 - X_1) = X - X_1\ (Y_2 - Y_1)$

$5.24 - 5[(0.94 - 1.15) \times 10^{-3}] = X - 1{,}15 \times 10^{-3}[(0.94 - 1.15) \times 10^{-3}]\ 10^{3}$ $X = 1.049$

$CR = 1.049 \times 10^{-3}$

From diagram interpolation obtained:

	a	b
	Lwl / ▼ $^{1/3}$	C_R
1	4,5	0,0016
2	5,21	0,001315871
3	5	0,0014

Correction coefficient of Ship Residual resistance

Correction CR to B/T

B/T = 11.20/ 3.50

= 3.20

With the following correction formula :

$10^3 C_R = 10^3\ C_R$ (B/T-2,5) + [0,16 (B/T - 2,5)]

= 1,045 + [0,16 x (3,20 - 2,5)]

= 1,43

Correction of CR to LCB

LCB = e% x L

= 0,9% x 58,40

= 0,53%

Standard LCB determination in% with standard LCB chart reference, Prisoner and Propulsion book p. 130 at Figure 5.5.15

LCB Standart = 0,65%

Since LCB is located in front of LCB Standart, the coefficient is:

103 CR = 103 CR + δ103CR / δLCB

Where , δLCB = LCB - $LCB_{Standart}$

= 0,79%-0,65%

= 12%

$\delta 10^3 C_R/\delta LCB$ = 0,15

Then the correction is

$10^3 C_R$ = 1,41

C_R = 0,00141

3. C_R correction due to ship limb, in this case that need to be corrected is:

-Boss propeller

For full CR vessels increased by 3-5%, then taken:

C_R = (1 + 15%) x C_R

= 1.47

-Brackets and propeller shafts

For CR slim vessels increased by 5-8%, then taken:

CR = (1 + 15%) x CR

= 1.38x10-3

g. Coefficient of Additional Resistance

The coefficient of adding resistance for model-ship correlation is generally of Ca = 0.0004. However experience shows that such a method is not always true, it is proposed a correction for the influence of roughness and influence as follows for the experimental shipping conditions of the initial calculation obtained ship displacement ie 1443.34 tonnes Displacement on the book Resistance And Propulsion of Ship p. 132 are:

	Displ (a)	Ca (b)
1	1000	0,0006
2	1443,34	0,000590148
3	10000	0,0004

Interpolasi

= (1b + (2a-1a)x(3b-1b))/(3a-1a)

= 0,00059

Based on the above interpolation results then obtained value:

Ca = 0,00059

h. Koefisien Tahanan Udara

Besarnya koefisien tahanan udara menurut (Harvald. 5.5.26 hal 132) adalah sebagai berikut :

$10^3 C_{AA} = 0{,}07$

$CAA = 0{,}07.10^{-3}$

i. Air Resistance Coefficient

The air resistance coefficient according to (Harvald 5.5.27 p. 132) is as follows :

$10^3\ C_{AS} = 0{,}04$, thes $C_{AS} = 0,\ 4.10^{-4}$

j. Coefficient of Ship Total Resistance

The coefficient of total vessel or C_T resistance can be determined by summing up all existing ship resistance coefficients:

CT = CR + CF + CA + CAA + CAS

$= (1.0411 + 1.618 + 0.2 + 0.07 + 0.04) \times 10^{-3}$

$= 3.85.\ 10^{-3}$

k. Total Resistance of Ship

$R_T = C_T \times 1/2 \times \rho \times v^2 \times S$

$= 3.85.\ 10^{-3} \times 1/2 \times 1025 \times (7.46)^2 \times 3013.91$

= 80989.1 N

= 80.99 kN, The total Resistance of this ship is still the price on the seatrial.

l. Service Ship Voyage

The planning voyage it was determined that the voyage route of the ship was Semarang-Batu Licin. Then the condition of shipping service area characteristics of this ship is taken additional price for East Asia shipping line that is equal to 15-20%. In this plan, an additional price of 15% is taken.

Thus,

$R_{T(service)} = R_T + 15\%\ R_T$

$= 80989.1 + (15\% \times 80989.1)$

= 93137.5 N

= 93.137 kN

m. Calculation of Effective Horse Power (EHP)

$EHP = (R_{T(service)} / 1000) \times v_s$

= (93137.5 / 1000) x 7.46

= 694.69 KW

= 931.22 HP

B. Calculation of Ship Propulsion Power Characteristics

In calculating the interaction between hull or ship body with propeller is used to determine the thrust or thrust force required by a ship based on the characteristics of the propellers mounted on the stern of the ship.

In this calculation the ship is determined to work with twin screw propellers (2 propulsions)

a. Calculation of Wake Fraction (w)

By using the formula given by Taylor,

Where Cb = 0.7209, then :

w = 0.283 + {[(0.314 – 0.283)/(0.75 – 0.7)]x(0.7209 – 0.7)}

= 0.285

Cb	ω
0,70	0,283
0,703	0,285
0,75	0,314

b. Calculation of speed of advance (va)

Va = (1 - w) Vs

= (1 – 0.2956) x 7.46

= 6.427 m/s

= 12.49 knot

c. Calculation of Thrust Deduction Factor (t)

t = k x w

= 0.7 x 0.285

= 0.097

d. Calculation of Thurst (T)

T = R_T/ (1-t)

= 80.989/(1-0.097)

= 103.120968 KN

e. Calculation of Power of Thrust (P_T)

Based on speed of advance

PT = T x Va

= 80.989 x 12.49

= 662.78 Kw

= 888.45 HP

f. Calculation of Quasy Propulsive Coefficient (QP_C)

Quasy Propulsive Coefficient is the coefficient obtained from:

$QP_C = \eta_{rr} \times \eta_H \times \eta_P$

Where :

η_{rr} = 1 – 1,1 taken 1,05 (PNA pg. 152)

= 1,05

η_H = (1-t)/(1-w)

= 1,05

η_P = 0,5 – 0,6 taken 0,55

= 0.55

Thus,

QP_C = 1.05 x 1.05 x 0.55

= 0.61

C. Calculation of Mechanical Power Characteristics of Propulsion System and Main Engine

a. Calculation of Delivery Horse Power (DHP)

DHP = EHP/QPc

= 1538.43 HP

b. Calculation of Shaft Horse Power (SHP)

ηSηB : losses of the rear of the ship

ηSηB = 0,98

SHP ` = DHP/ ηSηB

= 1569,83 HP

c. Calculation of Brake Horse Power (BHP_{SCR})

η_G : transmission gear efficiency

η_G = 0,98

$BHP_{SCR} = SHP/ \eta_G$

= 1601,87 HP

The above conditions are the output power at normal shipping time (SCR), while at the Maximum Continous Rating (MCR) ie

d. $BHP_{MCR} = BHP_{SCR}/0,85$

= 1885 HP

= 1405,87 kW

Based on the output power (BHP_{MCR}) the calculation some engine specifications are as follows

e. Selection of Main Engine and Gear Box :

1. Merk : Yanmar x 2

   Type : Z280ET2 (4 Stroke)

   Power Max : 1170 HP x2

   RPM : 560 RPM

2. Merk : Chongqing GWC3941

   Ratio : 1 : 3,063

f. D_B (Diameter of Blade)

DB = 0,96 x Do (ft) -> for single screw

DB = 0,98 x Do (ft) -> for twin screw

Main engine data is used to recalculate DHP

BHP_{MCR} = 873 kW

BHP_{SCR} = P_{BMCR} x 0,85

= 741,897 kW

SHP = $P_{BSCR} \times \eta_G$

= 727,059 kW

= 974,61 HP

DHP based of Engine

DHP = 712,52 kW

= 955, 12 HP

g. Determining Power Coeffien (BP)

Engine Blde Rotation (N) of 900 RPM then passes the gear box with a ratio of 5.95 to Np = 182.82 RPM

where, Va = 12,49 Knot

= 6,43 m/s

then,

DHP = 955,12 HP

D = 0,6T ~ 0,7T

= 2,1 < D < 2,45 m

= 6,89 < D <8,04 ft

$$B_{P1} = \frac{Np \times \sqrt{DHP}}{V_A^{2,5}}$$

$$= 10,2$$

D. Selection of Propeller

KMP. TRIMAS ELLISA use Propeller with 4 blade.

1. Oper Water Condition

Then from the Bp is plotted into the grid Bp-δ diagram, so that the value obtained pitch-diameter ratio (P / Do) and advance coefficient on open water conditions. Next calculate the diameter and pitch by:

Delta (δ_0) is obtained with , $\delta_0 = (1/J_0)/0{,}009875$

Diameter (Do) is obtained with, $Do = \delta_0 \times v_a / N$ (ft)

Pitch (Po) is obtained with, $Po = (P/D)o \times Do$ (ft)

Table 2 Selecting propeller by open water condition

N	0,1739 √ BP₁	Type	$(P/D)_0$	1/Jo	δ_O	D_O	P_O	Do (m)	Po (m)
182,82	0,56	B4 - 40	1,025	1,275	129,11	8,82	9,04	2,691	2,759
182,82	0,56	B4 - 55	0,999	1,295	131,14	8,96	8,95	2,734	2,731
182,82	0,56	B4 - 70	1,020	1,285	130,13	8,89	9,07	2,713	2,767
182,82	0,56	B4 - 85	1,075	1,245	126,08	8,62	9,26	2,628	2,825
182,82	0,56	B4 - 100	1,149	1,205	122,03	8,34	9,58	2,544	2,923

2. Behind Ship Condition

To obtain the diameter behind the vessel which size is smaller than the diameter of open water conditions. Glover (1992) expresses the relationship with the approach, by not changing the price of Bp then $(P/D)_B$ can be known by the price B is plotted back and cut with the value of $1/J_B$ on the Bp-δ diagram

D_B = 0,98 x Do (ft) -> for twin screw

$\delta_B = D_B \times N / v_A$

$1/J_B = \delta_B \times 0{,}009875$

Table 3 Selecting propeller by behind ship condition

N	$0{,}1739\ B_P^{1/2}$	Type	D_B (ft)	δ_B	$1/J_B$	$(P/D)_B$	P_B (ft)	ηB	D_B (m)	P_B (m)
182,82	0,56	B4 - 40	8,65	126,532	1,250	1,060	9,17	0,697	2,638	2,796
182,82	0,56	B4 - 55	8,78	128,516	1,269	1,035	9,09	0,697	2,679	2,773
182,82	0,56	B4 - 70	8,72	127,524	1,259	1,065	9,28	0,690	2,658	2,831
182,82	0,56	B4 - 85	8,44	123,554	1,220	1,120	9,46	0,677	2,576	2,885
182,82	0,56	B4 - 100	8,17	119,585	1,181	1,185	9,69	0,674	2,493	2,954

3. Calculation of Cavitation

$\sigma_{0,7R} = (1{,}882 + 19{,}62(h))/ (v_a^2 + (4{,}836 \times N^2 \times D^2)$ (PNA hal 182)

where, h = distance between center shaft with full of ships = 2,15 m

$$\tau C = \frac{T/Ap}{0{,}5\ x\ \rho\ x\ v_R^2}$$ (PNA pg. 182)

Dimana ;

T = 102,1 kN

$v_R^2 = v_a^2 + (0{,}7 \times \pi x\ N \times D)^2$ (Resistant and Propulsion of Ship pg.99)

$Ao = 0{,}25 \times \pi \times D^2$

Ap = A_D x (1,067 – 0,229 (P/D))

$\sigma_{0,7R}$ used to know the cavitation number on Burril's diagram (PNA 182) by way of cut with merchant ship propeller will be obtained τC Burril's.

Table 4 Selecting propeller by Burril's diagram

Type	$\sigma_{0,7R}$	V_R^2	τC	A_O	A_D/A_O	A_D	A_P	τC hit	koreksi
B4 - 40	0,125	353,3	0,075	5,46	0,40	2,18447	0,93222	0,000610863	-0,07
B4 - 55	0,121	363,2	0,074	5,63	0,55	3,09861	1,33874	0,000413816	-0,07
B4 - 70	0,123	358,3	0,077	5,55	0,70	3,88302	1,62576	0,000345469	-0,08
B4 - 85	0,130	338,8	0,078	5,21	0,85	4,42612	1,79889	0,000330119	-0,08
B4 - 100	0,138	320,0	0,080	4,88	1,00	4,87797	1,90507	0,000330043	-0,08

Then Data Propeller used:

Type : B4-55

N = 182,82

$(P/D)_B$ = 1,035

D_B = 2,68

η_B = 0,70

E. Engine Matching Process

After obtaining the ship resistance characteristic which is then converted to the propeller load characteristic and after obtaining the main engine working area, the next step is to plot the curves.

Because of the difference between the speed of the motor with the speed of propeller (the existence of reduction gear) then in the process of matching used derating step that is assuming that the amount of propeller rotation equal to motor rotation. The above is done by assuming that 100% of the parent motor rotation is equal to 100% propeller rotation. To plot the load curve of the propeller in the working area of main engine, in that curve the magnitude of the propeller rotation and motor rotation is the x-axis of the curve expressed in the scale of%.

Also in main engine working area, the engine power is expressed in% then in the matching process this propeller load is also expressed as a percentage and refers to the MCR power of the motor as 100% power.

In analyzing engine matching to consider are:

1. Matching is carried to obtain ship operation on service condition, so the propeller load curve at service time will be used as reference.
2. In matching the load curve must enter into the working area of the motor ie the area where the motor is safe to operate. The determination of the motor service working area depends on the Diesel Engine Service Range Chart.
3. The intersection points taken are the critical points between the propeller load curve and the Continuous Service Range of the motor working region.
4. After matching points are found, each point will be analyzed:
   - Main engine power, motor speed, propeller speed, propeller load
   - Specificity of Fuel Oil Consumption
   - Speed of the vessel achieved.

Table 5 Comparison of the use of single screw and twin screw propellers

Type	Single screw	Twin screw	Chosing
Power Engine (kW)	1405,87	703 x 2	860 kW x 2
Diameter of propeller (D_B) (m)	2,62	2,68	(avaliable)

Making table engine envelope depend of. bKW VS rpm Yanmar *Z280ET2*

With combine graphic correlation of *bKW VS rpm* Yanmar *Z280ET2*, at table of calculation of EPM analysis and engine envelope table, its can be made EPM graphic show as figure 4.:

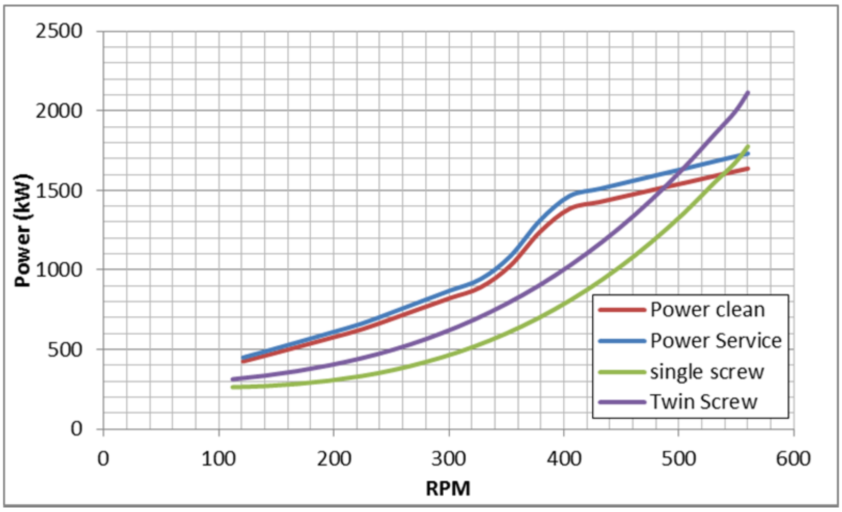

Figure 4 Correlation Engine Rotation and Power

F. Estimation of Ship Fuel Consumption

Fuel consumption on ships can be estimated by the following formula

$$Fuel\ Consumption = \frac{P_s\ x\ b_{me}\ x\ C_R x\ 10^{-6}}{V_s}$$

With Ps representing Power ship (kW), bme is a specific fuel (bme oil = 135g / BPHPh), CR is Cruise Range or cruise distance (nautical mile) and Vs is the speed of ship (m / s).

The calculation of the fuel consumption of vessel power at this calculation is taken by the specific fuel consumption value of 135 g / BHPh and the cruise distance is 900 nautical miles. The value is considered a problem restriction. this calculation of the velocity of the vessel is considered as the official velocity is 14 knots and the vessel is moving at a constant speed and without stopping (non-stop). The power gained from the experiments is an effective power so that for the calculation it should be sought for break horsepower (BHP) power which is the power that the engine must incur in order to achieve effective thrust. The power obtained is the maximum cruise range (MCR) of the machine to be used. The calculation results of fuel consumption and ratio to the weight of DWT.

$$Fuel\ Consumption\ = \frac{P_s\ x\ b_{me}\ x\ C_R x\ 10^{-6}}{V_s}$$

$$= \frac{860\ x\ 135\ x\ 900\ x\ 10^{-6}}{7.2}$$

= 14,51 ton

For 2 main engines requiring 2 x 14.51 tons is 29,02 tons for one trip

IV. Conclusion

Some of the machining changes that occur due to the change to twin screw system, among others:

1. Changes in the propulsion system using twin screw resulted in a change in propion size dimension to 2.68 m. This change to support main engine that is already available.
2. engine bed adjustment is required for supporting new engine position changes with twin screw system
3. The larger the diameter of the propeller the greater the efficiency, so also if the greater the ratio of the discus (blade area ratio) propeller efficiency will increase as well.

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