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SELECTING OF DIESEL ENGINE FOR HEAVY WEATHER SERVICE IN INTER ISLANDS TRADE IN INDONESIA SEAWATER

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ABSTRACT

One of the most important systems of the ship is the interaction between ship, machinery and propeller. Another aspect which influences the hydrodynamics design of ship is the need to ensure not only good smooth – water performance but also that under average service conditions at the sea the ship shall not suffer from excessive motions, wetness on deck, losing more speed than necessary in bad weather. In rough weather the ship's resistance will be changed by the actions of the waves and the wind, which result in change of the load on the propeller and usually a reduction of the propeller efficiency. The marine engineering study made here is in relation to the multipurpose inter insular cargo vessel of 3000 DWT, CARAKA JAYA III design concept. For the purpose of the design layout of the power plant for CARAKA JAYA III, it is necessary to make route plan for this ship. In this case two routes are made, one for West Indonesia, and one for East Indonesia. The results of the calculation of the added resistance for CARAKA JAYA III is 0.3 % to 18 % higher than resistance at design condition for sea state with Beaufort 1 to 4 and 38 % to 68 % higher than resistance at design condition for sea state with Beaufort 5 to 6. The propeller load diagram for CARAKA JAYA III shows that with the wind a head of Beaufort 5, the resistance increase by the factor f_{RS} = 1.35 and maximum ship speed V_S = 13 kn, the maximum propeller revolution n_{PSX} = 120 RPM, and the maximum propeller power P_{PSX} = 1526 kW. With a head wind of Beaufort 6 the, resistance increase by the factor f_{RS} = 1.66 at a maximum speed V_S = 12.4 kn., the maximum propeller revolution n_{PSX} = 115 RPM and the maximum propeller power P_{PSX} = 1477 kW. Therefore the selecting power of engine should have P_{PMC} = 1800 kW, engine revolution n_{MCR} = 600 RPM, and a maximum engine revolution n_{MAX} = 636 RPM. In this paper a method will be shown to pre-calculate the propeller load and the engine load in heavy weather conditions. With these values, the design conditions for the propeller and main engine can be made clearer for Caraka Jaya III ship.

Keywords: resistance, propeller and engine power in heavy weather

1. INTRODUCTION

The power increase in heavy weather is caused by an increase of resistance. The resistance increase in waves has been the subject of the number of interesting analytical and experimental studies. Theoretical studies of the problem have been carried out by Haverlock [4], Kreitner [5], Maruo [6], Jan Olaf [7], Lai Trung Tho [8], Zhi Shu et al [13] and a number others. However, those calculation methods which gave full consideration to the physics of this phenomenon have not been widely used in technical practice, because of the great mathematical difficulties involved. That is why a number of practical techniques have been developed, which use certain simplifying assumptions, thus facilitating the determination of the value of the added resistance due to the waves. Among such practical techniques, suggestions have been made by Gerritsma and Beakelman [1], Grossmann [2] and also by Xiaobo Yan [11].

Voyage reports show that with a headwind of Beaufort 8 the overall resistance of fully-loaded dry cargo containership increases by the factor f_{RS} = 3.1 and for a refer containership with almost no containers on deck the resistance goes up by the factor f_{RS} = 2.35, Grosmaann [3]. The recorded values of power increase factor f_{PS} = 4.45 on a stormy trip against wind force Beaufort 9 for 24 hour of containership Norasia Samantha, Grossmann [2].

2. EQUATION OF ADDED RESISTANCE

The added resistance according to the measured data ship voyage at open ship (Pacific, Atlantic and India Ocean) of 13 difference ship by Xiabo Yan [10], based on the result of this investigation the added resistance R_{AW} for open sea equation is derived :

$$R_{AW}(open\ sea) = C_0 BL^{-0.5} V_W^{\ 2} \quad (1)$$

The result of regression analysis by Xiabo Yan the value of C_o is 0.116.

The equation of the added resistance in Indonesia Sea, the sea state Indonesia's water is restricted water with low significant wave height at the same wind speed for open sea. The equation of added resistance for Indonesia Sea becomes:

$$R_{AW}(restricted\ sea) = 0.043\, BL^{-0.5} V_W^{\ 2.154} \quad (2)$$

Equation (2) is general equation which can be used to calculate the added resistance in irregular waves of a ship in any kind of restricted water in Indonesia Sea, Yusuf Siahaya [12]. The **e**quation of the added resistance in irregular wave base on an extended Schifrin Method [9] as follows:

$$RAW = z\,\rho\, g\, B^2 L^{-1} \sum_{\omega=0.2}^{2.2} \sigma_{AW}(\omega) S_\omega \Delta\omega \quad (3)$$

The equation (3) can be used to calculated the added resistance in all sea are as, where the spectrum is known

3. CASE STUDIES

To calculate the added resistance in irregular waves in Indonesia Sea, CARAKA JAYA III (CJ III) is chosen as an example for investigation. CJ III is a multipurpose inter insular for semi container ship of 115 TEU. The principal particulars of CJ III as follows:

Length Overall (m), L_{OA}	= 98
Length between perpendicular (m), L_{PP}	= 92
Breadth moulded (m) ,B	=16.5
Draft moulded (m) , T	= 5
Dead weight (tonne)	=3242

All calculation for CJ III is made for a fixed propeller design condition:

Ship speed	V_{SO} =	12.5 kn
Resistance	R_{SO} =	111 kN
Effective power	P_E =	713 kW

4. PROPELLER CHARACTERISTIC OF CJ III AT DESIGN CONDITION

Using the Wageningen B-Series [10] computer program at Institut fur Shiffskraftanlagen Technische Universitat Berlin (TUB) the diagram of the K_T – factor as a function of the P/D and advance number J can be determined, and the diagram shown the maximum propeller open water efficiency, η_0 will be obtained when K_{TO}/J_O^2 is tangent to curve, therefore the values of K_{TO}, P/D, and J_O for CJ III can be found from the following diagram,

J_O = 0.6590 K_{TO} = 0.137 η_0 = 0.6600

P/D = 0.95 K_{TO}/J_O^2 = 0.3994

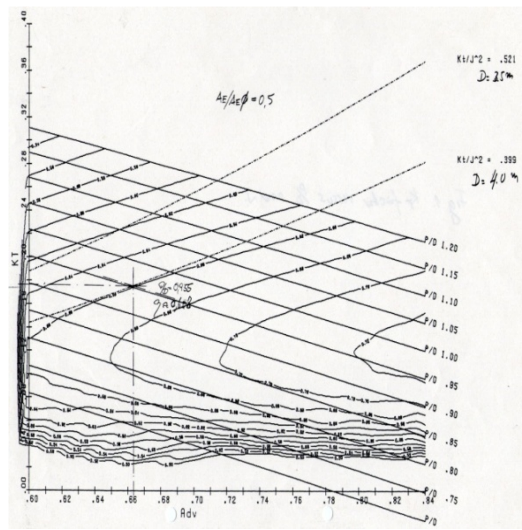

Figure 1: K_T factor versus P/D and J

The propeller characteristic CJ III in open water can be expressed as polynomials with the advance coefficient J.

$$K_{TS} = 0.3960\text{-}0.2020J\text{-}0.2125J^2 + 0.0378J^3 \quad (4)$$

$$K_{QS} = 0.2578\text{-}0.2497J\text{-}.0.1666J^2\ \text{-}0.0423J^3 \quad (5)$$

5. THE ADDED RESISTANCE OF CJ III ACCORDING TO EQUATION OF RESTRICTED WATER IN INDONESIA SEA

A method will be shown pre-calculate the propeller load and the engine load due to sea and wind condition. Calculation of the resistance increase f_{RS} and the power increase f_{PS} for added resistance due to heavy weather in Indonesia's seawater.
Total resistance due to weather condition:

$$R_{SS} = R_{AW} + R_{SOX} \quad (6)$$

Where, R_{AW} = the added resistance due to weather condition, R_{SOX} = resistance at design condition.
Resistance increase factor due to weather:

$$f_{RS} = R_{SS} / R_{SOX} = 1 + R_{AW} / R_{SOX}$$

$$= [K_{TS}/J_S^2] / [K_{TO}/J_O^2] \quad (7)$$

Propulsion Efficiency due to weather condition:

$$\eta_{DS} = f_{ES} \times \eta_{DO} \quad (8)$$

Where, f_{ES} propulsive increase factor, η_{DO} propulsive efficiency at design condition.

$$f_{ES} = \eta_{DS} / \eta_{DO} = [K_{TS}/K_{QS}]/[K_{QO}/K_{TO}]/J_S/J_O] \quad (9)$$

$$f_{PS} = f_{RS}/f_{ES} = [P_{SSX}/P_{SOX}]/[V_{SOX}/V_{SSX}] \quad (10)$$

Using the added resistance factor f_{RS}, the correlation between slip factor s' and the f_{RS} for CJ III as follows:

$$s' = 5.5857 f_{RS}^{-.05} - 4.5857 \quad (11)$$

When the slip factor for heavy weather condition is known than the new advance number J for heavy weather condition can be determined:

$$J_S = J_O (1 - s_S) = s' J_O \quad (12)$$

Where slip factor $s' = (1 - s_S)$ (13)

Resistance at design condition of CJ III can be expressed as:

$$R_O = a_{RO} . V_S^2 \quad (14)$$

$$a_{RO} = R_O / V_S^2 = 0.7104 \text{ kN/ (kn)}^2$$

The effective power P_E is proportional to the ship speed V_S^3 :

$$P_E = a_{PE} . V_S^3 \quad (15)$$

$$a_{PE} = P_E / V_S^3 = 0.365 \text{ kW/ (kn)}^3$$

- Results of calculation of CJ III at design condition are shown in Table 1.

Table 1: Design condition of CJ III

R_0	n_0	J_0	K_{T0}	K_{Q0}	T_0	Q_0	η_0
KN	rpm				KN	KNm	
111	105	6590	0.1736	0.267	141	86	0.6590

The added resistance R_{AW} of CJ III in Indonesia's seawater with difference wind speed are given in Table 2.

Table 2: The added resistance R_{AW} of CJ III

Bf	1	2	3	4	5	6
V_W (Kn)	2.0	5.0	8.5	13.5	19.0	24.5
R_{AW} (KN)	0.33	2.4	7.5	20.2	42.2	73.0

The total resistance increase due to weather R_{SSX} can be determined if the added resistance R_{AW} and the resistance at design condition R_{SO} are known. Table 3 shows the value of R_{SSX} at the variation of ship speed V_S

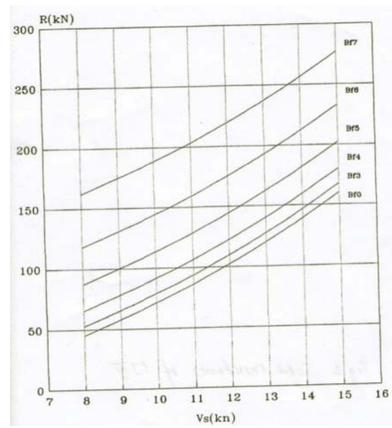

Figure 2: Total resistance of CJ III

Table 3: Total resistance R_{SSX}

Bf	1	2	3	4	5	6
$R_{SSX} = R_{AW} + R_{SOX}$ (KN)						
8	45.33	47.1	52.5	65.0	87.0	118.0
10	71.33	73.0	78.5	91.0	113.0	144.0
12	102.33	104.0	109.5	122.0	144.0	175.0
14	139.33	141.0	146.5	159.0	181.0	212.0

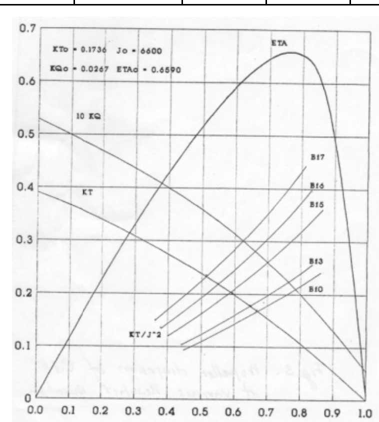

Figure 3: Propeller diagram of CJ III at different Beaufort Number.

6. THE ADDED RESISTANCE OF CJ III ACCORDING TO EQUATION OF SCHIFRIN METHOD

The added resistance of CJ III can be calculated from equation (3). Using the computer program (program zwide bestimung des zusatzwiderstande) create by Xiaobo Yan [11] in TUB Berlin, the added resistance R_{AW} according to Schifrin equation are calculated and shown in Table 4.

Table 4: The added resistance of CJ III

Bf	1	2	3	4	5	6
Vs	R_{AW}(Schifrin)					
8	0.003	0.24	2.65	17.20	40.0	59.0
10	0.003	0.26	2.72	19.00	47.0	71.0
12	0.003	0.27	2.75	20.40	53.0	83.0
14	0.003	0.28	2.75	21.50	60.0	96.0

The values of the added resistance in irregular wave R_{AW} (Schifrin Method) is shown in Figure 4 for different ship speed CJ III.

Table.2 and Table 4 are shown the added resistance evaluation of CJ according to equation (2) the added resistance R_{AW} Indonesia sea water (restricted water), equation (3) the added resistance R_{AW} (Schifrin Method). The difference between the two resistance increases is small for B_f 1 to 4, but there is a tendency

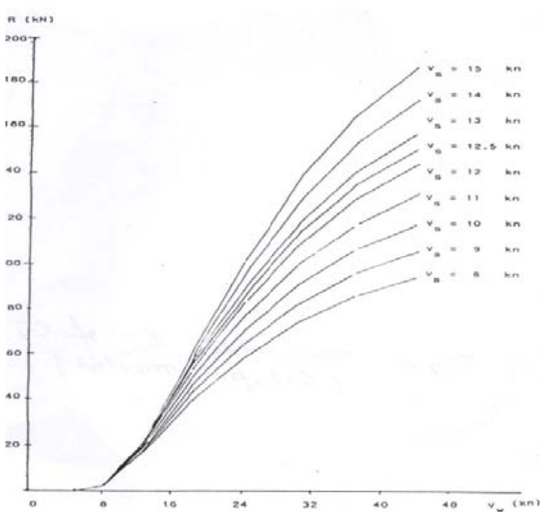

Figure 4: The added resistance R_{AW} of CJ III (Schifrin Method)

for Schifrin Method to give a greater added resistance for B_f 5 to 7. It can be said that the calculation result by Schifrin Method and restricted water equation (Indonesia sea water) are the same. Therefore the equation of restricted water and Schifrin Method can be used to calculate the added resistance in irregular wave in Indonesia seawater. However, the restricted water equation has advantages both with in theory and in practical use, and it is therefore proposed that the added resistance is calculated by restricted equation (2) can be used to calculate the power increased in heavy weather in irregular waves.

7. EVALUATION OF SAILING ROUTE IN INDONESIA RESTRICTED SEA WATER

For the purpose of design layout of the power plant of CJ III, it is necessary to make two route plans for the ship. In this case two routes are made, one for West Indonesia sea water, and one for East Indonesia sea water. In Indonesian sea water the direction of current and wind is differ for West Indonesia and East Indonesia. Therefore a sailing route plan is consisting of two sailing periods. At each part of the route it is assumed that the ship will be porting at several ports of call in the morning and sailing again in the evening. Figure 5, shows the western sailing route for CJ III, where the heavy weather from December to March.

The ship has to sail from Singapore to Balikpapan in 1616 Km in December the route is divided into 3 parts.

S_1 = 520 Km Singapore to Jakarta port
S_2 = 749 Km Jakarta to Makassar port
S_3 = 302 Km Makassar to Balikpapan port.

Total distance = 1616 Km

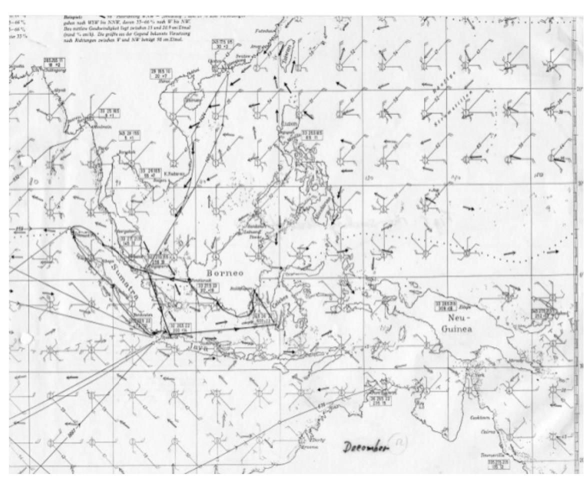

Figure 5: The western sailing route CJ III, in December

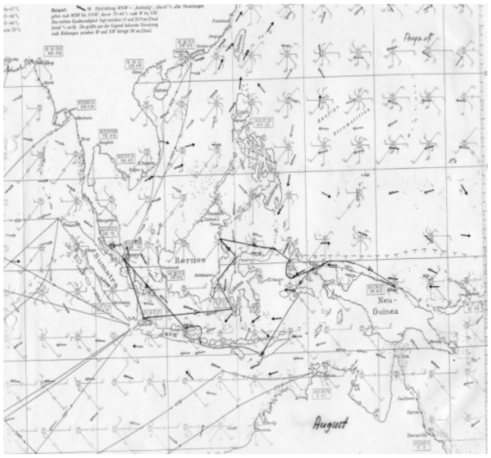

Figure 6: The eastern sailing route CJ III, in August.

When the whole voyage has to be finished in time t = 166 hours, the whole voyage speed should be V_{SM} = 1616/166 = 9.73 Km/h. The part of the route is against Bf 5 and Bf 6 and the first leg is against a current of V_{CU} = - 0.6 kn. In Table 5 the factors the added resistance f_{RS}, propeller efficiency factor f_{ES}, propeller power factor f_{PS} for all western routes are evaluated.

Table 5: Evaluation of route factors f_{RS}, f_{ES}, and $f_{PS.}$

Part	Length	Wind	f_{RS}	f_{ES}	f_{PS}
	Km	Bf			
S1	520	4	1.28	0.95	1.36
S2	749	5	1.63	0.91	1.76
S3	302	6	2.10	0.86	2.37

8. PROPELLER LOAD AT HEAVY WEATHER CONDITIONS

If the CJ III is sailing against Bf 5 the main engine should be constant speed n_{MSX} = 598 rpm. This will give the propeller a slip of S_S = 0.10, increase the resistance factor 1.63. From the propeller diagram for CJ III we get, J_S = 0.6050, K_{TS} = 0.1980, K_{QS} = 0.0370, η_O = 0.62, and the power factor, f_{PS} = 1.76 the ship speed CJ III is reduced at same time to V_{SSX} = 12 kn = 0.90 V_{MAX}, the heavy weather power demand of the engine is P_{MSX} = 1790 kW, and engine torque in this condition is Q_{MS} = 28.60 kNm. With this load conditions the selected engine should be, P_{MCR} = 1800 kW, n_{MCR} = 600 rpm, n_{MAX} = 636 rpm. One of the suitable engines for this purpose is the MaK – M 453.

The results evaluation of CJ III voyage in western and eastern Indonesia sea water can be compared the results investigation of Grossmann [2] when Noratian Samantha on trip against Bf 6 for 24 hours. The voyage record – show the behavior of the real system – propeller and ship- conforms very nice to this theoretical.

9. CONCLUSION

The aim of this investigation is to match ship, propeller and main engine for Caraka Jaya III to suit the requirements of the ship's service and to avoid overloading of the main engine in heavy weather conditions.

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