POWER PREDICTION PROBLEM SOLUTION

Preliminary power prediction is required for a single screw bulk carrier with the following details for 15 knots of service speed.

The contract requires that, on fully loaded trial, the ship achieves a speed 1 knot greater than the required service speed with engine developing 85% of its maximum continuous power.

The vessel particulars:

$$\begin{array}{|l|}\hline L_{BP} = 135.34\,m \\ B \quad = 19.30\,m \\ T \quad = 9.16\,m \\ C_B \; = 0.704 \\ \hline \end{array}$$

Stage 1: Effective Power prediction

- First estimate Effective power for TRIAL & SERVICE conditions for the program provided or another statistical method.
- To do this, specify a speed range which includes the trial & service speeds -5 knots and +2 knots of trial speed.
- Power prediction factor (1+x) is given by

$$\boxed{(1+x)_{FROUDE} = \frac{1}{1.2}\left(0.44 + 2.229L^{-1/4} + 10.058L^{-1}\right)}$$

- Assume that in average service conditions, the ship resistance is increased by 20% (i.e. is 1.2).
- Plot [$P_{E_{TRIAL}}$ & $P_{E_{SERVICE}}$ vs V_S curves

Solution

Speed range:

$$V_{S_{TRIAL}} = V_{S_{SERVICE}} + 1 = 16\,knots$$
$$V_S = 11,12,13,14,15,16,17,18\,knots$$

- *Actual Ship Dimensions:*

  L × B × T = 135.34 × 19.30 × 9.16 meters
- *Volume of actual ship*, ∇.

- $\nabla = C_B \times L \times B \times T = 0.704 \times 135.34 \times 19.3 \times 9.16 = 16{,}844\ m^3$ $0.60 \times T = 0.60 \times 9.16 = 5.5$ meters

  Midship Coefficient $C_M = 0.995$

  Length of Waterline, $L_{wl} = 2.5\%L + L = 3.3835 + 135.34 = 138.72$ meters.

  Bulb Section Area, $A_{BT} = 0.10 \times (C_M \times B \times T) = 0.10 \times (0.995 \times 19.3 \times 9.16) = 17.59\ m^2$

  Height of the centroid of the bulb from the keel, $H_{BT} = 0.50 \times T = 0.50 \times 9.16 = 4.58$ m.

  Stern parameter for moderate U form, $C_{Stern} = 5$

  Location of Longitudinal center of buoyancy from midship, LCB = 0.0 meters

  Propeller Diameter, $D = 0.60 \times T = 0.60 \times 9.16 = 5.5$ meters.

  Propeller Shaft Depth $H_p = 0.60 \times T = 0.60 \times 9.16 = 5.5$ meters

  (*) These variables are taken from similar ships and needed for Holtrop and Mennen Performance prediction method.

- *Power Prediction factor, (1+x)*

  Power Prediction factor (1+x) = 0.968 (According to Froude)

  (1+x) = (0.44 + 2.229/L**0.25 + 10.058/L)/1.20

  L = 138.720 m (Length of Waterline)

  Power Prediction factor (1+x) = 1.000 (Actual)

RESULTS OF EFFECTIVE POWERS

No	Vs (Knots)	RT (kN)	Pe (KW)	Pe(TRIAL) (KW)	Pe(SERVICE) (KW)
1-	10.000	80.079	411.929	411.929	494.314
2-	11.000	97.517	551.791	551.791	662.149
3-	12.000	118.215	729.718	729.718	875.662
4-	13.000	143.338	958.531	958.531	1150.238
5-	14.000	174.325	1255.416	1255.416	1506.499
6-	15.000	212.818	1642.106	1642.106	1970.528
7-	16.000	260.589	2144.754	2144.754	2573.705
8-	17.000	319.449	2793.520	2793.520	3352.224
9-	18.000	391.177	3621.986	3621.986	4346.383

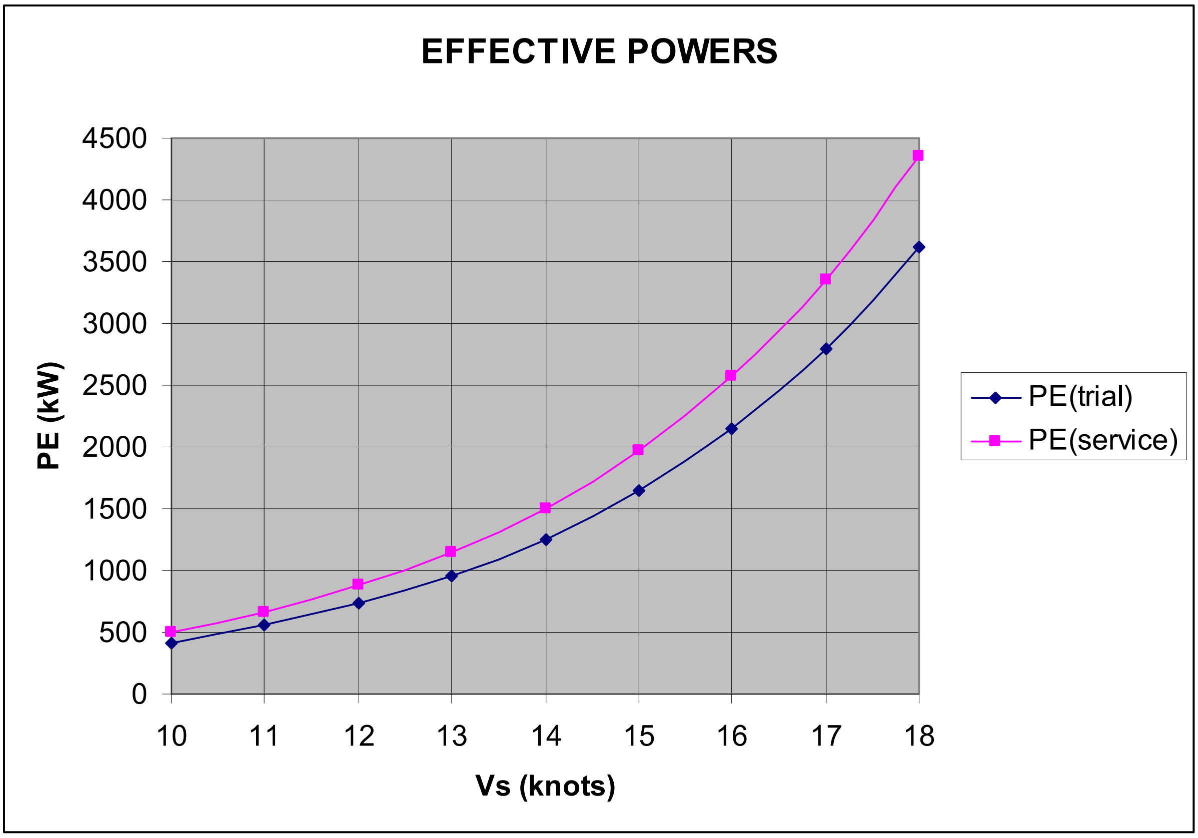

Figure 1. Effective powers.

Stage 2: Design of Suitable Propeller and Engine Selection

Calculation of propulsion coefficients gives,

```
  B   =   19.30000 m
  L   =  135.34000 m
  T   =    9.16000 m
  D   =    4.80000 m
  Cb  =  .704
 B/L  =      .14260
 D/L  =      .03547
------------------------------------------------------
 a   = 0.10*B/L + 0.149 =   .16326
 b   = 0.05*B/L + 0.449 =   .45613
 c   = 585 - 5027*(B/L) + 11700*(B/L)**2 =  106.06010
 w1  = a + b / (c*(0.98 - Cb)**3+1)  =   .3045
 w2  = -0.18+0.00756/(D0/L+0.002)    =   .0218
 w   = w1 + w2 =    .3263
------------------------------------------------------
 d   = 0.625*B/L + 0.08 =    .1691
 e   = 0.165 - 0.25*B/L =    .1293
 f   = 825 - 8060*B/L + 20300*(B/L)**2 = 88.4310
 t1  = d + e / (f*(0.98 - Cb)**3+1)  =    .2144
 t2  = 2.*(D/L-0.04)  =  -.0091
 t   = t1 + t2 =    .2053
```

- Therefore the wake fraction, thrust deduction coefficients and relative rotative efficiency are obtained as;

w = 0.326, t=.2053, η_R=1.

- Open water diameter $D_0 = \frac{D_B}{0.95} = \frac{5.50}{0.95} = 5.79\,m$

  This diameter of propeller should absorb the delivered power for trial condition, i.e. Vs(trial) = 16 knot, at the optimum R.P.M. which would correspond to maximum propeller efficiency.

  From figure 1 Vs(trial) = 16.000 knots => Pe(trial) = 2144.75 kW

- Assume η_D = 0.75

$$P_D = \frac{P_E}{\eta_D} = \frac{2144.75}{0.75} = 2859.67\,kW$$

$$V_A = V_{S_{trial}}\left(1-w\right) = 16\left(1-0.293\right) = 11.307\,knots = 5.816\,m/sec$$

$$R_T = \frac{P_E}{V_S} = \frac{2144.75}{0.5144\times 16} = 260.59\,kN$$

$$T = \frac{R_T}{\left(1-t\right)} = \frac{260.59}{\left(1-0.22\right)} = 334.05\,kN$$

$$\frac{K_T}{J^2} = 0.287$$

- To find optimum R.P.M., either select a range of R.P.M., e.g. 80~120 and calculate B_p-δ or K_T,K_Q,J diagrams or use the program "*PropCalc*" with the option "Optimum R.P.M". Since the thrust of the propeller is known the application of Keller's formula tells us the approximate value of expanded area ratio of the propeller as EAR = 0.368. In this case EAR is selected as 0.400 and the number of blade Z is.

$Z = 0.400$; $BAR = 0.400$

Wageningen B series is used

i	P/D	J	Kt	10Kq	eta0	Bp	delta
1	.500	.451	.0586	.0851	.4949	22.2668	224.2971
2	.510	.458	.0603	.0874	.5031	21.7643	221.0480
3	.520	.465	.0621	.0898	.5111	21.2869	217.9026
4	.530	.471	.0638	.0923	.5188	20.8329	214.8567
		…………………………………………….					
51	1.000	.751	.1620	.2862	.6765	11.4518	134.8704
52	1.010	.756	.1643	.2920	.6771	11.3666	133.9258
53	1.020	.761	.1666	.2980	.6777	11.2834	132.9990

```
 54   1.030    .767    .1689    .3039    .6782    11.2023     132.0896
 55   1.040    .772    .1712    .3100    .6786    11.1231     131.1969
 56   1.050    .777    .1735    .3161    .6790    11.0458     130.3206
 57   1.060    .782    .1759    .3223    .6793    10.9702     129.4602
 58   1.070    .787    .1782    .3286    .6796    10.8963     128.6153
 59   1.080    .792    .1805    .3349    .6798    10.8241     127.7856
 60   1.090    .798    .1828    .3413    .6800    10.7534     126.9706
 61   1.100    .803    .1852    .3477    .6802    10.6843     126.1700
 62   1.110    .808    .1875    .3542    .6803    10.6167     125.3833
 63   1.120    .813    .1898    .3608    .6804    10.5504     124.6103
 64   1.130    .818    .1922    .3675    .6805    10.4855     123.8505
 65   1.140    .823    .1945    .3742    .6805    10.4219     123.1037
 66   1.150    .828    .1968    .3809    .6806    10.3596     122.3696
 67   1.160    .832    .1992    .3877    .6806    10.2984     121.6478
 68   1.170    .837    .2015    .3946    .6806    10.2384     120.9380
                ............................................................
 89   1.380    .935    .2510    .5481    .6812     9.1695     108.3609
 90   1.390    .939    .2534    .5556    .6815     9.1246     107.8549
 ---|-------|-------|--------|--------|--------|-----------|-----------|

 SECILEN PERVANE = 60. PERVANEDIR

 P/D=1.090
 J=  .798 Kt=  .183 10Kq=  .341 eta=  .680
 Bp=  10.7534 delta= 126.9706
 T=    334.05 kN  Va=   5.816 m/s  RHO = 1025.0 kg/m3
 Z = 4. EAR =  .400 D =  5.789 m
 RPS=  1.260 dev/san RPM=  75.58 TORK= 361.006 kNm Pd= 2857.2 kW
```

According to the program output is shown in the table given above

$$\eta_{0_{max}} = 0.680 \, and \; N = 75.58 \, R.P.M$$

To confirm this

$$\eta_D = \eta_h \times \eta_R \times \eta_0 = \frac{1-t}{1-w} \times \eta_R \times \eta_0 = \frac{1-0.220}{1-0.293} \times 1 \times 0.680 = 0.750$$

$$\varepsilon = \eta_{D_{calculated}} - \eta_{D_{previous}} = 0.750 - 0.750 = 0$$

So the assumed value of $\eta_D = 0.75$ is found to be enough for the calculation.

- Based upon the latest value of $\eta_0 = 0.680$, The trial power

$$P_B = \frac{P_E}{\eta_D \times \eta_S} = \frac{2144.75}{0.750 \times 0.980} = 2918.3 \, kW$$

- Installed maximum continuous power

$$P_{B_m} = \frac{P_B}{MCR\%} = \frac{2918.3}{0.85} = 3433 \, kW$$

- Delivered power

$$P_D = P_B \times \eta_S = 2918.3 \times 0.98 = 2860 \, kW$$

- Therefore, the advance coefficient of the propeller at behind hull condition would be

$$J=\frac{V_A}{n\times D_B}=\frac{16\times(1-0.293)\times0.5144}{75.579/60\times5.5}=0.84$$

- The required values can be read-off the program output table given above as

```
DEVIR              -      N  =   75.579 RPM
KANAT SAYISI       -      Z  =    4
ILERLEME KATSAYISI   - J  =  .840
ITME SABITI        -     Kt  =  .217
MOMENT SABITI      -   10Kq  =  .042
ACIK SU VERIMI     - ETA-0  =  .662
PIC ORANI - P/D  - SABIT  = 1.168
ACINIM ALANI ORANI - EAR  =  .400
PERVANE CAPI  - DIAM      =    5.500 m
HATVE MIKTARI  - P        =    6.424 m
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- Engine selection:

Calculated optimum R.P.M = 75.579

Trial Power = 2918 kW

Installed Power = 3433 kW

The engine would be MAN B&W Diesel A/S – L42MC type. In this case since the engine speed is 176 RPM, a reduction gear to achieve 75 R.P.M.'s propeller is needed.

MAN B&W Diesel A/S — Engine Selection Guide

Engine type	Layout point	Engine speed r/min	Mean effective pressure bar	Power kW / BHP — Number of cylinders 4	5	6	7	8	9	10	11	12
L42MC	L_1	176	18.0	3980 5420	4975 6775	5970 8130	6965 9485	7960 10840	8955 12195	9950 13550	10945 14905	11940 16260
Bore 420 mm	L_2	176	11.5	2540 3460	3175 4345	3810 5190	4445 6055	5080 6920	5715 7805	6350 8690	6985 9535	7620 10380
Stroke 1360 mm	L_3	132	18.0	2980 4060	3725 5075	4470 6090	5215 7105	5960 7105	6705 9135	7450 10150	8195 11165	8940 12180
	L_4	132	11.5	1920 2600	2400 3250	2880 3900	3360 4550	3840 5200	4320 5850	4800 6500	5280 7150	5760 7800
S35MC	L_1	170	18.4	2800 3800	3500 4750	4200 5700	4900 6650	5600 7600	6300 8550	7000 9500	7700 10450	8400 11400
Bore 350 mm	L_2	170	14.7	2240 3040	2800 3800	3360 4560	3920 5320	4480 6080	5040 6840	5600 7600	6160 8360	6720 9120
Stroke 1400 mm	L_3	145	18.4	2380 3220	2975 4025	3570 4830	4165 5635	4760 6440	5335 7245	5950 8050	6545 8855	7140 9660