

Course #: NAME 324

Assignment # 3: **Approximate Power Prediction Method**

Hotrop and Mennen's Method

The total resistance of a ship can be subdivided into:

$$R_T = R_F(1+k_1) + R_{APP} + R_W + R_B + R_{TR} + R_A$$

Where,

R_F Frictional resistance according to the ITTC 1957 friction formula
 $= 0.5 \cdot \rho V^2 S C_F$.

$$C_F = 0.075 / (\log_{10} Re - 2)^2$$

$1+k_1$ Form factor describing the viscous resistance of the hull form in relation to R_F

R_{APP} Appendage resistance

R_W Wave-making and wave-breaking resistance

R_B Additional pressure resistance due to bulbous bow near the water surface

R_{TR} Additional pressure resistance of immersed transom stern

R_A Model-ship correlation resistance

The form factor of the hull can be predicted by:

$$1+k_1 = c_{13} \{ 0.93 + c_{12} (B/L_R)^{0.92497} (0.95 - C_p)^{-0.521448} (1 - C_p + 0.0225 lcb)^{0.6906} \}$$

In this formula, C_p is the prismatic coefficient based on the waterline length, L and lcb is the longitudinal centre of buoyancy forward of $0.5L$ as a percentage of L . Here, L_R is a parameter reflecting the length of the run according to:

$$L_R/L = 1 - C_p + 0.06 C_p lcb / (4C_p - 1)$$

$$C_{12} = \begin{cases} (T/L)^{0.2228446} & \text{if } T/L > 0.05 \\ = 48.20(T/L - 0.02)^{2.078} + 0.479948 & \text{if } 0.02 < T/L < 0.05 \\ = 0.479948 & \text{if } T/L < 0.02 \end{cases}$$

Where T is the average moulded draught.

$$C_{13} = 1 + 0.003 C_{stern}$$

C_{stern} will be -10, 0 and +10 if the afterbody form is of V-shaped, Normal and U shaped sections respectively.

The wetted area of the hull can be approximated by:

$$S = L(2T + B) \sqrt{C_M} (0.453 + 0.4425 C_B - 0.2862 C_M - 0.003467 B/T + 0.3696 C_{WP}) + 2.38 A_{BT} / C_B$$

where A_{BT} is the transverse sectional area of the bulb at the position where the still-water surface intersects the stem.

The appendage resistance can be determined from

$$R_{APP} = 0.5 \rho V^2 S_{APP} (1+k_2)_{eq} C_F$$

Where S_{APP} the wetted area of the appendages, $1+k_2$ the appendage resistance factor

Approximate $1+k_2$ values

Rudder behind skeg	1.5~2.0
Rudder behind stern	1.3~1.5
Twin-screw balance rudders	2.8
Shaft brackets	3.0
Skeg	1.5~2.0
Strut bossings	3.0
Hull bossings	2.0
Shafts	2.0~4.0
Stabilizer fins	2.8
Dome	2.7
Bilge keels	1.4

The equivalent $1+k_2$ value for a combination of appendages is determined from:

$$(1+k_2)_{eq} = \frac{\sum (1+k_2) S_{APP}}{\sum S_{APP}}$$

The wave resistance is determined from:

$$R_W = c_1 c_2 c_5 \nabla \rho g \exp \{ m_1 F_n^d + m_2 \cos(\lambda F_n^{-2}) \}$$

with

$$c_1 = 2223105 c_7^{3.78613} (T/B)^{1.07961} (90 - i_E)^{-1.37565}$$

$$c_7 = 0.229577 (B/L)^{0.333333} \quad \text{if } B/L < 0.11$$

$$= B/L \quad \text{if } 0.11 < B/L < 0.25$$

$$= 0.5 - 0.0625 L/B \quad \text{if } B/L > 0.25$$

$$c_2 = \exp(-1.89 \sqrt{c_3})$$

$$c_5 = 1 - 0.48 A_T / (BTC_M)$$

$$\lambda = \begin{cases} 1.446 C_p - 0.03 L/B & \text{if } L/B < 12 \\ = 1.446 C_p - 0.36 & \text{if } L/B > 12 \end{cases}$$

$$m_1 = 0.0140407L/T - 1.75254\nabla^{1/3} / L - 4.79323B/L - c_{16}$$

$$c_{16} = 8.07981C_P - 13.8673C_P^2 + 6.984388C_P^3$$

$$= 1.73014 - 0.7067C_P \quad \text{if } C_P < 0.8$$

$$= 1.73014 - 0.7067C_P \quad \text{if } C_P > 0.8$$

$$m_2 = c_{15}C_P^2 \exp(-0.1F_n^{-2})$$

$$c_{15} = -1.69385 \text{ for } L^3/\nabla < 512$$

$$= 0 \quad \text{for } L^3/\nabla > 1727$$

$$= -1.69385 + (L/\nabla^{1/3} - 8.0)/2.36 \quad \text{if } 512 < L^3/\nabla < 1727$$

$$d = -0.9$$

$$i_E = 1 + 89 \exp\{-(L/B)^{0.80856} (1 - C_{WP})^{0.30484} (1 - C_P - 0.0225lcb)^{0.6367} (L_R/B)^{0.34574} (100\nabla/L^3)^{0.16302}\}$$

$$c_3 = 0.56A_{BT}^{1.5} / \{BT(0.31\sqrt{A_{BT}} + T_F - h_B)\}$$

where h_B is the position of the centre of the transverse area A_{BT} above the keel line and T_F is the forward draught of the ship.

$$R_B = 0.11 \exp(-3P_B^{-2}) F_{ni}^3 A_{BT}^{1.5} \rho g / (1 + F_{ni}^2)$$

$$P_B = 0.56\sqrt{A_{BT}} / (T_F - 1.5h_B)$$

$$F_{ni} = V / \sqrt{g(T_F - h_B - 0.25\sqrt{A_{BT}}) + 0.15V^2}$$

$$R_{TR} = 0.5\rho V^2 A_T c_6$$

$$c_6 = 0.2(1 - 0.2F_{nT}) \quad \text{if } F_{nT} < 5$$

$$= 0 \quad \text{if } F_{nT} \geq 5$$

$$F_{nT} = V / \sqrt{2gA_T / (B + BC_{WP})}$$

$$R_A = \frac{1}{2} \rho V^2 S C_A$$

$$C_A = 0.006(L + 100)^{-0.16} - 0.00205 + 0.003\sqrt{L/7.5} C_B^4 c_2 (0.04 - c_4)$$

$$c_4 = T_F/L \quad \text{when } T_F/L \leq 0.04$$

$$c_4 = 0.04 \quad \text{when } T_F/L > 0.04$$

Problem: The characteristics of a ship is as follows:

L.O.W	L=205.00 m
L.B.P.	$L_{PP} = 200.00$ m
Breadth moulded	B = 32.00 m
Draught moulded on F.P	$T_F = 10.00$ m
Draught moulded on A. P.	$T_A = 10.00$ m
Displacement volume moulded	$\nabla = 37500$ m ³
Longitudinal centre of buoyancy	2.02% aft of $1/2L_{PP}$
Transverse bulb area A_{BT}	= 20.0 m ²
Centre of bulb area above keel line	$h_B = 4.0$ m
Midship section coefficient C_M	= 0.98
Waterplane area coefficient C_{WP}	= 0.75
Transom area	$A_T = 16.0$ m ²
Wetted area appendages	$S_{APP} = 50.0$ m ²
Stern shape parameter,	$C_{stern} = 10.0$
Propeller diameter,	D = 8.0 m
Number of propeller blades	Z = 4
Clearance of propeller with keel line	0.20 m
Ship speed	V=25.0 knos

Find $R_F, R_{APP}, R_W, R_B, R_{TR}, R_A, R_{total}$.

Reference: J. Holtrop and G.G. J. Mennen, 1982: **An Approximate Power Prediction Method**, International Shipbuilding Progress, Vol. 29, No. 335.