5. DETERMINATION OF SHIP RESISTANCE BY EMPIRICAL, SYSTEMATICAL and STATISTICAL APPROACHES

5.1 Prediction of Ship Resistance by Considering Similar Types of Ships

This class of methods may either be studied by means of simple formulas or by systematic hull series

a) Simple empirical formulas

These formulas can be used in preliminary design phase, since they are able to give only an approximate idea about the required power. Admiralty coefficient A_c is used to calculate necessary power to propel the type ship;

$$A_C = \frac{\Delta^{2/3} V^3}{P}$$

where Δ is the displacement in [ton], V is speed in [kn] and P is the power in [HP]. Once the A_C is calculated for the known (type) ship, then the necessary power for the new ship – which is taken as the same type of the known ship – can be predicted by :

$$P_n = \frac{\Delta_n^{2/3} V_n^3}{A_C}$$

by introducing new values Δ_n and V_n for newly designed ship. Similar formulas were developed for this purpose:

i) Harvald (1983) for effective power of the conventional ships;

$$P = \frac{\Delta^{2/3} V^3}{C} \quad \text{[kW]}$$

where displacement tonnage, Δ, is in [ton], velocity V is in [m/s] and

$$C = 3.7\left(\sqrt{L} + \frac{75}{V}\right)$$

where ship's length, L, is in [m].

ii) Watson (1960)

Break power is given for ships (in [kW])

$$P_B = [5\Delta^{2/3} V^3 (40 - 0.017L + 400(K-1)^2 - 12C_B)]/[15000 - 110N/\sqrt{L}]$$

where Δ[ton] is the displacement tonnage, V[m/s] is the ship speed, L[m] is the length of the ship, N[1/s] rotational speed of the propeller, C_B is the block coefficient and

K=1.06 for $0.64 \le C_B \le 0.80$

K=1.04 for $C_B < 0.64$

K=1.08-1.10 for $C_B > 0.80$

iii) Brown (1978) proposed the following formula for the effective power of naval ships:

(*) Note that: 1[HP]=745.7[W]

$$P_E = \Delta \cdot V\left(\frac{0.0571V}{\Delta^{1/6}} - 0.110\right) \text{ [kW]}$$

where displacement Δ is in [ton], ship speed V is in [kn].

iv) Kafalı (1988) derived a formula series 60 and similar type ships to obtain effective horse power*:

$$P_E = C \cdot \Delta \cdot V\left(\frac{V}{\sqrt{L}}\right)^2 [HP]$$

where displacement Δ is in [ton], ship speed V in [kn], L in [ft] and

$$C = (0.16\frac{B}{T} + 0.55)[0.05 - 0.03C_B + \frac{10^{(9.1C_B - 4.76)}}{1000}\left(\frac{V}{\sqrt{L}}\right)^{(10C_B - 5)}$$

v) Kupras (1983) gave the following effective horse power* for tankers;

$$P_E = C\frac{\Delta^{2/3}V^3}{427.1}[HP]$$

where displacement Δ in [ton], ship speed V in [kn], L in [m] ,and

$$C=0.987-0.0004L-0.275C_B$$

vi) For coastal ships, one can find additional info in Kafalı, K. (1988) "Gemilerin Dizaynı", İTÜ Kütüphanesi, Sayı 1365, pp.64-72.

b) Systematic (Standard) Hull Series

The initial attempts to investigate the effects of ship proportions and form on the resistance were due to Kent (1919) who developed merchant ship hull series and Taylor (1933) who based his hull form series on British armoured cruiser and used a number of 158 models in tow-tank experiments. (See: [1] Taylor, D. W. (1943) "The Speed and Power of Ships", 2nd rev. US Maritime Commission, and also in; [2] Baykal, R. & Dikili, C. (2002) "Gemilerin Direnci ve Makina Gücü", İTÜ İnşaat F. Matbaası, pp. 123-134)

In order to develop a more suitable series for single-screw merchant ships, SNAME initiated a project (Series 60) in 1948. Parallel to that of the SNAME, BSRA of UK developed independently another cargo ship series. One has to be aware of the fact that the usage of standard series for prediction of the effective power of a ship is deemed particularly for the hull forms derived by means of those standard series and should be carefully used for ships which do not have close similarity with those of the standard series. Here is the summary of the well-known standard series and their basic properties and characteristics:

1) Series 60 ([1] Todd, F. H. Et all (1957) "Series 60: The effect upon resistance and power of variation in ship proportions", Transactions SNAME, Vol. 65. [2] Sabit, A. S. (1971) "A

(*) Note that: 1[HP]=745.7[W]

tabulated analytical procedure based on regression analysis for the determination of the form coefficients and EHP for ships designed according to Series 60", European Shipbuilding, No.2)

For displacement, single screw, cruiser stern cargo ships with $0.6 \leq C_B \leq 0.8$, $5.5 \leq L/B \leq 8.5$, $2.5 \leq B/T \leq 3.5$. The speed range is: $0.1 \leq Fr \leq 0.27$. Calculated results are found to be lower than the test data.

2) BSRA cargo ship series ([1] Moor, D. I., (1961) "The BSRA Methodical Series- an overall presentation", Transactions RINA, Vol. 103. [2] Sabit, A. S., (1971) "Regression analysis of the resistance results of the BSRA series", International Shipbuilding Progress, No. 197.)

For displacement, single screw cargo ships with $0.59 \leq C_B \leq 0.80$, $2.1 \leq B/T \leq 6.4$. The speed range is: $0.15 \leq Fr \leq 0.24$.

3) UBC Trawler series (Calisal, S. M. And McGreer, D. (1990) "Model resistance tests of a systematic seriesof low L/B vessels", SNAME Marine Technology)

For Pacific fishing vessels with $0.53 \leq C_B \leq 0.61$, $2.6 \leq L/B \leq 4.0$, $2.0 \leq B/T \leq 3.0$. The speed range is: $0.2 \leq Fr \leq 0.43$.

4) İTÜ Balıkçı Gemisi Serisi (Kafalı, K., (1980) "Balıkçı Gemisi Formlarının İncelenmesi", İTÜ Gemi Enstitüsü Yayını No. 25.) For fishing vessels with $0.38 \leq C_B \leq 0.54$, $3.5 \leq L/B \leq 5.0$. The speed range is: $0.1 \leq Fr \leq 0.43$)

5) MARAD Series (Roseman, D. P., (1987) "Marad Systematic Series of full form ship models", SNAME Publication.)

For large tankers and bulk carriers with $0.80 \leq C_B \leq 0.875$, $4.5 \leq L/B \leq 6.5$, $3.0 \leq B/T \leq 4.75$. In addition to resistance, manoeuvring characteristics are also given.

6) US Naval Academy YP Series (Compton, R. H., (1986) "Resistance of systematic series of semi-planning transom-stern hulls", Marine Technology, Vol.23, No.4)

For semi-displacement, transom-stern hulls with $90 \leq \Delta/L \leq 160$, $4.0 \leq L/B \leq 5.2$. The speed range is: $0.1 \leq Fr \leq 0.6$ most likely used for patrol vessels. One should refrain from using this method when the design ship is outside of the range of the series.

7) Series 62/65 (Radojcic, D., (1984) "A statistical method for calculation of resistance of the stepless planning hulls", International Shipbuilding Progress, Vol. 31, No., 364.)

For planning (with high deadrise) transom-stern hulls with $2.4 \leq L/B \leq 6.7$, deadrise (between) 13.0^o-37.4^o. The results are recommended to be checked by other means as well.

(*) Note that: 1[HP]=745.7[W]