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CALCULATION OFDRAG FORCE OF TYPE 22 FRIGATE USING PTC MATHCAD PROGRAM

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***Abstract**: One of the basic problems of design, construction and operation of the ship is about ensuring the evolutionary qualities. This qualities depend largely on hydro and aerodynamic forces acting on the ship` s body and its movement which oppose.*
The theme of the study is to calculate the drag force of a ship caused by the waves, the wind, and also the ship towing power calculation, power efficiency propeller, and propeller machine. The specific characteristics of the ship belong to frigates class type 22. The calculation for case study was executed in Mathcad program.

***Key words**: drag, frigate, Froude number, wave, wind.*

Introduction

A ship should be designed to move efficiently through the water with a minimum of external forces which oppose.
Over a ship, moving through water at a certain speed, act the following categories of forces:

• gravity forces, whose resultant is $\overline{F_g}$ for size Δ;

• hydrostatic pressure forces whose resultant is $\overline{F_p}$ for size γV;

• hydrodynamic forces;

• inertial force $\overline{F_i}$ of mass vessel and entrained water moving determined by the speed variation in time;

• thrust force $\overline{T}$ of propellant (for motor vessels) or traction of cable trailer (for towed vessels).

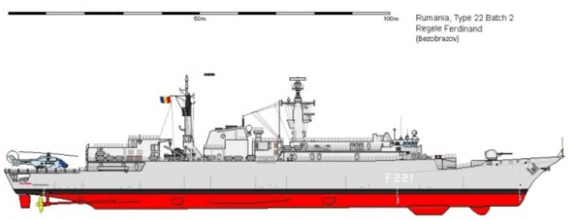

Figure 1. Frigate type 22

1. Initial data

The vessel used in the simulation, as a model, is a frigate type 22. Main characteristics of this ship are presented in table 1.

Tabel 1. Main characteristics of the 22 frigate

Length overall	$L_{WL} = 137.6\,m$
Beam	$B_{WL} = 14.75m$
Draught	$T_{WL} = 4.48m$
Displacement	$\Delta = 5300\ tons$
Abscissa center hull	$x_{BWL} = 3.934m$

Another initial data used for simulation are:

- the ratio between length and width:

$$L_{WL}/B_{WL} = 9.329m \tag{1}$$

- the ratio between beam and draught:

$$B_{WL}/T_{WL} = 3.292m \tag{2}$$

- the relative abscissa of hull center:

$$\frac{100 \cdot x_{BWL}}{L_{WL}} = 2.859 \tag{3}$$

- the ratio between length and volume:

$$\left(\frac{L_{WL}}{V^{\frac{1}{3}}}\right) = 65.583 \tag{4}$$

- block coefficient of hull:

$$C_B = 0.52 \tag{5}$$

- the longitudinal prismatic coefficient of finesse hull:

$$C_{LP} = 0.69 \tag{6}$$

- additional roughness coefficient:

$$C_{AR} = 0.3 \times 10^{-3} \tag{7}$$

- gravitational acceleration:

$$g = 9.81\ m/s^2 \tag{8}$$

- the correction coefficient for pressure resistance represent the ratio between beam and draught of the vessel at buoyancy:

$$\delta C_{P1} = 0.12\left(\frac{B_{WL}}{T_{WL}} - 2.5\right) \cdot 10^{-3} \tag{9}$$

$$\delta C_{P1} = 9.509 \times 10^{-5} \tag{10}$$

- the correction coefficient for pressure resistance to the geometrical shapes of cross sections of the extremities:

$$\delta C``_{P1} = -0.1 \times 10^{-3} \tag{11}$$

- resistance correction coefficient of friction, wetted surface curve:

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$$k_C = 1.025 \qquad (12)$$

2. Case study

We will determine the drag force parameters using Mathcad PTC program [5]. In practice, the main drag force, $R_i\,, i = \overline{1,q}$is determined corresponding to a range of speeds,$v_i\,, i = \overline{1,q}$, which includes the speed required by the design theme.

Determination of the main drag force is based on the equation (13):

$$R = C_R \cdot \frac{\rho \cdot v_i^2}{2} \cdot S \;[kN] \qquad (13)$$

where:

$$C_R = C_F + C_P = C_F + C_W + C_{Pv} \qquad (14)$$

$$S = L_{WL} \cdot T_{WL} \cdot \left(1.36 + 1.13 \cdot C_B \cdot \frac{B_{WL}}{T_{WL}}\right)[\mathrm{m}^2] \qquad (15)$$

C_R – coefficient for main drag force;

S – thesurface of the wetted hull, using Munaghan `s formula;

C_F – coefficient of friction resistance of the hull;

C_P – coefficient for pressure resistance.

We introduce in Mathcad the following relation:

- Reynolds number:

$$R_{ei} = \frac{v_i \cdot L_{WL}}{\upsilon} \qquad (16)$$

- resistance friction coefficient of plate smooth equivalent:

$$C_{FOi} = \frac{0.075}{(\log(Re_i) - 2)^2} \qquad (17)$$

- resistance friction coefficient of the hull:

$$C_{F1i} = k_C \cdot C_{FOi} + C_{AR} \qquad (18)$$

- Froude number:

$$Fr_i = \frac{v_i}{\sqrt{g \cdot L_{WL}}} \qquad (19)$$

- the difference of relative abscesses:

$$difere_i = \frac{100 x_{BWL}}{L_{WL}} - Abscisa_i [\%] \qquad (20)$$

- correction for the position of the center of hull length:

$$\delta C_{P2i} = a \cdot (3.355 \cdot Fr_i - 0.6) \cdot difere_i \cdot 10^{-3} \qquad (21)$$

Using the relation (21), the correction for vessel shape is:

$$\delta C_{P3i} = \delta C'_{P3i} + \delta C''_{P3i} \qquad (22)$$

The coefficient of pressure resistance is:

$$C_{Pi} = C_{PSdi} + \delta C_{Pi} + \delta C_{P2i} + \delta C_{P3i} \qquad (23)$$

Using the relations (18), (23), we determinate the coefficient for main drag force:

$$C_{Ri} = C_{Fi} + C_{Pi} \qquad (24)$$

The main drag force result from (15), (24):

$$R_i = C_{Ri} \cdot \frac{\rho \cdot v_i^2}{2} \cdot S \;[kN] \qquad (25)$$

The resistance due to appendices, where $C_{AP} = 0.25 \cdot 10^{-3}$:

$$R_{iAP} = C_{AP} \cdot \frac{\rho \cdot v_i^2}{2} \cdot S \;[kN] \qquad (26)$$

The drag force generated by waves, where $C_{VM} = 0.4 \times 10^{-3}$is :

$$R_{iVM} = C_{VM} \cdot \frac{\rho \cdot v^2}{2} \cdot S \;[kN] \qquad (27)$$

The drag force generated by the wind, where $k_{aer} = 0.02$ is:

$$R_{AAi} = k_{aer} \cdot R_i \;[kN] \qquad (28)$$

Using relations (26), (27), (28), the supplementary resistance force is:

$$R_{Si} = R_{iAP} + R_{iVM} + R_{AAi} \;[kN] \qquad (29)$$

The total dragforce is:

$$R_{Ti} = R_i + R_{Si} [kN] \qquad (30)$$

Power towing vessel using (30) is:

$$P_{Ei} = R_{Ti} \cdot v_i [kW] \qquad (31)$$

Using relation (30), we determinate:

- the power of the propeller:$P_{Di} = \frac{1.36 R_{Ti} \cdot v_i}{\eta_D}$ [CP] (32), where the efficiency propeller is$\eta_D = 0.6$.
- the power on the axis of the propeller: $P_{Bi} = \frac{1.36 R_{Ti} \cdot v_i}{\eta_D \cdot \eta_S}$[CP] (33), where the efficiency propeller axis is $\eta_S = 0.97$.
- the effective power to the main machine flange:$P_{Si} = \frac{1.36 R_{Ti} \cdot v_i}{\eta_D \cdot \eta_S \cdot \eta_G}$[CP] (34), where the efficiency reversing device and reduced rotational speed is $\eta_G = 0.9$.
- the power indicated on the main machine: $P_{ii} = \frac{1.36 R_{Ti} \cdot v_i}{\eta_D \cdot \eta_S \cdot \eta_G \cdot \eta_M}$[CP](35), where the machine's mechanical efficiency is $\eta_M = 0.8$.

The results for different value of speed, are systematically presents in table 2.

Table 2 Results using Mathcad PTC[5]

	5 kts	7 kts	10 kts	15 kts	20 kts
v	2.57	3.598	5.14	7.71	10.28
R_{ei}	3.041 × 10	4.257 × 10	6.081 × 10	9.122 × 10	1.1216 ×
C_{FOi}	1.784 × 10	1.707 × 10	1.63 × 10	1.548 × 10	1.494 × 1
C_{F1i}	2.129 × 10	2.049 × 10	1.97 × 10	1.887 × 10	1.831 × 1
Fr_i	0.07	0.098	0.14	0.21	0.28
C_{PSd}	$0.25 \cdot 10^{-3}$	$0.48 \cdot 10^{-3}$	$1.49 \cdot 10^{-3}$	$2.25 \cdot 10^{-3}$	$3.25 \cdot 10^{-3}$
$Abscis$	1	1	2	2.2	2.5
$difere$	1.859	1.859	0.859	0.659	0.359
δC_{P2i}	−5.093 ×	−3.785 ×	−8.416 ×	5.143 × 10	9.121 × 1
δC_{P3i}	-1×10^{-4}	-1×10^{-4}	-1×10^{-4}	-1×10^{-4}	-1×10^{-4}
C_{Pi}	−2.643 ×	9.663 × 1	1.401 × 1	2.297 × 1	3.336 × 1
C_{Ri}	1.865 × 1	2.146 × 1	3.371 × 1	4.183 × 1	5.168 × 1
R_i	12.82	28.916	92.708	258.844	568.438
R_{iAP}	1.719	3.369	6.875	15.468	27.499
R_{iVM}	2.75	5.39	11	24.749	43.999
R_{AAi}	0.256	0.578	1.854	5.177	11.369
R_{Si}	4.725	9.337	19.729	45.395	82.867
R_{Ti}	17.546	38.253k	112.437	304.238	651.304
P_{Ei}	45.092	137.63480	577.92705	2.34568 ×	6.69541 ×

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P_{Di}	102.208	311.972	1.31 × 10	5.317 × 1	1.518 × 1
P_{Ei}	105.37	321.621	1.35 × 10	5.481 × 1(	1.565 × 1
P_{Si}	107.52	328.185	1.378 × 1(	5.593 × 1(	1.596 × 1
P_{ii}	134.4	410.231	1723 × 10	6.991 × 1(	1.996 × 1
η_P	0.456				

CONCLUSION

The drag force of a ship depends on her velocity. Therefore, drag force is always specified at a particular velocity. Furthermore, we understand that the drag will depend on the condition of the sea. We cannot expect that the drag force of a ship in a rough sea to be the same as the drag force of the ship in a calm sea. Also, operating conditions for ship must be specified. Therefore, drag force of a ship is defined as the force required towing the ship in calm water at a constant velocity.
The table 2 shows that at a slow or medium speed of frigate, the wavemaking resistance is small compared with frictional resistance. At high speeds, the wavemaking resistance increases and can be 50 - 60% of total drag force.
An additional resistance, which may be considerable, is the wind force acting on the ship` s body. Even is a small resistance component, it is important because it could influence the aerodynamic shape.

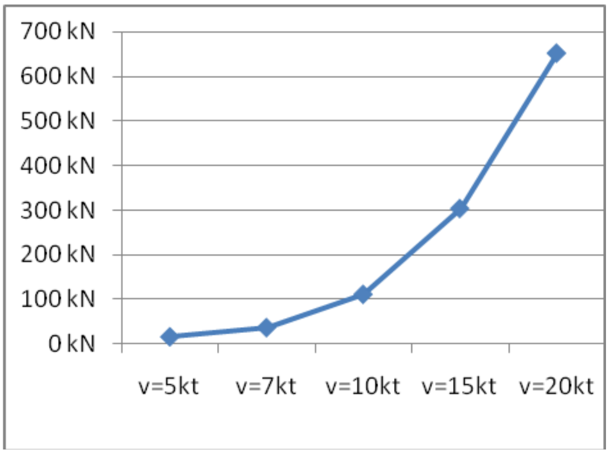

Figure 2 The graphic of total resistance of the frigate

Using the relation (31), thefigure 2, shows that for a speed of 5 or 7 knots, the variation oftotal drag forceis not major. Starting with 13 knots speed, the resistanceforce is tripled, reaching 30 times higher.

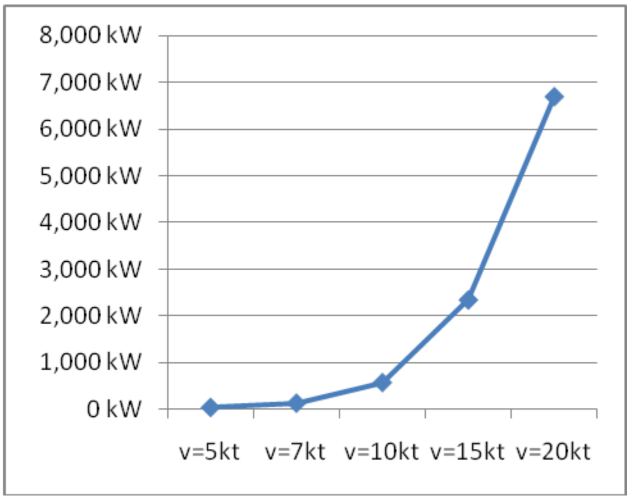

Figure 3 The graphic of effective power of the frigate

The drag force variation caused by the variation of the speed, waves, the wind etc., further lead to a change in the propeller's speed and, consequently, the drive power[3].Figure 3 shows a different value of power for different value of speed. For example, for 5 knots, the power used is 45 kW, but once we increase the speed (for 10 knots we have 570 kW), the power increases too. This is the reason that the ship's propulsion system

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should be adapted to these changes in load because once increased the speed of frigate, the power of towing, the power of propeller and machine increase too.
This type of calculation of the drag force of a ship is necessary for choose the drive motor and the main elements of the axial line.

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