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Establishment of criterion equation of water flow phenomenon around the ship

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Abstract : Applying similarity theorem on the study of water flow around ship's hull, similarity criterias are obtained, by which it can be determined physical size values of the prototype vessel, based on measurements performed on the model ship..

1. Introduction

According to the theory of similarity on a single scale, it can be established a complex relationship between the physical sizes contributing to the evolution of studied phenomenon. This relationship is set by „Π" theorem, which represents a connection between similarity criterias obtained between the physical sizes of the analyzed phenomenon.

$$\Phi(\Pi_1, \Pi_2, \ldots\ldots.., \Pi_{n-k}) = 0 \tag{1.1}$$

This ecuation consisting all the similarity criterias is called criterial ecuation and represents the first study stage on the phenomenon model.

2. Establishment of Criterion Equation of Water Flow Phenomenon Around the Ship

In the first phase of the study it is determined the physical quantities which are dependant on the flow of water around the ship's hull:

$$f(L, B, T, \delta, d, n, v, \rho, \eta, g, R) = 0 \tag{2.1}$$

where:
L – ship length [m];
B – overall breadth [m];
T – ship draught [m];
δ – boundary layer thickness [m];
d – propeller diameter [m];
n – propeller speed [rot/s];
v – propeller transfer speed [m/s];
ρ – water density [kg/m^3];
η – water dynamic viscosity [kg/ms];
g–gravitational acceleration [m/s^2];
R – ship advance resistance [$kg \cdot m/s^2$].

As main physical sizes it is chosen: propeller diameter d, water density ρ , and water velocity through the propeller disk. According to Π theorem, it will result n-k = 11-3= 8 as non-dimensional complex sizes. In the first phase, relation 2.1 will have the following form:

$$\Pi = \rho^{x_1} \cdot v^{x_2} \cdot d^{x_3} \cdot n^{x_4} \cdot \eta^{x_5} \cdot g^{x_6} \cdot L^{x_7} \cdot B^{x_8} \cdot T^{x_9} \cdot \delta^{x_{10}} \cdot R^{x_{11}} \qquad (2.2)$$

Operating with measuring units in SI for physical sizes from relation 2.2 it will be obtained:

$$\Pi = \left(\frac{kg}{m^3}\right)^{x_1} \left(\frac{m}{s}\right)^{x_2} m^{x_3} \left(\frac{1}{s}\right)^{x_4} \left(\frac{kg}{ms}\right)^{x_5} \left(\frac{m}{s^2}\right)^{x_6} m^{x_7} m^{x_8} m^{x_9} m^{x_{10}} \left(\frac{kg \cdot m}{s^2}\right)^{x_{11}} \qquad (2.3)$$

or $[\Pi] = kg^{x_1+x_5+x_{11}} \cdot m^{-3x_1+x_2+x_3-x_5+x_6+x_7+x_8+x_9+x_{10}+x_{11}} \cdot s^{-x_2-x_4-x_5-2x_6-2x_{11}}$

The condition of homogeneity of the dimensional relation leads to the following system of equations:

$$\begin{cases} x_1 + x_6 + x_{11} = 0 \\ -3x_1 + x_2 + x_3 - x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} + x_{11} = 0 \\ -x_2 - x_4 - x_5 - 2x_6 - 2x_{11} = 0 \end{cases} \qquad (2.4)$$

The dimensional matrix of variables is constructed:

$$\begin{array}{cccccccccccc} & \rho & v & d & n & \eta & g & L & B & T & \delta & R \\ Kg & 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 \\ m & -3 & 1 & 1 & 0 & -1 & 1 & 1 & 1 & 1 & 1 & 1 \\ s & 0 & -1 & 0 & -1 & -1 & -2 & 0 & 0 & 0 & 0 & -2 \end{array} \qquad (2.5)$$

$$\left\| \begin{array}{ccccccccccc} 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 \\ -3 & 1 & 1 & 0 & -1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & -1 & 0 & -1 & -1 & -2 & 0 & 0 & 0 & 0 & -2 \end{array} \right\| \qquad (2.6)$$

Applying Kronecker's theorem, it is calculated the rank of dimensional matrix, which is of the order 3:

$$\begin{cases} 1 \quad 0 \quad 0 \\ -3 \quad 1 \quad 1 \quad = \quad 1 \\ 0 \quad -1 \quad 0 \end{cases} \qquad (2.7)$$

Since all the minors of ordinal 4 are null, it results that the main determinant is of ordinal 3 and the rank is r=3. System 2.4 is usually solved by Cramer's rule and system solution matrix is obtained:

$$\begin{array}{c|ccccccccccc} & x_1 & x_2 & x_3 & x_4 & x_5 & x_6 & x_7 & x_8 & x_9 & x_{10} & x_{11} \\ & \rho & v & d & n & \eta & g & L & B & T & \delta & R \\ \Pi_1 & 0 & -1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \Pi_2 & -1 & -1 & -1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ \Pi_3 & 0 & -2 & 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ \Pi_4 & 0 & 0 & -1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ \Pi_5 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ \Pi_6 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ \Pi_7 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ \Pi_8 & -1 & -2 & -2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{array} \tag{2.8}$$

$$\begin{Vmatrix} 0 & -1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & -1 & -1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -2 & 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ -1 & -2 & -2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{Vmatrix} \tag{2.9}$$

The number of lines in the above matrix represents the number of non-dimensional complexes which fully describe the phenomenon studied. In case of the water flow around ship's hull, non-dimensional complexes are the following:

$$\Pi_1 = v^{-1} \cdot d^1 \cdot n^1 = \frac{nd}{v};\ \Pi_2 = \rho^{-1} \cdot v^{-1} \cdot d^{-1} \cdot \eta^1 = \frac{\eta}{\rho v d};\Pi_3 = v^{-2} \cdot d^1 \cdot g^1 = \frac{gd}{v^2};$$
$$\Pi_4 = d^{-1} \cdot L^{-1} = \frac{L}{d};\ \Pi_5 = d^{-1} \cdot B^1 = \frac{B}{d};\ \Pi_6 = d^{-1} \cdot T^1 = \frac{T}{d}; \tag{2.10}$$
$$\Pi_7 = d^{-1} \cdot \delta^1 = \frac{\delta}{d};\quad \Pi_8 = \rho^{-1} \cdot v^{-2} \cdot d^{-2} \cdot R = \frac{R}{\rho v^2 d^2}$$

Thus, function 2.1 becomes a function of 8 non-dimensional complexes which represents the criterial ecuation of the studied phenomenon:

$$\Phi\left(\frac{nd}{v}, \frac{\eta}{\rho v d}, \frac{gd}{v^2}, \frac{L}{d}, \frac{B}{d}, \frac{T}{d}, \frac{\delta}{d}, \frac{R}{\rho v^2 d^2}\right) = 0 \tag{2.11}$$

From this equation, it is deducted the physical size intended to be calculated, namely ship's resistance.

$$\mathrm{R} = \rho v^2 d^2 \Phi_1\left(\frac{nd}{v}, \frac{\eta}{\rho v d}, \frac{gd}{v^2}, \frac{L}{d}, \frac{B}{d}, \frac{T}{d}, \frac{\delta}{d}\right) \tag{2.12}$$

3. Conclusion

Knowing the similarity criteria of the water flow phenomenon around the ship's hull and having physical sizes results on the single scale model it can be easily determined the value of these physical sizes on the prototype ship for which this study was made. The relationships established between physical sizes on the model and those on the prototype are called the law of the model.

References

[1] Vasilescu Al., A., *Analiză dimensională şi teoria similitudinii,* Editura Academiei, Bucureşti, 1969.
[2] Reynolds, A., J., *Curgeri turbulente în tehnică,* Editura tehnică, Bucureşti, 1982.
[3] Bella, D., I., *Dinamica della nave, vol I,* Editore Briano, Genova, 1950.
[4] Carafoli, E , Constantinescu, V. N., *Dinamica fluidelor incompresibile,* Editura Academiei, Bucureşti, 1981, p. 114-135.