THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE XI – SHIPBUILDING. ISSN 1221-4620
2017

SMALL SHIPS RESISTANCE ESTIMATION IN PLANNING DOMAIN

Dan Obreja
"Dunarea de Jos" University of Galati,
Faculty of Naval Architecture, Galati, Domneasca
Street, No. 47, 800008, Romania,
E-mail:dan.obreja@ugal.ro

ABSTRACT

The present paper investigates a theoretical method proposed by Mordvinov in order to estimate the small ship resistance in the planning domain. The practical evaluation of this problem with satisfactory accuracy constitutes an important element in the initial design phase. The computer code PHP-NM-RI-G, realised in the Research Centre of the Naval Architecture Faculty of "Dunarea de Jos" University of Galati was described and run in order to compute the resistance performance of a small ship in planning domain. The components of the planning ship resistance were determined and a comparative analysis was performed. The computer code may be applied in the initial design process of planning small ships.

Keywords: small ships, resistance, planning domain

1. INTRODUCTION

One of the most important hydrodynamics performances of the planning small ships is the ship resistance.

The planning operating mode may be determined according to the Froude number value Fn_∇, defined on the basis of the ship volumetric displacement ∇ and the ship speed v, by using the relation

$$Fn_\nabla = \frac{v}{\sqrt{g \times \nabla^{1/3}}} \quad (1)$$

where g is the gravitational acceleration.

The planning domain is fulfilled if:

$$Fn_\nabla > 3 \quad (2)$$

In this paper, the method proposed by Mordvinov ([1], [2]) was presented and applied in order to determine the ship resistance of a small monohull, with 9.2 m in length, in the planning domain.

In this case, the *total ship resistance* R_T may be evaluated by using the relation ([1], [2])

$$R_T = R + R_{APP} + R_A \quad (3)$$

where R is the bare hull resistance, R_{APP} is the appendage resistance and R_A is the aerodynamic resistance. In the following chapter, the components of the total resistance will be investigated.

2. THEORETICAL METHOD

The *bare hull resistance* is calculated by means of the relation ([1], [2])

$$R = R_F + R_P \quad (4)$$

where R_F is the frictional resistance of the equivalent plane plate and R_P is the pressure resistance.

The *frictional resistance* is determined by the following expression

$$R_F = \left(C_{F_0} + \Delta C_F\right) \times \frac{\rho \times v^2}{2} \times S \quad (5)$$

where, C_{F_0} is the frictional resistance coefficient of the equivalent plane plate, ΔC_F is an additional coefficient due to the roughness of the hull and holes [1], ρ is the water density and S is the wetted surface area of the planning ship.

The frictional resistance coefficient of the equivalent plane plate is determined on the basis of the Prandtl-Schlichting relation

$$C_{F_0} = \frac{0.455}{\left(\log \mathrm{Re}_{l_w}\right)^{2,58}} \tag{6}$$

depending on the Reynolds number

$$\mathrm{Re}_{l_w} = \frac{v \times l_w}{\nu} \tag{7}$$

where l_w is the wetted length of the equivalent plane plate and ν is the kinematic viscosity of the water.

The wetted surface area of the planning ship may be determined by means of the relation

$$S = \lambda \times B^2 \tag{8}$$

where B is the breadth of the small ship and the relative aspect ratio λ is defined by using the following expression

$$\lambda = l_w / B \tag{9}$$

The relative aspect ratio λ may be determined by using the diagram presented in Figure 1 [1], depending on the coefficient m_Δ and the Froude number Fn_B, computed on the basis of the following relations

$$m_\Delta = x_G / B \tag{10}$$

$$Fn_B = \frac{v}{\sqrt{g \times B}} \tag{11}$$

where x_G is the longitudinal centre of gravity.

The *pressure resistance* may be determined by formula ([1], [2])

$$R_P = g \times \Delta \times tg\alpha \tag{12}$$

where Δ is the ship displacement.

The attack angle α may be estimated by means of the relation

$$\alpha = g \times \Delta / \left(\frac{\rho \times v^2}{2} \times B^2 \times F\right) \tag{13}$$

where the factor F is given by the expression

$$F = \frac{0.7 \times \pi \times \lambda}{1 + 1.4 \times \lambda} + \lambda^2 \times \frac{\lambda - 0.4}{\lambda + 0.4} \times \frac{1}{Fn_B^2} \tag{14}$$

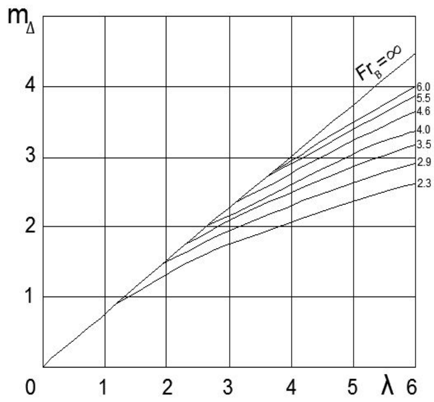

Fig.1. Relative aspect ratio λ

The *appendage resistance* is calculated by means of the relation ([1], [2])

$$R_{APP} = k_{APP} \times R \tag{15}$$

where k_{APP} is the appendages coefficient, depending on the complexity of the appendages and the Froude number Fn_∇ [1].

The *aerodynamic resistance* may be calculated by using the expression ([1], [2])

$$R_A = C_A \times \frac{\rho_a \times \left(v + v_v\right)^2}{2} \times S_e \tag{16}$$

where C_A is the aerodynamic coefficient, ρ_a is the air density, v_v is the wind speed and S_e is the aerodynamic surface area (projected on the midship section).

By using the presented theoretical model, a computer code PHP-NM-RI-G was developed at the Research Centre of the Naval Architecture of "Dunarea de Jos" University of Galati, in order to perform practical applications on the planning ships resistance evaluation, of monohull type ([3], [4]). In the next chapter, a practical application is performed.

3. PRACTICAL EVALUATION

In this chapter, the ship resistance evaluation was exemplified, for a planning ship having 9.2 m in length and running in fresh water in the domain speeds between 25 Kn and 32 Kn.

The input data module of the computer code PHP-NM-RI-G comprises the main characteristics of the small ship and the operating conditions, which are presented in Table 1.

Table 1. Main characteristics of the planning ship and operating conditions

Ship characteristics and operating conditions	Value
Length of waterline, L_{WL}	9.2 m
Breadth, B	2.2 m
Volumetric displacement, ∇	4.6 m^3
Longitudinal centre of gravity (from transom), x_G	4.15 m
Wetted surface area (bare hull), S	12 m^2
Appendages coefficient, k_{APP}	15 %
Aerodynamic frontal surface area, S_e	6.5 m^2
Aerodynamic coefficient, C_A	0.9
Design speed of the planning ship, v	29 Kn
Wind speed, v_v	8 m/s

The diagrams of the planning ship resistance components (frictional, pressure, appendages and aerodynamic) are presented in the Figures 2-5.

Figure 6 depicts the diagram of the total ship resistance. Also, the total ship resistance components, according to relation (3) are shown in Figure 7. All the diagrams have the ship speed on the abscissa.

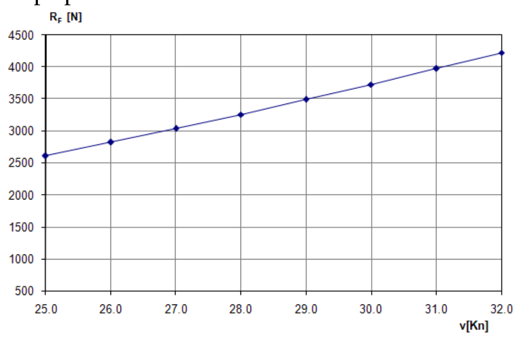

Fig.2. Frictional resistance

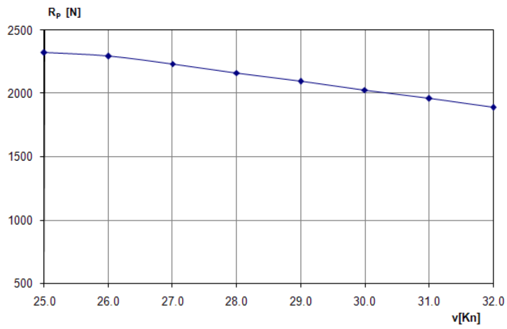

Fig.3. Pressure resistance

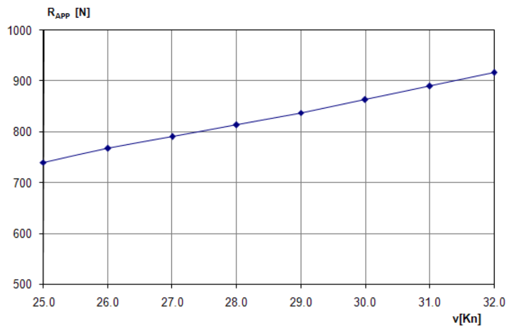

Fig.4. Appendages resistance

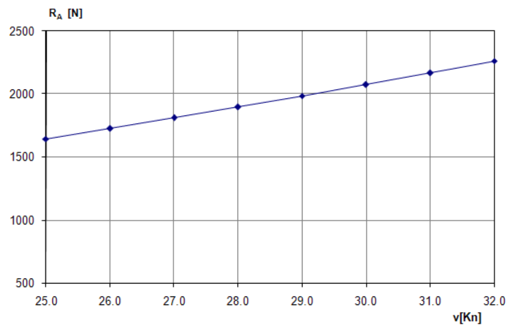

Fig.5. Aerodynamic resistance

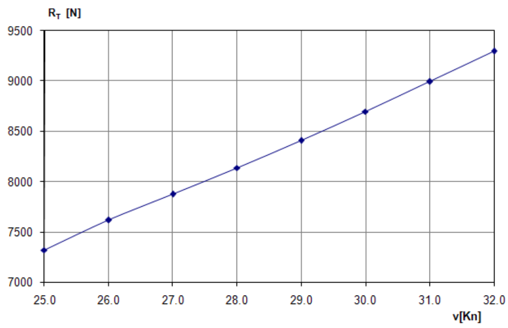

Fig.6. Total ship resistance

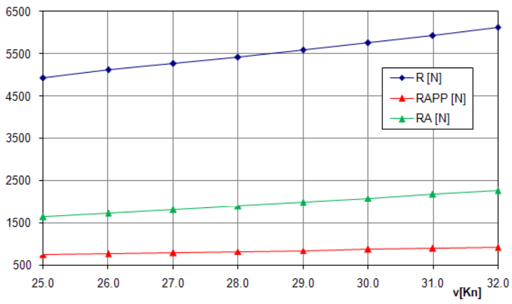

Fig.7. Total ship resistance components

The analysis of the previous figures allows the following observations:

- the frictional resistance increase with ship speed and is the most important component of the total resistance;
- due to the planning domain ($Fn_\nabla > 3$), the pressure resistance component decrease with ship speed increasing;
- the appendages resistance and aerodynamic resistance increase with ship speed;
- all the curves of the ship resistance components are monotones (without local maximum values).

4. CONCLUDING REMARKS

The ship resistance represents one of the most important hydrodynamics performances of the planning ships. The practical evaluation of this problem with satisfactory accuracy constitutes an important element in the initial design phase.

An efficient method proposed by Mordvinov was used in order to estimate the ship resistance of a small monohull, in the planning domain.

The total resistance includes the bare hull resistance, appendage resistance and aerodynamic resistance. The bare hull resistance is calculated by summing the frictional resistance and the pressure resistance.

Based on the Mordvinov method, a computer code was developed in the Research Centre of the Naval Architecture Faculty. A practical evaluation of the resistance performance was exemplified, for a planning ship having 9.2 m in length and running in fresh water in the domain speeds between 25-32 Kn.

The comparative analysis of the ship resistance components reveals the high value of the frictional resistance (41.5 % from total resistance, at the design speed). Also, an important contribution of pressure resistance (24.9 %) and aerodynamic resistance (23.6 %) was observed. The contribution of the appendages resistance is 10 % related to the total ship resistance.

The PHP software platform is used both in teaching applications and research activities, related to the hydrodynamics performances estimation of the ships, in initial design stage.

Acknowledgements

The author thanks Mr. Alexandru Andoniu and Mr. Dorin Iulian Chiracu, who have developed the computer code in Java language.

The research was supported by the Research Centre of the Naval Architecture Faculty, in "Dunarea de Jos" University of Galati, which is greatly acknowledged.

REFERENCES

[1]. **Mordvinov, B.G.,** *Spravocinic po malotonnajnomu sudostroeniu*, Sudostroenie Publishing House, St. Petersburg, 1988 (in Russian).

[2]. **Obreja, C.D.**, *"Hydrodynamic particularities of the small ships design"*, The University Foundation "Dunarea de Jos" Publishing House, Galati, 2004 (in Romanian).

[3]. **Obreja, C.D., Pacuraru, S.**, *"Small ships hydrodynamics. Numerical Laboratory"*, The University Foundation "Dunarea de Jos" Publishing House, Galati, 2016 (in Romanian).

[4]. **Obreja, C.D.**, **Andoniu, Al., Chiracu, D.I.,** *"PHP NM-RI-G computer code"*, The Research Centre of the Naval Architecture Faculty, "Dunarea de Jos" University of Galati, 2012.

Paper received on December 10th, 2017

