ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE XI – SHIPBUILDING. ISSN 1221-4620
2015

PRACTICAL EVALUATION OF HIGH-SPEED ROUND BILGE CATAMARAN RESISTANCE

Dan Obreja
"Dunarea de Jos" University of Galati,
Faculty of Naval Architecture, Galati, 47
Domneasca Street, 800008, Romania,
E-mail:dan.obreja@ugal.ro

Dorin Iulian Chiracu
"Dunarea de Jos" University of Galati,
Faculty of Naval Architecture, Galati, 47
Domneasca Street, 800008, Romania,
E-mail: dorin.chiracu@gmail.com

ABSTRACT

The accurate practical evaluation of the high-speed catamaran resistance in still water is a crucial problem in naval architecture. Even if a lot of research was carried out in this field, the accuracy of the speed-power prediction depends on the hull shapes and the typical restrictions of the methods. The present paper examines the results obtained using an in house computer code, developed in order to calculate the round-bilge catamaran resistance. The wave resistance coefficient was calculated on the basis of typical regression coefficients provided in the scientific literature. The computer code may be used in order to estimate the high-speed round bilge catamaran resistance in initial design stages.

Keywords: resistance, catamaran, round bilge, computer code.

1. INTRODUCTION

In the initial design stages of high speed catamarans, it is necessary to predict the resistance performance with a satisfactory level of confidence. As a consequence, specific initial hydrodynamic computer tools must be generated and an accurate practical evaluation must be obtained.

Although a considerable amount of research was performed in this field, the accuracy of the speed-power prediction depends on the hull shapes and the typical restrictions of the methods.

During the last decade, important progress was made in this field. We can observe that different computer methods were introduced, depending on the hull shapes. Specific tools were generated for round bilge and chine shapes.

The paper of Sahoo, Browne and Salas [2] proposes the regression coefficients to compute the wave resistance of the catamaran and demi-hull configurations, with round bilge shapes. The systematic model series used by the authors were based on the typical forms of the high-speed ferry industry in Australia. The regression analysis was performed on the basis of CFD results obtained by means of the SHIPFLOW code, for a range of Froude numbers between 0.4 and 1.

The paper of Sahoo, Salas and Schwetz [3] examines the most important methods used in order to predict the deep water wave resistance of the catamarans with round bilge and chine shapes. A regression model was developed to determine the form factor of catamaran ($1+\gamma k$), as a function of the different geometrical characteristics and the demi-hull form factor ($1+k$), based on Molland's series [1].

The paper of Schwetz and Sahoo [4] proposes ten models of round bilge and chine catamaran series, in order to determine the variation of the wave resistance coefficient depending on the basic hull parameters.

On the basis of the regression coefficients proposed by the authors mentioned above, an in house computer code was performed in order to determine the high-speed catamaran resistance, having a round bilge. A summary of the mathematical model is discussed in the following chapter.

2. MATHEMATICAL MODEL

The computation of the catamaran resistance poses a complex problem due to the interference effects between the demi-hulls. Thus, the flow around a symmetric demi-hull is asymmetric because of the influence of the other demi-hull (body interference). On the other hand, the interference effect on wave resistance may be observed as a result of the existence of two demi-hulls (wave interference).

Applying the ITTC'78 method, the catamaran resistance coefficient C_{Tcat} may be calculated by means of the following relation

$$C_{Tcat} = (1+\gamma \cdot k)C_F + \tau \cdot C_w \qquad (1)$$

where C_F is the frictional resistance coefficient of the demi-hull in isolation, C_w is the wave resistance coefficient of the demi-hull in isolation, γ is the viscous interference factor, and τ is the wave interference factor defined on the basis of the relation

$$\tau = \frac{C_{wcat}}{C_w} \qquad (2)$$

For the demi-hull in isolation the interference factors γ and τ have unitary values. Furthermore, by applying relation (2), the catamaran wave resistance coefficient C_{wcat} may be calculated by the relation

$$C_{wcat} = \tau \cdot C_w \qquad (3)$$

The form factor of the catamaran ($1+\gamma k$) is determined by means of the relation proposed by Sahoo et al. [3], on the basis of Molland's series [1], depending on the following parameters

$$(1+\gamma \cdot k) = f\left(\frac{B}{T};\frac{L}{\nabla^{1/3}};\frac{s}{L};(1+k)\right) \qquad (4)$$

where L is the waterline length, B is the demi-hull beam, T is the draught, ∇ is the volumetric displacement of the demi-hull, and s is the catamaran demi-hull spacing. The regression coefficients of the function (4) are shown in reference [3].

The frictional resistance coefficient C_F of the demi-hull in isolation may be calculated using the ITTC'57 ship model correlation line

$$C_F = \frac{0.075}{(\log R_n - 2)^2} \qquad (5)$$

where R_n is the Reynolds number, depending on the catamaran speed v and the kinematic viscosity of the fluid ν

$$R_n = \frac{vL}{\nu} \qquad (6)$$

The wave resistance coefficients of the catamaran C_{wcat} and of the demi-hull in isolation C_w were proposed by Sahoo et al. ([2], [3]) as follows:

$$\begin{aligned} C_{wcat} &= e^{c1} \cdot \left(\frac{L}{B}\right)^{c2} \cdot \left(\frac{B}{T}\right)^{c3} \cdot (C_B)^{c4} \cdot F_1 \\ F_1 &= \left(\frac{L}{\nabla^{1/3}}\right)^{c5} \cdot (i_E)^{c6} \cdot \beta^{c7} \cdot \left(\frac{s}{L}\right)^{c8} \end{aligned} \qquad (7)$$

$$\begin{aligned} C_w &= e^{c1} \cdot \left(\frac{L}{B}\right)^{c2} \cdot (C_B)^{c3} \cdot F_2 \\ F_2 &= \left(\frac{L}{\nabla^{1/3}}\right)^{c4} \cdot (i_E)^{c5} \cdot \beta^{c6} \end{aligned} \qquad (8)$$

where C_B is the block coefficient of the demi-hull, i_E is the half angle of entrance and β is the dead rise angle at amidships. The regression coefficients c_i of the functions (7) and (8) are seen in references [2], [3].

The total resistance of the catamaran may be determined by means of the relation

$$R_{Tcat} = \frac{1}{2} C_{Tcat} \cdot \rho \cdot v^2 \cdot S_w \qquad (9)$$

where ρ is water density and S_w is the wetted surface area of the catamaran, given by the relation found by Mumford

$$S_w = 1.7LT + \frac{\nabla}{T} \qquad (10)$$

or by the following expression

$$S_w = \frac{\nabla}{B}\cdot[\frac{1.7}{C_B - 0.2\cdot(C_B - 0.65)} + \frac{B}{T}] \quad (11)$$

This algorithm may be applied using the restrictions given in Table 1, where F_n represents the Froude number.

Table 1. Range of parameters

L/B	10 ... 15
B/T	1.5 … 2.5
C_B	0.4 … 0.5
$L/\nabla^{1/3}$	8 … 12
s/L	0.2 … 0.4
i_E	4 … 11
β	23 … 45
F_n	0.4 … 1

3. PRACTICAL ASSESSMENT

On the basis of the mathematical model described in the previous chapter, a computer code was applied in order to calculate the high-speed round bilge catamaran resistance. The code was used in this paper in order to analyse the resistance performance of the three catamaran models in the series of Sahoo et al. [2]. The geometrical parameters, the main dimensions, and the hydrostatics of the models are shown in Tables 2, 3 and 4. The body plans of the models are depicted in Figures 1, 2 and 3 [2]. The speed domain was selected within the range 20-40 Kn.

Table 2. Main parameters of the models

Model	L/B	B/T	C_B	$L/\nabla^{1/3}$
1	15	1.5	0.4	9.45
4	15	2.5	0.4	11.2
6	12.5	2.5	0.45	9.54

Table 3. Main dimensions of the models

Model	L [m]	B [m]	T [m]	i_E [deg]	β [deg]
1	15	1.5	0.4	5.43	42.99
4	15	2.5	0.4	4.	23.32
6	12.5	2.5	0.45	8.6	30.37

The evolution of the catamaran wave resistance coefficient C_{wcat} depending on speed, for the models 1, 4 and 6 is seen in Figures 4, 5 and 6.

A similar representation of the catamaran resistance R_{Tcat} for the three models is shown in Figures 7, 8 and 9.

The evolution of the wave resistance coefficient of the demi-hull in isolation C_w depending on the speed, for the models 1, 4 and 6 may be seen in Figures 10, 11 and 12.

Table 4. Hydrostatics of the models

Model	Δ [t]	∇ [m^3]	S_w [m^2]
1	151.93	148.22	246.1
4	91.08	88.86	181.97
6	147.69	144.09	231.71

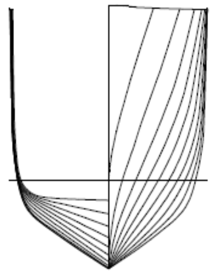

Fig.1. Body plan of model 1

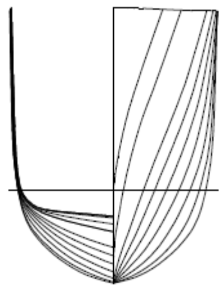

Fig.2. Body plan of model 4

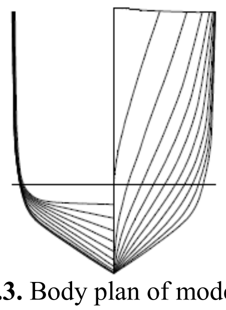

Fig.3. Body plan of model 6

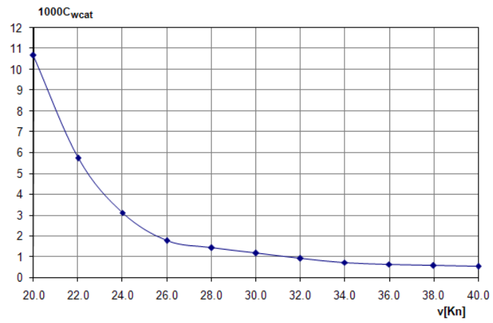

Fig.4. C_{wcat} of model 1

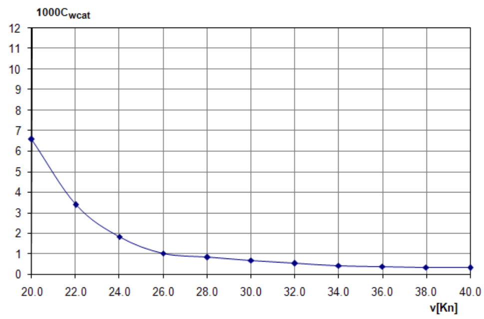

Fig.5. C_{wcat} of model 4

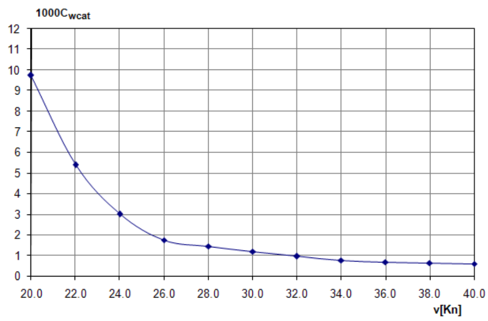

Fig.6. C_{wcat} of model 6

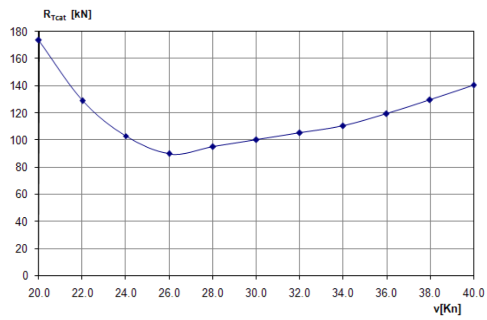

Fig.7. R_{Tcat} of model 1

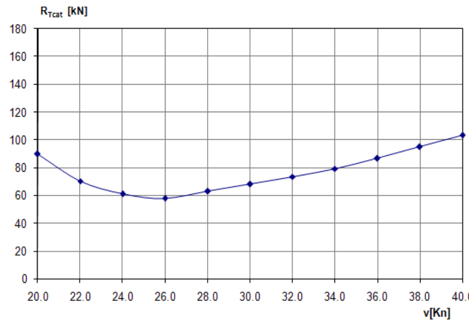

Fig.8. R_{Tcat} of model 4

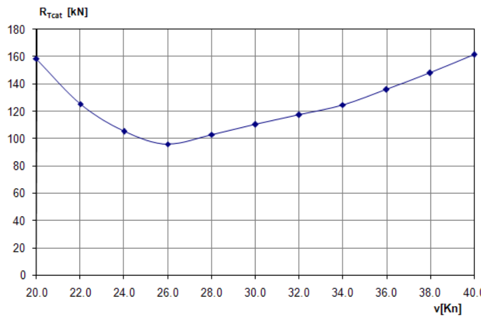

Fig.9. R_{Tcat} of model 6

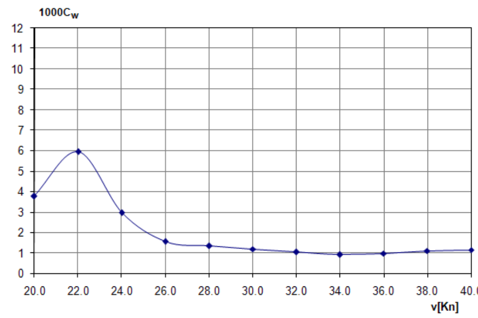

Fig.10. C_w of model 1

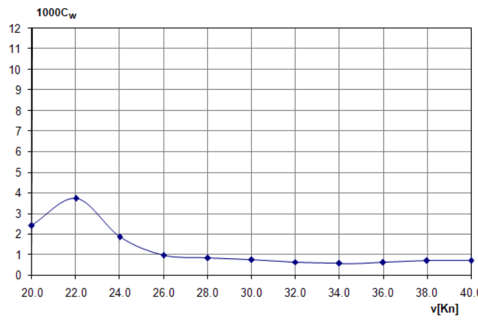

Fig.11. C_w of model 4

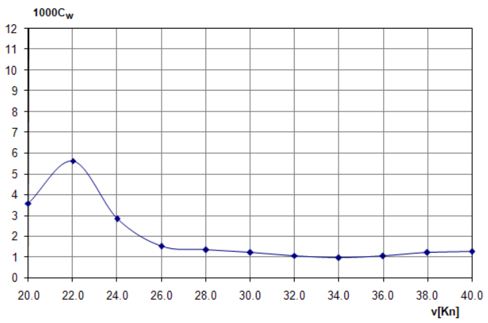

Fig.12. C_w of model 6

On the basis of the computer code results, the following observations may be made:

- the values of C_{wcat} decrease when the speed increases;
- for all the models examined, the minimum value of R_{Tcat} is obtained for the speed v=26 kN;
- for all the models, the maximum value of C_w (for the demi-hull in isolation) is obtained at the speed v=22 kN;
- the minimum values of the function R_{Tcat} are obtained for the model 4, correlated with the largest value of the *L/B* ratio and the smallest values of C_B and S_w.

4. CONCLUDING REMARKS

It goes without saying that the prediction of the catamaran resistance performance, with a satisfactory level of confidence, for the initial design stages is extremely necessary. Hence, specific hydrodynamic computer codes must be created and tested in order to obtain an accurate practical assessment.

The results obtained using an in-house computer code, developed in order to calculate the high-speed round-bilge catamaran resistance were examined in this paper.

Depending on the hull forms, different computer methods were introduced and presented in the scientific literature, and specific tools were generated for round bilge and single or hard chine forms.

Due to the interference effects between the demi-hulls, the computation of the catamaran wave resistance poses a difficult problem.

In this paper, the results obtained on the basis of an in-house computer code, in order to determine the high-speed round bilge catamaran resistance, were described.

The catamaran resistance coefficient was obtained by applying the ITTC'78 method.

The frictional resistance coefficient of the demi-hull in isolation depends on the Reynolds number, and was calculated by means of the ITTC'57 ship model correlation line.

The wave resistance coefficients of the catamaran and of the demi-hull in isolation were calculated on the basis of the relations and regression coefficients proposed by Sahoo et al. ([2], [3]).

The regression model developed by Sahoo et al. [3] based on Molland's series [1] was used to calculate the catamaran form factor.

A computer code was used in order to calculate the high-speed round bilge catamaran resistance. This code was employed in order to analyse the resistance performance of three catamaran models in the series of Sahoo et al. [2].

This computer code may be used at the preliminary stages of a high-speed round bilge catamaran design, in order to obtain the optimum values of the main dimensions and geometrical parameters, related to the resistance performance.

Acknowledgements

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

REFERENCES

[1]. **Molland, A.F., Wellicome, J.F., Couser, P.R.**, *"Resistance experiments on a systematic series of high speed displacement catamaran forms: variation of length-displacement ratio and breadth-draft ratio"*,

Ship Science Report, No. 71, University of Southampton, UK, 1994.

[2]. **Sahoo, P.K., Brown, N.A., Salas, M.**, *"Experimental and CFD study of wave resistance of high-speed round bilge catamaran hull forms"*, Proceedings of 4th International Euro Conference on High Performance Marine Vehicles, Rome, Italy, 2004.

[3]. **Sahoo, P.K., Salas, M., Schwetz, A.**, *Practical evaluation of resistance of high-speed catamaran hull forms-part I"*, Ships and offshore structures, Vol.2, Issue 4, pp. 307-324, 2007.

[4]. **Schwetz, A., Sahoo, P.K.**, *Wave resistance of semi-displacement high speed catamarans through CFD and regression analysis"*, Proceedings of 3th International Euro Conference on High Performance Marine Vehicles, Bergen, Norway, pp. 355-368, 2002.

Paper received on September 15th, 2015