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CFD STUDY ON PARAMETERIZED BARGE HULL

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ABSTRACT

The present study is focused on an improvement of the Europe 2B barge hull forms. The geometry of the barge shape is parameterized so that the model form can be modified according to several variables seeking the minimal barge resistance condition. Barge hydrodynamic resistance is assessed by CFD techniques, based on the FVM method. For the improved barge shape results a decrease of about 2% for the barge resistance.

Keywords: DS-draught survey, barge resistance, CFD, shape improvement

1. INTRODUCTION

For the river cargo transport the barges are still the main option, because the water is shallow and the rivers have bends that are not suitable for large ships. So, the dimensions of a river ship must be quite small compared to a maritime ship, without putting away the necessity of having optimized the hull shape for a smaller ship resistance.

In order to improve the hull shape, in terms of fuel consumption efficiency, the naval architect needs an effective tool for modelling and parametric changes of the hull form. For an efficient hull shape design, a multi-parametric geometric approach must be applied. For the ship geometry design field, many approaches for hull shape modelling and parameterization had been developed [1], [2], [3], [4], [5], [6]. A review of the theoretical background of several methods for the ship hull modelling and parameterization is included in reference [7].

This study is focused on the parameterization of the Europe barge 2B hull using CAESES software by FRIENDSHIP SYSTEMS [3],[11], which allows to generate automatically series of barge shapes. The barge shape model includes curves and surfaces modelled by B-splines.

For each geometric realisation, the flow around the hull is computed and the ship resistance is predicted by CFD - Computational Fluid Dynamics method, with NUMECA/ FINE Marine [10] software.

2. PARAMETRIC MODEL

By parametric modelling, a series of hulls from initial/parent design are generated. In this study, the barge type Europe 2B [8] from Navrom SA Galati is considered as the initial shape. This barge is used on the Danube River.

Table 1 presents the barge type Europe 2B [8] main dimensions.

Table 1. Main dimensions of the Europe 2B barge hull [8].

Dimension	Symbol	Value [m]
Length overall	L	76.50
Beam B	B	10.96
Depth D	D	3.20
Draft T	T	2.70

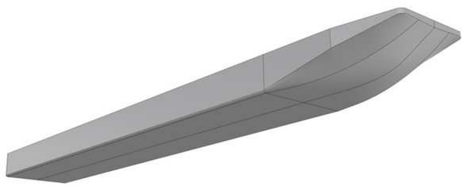

Fig.2.1 Europe 2B barge hull, CAD model.

For starting building the parametric hull model, first the CAD model of the initial hull has been generated. Figure 2.1 presents the initial barge shape by Rhino [9] program. Afterwards the CAD process continued to measure with high accuracy the main dimensions of the hull and the angles of K1 and K2 knuckles projected on the baseline and the angles of the same knuckles and bow profile projected on the centre-line (Fig.2.2). After mapping the entire geometry of the hull, it was possible to go develop the CAD hull model by the CAESES [11] software.

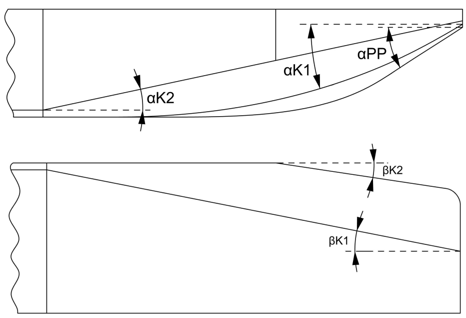

Fig.2.2 Local geometrical parameters.

The geometric variables are global and local parameters.

The global parameters are used for the barge CAD model definition.

Table 2 presents the list of global parameters.

The local parameters are used to obtain different local barge shapes. This study is focused on the geometric changes at the bow, being considered with higher influence to the improvement to the barge resistance.

Table 3 presents the list of local parameters.

Figure 2.2 presents the selected local parameters.

Table 2. Global parameters considered for the barge shape.

No.	Dimension	Symbol
1	Length overall	L
2	Beam	B
3	Depth D	D
4	Bilge radius	BR

Table 3. Local parameters considered for the barge shape.

No.	Local parameter	Symbol	Value	Range
1	Longitudinal angle of K1 knuckle	αK1	25.05°	15°-60°
2	Horizontal angle of K1 knuckle	βK1	11.16°	5°-19°
3	Longitudinal angle of K2 knuckle	αK2	11.96°	-
4	Horizontal angle of K2 knuckle	βK2	8.57°	0°-20°
5	Bow angle	αPP	32.6°	20°-50°

In CAD model by CAESES [11], software starts with the points from stern to bow, following up the coordinated relation between points. So the points mesh for the whole barge shape is obtained.

P1(x1,y1,z1) → P2(x1+a,y1+b,z1+c)

Based on the points mesh, there have been created the next CAD objects: curves and barge surfaces, taking into account the geometric gradients at K1 and K2 knuckles.

Because the knuckle curves (Fig.2.2) are three-dimensional, they have been built by a macro-code (Fig.2.3), using their X-Y centre-plane projection curve and X-Z base-plane projection curve.

```
genericcurve k1()
k1.setX(c1.getPos(t).getX())
k1.setY(c1.getPos(t).getY())
k1.setZ(c2.getPos(c2.ft(0,c1.getPos(t).getX())).getZ())
```

Fig.2.3 Code for a 3D-curve starting from the projection 2D-curves.

The CAD geometric parametric model is tested on each variable. The local parameters could generate in some zones a surface under the base-plane, requiring supplementary conditions in the macro-code (Fig.2.3). Those conditions are presented as the parameters range in Table 3.

3. CFD SIMULATIONS

The CFD ship resistance analysis in still water is done by the NUMECA/Marine [10] software. The fluid flow solution is based on incompressible RANS - Reynolds-Averaged Navier-Stokes formulations, with non-structured grid, VFM finite-volume method, with near-wall low-Reynolds number turbulence models. The free-surface flow is modelled with a multi-phase flow approach. The ship's CFD model has free trim and sinkage.

The CFD model has a non-structured grid with about 2 million cells. The domain covers one ship length upstream of the bow, half above, one and a half ship length out from the side and bottom of the hull, and two ship length downstream of the stern.

A grid refinement has been applied on the bow and the stern part of the hull, and layers of high aspect ratio cells tangentially to the wall have been inserted in order to correctly resolve boundary layers (see Fig. 3.1).

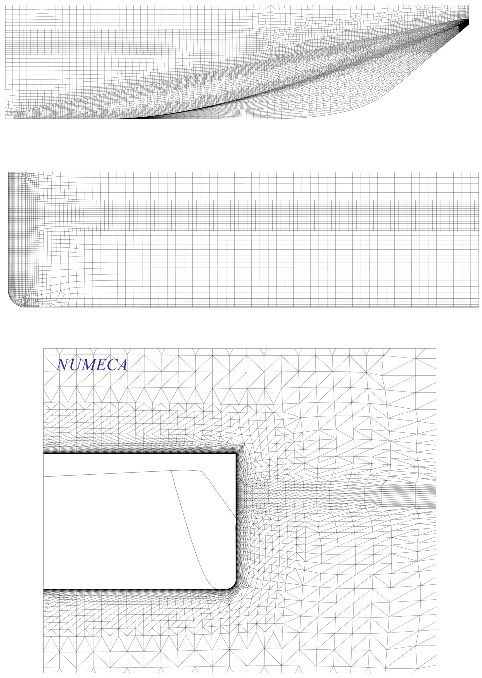

Fig. 3.1 Grid refinement on fore (top), aft (middle), boundary layer (bottom).

A trial set of seven numerical simulations were performed, at the beginning to check the performances of the initial / parent barge hull, for a range of speeds form 6-18 km/h with a step of 2 km/h.

Table 5 presents the results of the initial barge resistance (Rt). From Fig. 3.2 results the correlation between speed and wave characteristics. The wave system develops well in all the cases (Fig.3.2).

The initial computational cases are marked by "parent", "original" or B01-00 hull.

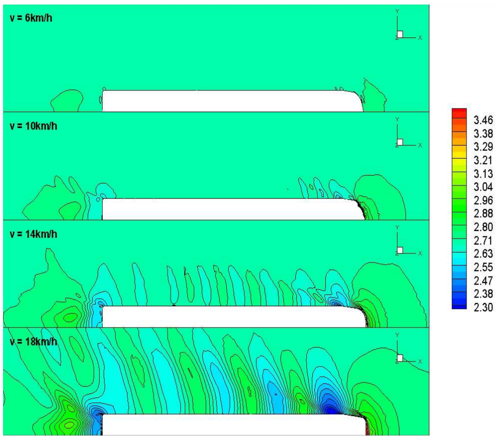

Fig. 3.2 Wave elevations profiles drawn for ship speeds range 6-18 km/h.

Considering the characteristics of the parent hull, twenty-five more hull forms have been derived from it, based on the parametrical model. All of them have the overall geometry kept basically unchanged, except for the bow which has been systematically modified according to the five particular parameters based on the angle of the bow profile, knuckle K1 and K2, described in Fig. 3.3 and Table 3. All the modified hulls have been numerically simulated for the same speed range, 6-18 km/h. If we consider in the analysis only the results obtained for the design speed (12 km/h), the optimum hull is B01-24 which decreases the total resistance of the initial hull by 2.04%, and also the hull B01-17 by 2.00%.

Table 4 presents the barge resistance for the derivate hulls.

The third set of computations have been performed in order to check if the resistance reduction for the B01-24 hull is consistent along the entire speeds range.

Table 5 presents the resistance results for the seven speeds. The results are pointing out that for the optimum hull B01-24 the ship resistance decreases the for all the selected speeds.

Table 4. Total ship resistance for each derived hull.

No.	RG[m]	αPP[◦]	αK1[◦]	αK2[◦]	βK1[◦]	βK2[◦]	θOP[◦]	Rt[kN]	diff.[%]
B01-00	0.25	32.6	25.05	11.96	11.16	8.57	2.75	38.58	-
B01-01		27.6						38.75	0.45%
B01-02		37.6						38.29	-0.74%
B01-03			20.05					38.51	-0.17%
B01-04			30.05					38.71	0.34%
B01-05				11			0	38.71	0.36%
B01-06				12.5			5.5	38.66	0.22%
B01-07					6			38.22	-0.92%
B01-08					19			39.10	1.37%
B01-09						0		38.77	0.51%
B01-10						15		38.87	0.76%
B01-11	0.3							38.60	0.07%
B01-12	0.35							38.43	-0.37%
B01-13		37.6			6			38.13	-1.17%
B01-14		35			7			38.22	-0.93%
B01-15		40			6			38.02	-1.44%
B01-16		45			6			37.85	-1.90%
B01-17		50			6			37.81	-2.00%
B01-18		37.6			5			38.31	-0.69%
B01-19		50						38.17	-1.05%
B01-20		37.6	20		6			37.82	-1.96%
B01-21		50	20		6			37.87	-1.83%
B01-22		40	20		6			38.13	-1.16%
B01-23		40	20		8			38.12	-1.19%
B01-24		40	18		6			37.79	-2.04%
B01-25		40	18		8			38.05	-1.37%

Table 5. Comparison of original (B01-00) and modified hull (B01-24).

No.	v [km/h]	Rt[kN] Orig.	Rt[kN] Mod.	Diff. [%]
1	6	9.74	9.60	-1.42%
2	8	16.88	16.65	-1.36%
3	10	26.41	26.03	-1.42%
4	12	38.58	37.79	-2.04%
5	14	53.88	53.38	-0.93%
6	16	73.88	72.85	-1.40%
7	18	98.91	98.27	-0.64%

In order to clarify the modification performed on parent hull to get optimum hull, Figure 3.3 depicts the transversal projection of the lines plan drawn for the original and modified hull (top) and also a longitudinal projection (bottom).

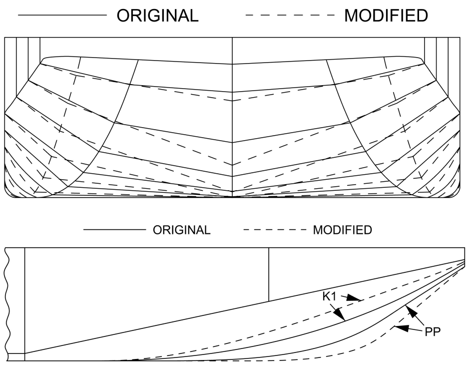

Fig. 3.3 The geometry of parent and improved hull.

A comparison between the pressure fields computed around the bow is shown in Fig. 3.4, while Fig. 3.5 depicts the comparison between free-surface topologies computed around the hulls.

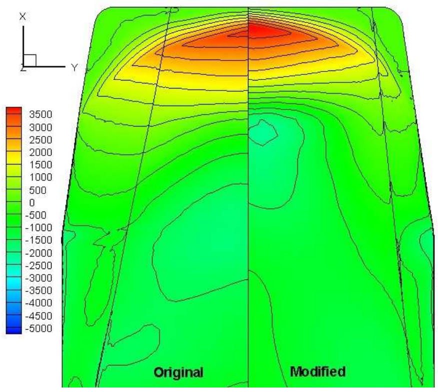

Fig. 3.4 The bow pressure distribution. Initial / parent and improved hull.

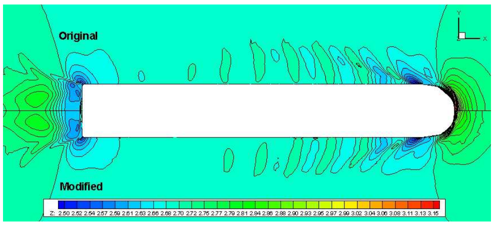

Fig. 3.5 The free surface topologies for the initial and optimized hull.

5. CONCLUSIONS

An automated procedure for improvement of hull forms based on parametric modelling and RANS computation techniques has been successfully implemented for Europe 2B barge.

Starting from the initial / parent barge shape a series of hulls have been generated. The ship resistance numerically computed for each hull have been checked for the design speed in order to find the optimum hull in terms of ship resistance.

The comparative analysis revealed that the optimum hull (B01-24) could lead to an decrease in resistance of 2.04 % for the design speed. Also optimum hull has been analyzed for seven speeds from 6 km/h to 18 km/h, in order to check if the improvement is consistent with speed. The computations showed that for the optimum hull the resistance is decreased for each speed with an average of 1.32%, between a range from 0.64 to 2.04%.

Further studies will be extended for other ship types and the improvement of the analysis methodology.

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