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# NUMERICAL STUDY CFD OF "FANCAT" CATAMARAN`S SHAPES

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## ABSTRACT

*The main objective of this work is to find the optimal shape from hydrodynamic resistance and waves for a catamaran hull. The main issue is to reduce the hydrodynamic resistance and the wave system generated without influencing propulsion performances. Also because this catamaran is designed for inland it is very important to study the waves system in order to protect the rivers environment.*

**Keywords:** CFD, free-surface, flow, hydrodynamic resistance, shape.

## 1. INTRODUCTION

In recent years, emphasis has been placed on reducing pollution by reducing fuel consumption. In the naval field, this is possible by adapting forms to reduce the hydrodynamic resistance that results in the use of low-power motors.

## 2. CONTENT

Four types of catamaran hulls were analyzed for this study. The catamaran is propelled by 2 azimuth thrusters, which leads to a complicated shape of the aft region. The shapes and dimensions of the forward region have not been varied (type V) each side hull being symmetrical with its own centre line . The analysis is based on the optimization of the aft forms so as reduce the forward resistance without affecting propulsion performance. The analysis was done with the CFD software: Numeca Fine Marine.

### 2.1. Description

"FANCAT" is a passenger ship with a capacity of 74 passengers, with a speed of 25 km/h and sailing on the Danube (Braila-Tulcea route).

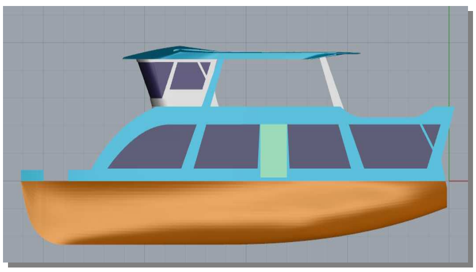

**Fig. 1.** "FANCAT" Catamaran

## 2.2. Main Characteristics

The principal particulars of the ship are presented in the table below:

**Table 1.** Main particulars of the ship

| | | |
|---|---|---|
| L | 21 | m |
| B | 6,6 | m |
| H | 2,3 | m |
| T | 1,4 | m |
| V | 7 | m/s |
| Δ | 42 | t |

## 3. SHAPE'S

### 3.1 Shape I - Particularities of the forms

• The chine of the midship has a dead-rise angle of $20^0$;

• Immersed transom with At=0,01$m^2$ (transversal area immersed);

• Stern profile contains 3 inflection points that extend over a length of 5,6m;

• In the aft region, the bilge is at an angle of $90^0$ which generates an inflection point.

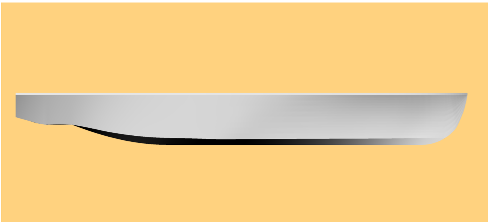

**Fig. 2.** Shape I – Longitudinal View

### 3.1.1 Analysis

The results of the analysis are as follows:

• The hydrodynamic resistance is 15,2 kN;

• The height of the wave created by the ship is 1 m from the waterline and the width of the wave is 1 m from the centre-line;

• In the aft, the wave elevation decreases by 0,8 m below waterline.

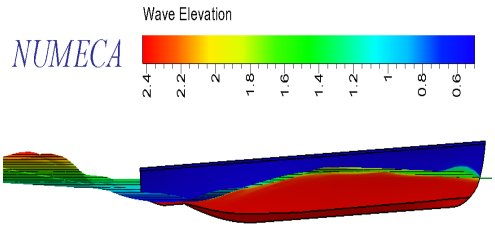


**Fig. 3.** Shape I – Wave Elevation – Longitudinal view

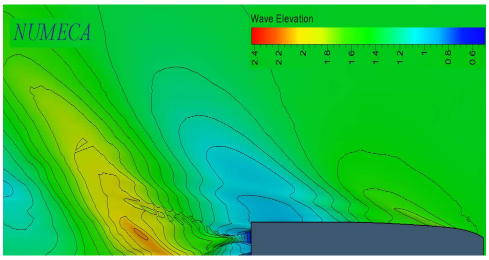


**Fig. 4.** Shape I – Wave Elevation –Top view

### 3.2. Shape II - Particularities of the forms

• The chine of the midship has a dead-rise angle of $20^0$;

• Immersed transom with At=0,013$m^2$ (transversal area immersed);

• The inflections of stern profile were smooth (extending to a length of 6 m);

• The chine of the midship has a dead-rise angle of $12^0$.

**Fig. 5.** Shape II – Longitudinal View

### 3.2.1 Analysis

The results of the analysis are as follows:
• The hydrodynamic resistance is 14,6 kN;
• The height of the wave created by the ship is 1,1 m from the waterline and the width of the wave is 1,1 m from the centre-line;
• In the aft, the wave elevation decreases by 0,9 m below waterline.

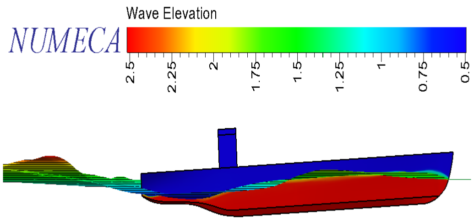


**Fig. 6.** Shape II – Wave Elevation – Longitudinal view

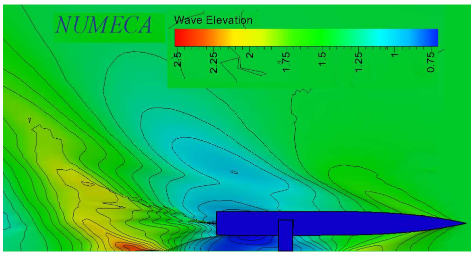


**Fig. 7.** Shape II – Wave Elevation – Top view

### 3.2.2 Comparison between Shape I – Shape II

• The hydrodynamic resistance was reduced by 0,6 kN;
• The wave elevation increased by 0,1 m.

## 3.3. Shape III - Particularities of the forms

• The chine of the midship has a dead-rise angle of $20^0$;
• Not Immersed transom;
• Without inflection point in stern profile;
• The bilge is round in the aft region;
• There is an inflection point in the crossing area between the chine and the round bilge.

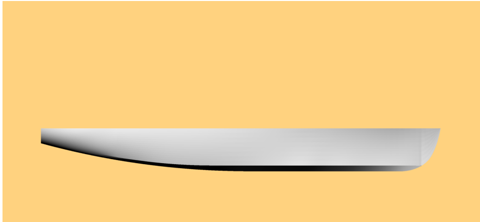

**Fig. 8.** Shape III – Longitudinal View

### 3.3.1 Analysis

The results of the analysis are as follows:
• The hydrodynamic resistance is 16,9 kN;
• The height of the wave created by the ship is 0,8 m from the waterline and the width of the wave is 3 m from the centre-line;
• In the aft region, the wave elevation is 0,8 m below waterline.

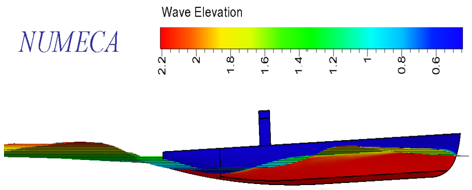


**Fig. 9.** Shape III – Wave Elevation – Longitudinal view

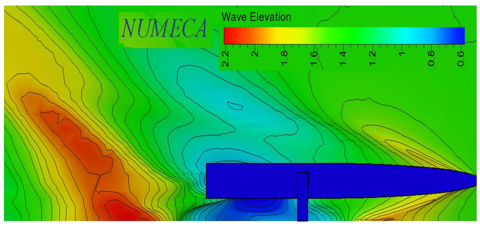


**Fig. 10.** Shape III – Wave Elevation – Top view

### 3.3.2 Comparison between Shape II – Shape III

• The hydrodynamic resistance was increased by 2,3 kN;
• The wave elevation increased by 0,3 m.

### 3.4. Shape IV - Particularities of the forms

- The bilge is round in the midship area
- Immersed transom with At=0,015 $m^2$ (transversal area immersed );
- No inflection point in stern profile;
- The bilge is round in the aft region.

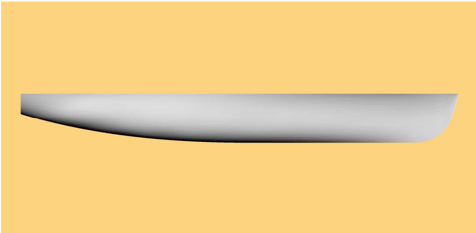

**Fig. 11.** Shape III – Longitudinal View

### 3.4.1. Analysis

The results of the analysis are as follows:
- The hydrodynamic resistance is 13,6 kN;
- The height of the wave created by the ship is 1 m from the waterline and the width of the wave is 1 m from the centre-line;
- In the aft, the wave elevation decreases by 0,6 m below waterline.

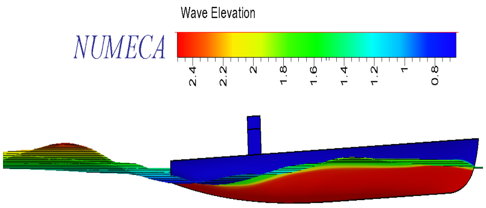


**Fig. 12**. Shape IV – Wave Elevation – Longitudinal view

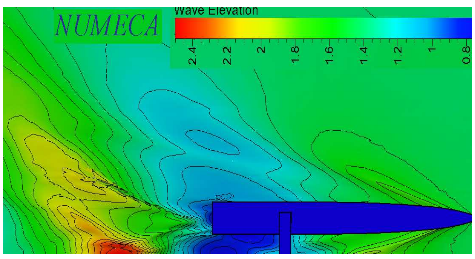


**Fig. 13.** Shape IV – Wave Elevation – Top view

### 3.4.2 Comparison between Shape II – Shape IV

- The hydrodynamic resistance was reduced by 1 kN;
- The wave elevation reduced by 0,3 m.

## 4. THEORETICAL BACKGORUND

Mesh used:
- On the x-axis: 30 cells;
- On the y-axis: 12 cells;
- On the z-axis: 12 cells.

Mesh was calculated based on the Courant number:

$$Co = \frac{\Delta t Fc}{Vc} = \Delta t \sum_{f} Max(-F(U),0)/Vc$$

Where $\Delta t$ is the time increment, Fc is the total flux out of the cell and Vc is the velocity.

Courant number used: Co < 0,3.

The analysis was carried out in the domain: Buffer Layer 5 < y+ <30 , where y+ has value by 25.

Dimensionless wall distance is calculated using the below formula:

$$y^+ = \frac{u_t y}{\vartheta}$$

Where $u_t$ is the friction velocity, y is the distance to the nearest wall and $\vartheta$ is the local kinematic viscosity.

## 5. CONVERGENCE

The convergence was obtained at 5000 iterative cycles, but about 8700 iterative cycles were calculated to capture the hydrodynamic phenomena.

The number of iterative cycles was calculated for each shape.

The simulation was accomplished by the progressive speed increase from 0 m/s to 7m/s in the range of 0 – 1000 iterative cycles. After 1000 cycles the speed is constant.

The Navier-Stokes equation has been permanently pursued. The residues were graphically displayed, thus following the iteration process so that any errors of calculation could be detected in time.

In figures 14, 15 is presented the residues evolution.

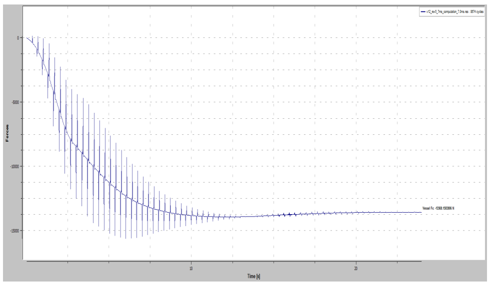

**Fig. 14.** Shape IV – Hydrodynamic Resistance

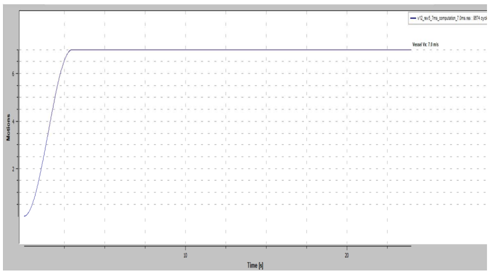

**Fig. 15.** Shape IV – Speed of the ship

## 6. CONCLUDING REMARKS

In conclusion, the shapes that have inflection points in the stern profile and in the hull's surfaces increase the wave elevation and hydrodynamic resistance.

Shape IV is the most optimal in terms of hydrodynamic resistance and wave elevation.

**Table 2.** Hydrodynamic particulars of the shapes

| Shape | Hydro resist. [kN] | Wave height [m] | Wave width [m] | Wave decrease [m] |
|---|---|---|---|---|
| I | 15,2 | 1 | 1 | 0,8 |
| II | 14,6 | 1,1 | 1,1 | 0,65 |
| III | 16,9 | 0,8 | 3 | 0,8 |
| IV | 13,6 | 1 | 1 | 0,6 |

## 7. RECOMMENDATIONS

It is recommended to check our results based on model towing tank attempts.

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