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DESIGN ASPECTS OF INLAND NAVIGATION CATAMARANS

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ABSTRACT

The paper aims to identify the main aspects in design of catamarans for inland navigation, but not limited to, and to present some approaches related to this aspects. The catamarans have some consistent advantages against conventional monohull: larger deck area, better transverse stability and in general improved behaviour in waves. As consequence the catamarans have gained ground in a wide range of applications: inland/maritime passenger ships, passenger or car/passenger ferries, inland cargo ships and even Navy ships. The main design aspects discussed in this material are: hydrodynamic efficiency, hull and deck structure design, passenger/cargo space arrangement, machinery and installations aspects, intact and damage stability aspects. The methods presented here, related with the above aspects, are based on international ship design and construction rules, results of structure design investigations and towing tank experiments developed in other paperwork. Based on the author’s experience in designing inland passenger catamarans, this paper gathers valuable information which is meant to create an overview on the catamaran design and the compromises needed to fulfil different designing criteria, Class requirements and other specific restrictions.

Keywords: catamarans, design rules, FEM analysis, light weight materials

1. INTRODUCTION

The idea of this paper is to create an overview, by presenting together in a single work, the main steps in designing catamarans in general and further focusing on inland navigation passenger catamarans.

Because the high-speed monohull ships, with very high length/beam ratio, have low wave-making resistance, but also low transverse stability, a better option proved to be the catamaran concept. The catamarans have two slender hulls, with lower resistance, high transverse stability and more space on decks.

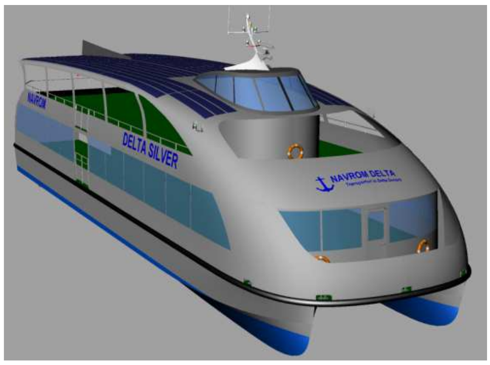

Fig.1 3D view of the catamaran

This led to a vigorous development of catamarans since 1980s, so almost 60% of the high-speed ferry market is currently supplied by this type of ship.

The catamarans proved their advantages also in other applications: inland/maritime passenger ships, inland cargo ships and even Navy ships.

The particularities of catamaran design, compared with monohulls, dealing with the following themes: hydrodynamic efficiency, structure design, passenger/cargo space arrangement, machinery/installations and stability issues, are highlighted bellow.

The available methods used to solve the above subjects and good examples are presented in this material.

2. ASPECTS AND METHODS IN DESIGNING OF CATAMARANS

For a good design the following aspects must be treated carefully:

2.1 Hydrodynamic Efficiency

Besides the common problems with monohulls, such as wave and friction resistance, the twin hull ships have a specific issue regarding the interference between the waves produced by the each hull. Thus depending on the speed and beam of each hull, the distance between hulls must be carefully chosen so as to obtain a low wave resistance.

The methods available for this aspect of catamarans are:

i) **Systematic results** as preliminary method:

- Faltinsen O.M. in his book [2] declares that the coefficient of residual resistance C_R decreases when the relative distance between the hulls (2p/L) increases (Fig. 2).
- Dubrovsky V., Lyakhovitsky A. in their book [3] reveal that the coefficient of residual resistance C_R, given by the equation below, presents an alternating variation depending on the relative distance between the hulls ($2\overline{b} = 2b/L$):

$C_R = C_{VP} {*} K_F(2\overline{b}) + C_W(F_n) {*} K_W(F_n, 2\overline{b})$

where:

C_{VP} – "form" viscous resistance coefficient;
K_F – correction factor for "form" viscous resistance (Fig. 3);
C_W – wave-making resistance coefficient;
K_W – correction factor for wave-making resistance (Fig. 4).

- Voytkunsky Y.I in his work [4] shows that the coefficient of residual resistance C_R, given by the equation below, presents an alternating variation, but with some different values for viscous and wave-making factors:

$C_R = (C_V - C_{F0})K_V + C_W {*} K_W$

where:

C_V – "form" viscous resistance coefficient;
C_{F0} – friction resistance coefficient;
K_V – correction factor for "form" viscous resistance (Figure 5);
C_W – wave-making resistance coefficient;
K_W – correction factor for wave-making resistance (Fig. 6).

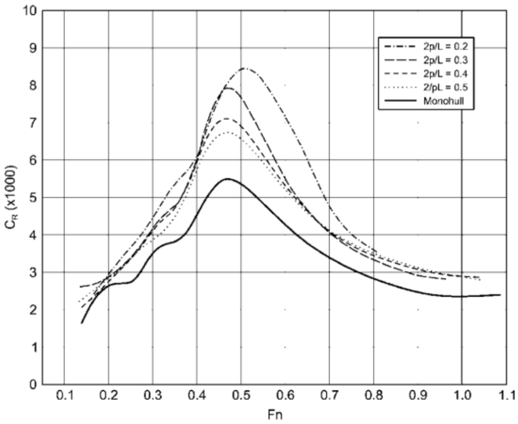

Fig.2 Residual resistance coefficient C_R

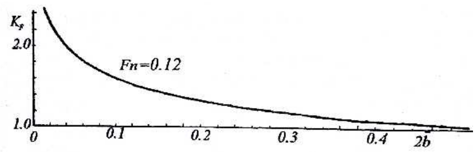

Fig.3 Viscous resistance factor K_F

ii) **CFD** calculations can be used as an advanced investigation method for wave interference of twin hull ships, but in general they still need an experiment validation.

iii) **Towing tank experiment**, being the most expensive method, is used, in general, as a validation after the hull forms and relative distance between the hulls have been established with other instruments.

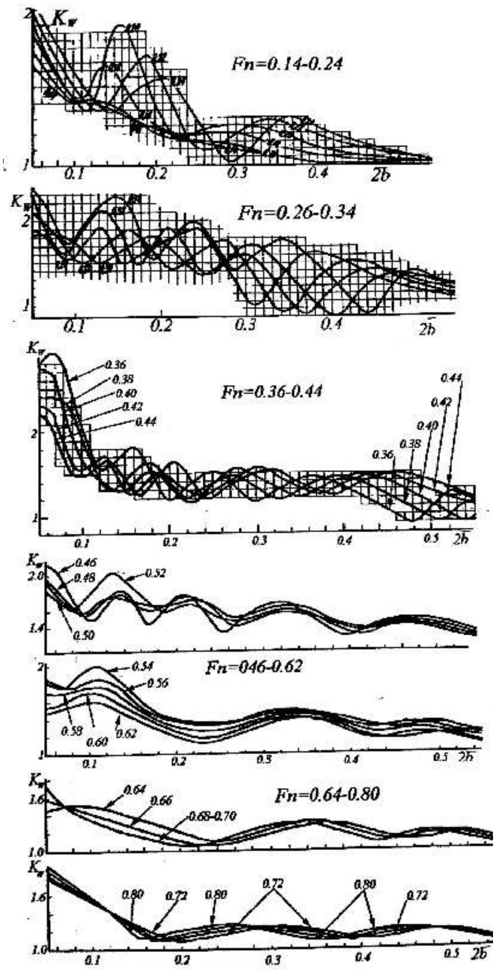

Fig.4 Wave resistance factor K_W

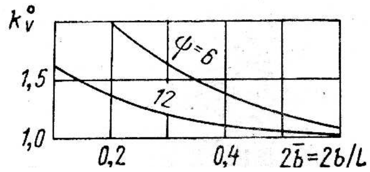

Fig.5 Viscous resistance factor K_V

Conclusion: because the interference between waves of the twin hull ships is a sensitive subject, the systematic results can be used as a preliminary method, but the final results should be validated with a towing tank experiment.

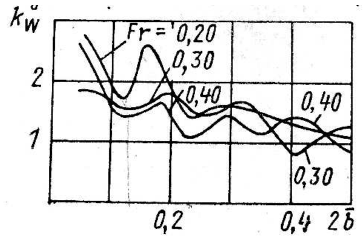

Fig.6 Wave resistance factor K_W

2.2 Structure Design

For structure design there are in general two approaches available: Rule based scantling and direct calculation. The second method is more an optimization tool for the structure previously dimensioned according to Rules.

i) Rules - The structure design in general starts from a scantling according to international ship building Rules requirements.

Bellow are listed some relevant Rules as for example:

- BV Rules for Inland Navigation Vessels [5];
- DNV-GL – Inland navigation vessels [6]
- RMRS – Rules for the classification and construction of inland navigation ships [7];
- ISO 12215 – ships up to 24 m length [8];

Depending on various parameters, like the main dimensions and type of ship, displacement, speed, loads from passenger or cargo etc, the Rules require the minimum characteristics of different structure elements: shell plates and deck thickness, ordinary and secondary stiffeners section modulus, etc.

The particularity of catamarans is the structure of the deck connecting the two hulls. The deck beams are checked supplementary according to "torsion of catamarans" theory presented in some Rules (e.g. BV Rules [5] - Part B, Chapter 5, App 5 Torsion of catamarans). The torsion of the catamaran deck Figure 7, when navigating in oblique waves, is decomposed in a bending moment M_i and a shear force F_i in each beam, at different cross section on ship length. The checking criteria is considering the normal and shear stress limits of the material, but also the deck deflection y_i should be kept within some service limits.

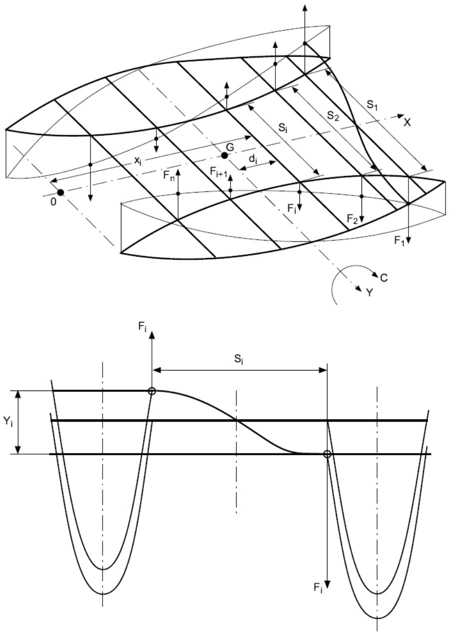

Fig.7 Torsion of catamarans

ii) Direct calculation, either by simplified beam elements or by FEM analysis.

For catamarans the weight of the deck connecting the tow hulls represents an important percentage from the total structure weight. In consequence, especially for medium and high speed crafts, light weight materials, like aluminium or glass reinforced plastics GRP, must be used and the weight optimization of the connecting deck is a significant goal.

As demonstrated in other studies by direct analyze method, important structure weight reduction can be achieved.

For example, in reference [9], it was analyzed an aluminium alloy structure for a 28 meters length catamaran. The weight reduction that was possible to be obtained was about 18% from the Rules based scantling structure.

Also for the reduction of weight it is worth making an economic analyze regarding the use of adapted strength stiffeners, instead of standardized profiles, for different longitudinal/transverse structure elements.

Conclusion: lightweight materials must be used and attention must be paid to connecting deck structure.

2.3 Space Arrangement

A typical deck arrangement for inland navigation passenger catamaran is presented in Figure 8 below.

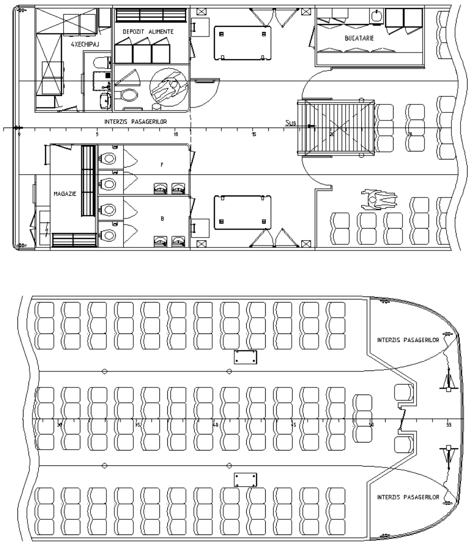

Fig.8 Deck arrangement

The main aspects to be solved and minimal technical requirements according [10] are:

- mooring area at aft end and mooring/anchoring area at fore end;
- embarkation doors, generally positioned aft or middle, shall have a minimum clearance of 1,5 m;
- connecting corridors shall have a clear width of at least 0,8 m in general or 1,3 m if use by persons with reduced mobility;

- muster areas, available for passenger rescue, shall have minimum surface according Rules;
- stairs shall have a clear width of at least 0,8 m and be in accordance with EN13056:2000 standard;
- sanitary spaces, generally located near the embarkation doors, shall have at least one toilet for use by persons with reduced mobility.

Conclusion: The enlarged deck surface available for catamarans makes them a good choice versus monohulls.

2.4 Machinery and Installations

According to [10] the inland navigation passenger, vessels shall meet the following requirements:
- they shall be equipped with a second independent propulsion system, placed in a separate engine room from the main propulsion system. For catamarans this is an easy job, because in each hull two separate engine rooms are accommodated, ensuring the required redundancy;

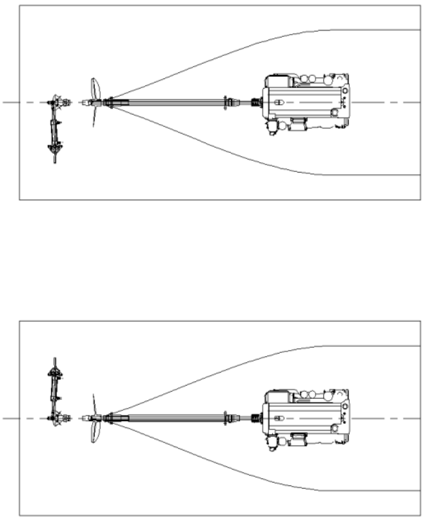

Fig.9 Propulsion arrangement

- each watertight compartment shall be fitted with bilge level alarm and pump out possibility. In this case, for twin hull ships, will result a double quantity of alarms and piping compared to the monohulls arrangement;
- the emergency power plant and the second fire extinguishing/bilge pump shall be installed outside the main engine room. Again the two hull ship complies with this requirement;

A specific problem for catamarans is the rudders synchronization, because a rigid rod in general cannot be used between the two hulls. One solution is the hydraulic connection between cylinders actuating rudders.

Conclusion: The twin hull ship presents an advantage by having two independent engine rooms.

2.5 Intact and Damage Stability

The intact and damage requirements are intended to establish a minimum safety level in terms of stability.

The intact stability requirements refer to:
- criteria of righting lever curve GZ, such as maximum righting lever, aria under righting lever curve;
- minimum initial metacentre height GM;
- maximum allowable heeling angle under action of external factors, such as moment due to one-sided accumulations of passengers, moment due to wind pressure, moment due to centrifugal force caused by turning of the vessel;
- minimum residual safety clearance.

The damage stability requirement refers to a minimum distance from damaged waterline to prevent down flooding. The longitudinal, transverse and vertical extent and also the damage location are imposed by the Rules.

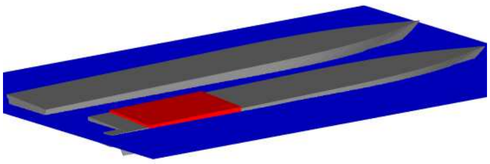

Fig.10 Floating in damaged condition

Conclusion: The catamarans have a significant increased intact stability compared to monohulls.

3. CONCLUSIONS

This work intended to present some advantages but also disadvantages of inland catamarans passenger vessels, such as:
- an additional hydrodynamic issue, due to hull interference;
- an additional structure design issue due to torsion of catamarans;
- an enlarged deck space available for catamarans;
- the advantage of two independent engine rooms for catamarans;
- the increased intact stability for catamarans.

The author hopes that this article will give the reader an opportunity to make an objective analysis of the catamaran design and also of the feasibility of catamarans for different applications.

Acknowledgements

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