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On the design of small passenger ships operating in restricted area – a case study – Delta of Danube

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Abstract. Following the "Healthy oceans, seas, coastal and inland waters" Horizon Europe mission area, the present research is focused on finding practical ways to overcome the specific restrictions imposed by the particularities of the Danube Delta area on small passenger ship design. The focus is given to the hydrodynamic analysis as a tool to reduce the negative effects of small ships avoiding the constant aggression to which the fauna and flora of the area are subjected to.

1. Introduction

Taking into account the new strong requirements regarding environmental protection, the design of ships dedicated to inland navigation is now in the position to find solutions even more complicated as compared to seagoing ones. These harder conditions are related to the specific restrictions imposed by the particularities of the locations. A representative example is the location of the Danube Delta Biosphere, where adequate solutions have to be found.

To protect both the fauna and the vegetation special precautions directly linked to phonic pollution (noise), chemical pollution and the influence of the own waves due to the navigation in channels and shallow water conditions on the banks of rivers and lakes are to be considered.

Consequently, the main goals consist of finding practical ways to overcome this number of barriers and define a so-called "best compromise". As a matter of fact, this has to lead the designer to develop much more than a ship but defining an integrated concept, suggesting a system able to build an infrastructure that can be profitable also from the economic point of view. The components are briefly described below.

2. A future feasible concept

Practically, the Danube Delta Biosphere is a unique location offering fantastic opportunities also from the touristic point of view and then, the main task should be to find the most appropriate means to use this natural treasure in a very ecological manner taking into consideration the existing restrictions on one hand and to create a large, secured and comfortable access for tourists on the other hand. In other words, this means to find the answers to the following questions: how to reach the area – where to stay – how to visit the reservation?

For the first two items, there are practical solutions already in place that can be subject to further improvements, the main goal remaining to obtain feasible answers on how to avoid the most catastrophic impacts on climate change [1], taking into account the limitations and the new provisions related to the reductions of the greenhouse gas (GHG) emissions which are a key problem.

Consequently, the main important challenges are related to:

i. the drastic limitation of noise and chemical pollution when classic solutions are considered;
ii. the negative impact due to the vessel-induced waves both on riverbank erosion and fish eggs deployment during the specific periods;
iii. the use of unconventional materials which are environmentally friendly avoiding water pollution.

3. A brief description of the main aspects

Taking into account the above-mentioned aspects, the identification of the next steps to be followed becomes mandatory, based on the previous experiences and the specific requirements of the authorities and clients. These aspects are concentrated in some important directions and briefly analyzed, providing also some relevant examples for a better understanding of the practical problems to be approached.

I. Mission definition

It is the first stage when input data have to be clearly stated. This means defining the area to be visited, identifying the main characteristics of the navigation channels, the average ship speed, the specific restrictions to be considered, voyage duration, number of passengers etc. The accuracy of the input data plays a very important role to fulfill the owner requirements.

II. Preliminary design stage

Based on the input data, the preliminary body plan and a General Arrangement Plan can be defined. To avoid future major corrections, some preliminary computer codes have to be used being able to estimate the future performances of the ship in terms of static stability, speed, manoeuvrabilityperformances etc. The existences of these preliminary modules are of paramount importance placing the ship in a so-called “optimized area” where future modifications will not lead to major changes. Consequently, an important volume of rework will be avoided.

III. Hydrodynamics module

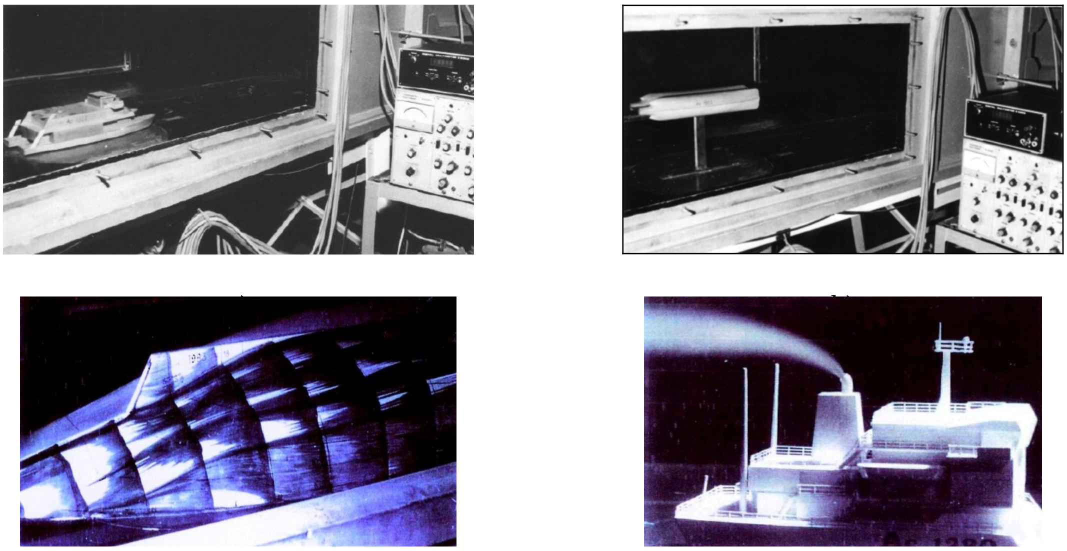
This the most important stage as far as, based on the results obtained during the hydrodynamic analysis, a final decision has to be reached.

For a correct evaluation, the principal factors to be considered are directly linked to the specific conditions on the location. There are enough accurate techniques that can be used at this stage, including the experimental approaches if hydro-aerodynamics facilities are available. Such aspects are further presented to create a complete overview of the problem.

The powering module is by far the most important one. This means that a first evaluation of the merits of the preliminary body plan has to be performed. There are several ways to carry out an evaluation:

– using existing computer codes to investigate the fluid flow around the ship’s hull identifying the areas where the lines have to be improved;
– using the aerodynamic tunnels, being the cheapest and the quickest experimental investigation. To this purpose, experimental tests like streamline ones and the aerodynamic coefficients evaluation for both underwater hull and the aerodynamic part respectively can be performed [2].

This first step is very helpful in order to observe if some modifications are already necessary or the next stage can be accomplished.



c) d)

Photo 1. a) aerodynamic coefficients of the above water body; b) aerodynamic coefficients of the underwater body; c) stream lines visualization; d) test of smoke dispersion from the funnel.

The results provided by the experimental tests are very useful for the evaluation of the aerodynamic resistance, as a component of the total resistance of the ship. Mention should be made that the theoretical evaluation is practically not enough accurate and the approximate values using different series, like [3] can't be used for such type of ships. Moreover, due to the open area of the location, wind forces from different directions have to be calculated using new techniques [4].

The next step is dedicated to the evaluation of the hydrodynamic resistance of the ship. Due to the special geometry of the body, the utilization of the so-called classical methods is very often impossible [5] and specific tools have to be used [6]. Again, if experimental facilities are available this is the best solution which can be considered. The existing computer codes could be used but, due to the complexity and particularities of the forms, the theoretical results have to be validated by experiments.

A correct evaluation of ship hydrodynamic resistance could identify a high wave resistance component that has to be avoided, firstly due to the effect on the total hydrodynamic resistance and secondly because of high own waves which are not allowed. The said own waves have a negative impact on the banks contributing on one side to erosion and on the other side affecting the fish eggs during reproduction time. A practical example is investigated in [7] for a small passenger ship having L_{pp}=22.4 m, B=4.4 m, T_m=1.1 m, and a displacement of 53.5 t. High wave resistance values have been identified.

Photo 2. The small passenger ship [7]

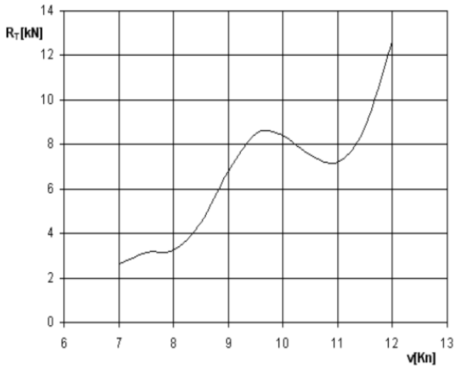


Figure 1. Ship resistance diagram [7]

A catamaran could be the best solution having better stability and a higher deck surface. However, deep investigations have to be performed in connection with the channel configuration in the areas to be visited as well as with the influence of the distances between the two hulls on the hydrodynamic resistance. The latter subject was approached based on theoretical calculations and experimental investigations [8]. It is important to mention that the destination of the proposed catamaran is supposed to be the Danube Delta.

Figure 2. A general view of the catamaran [8]

All the above-mentioned hydrodynamic components are evaluated for the bare hull case. The existence of the appendages for such kind of ships could play an important role in significantly increasing the total hydrodynamic resistance. A relevant example can be found in [9] where the results of the experimental tests show an important influence of the appendages. The application was carried out for a yacht of 12.78 m in length. The results are presented in Figure 3.

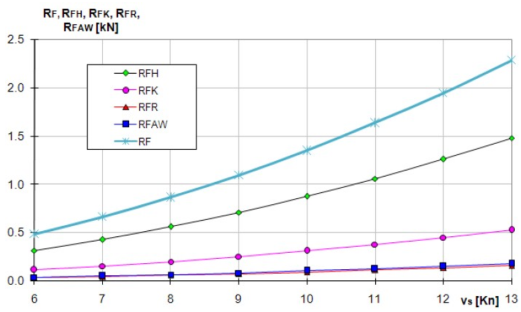


Figure 3. Frictional resistance of the hull with appendages and its components [9]

The influence of the heeling angle on the total hydrodynamic resistance has been also investigated due to the relevant influences. Such situations could be the result of the wind or wrong distribution of the weights or passengers on board of the ship. The results are presented in Figure 4.

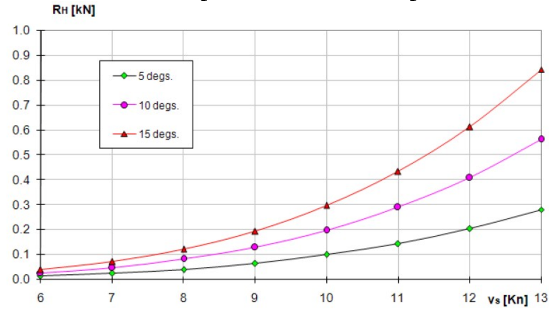


Figure 4. Heel resistance component of the yacht [9]

Additionally, a complete analysis has to take into consideration the influence of the specific conditions on the location due to the significant influence of the navigation in narrow canals and/or in shallow water. This could lead to significant contributions to the total hydrodynamic resistance and speed limitation in a certain area.

Due to the already mentioned restrictions, the manoeuvrability qualities have to be carefully investigated. As compared to merchant ships, the IMO criteria will not play a relevant role during the analysis. However, standard tests have to be performed using hydrodynamic facilities, which are by far preferable instead of using numerical calculations/simulations due to the complex arrangement of the aft part of the body. On the other hand, the existing computer applications can be used with the mention that these kind of sophisticated applications are not cheap and are mainly recommended during the next stages of the project. In fact, an important aspect is the ability to find the best steering system in combination with the propulsion unit [10], [11]. If the turning ability plays an important role for a large area, zig-zag manoeuvres are very important as compared to course keeping ones, when the ship needs to have a quick reaction in restricted waters [12]. As already mentioned, during the next design stages, a more accurate analysis can be performed if Computational Fluid Dynamic (CFD) applications or hydrodynamic tests, using Planar Motion Mechanism (PMM), can be carried out. Then, hydrodynamic derivatives can be precisely evaluated and used as input data in a computer code or a simulation model [13].

This is the last step to be performed and practically the most complex one which has to take into account the results already achieved in order to lead, at least in a preliminary manner, to the definition of the hull-propeller-steering interaction. At this stage, comparative evaluations between classical propulsion and much more environmentally friendly solutions can be carried out. Based on the existing procedures and experience gained during different approaches, this stage can be investigated by using proved computer codes or hybrid ones [14], [15], [16]. Due to the complexity of the problem, the propulsion alternatives will be further analyzed in a dedicated module which is not part of the present paper. Mention should be made that, in any case, classical or ecological solution, the evaluation of the interactions is mandatory for an efficient and low consumption system.

For a better understanding, the proposed approach can be summarized in a synthetic flow chart presented in Figure 5.

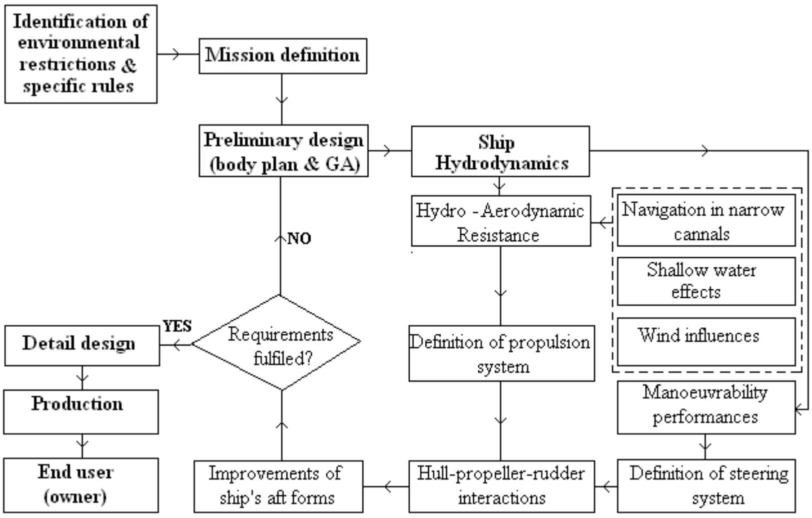


Figure 5. Synthetic flow chart for the proposed approach

4. Some previous examples

During the years, the necessity to be able to explore and visit the Danube Delta was investigated and two prototypes have been built taking the advantage of the existence of hydrodynamic facilities. The research was started in 1996 having as main objectives to develop and promote unconventional propulsion and ecological solutions of high performances systems avoiding chemical and noise pollution. Moreover, in order to reduce the amplitude of the waves produced by ship, hydrodynamic tests have been carried out in the towing tank. As a result, a single hull boat for 10 passengers (Photo 3) and a catamaran for 20 passengers (Photo 4) have been built in ICEPRONAV SA workshop, both of them using electric propulsion provided by solar cells.

Photo 3. The single hull solution

Photo 4. The catamaran solution

5. Conclusions

The aim of the present paper was to highlight the main problems which could arise during the design of navigation units are intended to be used in restricted areas. Some particular observations have been drawn up and the special care has to be dedicated when operating in the Delta of Danube areal.

The main steps have been identified and some useful remarks are suggested. There are also underlined the merits of the different approaches, both theoretical and/or experimental ones, as practical tools for an optimum design.

Considering the particularities and the special requirements, the design of an optimum solution is not a simple task and has to be carefully investigated using reliable and validated applications.

Taking into account a large variety of practical problems, the present paper could be looked as feasible concept.

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