



POLISH ACADEMY OF SCIENCES - COMMITTEE OF MATERIALS SCIENCE
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Design and naval engineering. Techno-economic project optimization

X. Leiceaga^a, J. Prieto^b, M. Rodríguez^b, F.G. Zapatero^c, E. Soto^c, M. Teijeiro^d, J. Diaz^e

Departamento de Deseño na Enxeñería, Universidade de Vigo,
Lagoas-Marcosende s/n Vigo, España.

^a Ingeniero Industrial, Catedrático de Departamento

^b Ingeniero de Minas

^c Ingeniero Industrial

^d Ingeniero Técnico Industrial

^e Ingeniero Técnico Naval

Due to the increase of the complexity in the production operations, and to the low times of delivery that demands the present market of the naval sector, it is necessary the to use of CAD/CAE programs that acquire the paper of integrators of the phases of design, planning and the processes of manufacture.

In a new construction ship, a high amount of information is handled, managing it totally in two dimensions until the finish stage of the project, previous to the manufacture, where it begins to be common to make the development of the steel in three dimensions. Therefore, during the project evolution there isn't a complete 3D representation of the ship, which forces in numerous occasions to make modifications when the ship was already constructed. This increases the manufacture's cost and delays the delivery time. These modifications could be avoided with a 3D model that allows the synchronized visualization of all its components, as happen when they are constructed.

1. SCOPE

The first phase in the shipbuilding process consists in elaborating a project that reflects the global design of the ship, according to the shipowner requirements and to the classification societies specifications [1]. For it, in the shipyards and technical offices they counted with a high number of informatic programs (of delineation for the generation of drawings, spreadsheets for estimations of budgets, specific programs of naval architecture, steel development...) that although they suitably makes the tasks for which they have been created, they do not interact. For this reason, is necessary to introduce the data from zero whenever begins the work with each one of the programs, generating a mistakes source between the different ways that exits to treat a same information.

This way of proceeding, delays the obtaining of the documentation handled in this phase, like the drawings and the bill of materials, and which is necessary for the following stage, like the estimation of weights and location of gravity centers.

The undetected incoherences during the project stage are transmitted until the production stage, elevating substantially as much the ship's delivery times like the costs of the global process. An example, is the cost of the positioning and welding of a small steel element used to complete the union of the secondary reinforcements to its passage through the primary reinforcements of the structure, following the ideal production process, it can be considered about 3 €. If the same element, for whatever reason, is necessary to be incorporated into the structure once the block is in tier, before the launching, the price is multiplied by ten (are needed a boilermaker, a welder, jobs in heights with scaffolds assembly, etc.) and it is even greater if we consider the damage over other works (burned painting, cables that are necessary to be retired, etc.).

2. INTRODUCTION

Due to the present situation that lives the naval sector [2], it did emerge the need to find a methodology that allows the approaching to a ship making project and all his tasks from one only platform, that is based on a CAD generic program that allows to create a 3D model of the complete ship, optimizing the process.

The present conjuncture of the naval industry, obligates to satisfy certain requirements to the selected platform, as can be:

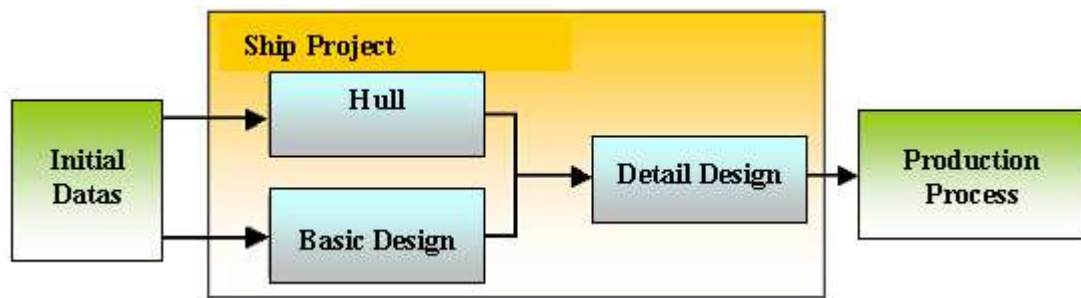
- Low cost; so that it is accessible to all the auxiliary companies of the sector and to the great shipyards.
- Developmentable; in way that allows, by programming algorithms, to implement utilities not present in the basic CAD tool.
- Customizable in Network; in order to make possible the synchronized work of a group of people in a common project.

The selection of the program in which to base the design, was made after of a stage of analysis of several software. In this first stage of this search was found that the generic type modeling programs, as opposed to the specific ones of the sector, had a greater range of geometric primitives, and modeling tools that accelerate the design process enormously, having those a much smaller cost.

In the following phase of the search, was selected as basic design tool the program MicroStation (since the v8 version) to satisfy the previously exposed requirements, and in addition of being capable to work with parametrics surfaces, necessities for the generation of the ship's hull. Another important characteristic is the capacity to handle a great variety of standards formats for geometries interchange, for later incorporation in other applications (FEM calculations, simulations) without repeating modelling stages.

3. WORKING METHODOLOGY

The departure point to apply a new program in a concrete field, is to establish a strategy to perform all the facets of that sector. In the case of naval engineering they are a great variety of tasks that, although in an ideal process are made in a consecutive way, the market situation forces to make them at the same time. Consequently the established strategy must be flexible, making possible the feedback of the generated information on each stage. The following scheme reflects in a global way, the process established for the creation of ships projects.



Scheme 1. Ships design process

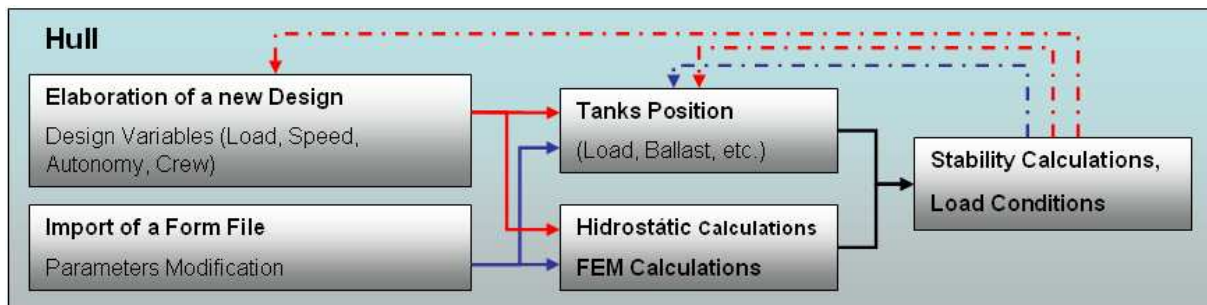
The **Błąd! Nie można odnaleźć źródła odwołania.** proposes a strategy that starts from the preliminary data that define the ship (capacity and load type, extreme dimensions ,speed, etc.) allowing the beginning of the hull modelling task and the rest of the elements that conforms the ship. Later, when the form of the hull is defined, the elements of the internal structure are adapted to it.

The following step consists in defining with greater detail all elements, providing the necessary information to schedule the production processes.

Next, a route through the different activities from the design process of a ship will be made.

3.3.Hull modelling

Within this activity, two alternatives are distinguished, depending if the model to create has slight variations with respect to another previously generated hull, or if the design is completely new.



Scheme 1. Hull design tasks

A) Classic elaboration, from a previous design

In case that the hull to design is based in some other already generated, the information that defines its form will be available. This information can come from a 3D model or a 2D document, named form file, in which the needed reference lines to generate the surfaces of the hull are reflected, in this case it must proceed as is explained in [4].

B) Elaboration of a new design

The departure point to begin the modelling of a new hull will be to know the parameters that define the load, the speed, autonomy and the crew required by the shipowner. Knowing this data, a parallelepiped is created whose dimensions are determined by length (x-axis), width (y-axis) and height (z-axis) values of the new hull, respecting the coordinates system standardized in the naval sector.

Subsequently, the main reference lines are generated (with straight lines), limited to the previous parallelepiped (see Figure 1).

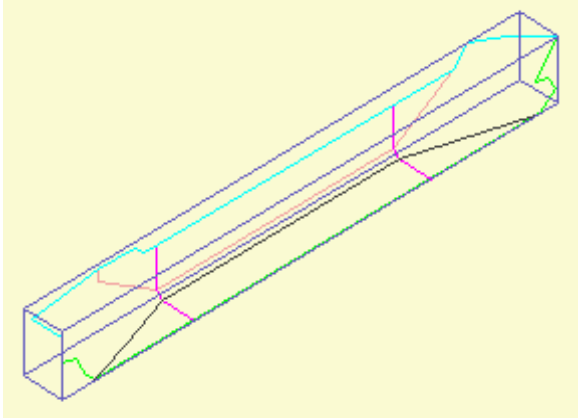


Figure 1. Representation of the hull forms with straight lines

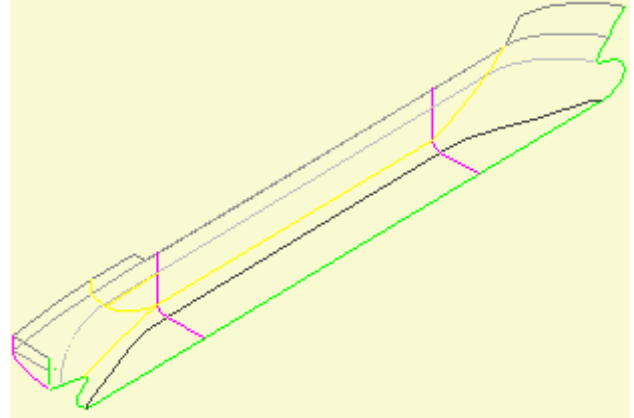


Figure 2. Representation of the hull forms with curved lines

The following step consists, because of the hydrodynamic requirements that has the hull, in smoothing those lines to obtain the previous references as curved lines, providing a schematic three-dimensional representation of the final form of the hull on which defining hull surface is created (Figure 2).

Due to the high degree of complexity that presents the complete surface, is necessary to create it from minor size surfaces that compose the hull in its totality. These minor size surfaces are named patches, and are generated by NURBS type parametric surfaces, starting from their edges (Figure 3). The layout of the edges is made by B-Spline curves, supporting them in the previous curved references, guaranteeing that two contiguous patches have a single common edge [4].

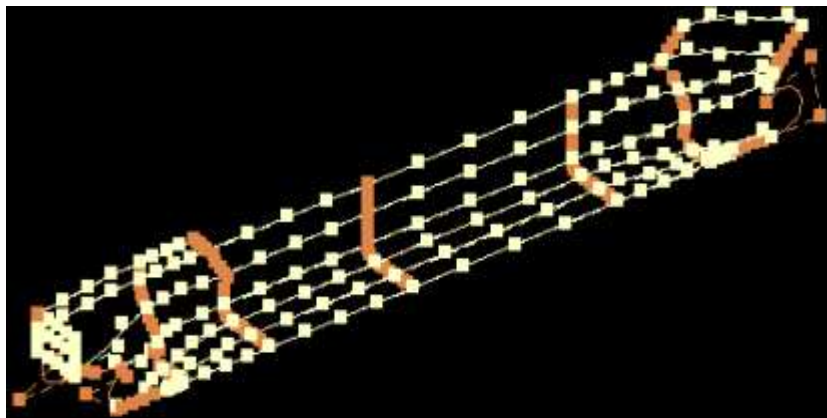


Figure 3. Edges of the hull patches

The ship's hull must be smoothed, for that reason, is necessary to maintain the continuity from the first derived throughout all its surface. When handling parametric surfaces, the continuity inside each patch is guaranteed, whereas to maintain it between patches it implies that the adjacent control points to each common edge are aligned with those of the edge.

In order to assure the continuity between patches, two new tools were developed by programming in MDL language, that were implemented in the basic program. The first tool is used to make two edges, of consecutive patches, continuous (see Figure 4 and Figure 5).

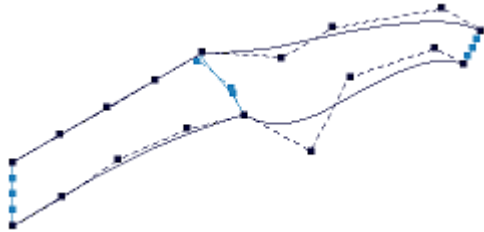


Figure 4. Non aligned b-spline edges, before applying the tool

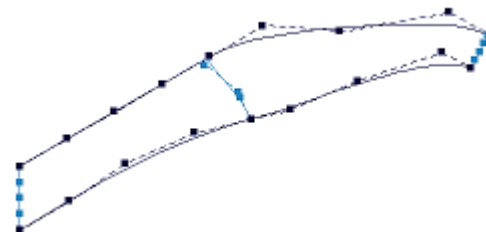


Figure 5. Aligned B- spline edges after applying the tool

When all the edges have been arranged and aligned (as it is observed in Figure 3), will be created, one by one, all the patches. After this, is applied the second developed tool. This tool, act directly over the surfaces, making the alignment of the adjacent control points, in order to the control points of the common edge. The control points over the edge will be not modified in the surface smoothing phase, because they were aligned in the previous stage. Avoiding then, the cracks generation between patches (see Figure 6 to Figure 8).



Figure 6. Non continuous contiguous patches

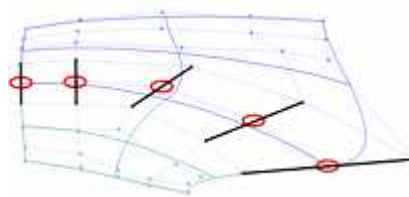


Figure 7. Control points alignment



Figure 8. Continuous patches

Previously of having these tools it was necessary to make the alignment of the points manually, investing in it a bigger amount of time, without reaching the same precision degree. Doing the process explained previously with all the patches, is obtained the model of the complete hull as is showed in Figure 9.



Figure 9. 3D hull model

At this moment, to validate the hydrostatic and structural behavior of the hull will be necessary, at the same time that the load spaces distribution is made, this is necessary for the accomplishment of the stability calculus. With the purpose of obtaining the hydrostatic curves

of the straight hull, a new tool that measures the parameters from the 3D model of the hull in CAD program was created, which does possible the direct export of the data to a spreadsheet in which to draw the information (see Figure 10).

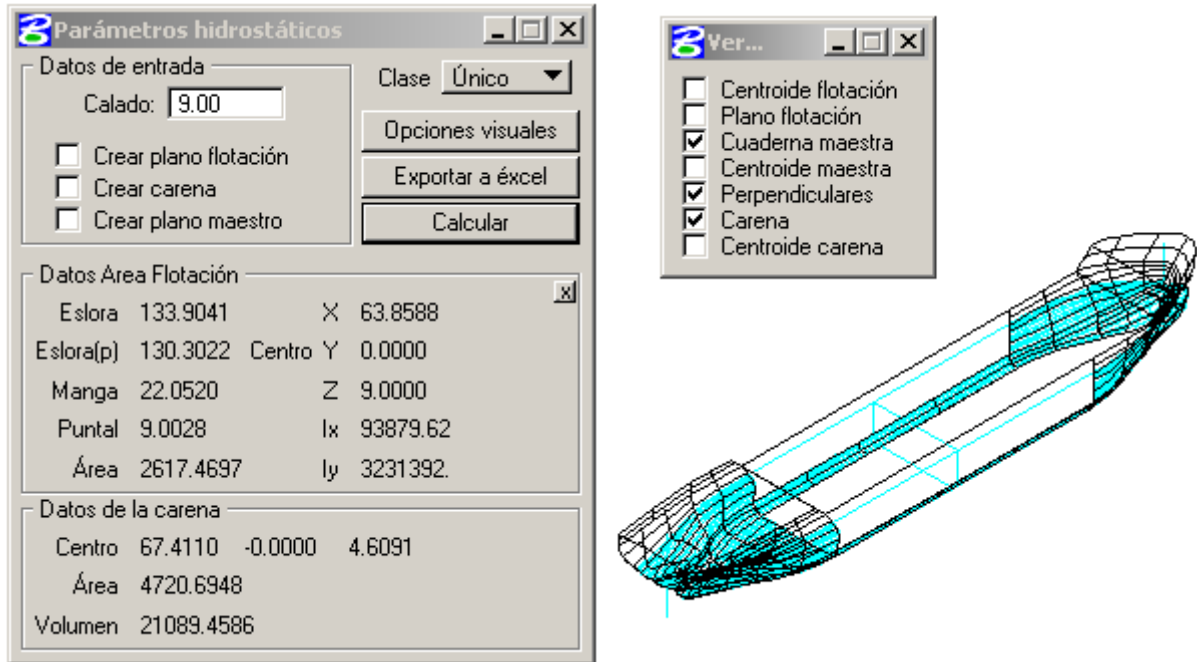


Figure 10. Hydrostatic parameters tool

When the load spaces disposition has been established (distribution of tanks), it could be studied the stability, handling the same departure data, and applying the classic equations of the naval architecture [5].

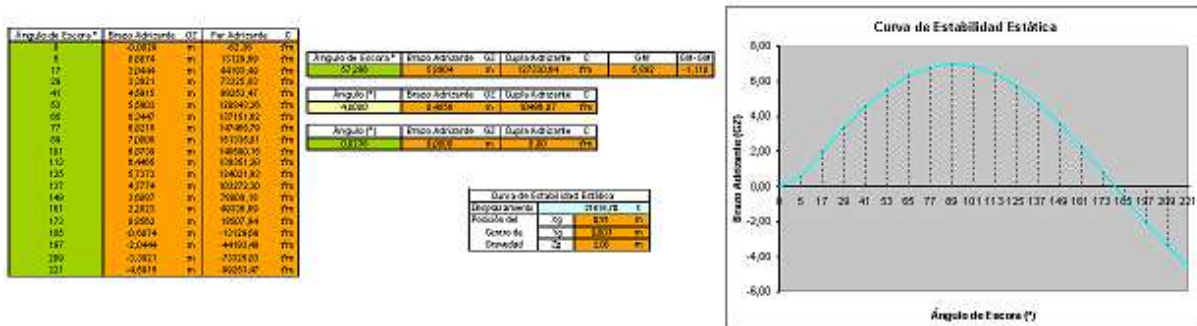


Figure 11. Static stability curve

At this moment, is being developed a new tool to calculate the exact transversal and longitudinal inclining of the ship, with any load conditions starting with the exact positions of weights and gravity centers of the elements of the model, calculating the stability without the simplifications that until now where made to determine it. Another possibility is the exportation of the model, by interchange formats (iges, parasolid, etc.) towards programs of analysis by finite elements and accomplish of hydrodynamics tests (CFD).

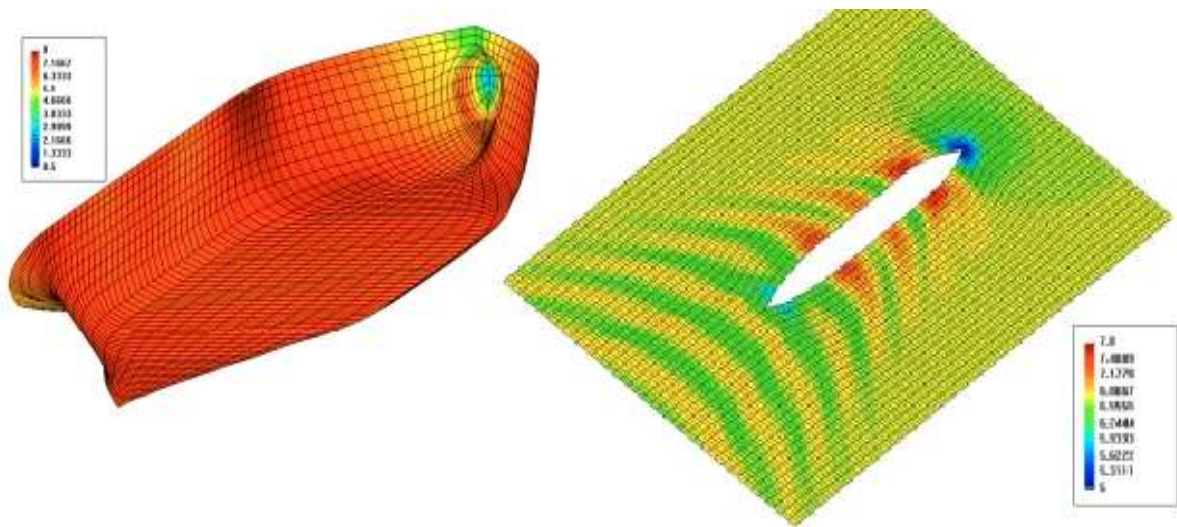
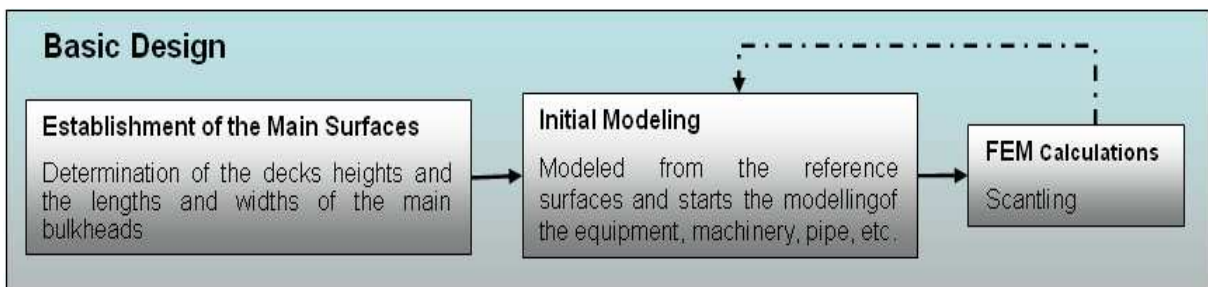


Figure 12. CFD, Distribution of the hull pressure, and waves system caused by the ship [6]

In function of the results obtained on those phases of calculus and analysis, is possible to return to previous phases of the process of design and make the oportune modifications (readjustment of the distribution of tanks and loads, to modify the forms of the hull) on the design until obtaining optimal results.

3.4. Basic design

At the same time to the hull design, the design of the remaining elements included in the ship advances. The Scheme 2 shows the activities to developed in this phase.



Scheme 2. Basic Design Tasks

The first step of the basic design consists in the establishment of the heights, lengths and widths of the surface levels that will represent the future decks of the ship, maintaining the established dimensions in the designed hull. Moreover, in this phase is made the space distribution of the ship to establish the location for the machinery room, loads, tanks, etc (Figure 13).

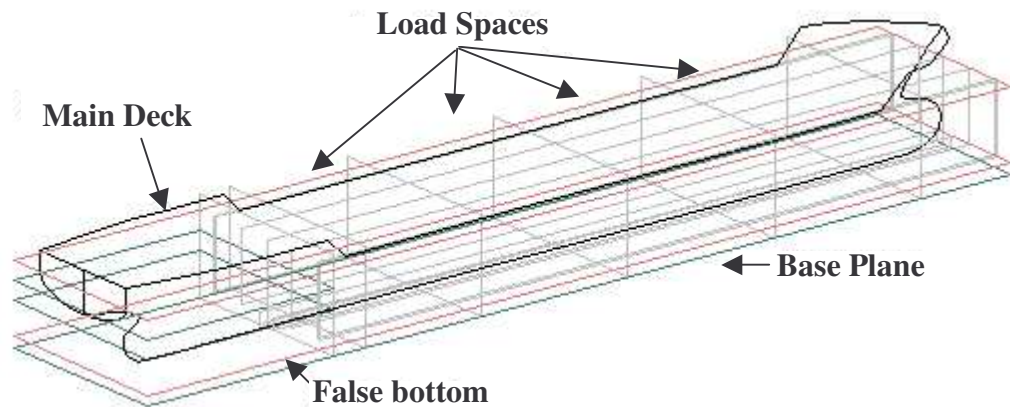


Figure 13. Reference surfaces and lines

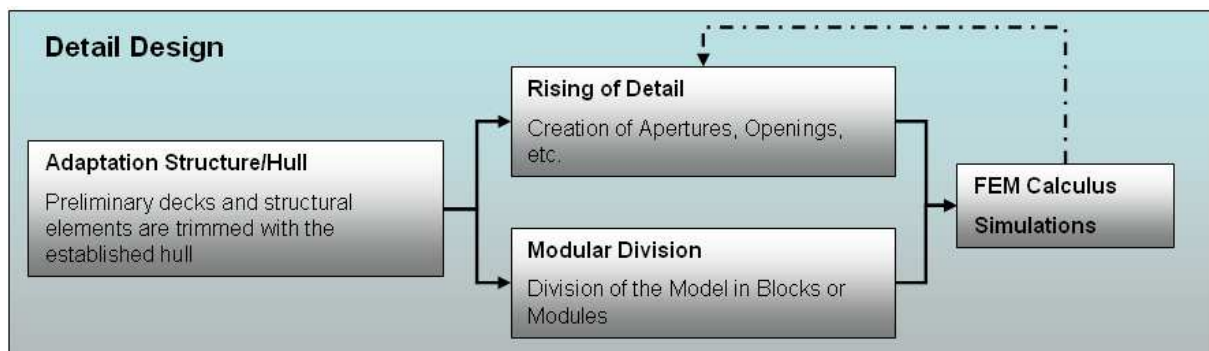
Once established the reference heights, the structure and the equipment the design of the ship begins (machinery, pipe, accessories, etc.), staying within the spread defined by the references.

The following step, will consist in the situation and separation establishment, of the primary resistant bulkheads and the secondary reinforcements. Next, its behavior will be validated by FEM analysis, establishing the thicknesses and the cross-sectional sections of them.

3.5. Detail design

This stage consists on elevating the definition degree of the designed elements. Following an ideal exposition, this phase would start when the hull design and the basic design stage are finalized, nevertheless, in it practices it begins once is finished the hull design and with the basic design in whatever point in which it is. By this way, the end of the basic design and the beginning of the detail design are overlapped, avoiding the breaks off in the design tasks and reducing the project global time.

The first task of this phase will be the trimming of the structural elements accommodating them to the hull, relocating the elements, because the reduction of space, could let some outside from the limits established by the hull.



Scheme 3. Detail Design Tasks

Consecutively, a constructive division of the design in modules or blocks is made while the detail degree rises progressively. This consists in the incorporation of reinforcements not generated in the previous stages and in making the openings on the structural elements, as the access in bulkheads, apertures in longitudinal reinforcements, etc (Figure 14).

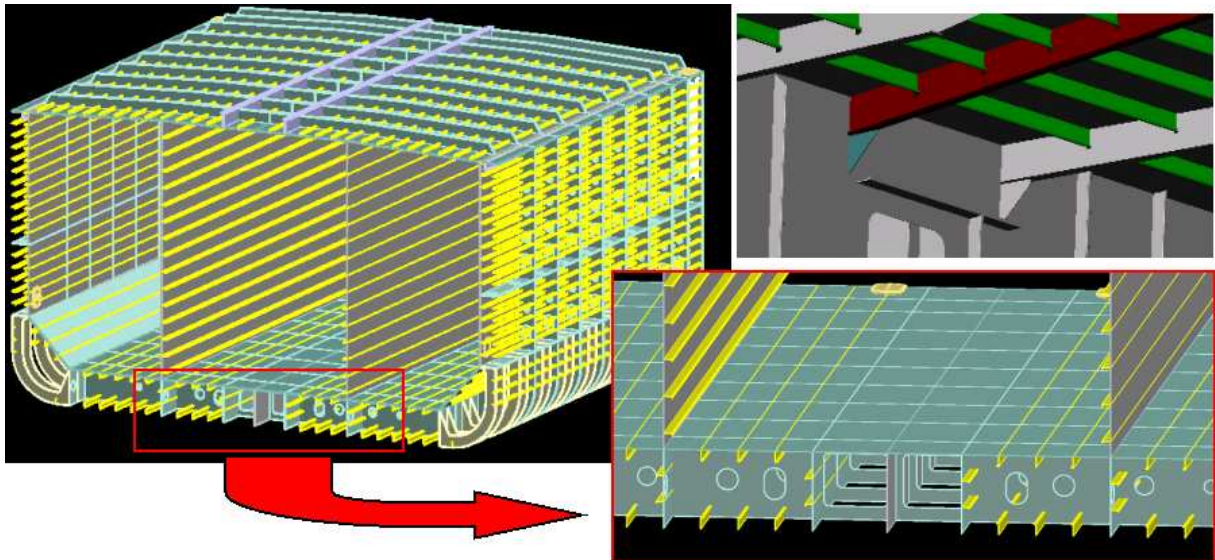


Figure 14. Details of structural elements

In order to optimize the structural design behavior, FEM calculations of precise zones of the model can be made (Figure 15) to detect the points with greater tensions or deformations, and to incorporate in them a greater charge of reinforcements if this were necessary.

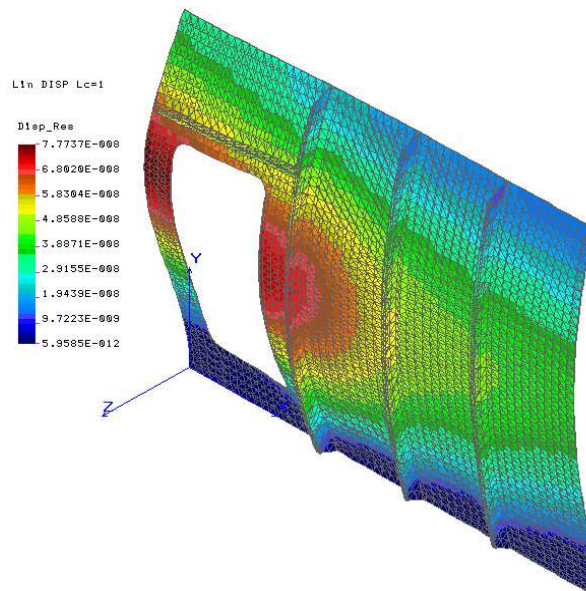


Figure 15. FEM analysis of a reinforced bulkhead

Continuing the described procedure, is possible to make the 3D model of all the elements, obtaining the complete model (Figure 16). The possibility of visualizing all the combined

elements to the way that they will be collocated when the ship is constructed, allows to detect the interferences between them and taking advantage of the util space. Recent studies [7] indicate that the variations in the use of the space in a ship are caused by quality differences and efficiency of the designs, concluding that the 3D models contribute with a greater effectiveness than the traditional 2D designs. Analyzing the space/weight relation of the recent manufacture ships, is observed that the more efficient boat presents generally around 20 %, and sometimes until 40 %, more effective area by ton compared with the less efficient boat.

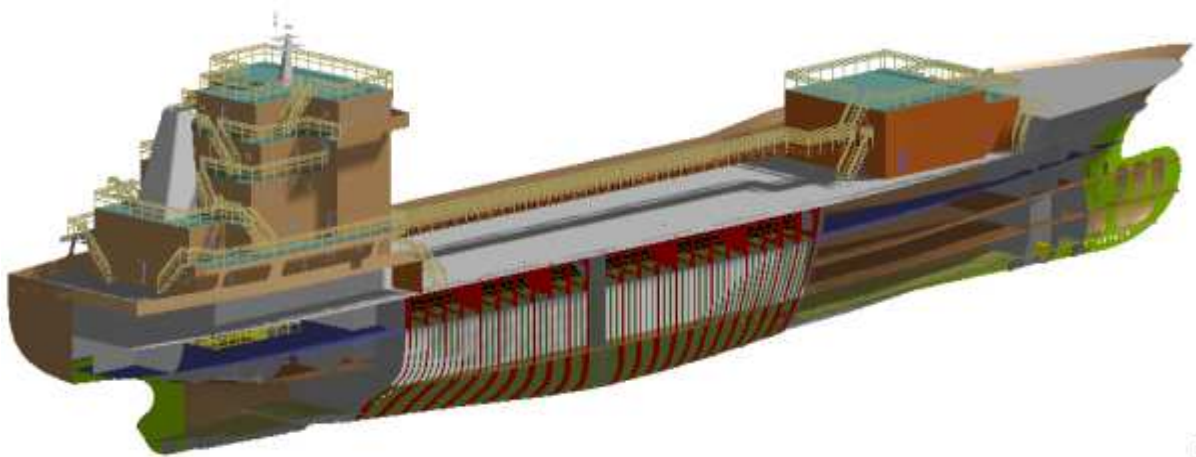


Figure 16. 3D model of the ship

The same elements generated for the creation of the model are used for the accomplishment of dynamics simulations (Figure 17), very useful to plan blocks maneuvers, to study the hoisting of the anchor, etc.

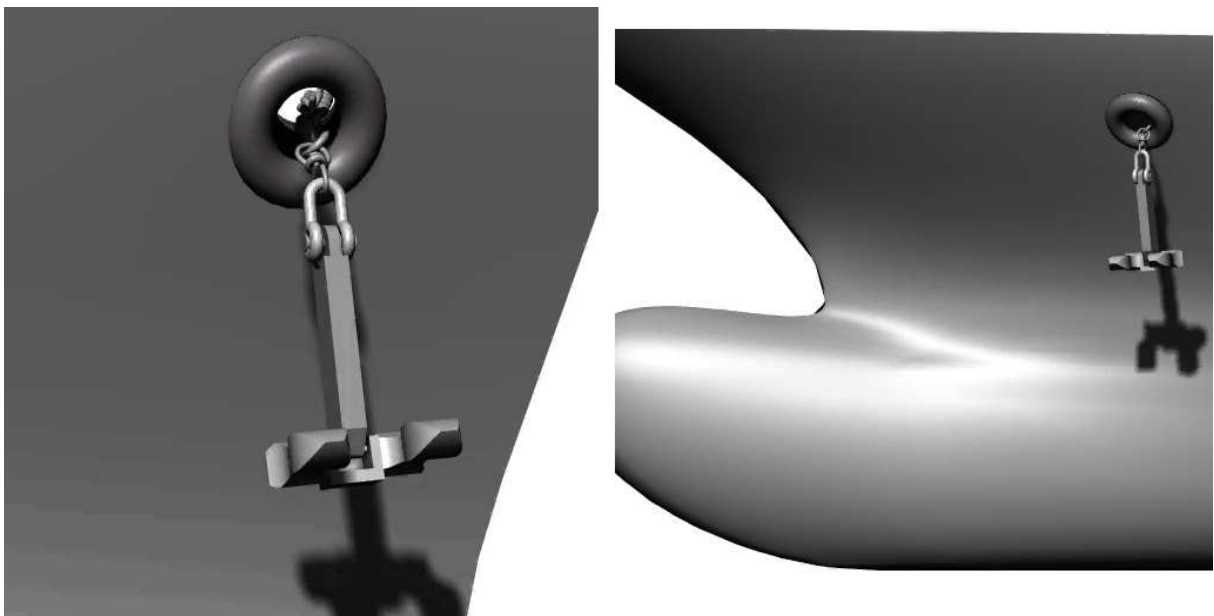


Figure 17. Anchor rising simulation

4. TECHNOLOGICAL SUPPORT

For the methodology development previously explained, it is necessary to have a set of tools integrated in the working platform. These services make possible working in network and the use of data bases, as the managing of all the information generated from the model.

4.1. Working Net

The ample variety of existing disciplines in the naval design, demands that different people are in charge separately, although coordinately, of the design of each one of them. Due to this it is necessary to establish a network, between all the design participants, so that they were capable to simultaneously make all the disciplines. The platform used, is configured to work, with a set of work terminals, against a common server that stores all the information of the project, by this way is possible to work at any moment with an only model, eliminating the eventuality of generating documents that represent contradictory the same element.

With respect to the security, the central server is connected to another computer that makes backups automatically. Moreover the server allows to manage what users can create, modify and visualize the information relative to the project, being able to make the encoded transmissions of the data.

4.2. Data Bases

The platform allows to work directly with data bases in the basic design program, distinguishing two types:

- Internal data bases, used to store predesigned elements as pieces libraries.
- External data bases, used to store product characteristics as materials, suppliers, prices, etc.

The externals and the internals data bases, are expandable by all the users (with permission of data bases modification), and they are available since the moment of their creation, to all of them.

4.3. Drawings and Bill of Materials

Although the platform allows to have a complete ship 3D model, by contractual reasons, of classification and production, being necessary to transfer the information to 2D drawings. The edition of these drawings, is directly made from the virtual model in an immediate process. This process consists in orienting the model in the wished position, and importing this View in a 2D working file, by this way, whenever it is necessary to make a modification on the model, the plane will be automatically updated, accelerating enormously the obtaining process of drawings in each project phase.

The bill of materials are documents that manage the count of the elements incorporated on the design. This count is automatically made from the model 3D. Due to the data bases connections, is possible to obtain the weights and the location of the gravity centers for each one of the designed element, and to compose by this way the weight and the exact center of gravity of all the ship. These data, feedback the calculate tools implemented in the program (Figure 10 and Figure 11) and gain precision according to the advance in the elements design.

5. CONCLUSION

A very significant part of the European naval sector is going through great difficulties due to the aggressive competition practiced by foreign countries, that finance the purchases of the ships constructed in their territory. These subventions make possible that certain shipyards can supply their boats, at international level, to a minor cost from the production real cost. The European Commission tries to act against this situation in two fronts: demanding the arbitration of the World Trade Organization (WTO) and, by the other hand, gives temporary aids to the affected European companies, through a subventions mechanism that could reach in maximums, under communitarian supervision, until 14% of the value of the boat. Actually, these aids are blocked because of the opposition of some European countries [8].

While the fight in cost stays, the platform presented/displayed in this communication could equip the European shipyards with a tool that allows them to recover or to gain quota of market, constructing ships of greater quality in much less time. This opportunity arises from capacities provided by the platform, emphasizing the integration obtained according to two different ways. One of them is the coordination obtained by the network that works in real time on a unique model. The other integration level comes from the creation of a tool that, make the design of all ship disciplines, allows to execute the naval architecture calculations and to communicate quickly with other programs for the accomplishment of simulations and FEM analysis.

In addition, all these applications (CAD, FEM, Data bases, etc.) are based on commercial programs, that allow to reduce the software investment, guaranteeing its continuous update. Other advantages to emphasize are: edition and automatic update of drawings and bills of material, detection of interferences previously to the production, functionality evaluation of the spaces, ...

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