Ships' virtual prototyping

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Summary

1 Introduction

This document describes why Virtual Prototypes (VPs) can be useful for modern and future ship design processes, and briefly depicts how the VPs of the two case study ships of the METRO project have been created (in Figure 1 an example of the result for the RoRO-Pax vessel is shown). The VPs for the two ships have been prepared focusing on the external forms and the structures, using the stability characteristics and weight calculation of the hull as a validation tool. The VPs can be enriched further with all the machinery, providing a complete ship's model in a single software.

The VPs have been created in Paramarine® software, as explained in Chapter 3, and the files for both ships can be made available to the Project Partners, as well as to other interested stakeholders by means of a specific request to University of Trieste – Integrated Ship Design Lab. (email: vbucci@units.it).

Figure 1 - First render of RoRo Pax METRO project's ship, extracted from the VP software.

2 The use of virtual prototypes in integrated naval design

Due to the increasing complexity of ships, the shipbuilding design approach undergone a lot of changes in the past decades. The traditional design approach, which requires the use of several software to elaborate and manage the huge amount of data involved in ship value chain, presents some important limitations. First, the software used for designing a ship are not integrated, thus almost always need significant activities/work for making it possible to exchange data with other software or specific tools. Second, due to the complexity of the product, the work is usually subdivided among different teams, each addressing a single aspect of the whole process independently. As a result, the information generated during the design process often require additional work for building all the required relations between all of them, and the resulting process is not efficient.

Such limitations add to another peculiarity of the ship design and building process, which is the high cost for modifications to the design that need to be performed in late design phases. In fact, 70 % (or more) of the final cost and performance of the ship is essentially “locked in” during the early-stage design phase (Figure 2). Thus, all the decisions and actions that are taken in the later design stages, or during construction, or during operations, are more expensive and time consuming if compared with the ones made during early-stage design. Such peculiarity makes the above-mentioned limitations a huge impacting factor for the shipbuilding process. Indeed, an issue that arise from an unexpected interaction between subsystems designed by two separate teams can be identified only during later design stages, when all the information is put together, being the two teams working independently until that moment. Then, corrective actions have to be put in place, but these are made at a stage where the modifications cost is significant, as previously mentioned. This commonly happens in shipbuilding, but modern design approaches and software can be exploited to overcome these limitations.

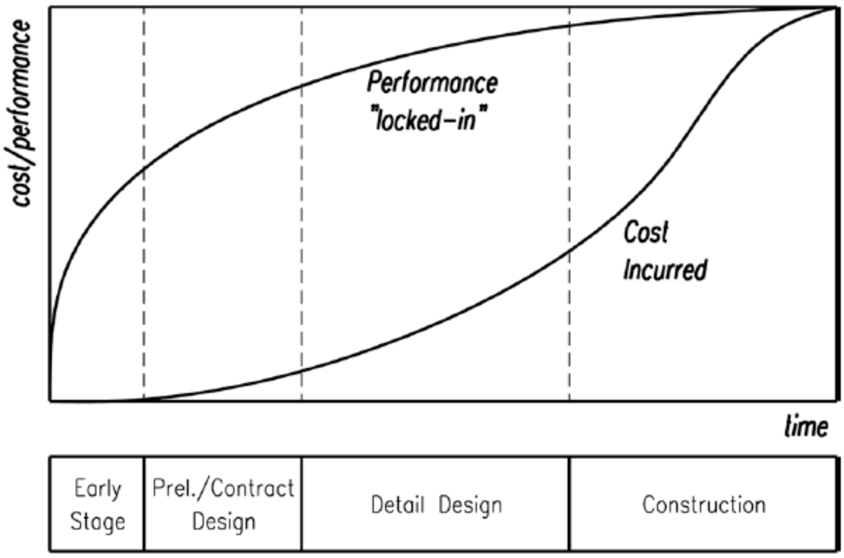

Figure 2 - Cost/performance vs time during the ship design and construction phases

Four different approaches are actually being proposed for solving the above-mentioned limitations:

1. Concurrent engineering: Integrated design teams, electronically connected, employing a new integrated multitasking and multi-functional design methodology enabled by new computer tools;
2. Systems engineering: a top-down integration of systems into a ship from the early-stage design;
3. Adoption of new technologies: assessing and integrating emerging technologies with new ship design in order to obtain their fast, cheap, and reliable proof-of-concept;
4. Modelling and simulation: Virtual prototypes based on 3D parametric digital models navigable by means of Virtual Reality.

In a modern innovative design methodology, one (or all) these methods must be included in early-stage design phase, where the achievable advantages coming from their use can be maximized. To reach this goal, a possible solution is the adoption of specific Product Life-Cycle Management (PLM) software tools, called Computer System Integrators (CSIs) (Figure 3).

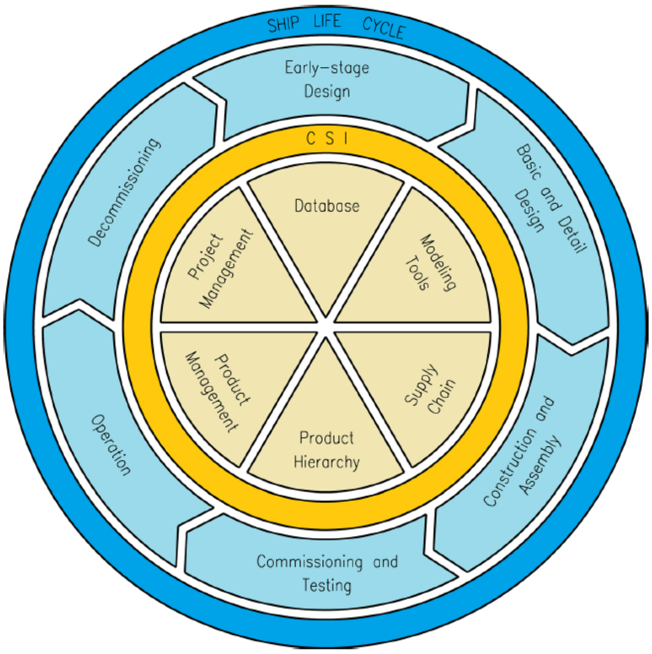

Figure 3 - PLM elements within a simplified ship life-cycle

CSIs are composed by several modules and allow to both manage the data exchange between the various design tools and follow the evolution (of the product design and its engineering) caused by requests coming from each participant (designers, owners, builders, regulatory, and classification bodies). Being it possible for all the involved parts to work on the same ship model, continuously updated, an uninterrupted check and approval process is performed. The latter allows to find critical issues and unfeasible intersections among subsystems as soon as possible, thus making it possible to correct them before reaching the later design stages (saving times and cost).

CSI modelling tools allow the creation of the so-called Virtual Prototype (VP). Already defined by Wang in 2003 as "a computer simulation of a physical product that can be presented, analysed, and tested from concerned product life-cycle aspects such as design/engineering, manufacturing, service, and recycling as if on a real physical model", the construction and testing of VPs (called Virtual Prototyping techniques) transformed the virtual design model in a direct design object. In fact, VP is subjected to checks, analyses and simulations and comes to coincide in substance with the finished product itself, allowing to extrapolate a high number of outcomes (Figure 4). The significant advantages of using a VP make the effort of producing a one worthwhile.

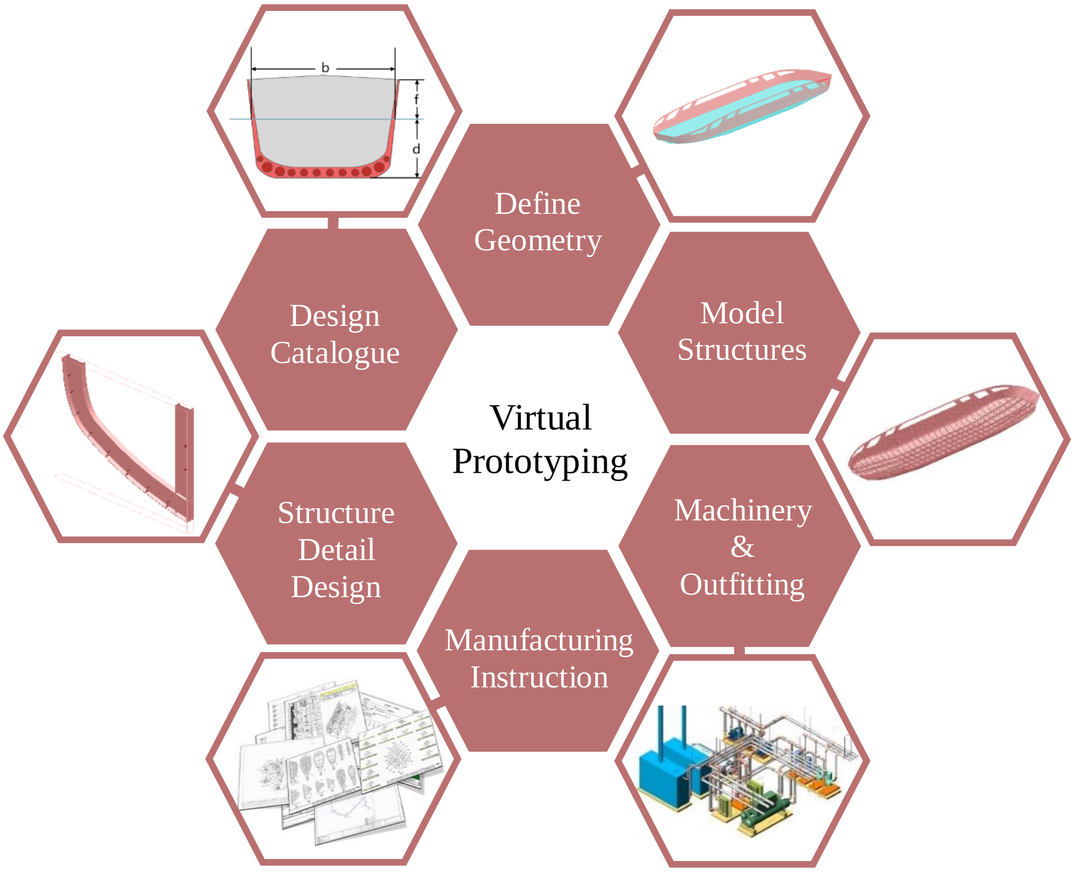

Figure 4 – Possible outcomes of a Virtual Prototype

The VP software also provide a 3D parametric master model, which can be accessed through virtual reality. This enables rich visualization of design choices and analysis of physical fit of components and arrangements, including verification of intersections between hull, systems and structures. This 3D model can also be used to analyze ship construction, maintenance and repair activities through visualization and analysis of maintenance envelopes and interferences. Inclusion of avatars enable the measurement of human-machine interface issues. These capabilities provide the opportunity of making production-related decisions in early-stage design and, if connected with Virtual Reality, allows the fast proof-of-concept of new technologies and a faster process of proposal and approval of solution by the owner.

In order to build a VP it is required to apply Virtual Prototyping techniques, which can be divided in three different categories:

- Surface modelling: the resulting object is formed by only its external surfaces;
- Volumetric modelling: the resulting object is formed by entity set that form surfaces implicitly;
- Solid modelling: a full volume forms the resulting object.

For the purpose of this work, the solid parametric modelling was chosen. Such a technique allows generating a full volume by typing numerical parameters such as height, length, depth, radius and angles. Thanks to this modelling approach, it is also possible to modify the model geometry without rebuilding all the VP. Indeed, structural elements (e.g., bulkheads) can be easily relocated, while the VP model automatically adapts all the other existing surfaces and elements to the new configuration. As far as changes in ship main dimensions are concerned, the VP is able to maintain the reference points for structural elements previously generated and to support the designer in adapting the existing geometries where a human intervention is required. Such a capability is crucial when the main aim is performing comparisons between different configurations and layouts of the ship machinery.

3 Specific characteristics of the software tool used for the METRO ship's VPs building

To create the VPs of the target project's ships, the Paramarine® CSI modelling tool (from the company Qinetiq®) was used. The software provides capabilities for performing studies in several naval expertise areas, like maneuverability, seakeeping, stability, propulsion, and also provide a structural calculation module. The programming paradigm of Paramarine® is "Object Oriented" C++. This means that all the geometrical elements, physical data, and analysis results are contained in objects, which also memorize how they were created and how they are linked to each other.

The hierarchical system that is created by means of this approach allows identify ascending and descending objects (Figure 5, where also the placeholders of various colors that are used to identify the first level of ascending objects are visible). By modifying an element contained in such hierarchy, a direct automatic modifications is achieved in all the related elements.

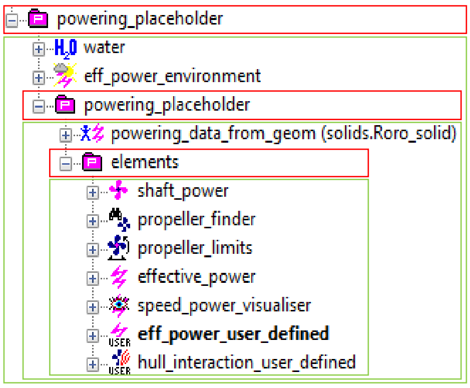

Figure 5 – Example of hierarchical system for powering: ascending (red box) and descending (green box) objects

As an example, if some main geometrical characteristic of the ship is modified (e.g., overall length, beam, or depth), the software is capable of performing by itself all the calculation/modifications that are needed to adapt the existing elements to the new ship characteristic (such as stability calculation or hull structure's frame pattern modification), without requiring the user's intervention.

To achieve the correct hierarchical ordering of all the elements, the first ascending object is constituted by the hull and superstructure geometries. Then, all the placeholders pertaining to the different naval expertise areas useful for the correct ship design follow. Specifically, these are therefore descending object of the hull and superstructure geometry and, in turn, ascending object of their same areas (Figure 6).

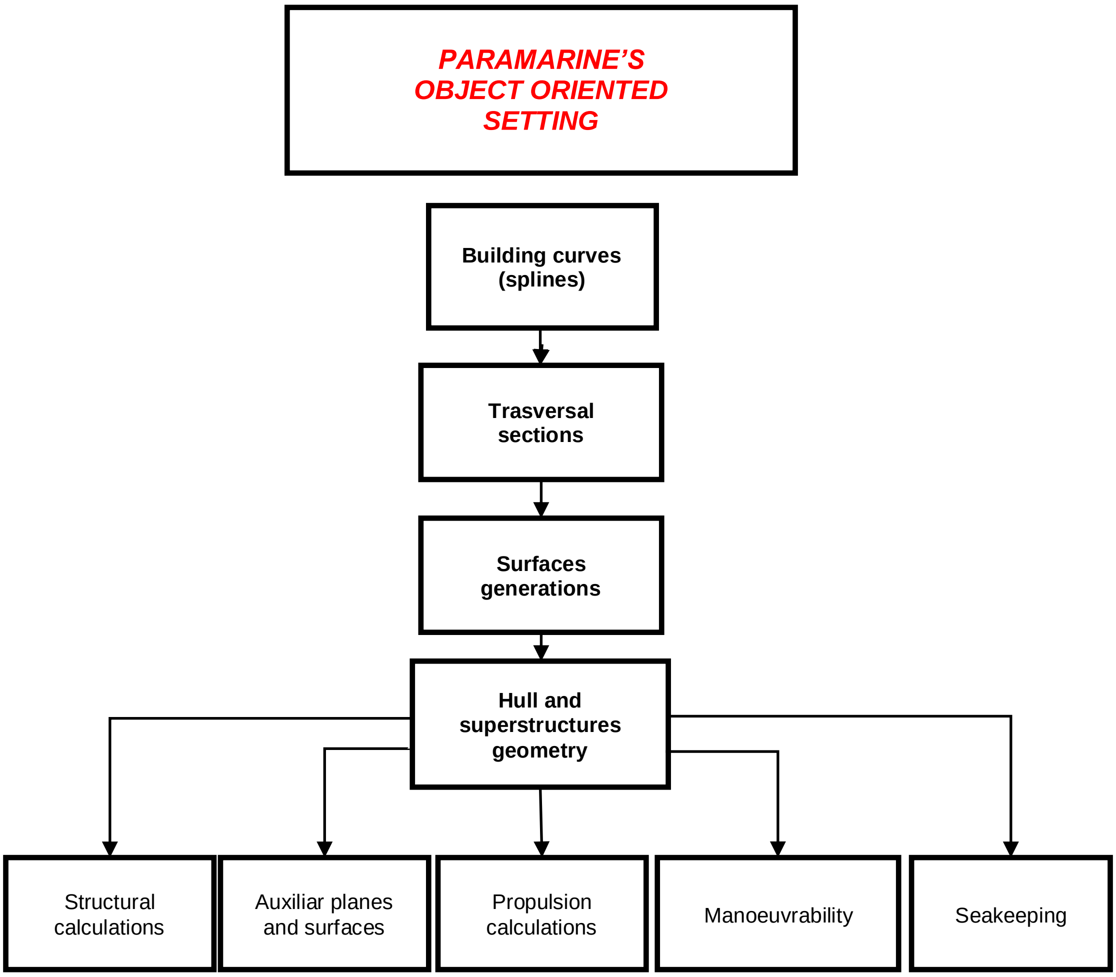

Figure 6 – Paramarine®'s work schedule

4 Description of the methodology used for the creation of the METRO ship's VPs building

The step-by-step methodology used to build the METRO project ship's VPs in the Paramarine® CSI modelling tool is summarized in Figure 7.

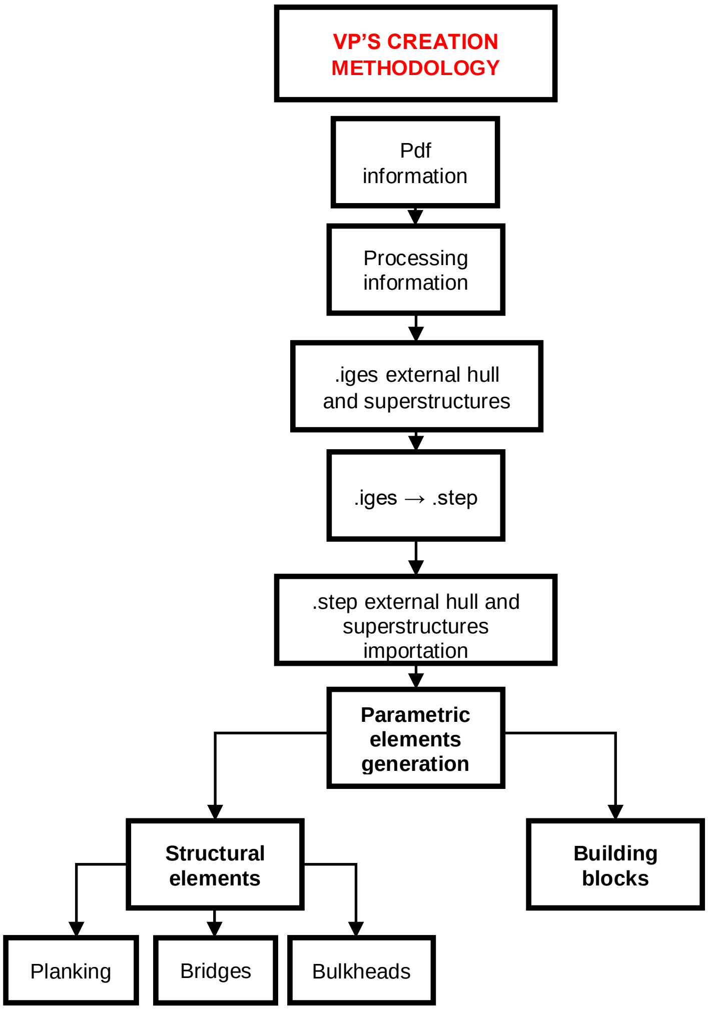

Figure 7 – VP's creation methodology

As above-mentioned, the creation process of the VPs begins with the definition of the hull and superstructure geometry. Due to its user-friendliness, in the case of the METRO project ships Rhinoceros® has been used to create the first external hull and superstructure development, starting from the available ship design information (pdf documents and drawings).

The first steps allow building a .iges Rhinoceros® model, which can be then imported in Paramarine® in .step format. This passage is significant, because the latter format allows the CSI software to recognize the model as a solid, while importing the model using the first format makes the CSI software consider all the surfaces as separate elements, still to be merged (which required additional work directly in Paramarine® environment).

Once the external hull and superstructure are correctly imported in the CSI, the bulkheads, the bridges, and the planking have been modelled as parametric elements. Other elements have been also modeled in addition to the structural elements, by means of building blocks (boxed volumes with a given weigh):

- for the Ro-Ro Pax vessel, passengers' cabins;
- for the Double-Ended ferry case study, embarked vehicles.

Starting from the previously modeled elements, placeholders dedicated to all naval expertise areas of concern have been created. These allow to obtain from the software, thus without requiring specific design/calculation work to the user, the following information:

- Structural weight and mid ship section;
- Cabin weight for the Ro-Ro Pax case study, and vehicles weight for the Double-Ended Ferry case study;
- Hydrostatic calculation, cross curves and GZ curves;
- Power prediction.

5 METRO ship's VPs results - examples

The VPs for the two ships designed during the METRO project have been prepared, focusing on the external forms and the structures, using the stability characteristics and weight calculation of the hull as a validation tool. The VPs can be enriched further with all the machinery, providing a complete ship's model in a single software. In the following examples pertaining the renderings, documentation, data, and other results directly obtainable by means of the correct interrogation of the ships' VPs are briefly shown.

5.1 Ro-Ro Pax vessel

The Ro-Ro passenger ship designed during the project (Figure 8) is compliant with SOLAS regulations for Short International Voyages. The Vessel is designed with stern and bow ramp for facilitated loading/unloading of ro-ro cargo and passengers in fully enclosed main cargo hold. Hostable car deck designed for stowage of cars only has end panels acting as access ramps

The ship is driven by a dual fuel engine machinery propulsion unit consisting of two medium speed, four stroke, non-reversible main engines, coupled to reduction gears, propulsion shafts and controllable pitch propellers. Two shaft generators and one emergency diesel generator unit to be provided, as well as battery pack for pure battery operation (maneuvering, low speed and emergency – PTI operation) and hybrid "peak shaving" operation, used to store energy when the power demand is reduced and to restitute the energy when such demand is high, while running main engines at constant speed and at optimized load.

The main characteristics of the ship are depicted in Table 1.

Hereafter some preliminary results obtained from the VP are depicted, from Figure 9 to Figure 21.

Figure 8 – Concept design of the Ro-Ro Pax vessel - rendering

Table 1 - Main characteristic of Ro-Ro Pax vessel

Main characteristics		
Length, overall	129,00	*m*
Length, between perpendiculars	123,00	*m*
Breadth, molded	23,6	*m*
Hull depth to freeboard deck (midship)	8,00	*m*
Draught, scantling	5,6	*m*
Draught, design	5,25	*m*
Deadweight, scantling draught	~ 2240	*t*
Deadweight, design draught	~ 1400	*t*
Speed, service	15,5	*kn*
Capacity		
Max passengers on board	~ 1335	*persons*
Crew	75	*persons*
Trailer capacity	631	*lane meters*
Cars capacity, total	350	*CEU*

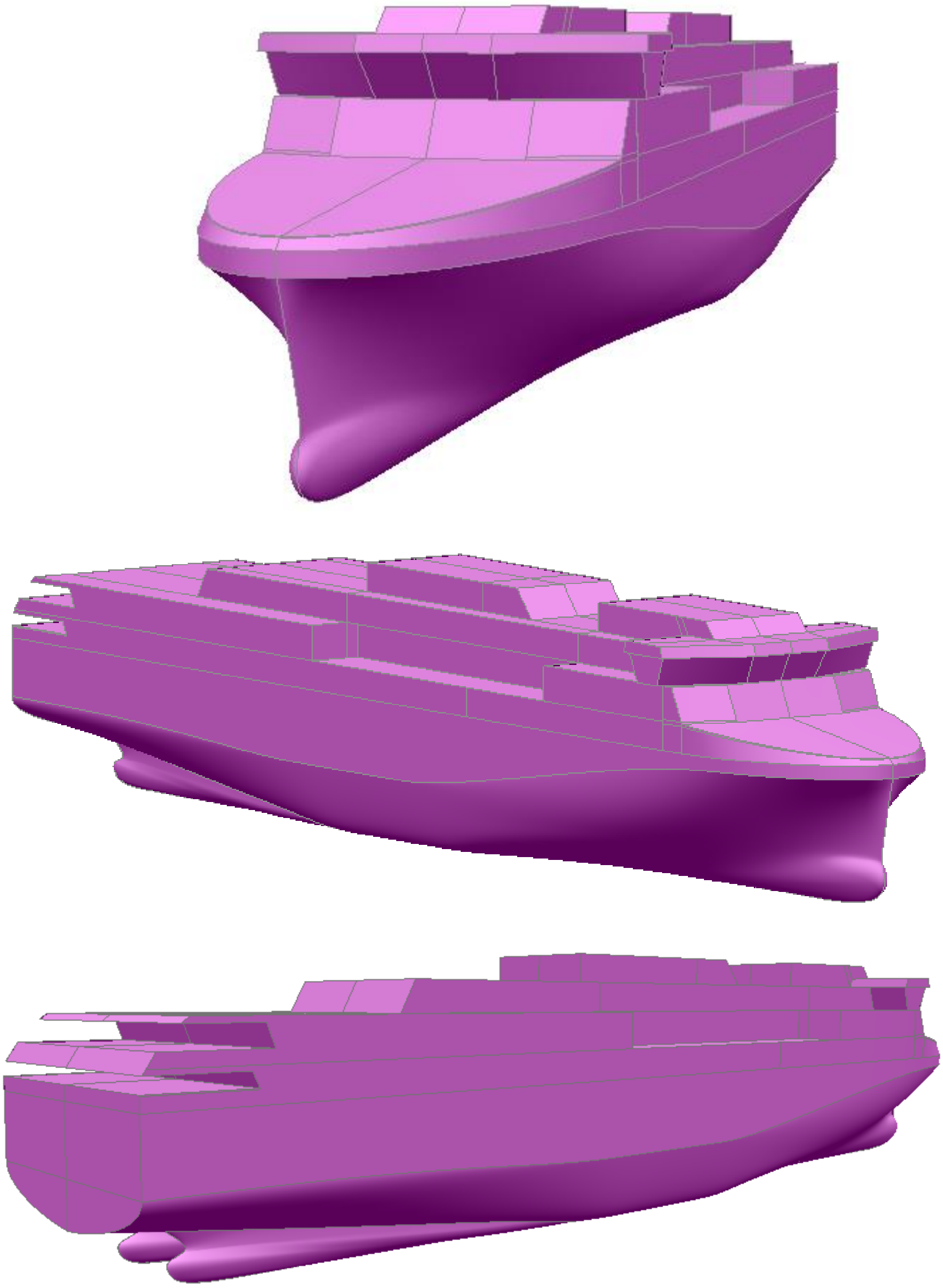

Figure 9 – First Rhinoceros® render

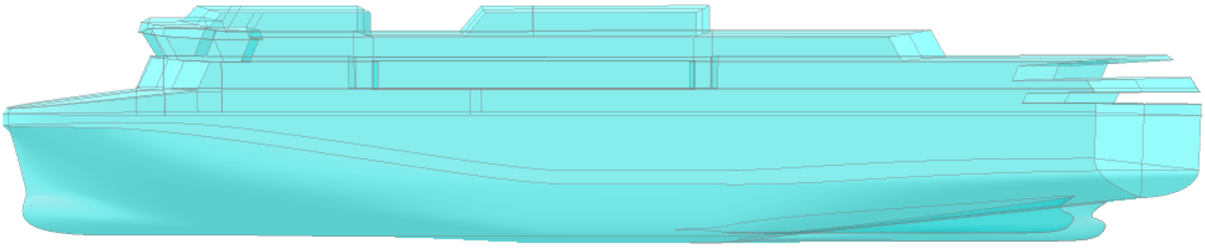

Figure 10 – First Paramarine® render

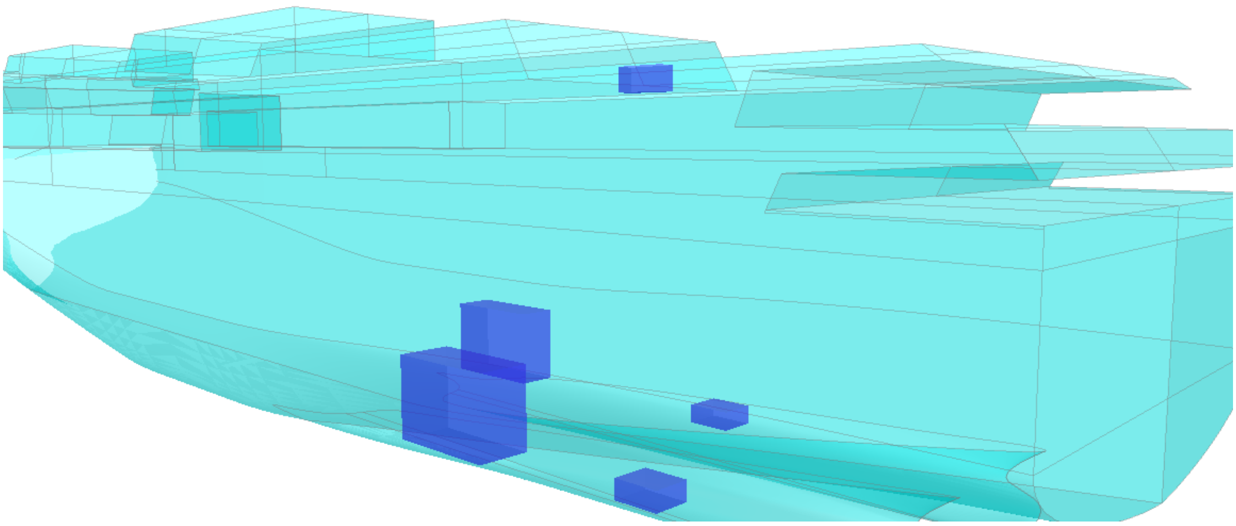

Figure 11 – Engines and generators box models

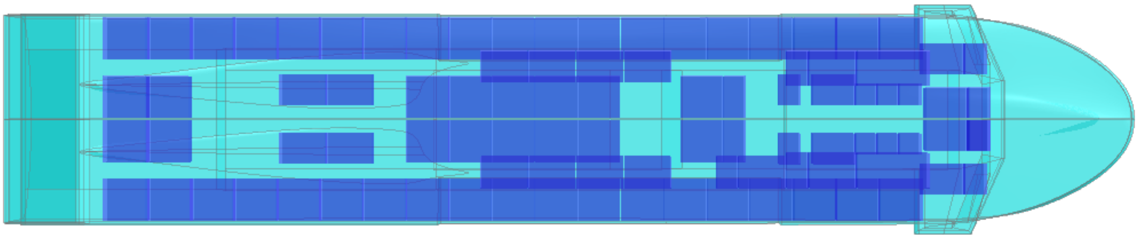

Figure 12 – Cabins longitudinal placement

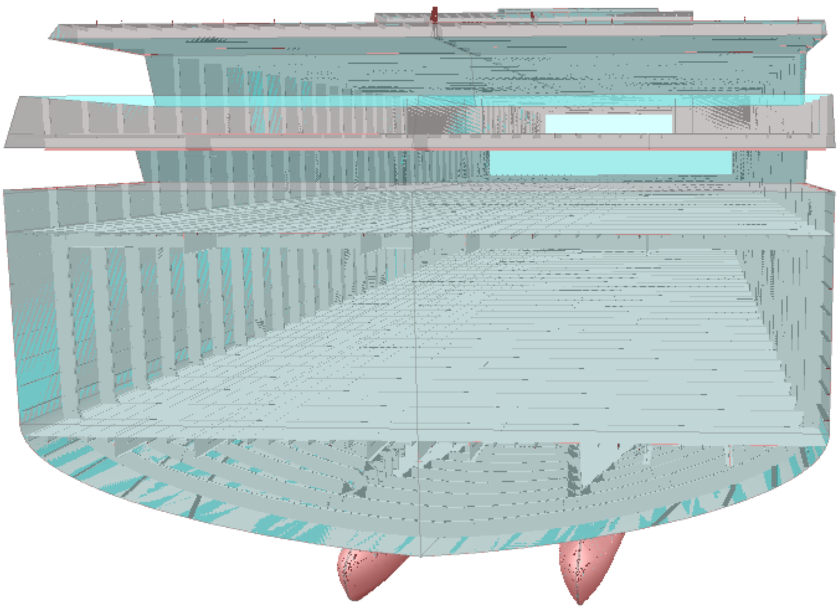

Figure 13 – Structural frame view

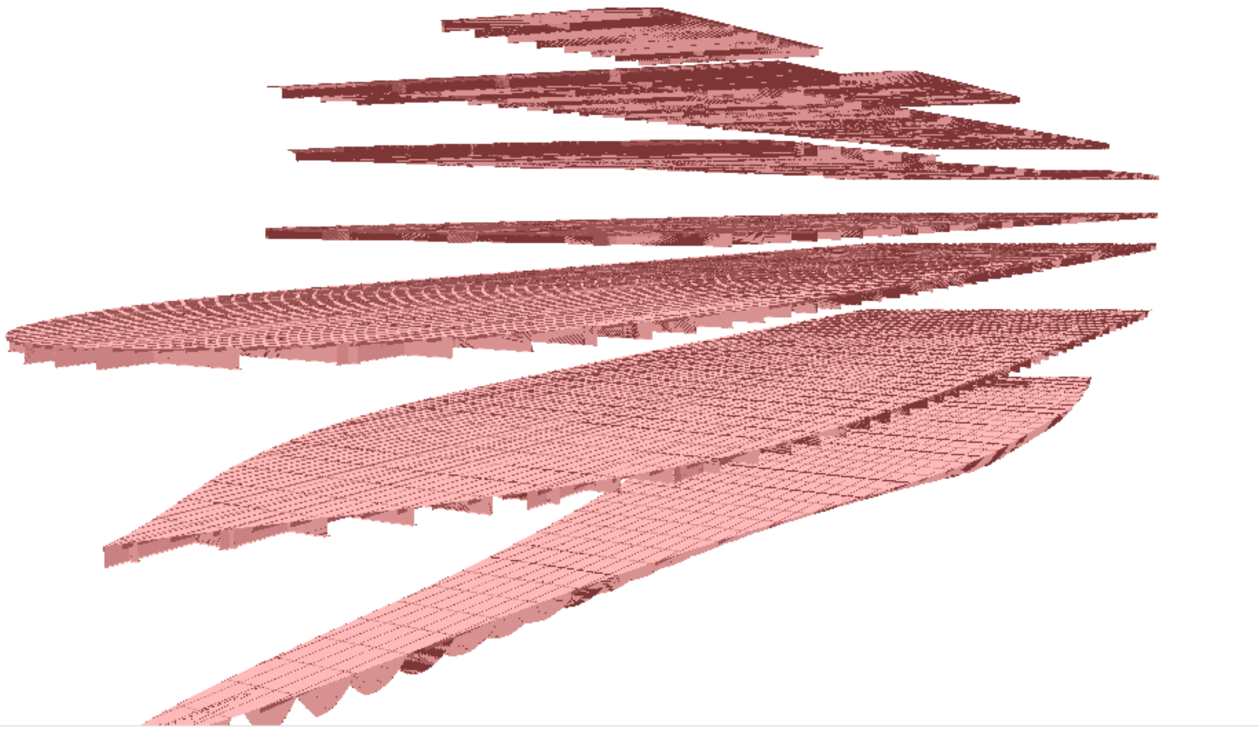

Figure 14 – Particular - Decks

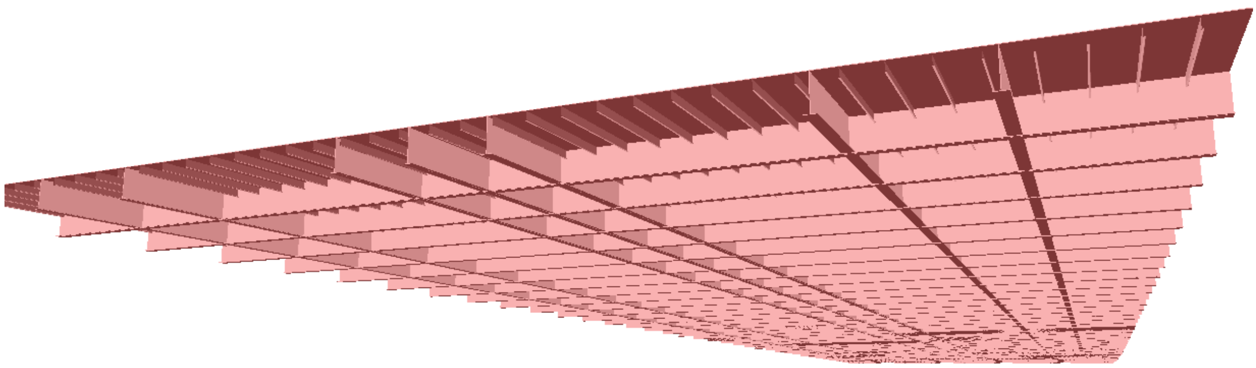

Figure 15 – Particular – Deck with profiled bars

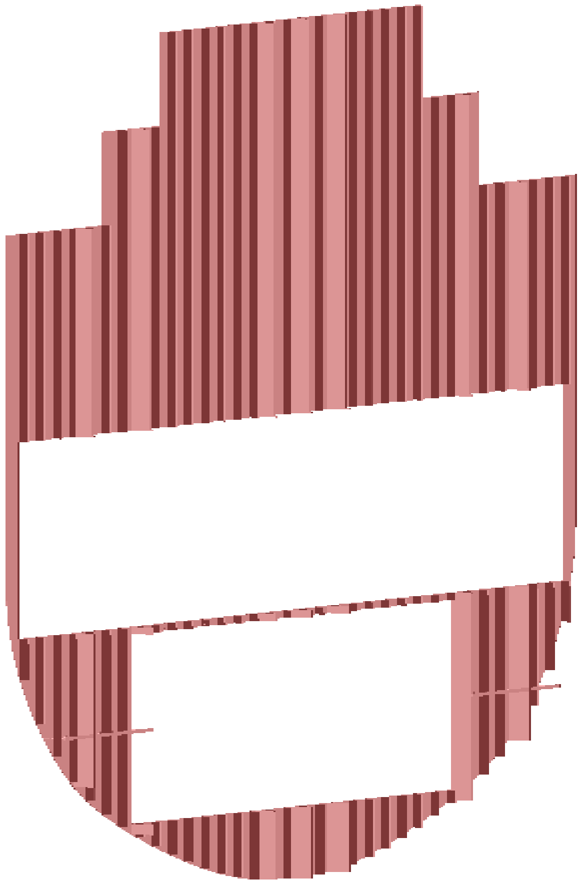

Figure 16 – Particular – 3D Transversal bulkhead

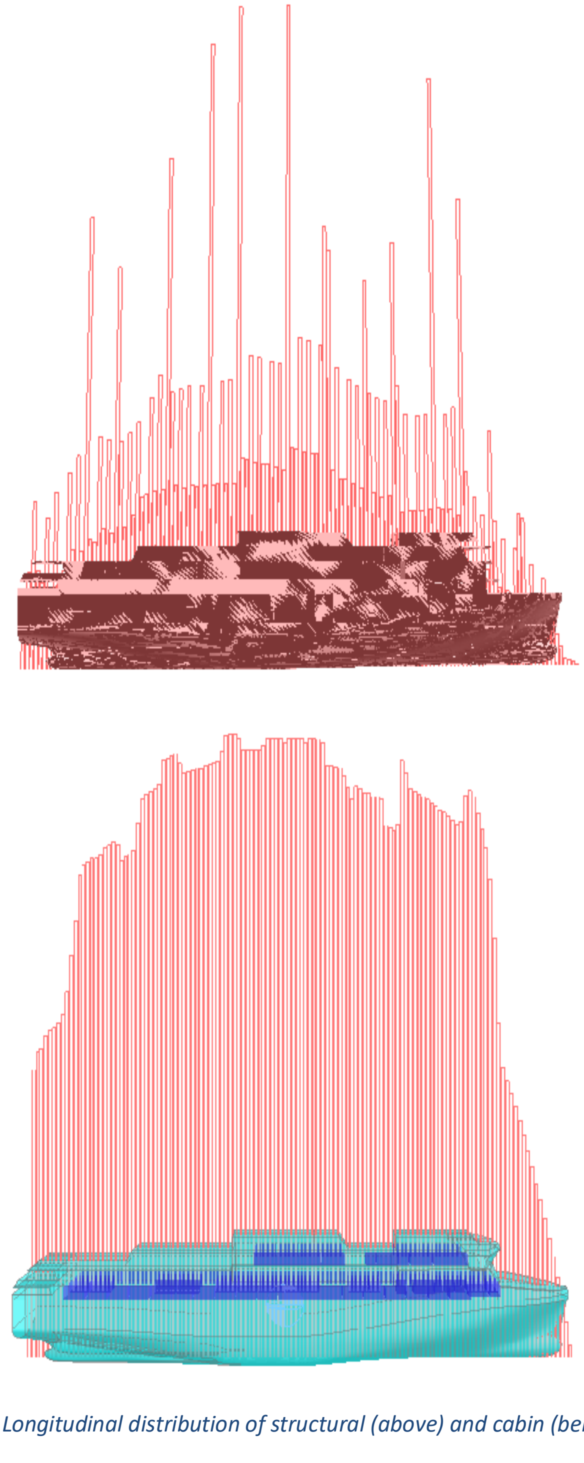

Figure 17 – Longitudinal distribution of structural (above) and cabin (below) weight

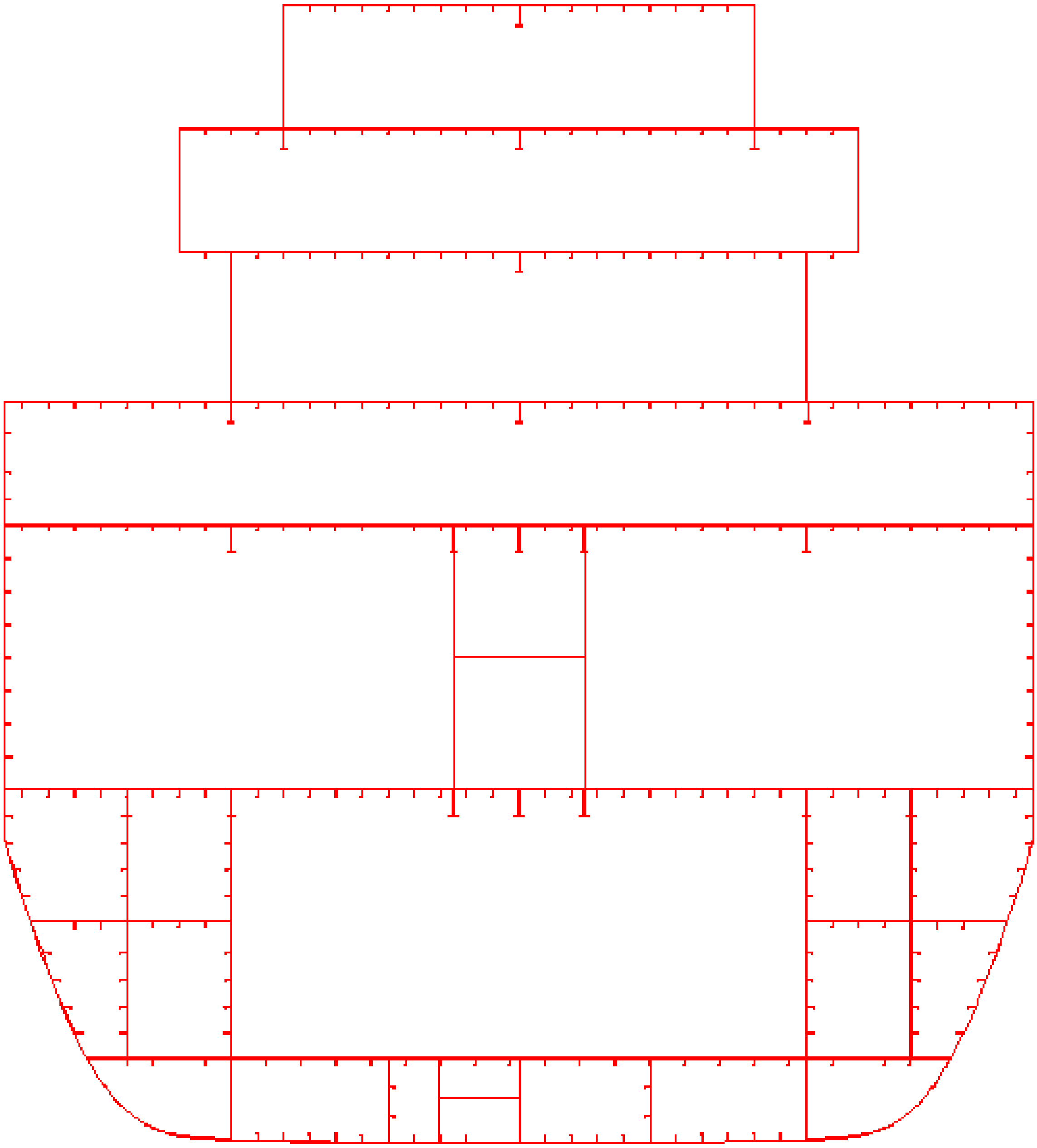

Figure 18 – Midship section

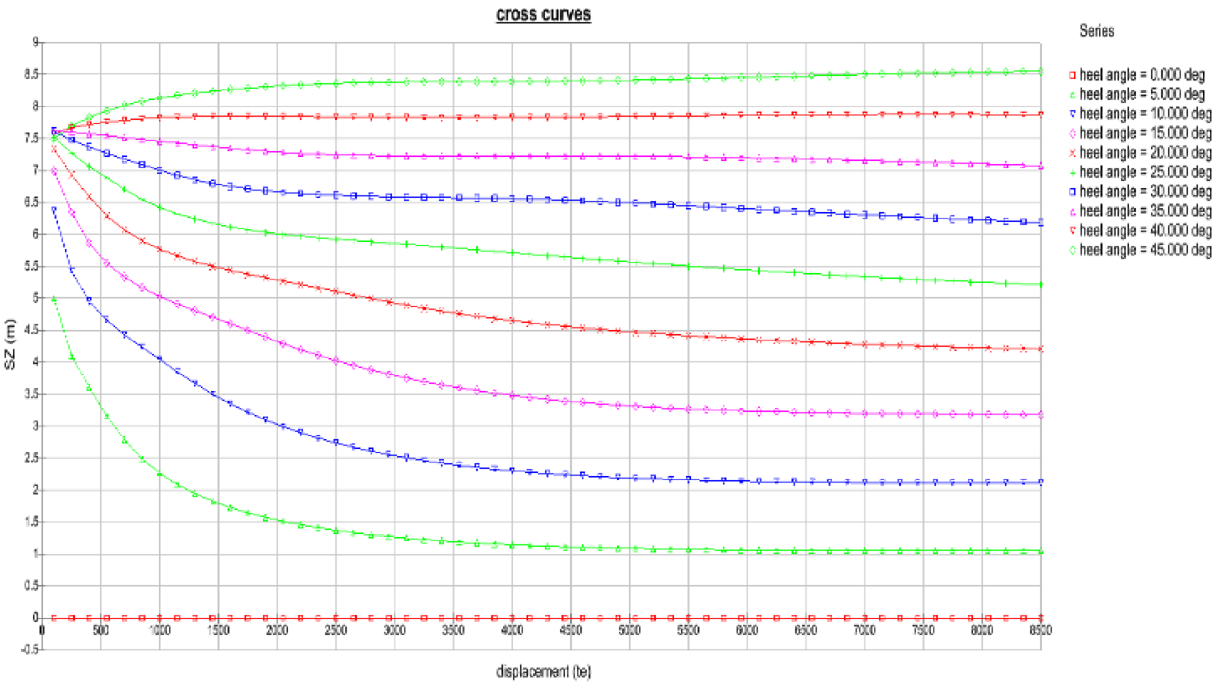

Figure 19 – Cross curves

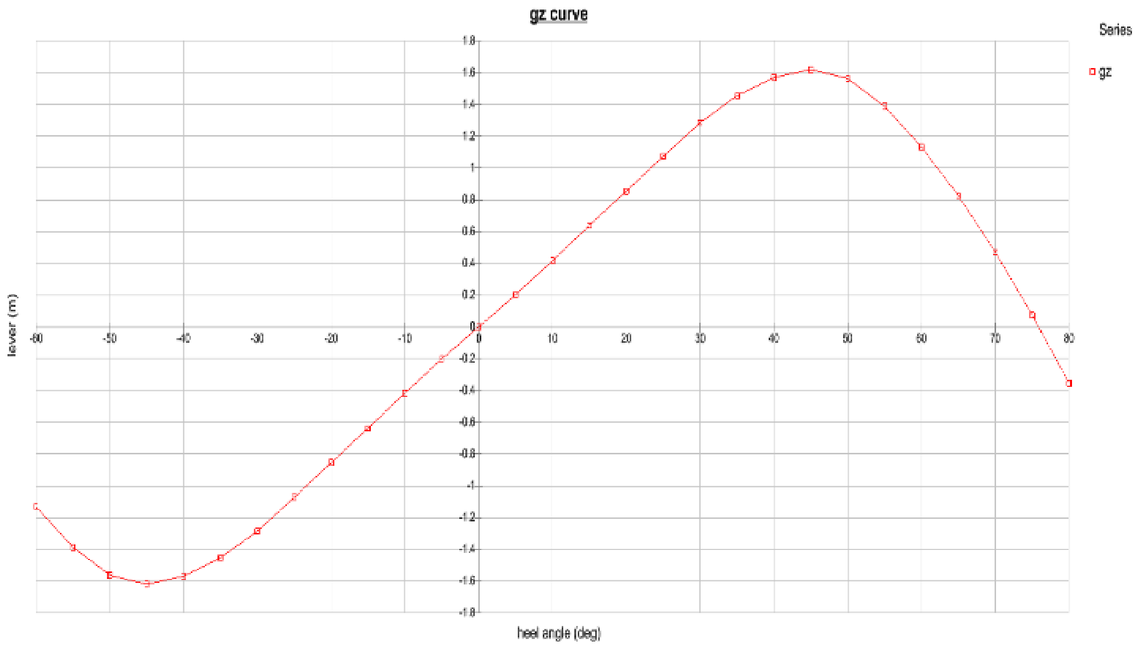

Figure 20 – GZ curve

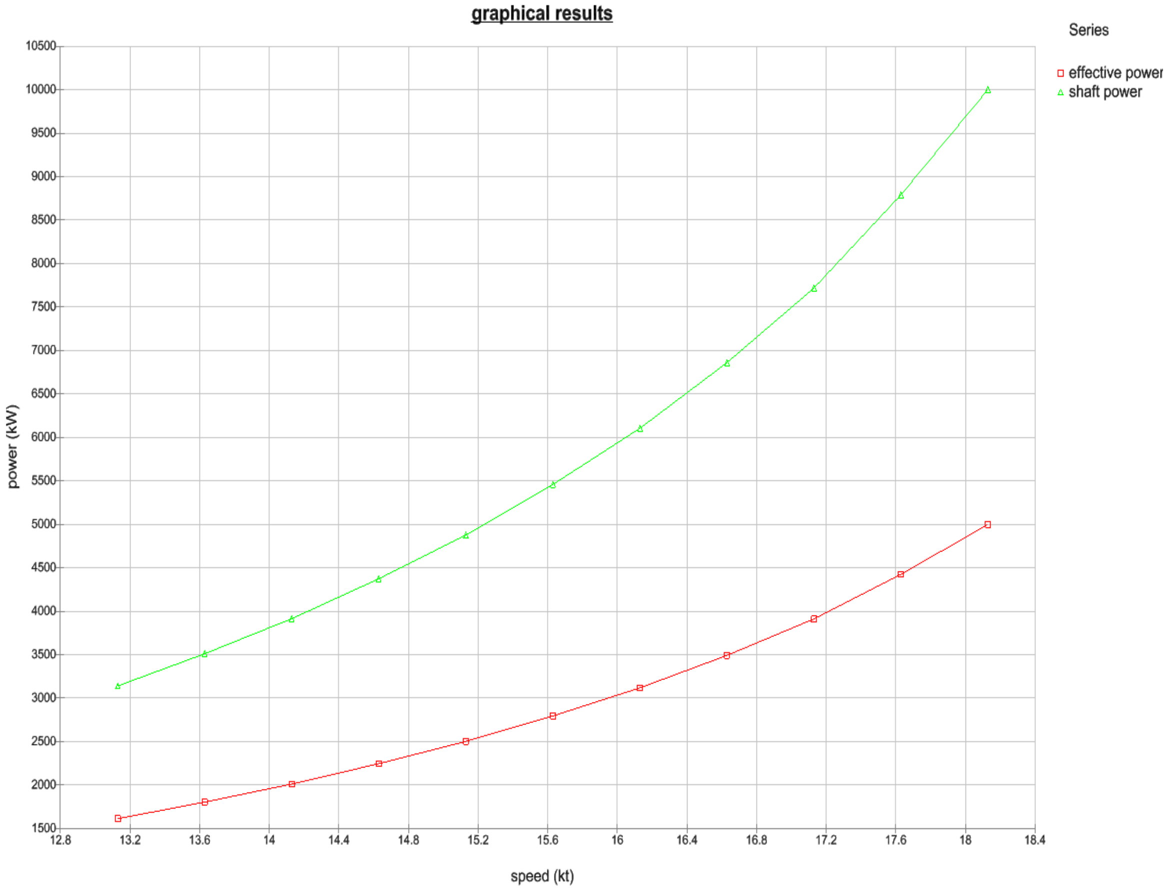

Figure 21 – Effective and shaft power

5.2 Double-Ended ferry

The double ended car & passenger ferry designed during the project (Figure 22) is intended for restricted waters operation in Croatia. The propulsion is based on a diesel electrical hybrid solution with a battery system. The vessel is able to operate in pure battery mode, with the possibility to charge the batteries from a suitable quick connecting shore power system when the vessel is at quay. Power generating plant consists of diesel gensets and batteries.

The cargo space is arranged on the main deck as open ro-ro space and a closed ro-ro space below the main deck. The open ro-ro space is intended for private cars as well as lorries, buses, trucks and trailers. The closed ro-ro space below main deck is intended for private cars and vans. The lower car deck is accessible from the main deck by two fixed ramps, one forward and one after. The hull lines are characterized as symmetrical double ended ferry lines made for minimum resistance and are made of welded steel construction (included superstructure).

The main characteristics of the ship are depicted in Table 1.

Hereafter some preliminary results obtained from the VP are depicted, from Figure 22 to Figure 28.

Figure 22 – Concept design of the Double-Ended ferry - rendering

Table 2 - Main characteristic of Double-Ended ferry

Main characteristics		
Length, overall	101,90	*m*
Length, between perpendiculars	92,70	*m*
Breadth, moulded	20,0	*m*
Hull depth to lower car deck (midship)	1,05	*m*
Hull depth to higher car deck (midship)	3,80	*m*
Draught, max	2,50	*m*
Draught, design	2,30	*m*
Deadweight, max draught	~ 1000	*t*
Deadweight, design draught	~ 660	*t*
Speed, service	10	*kn*
Capacity		
Max passengers on board	600	*persons*
Crew	12	*persons*
Trailer capacity	22	*units*
Cars capacity, main deck	130	*PCU*
Cars capacity, lower deck	40	*PCU*

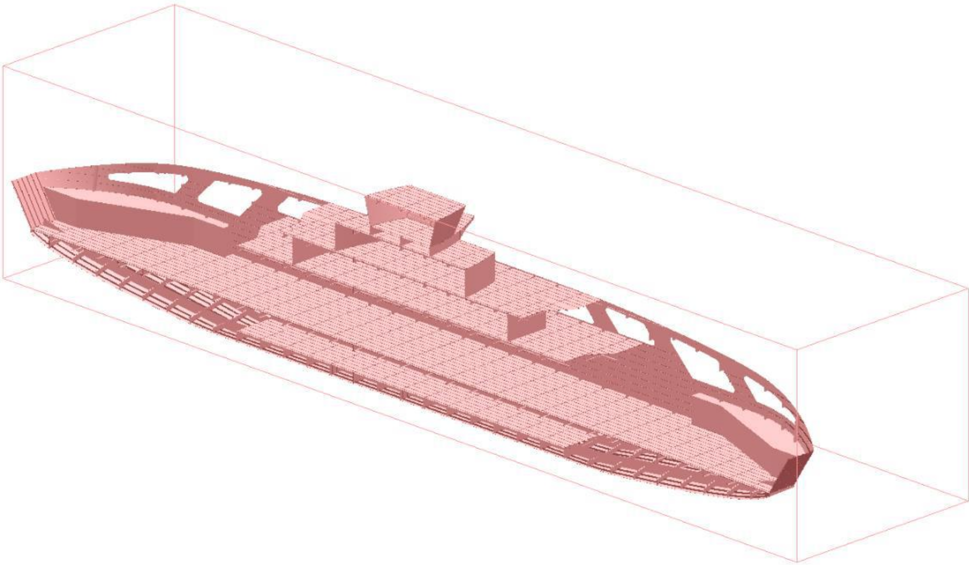

Figure 23 – 3D Longitudinal section

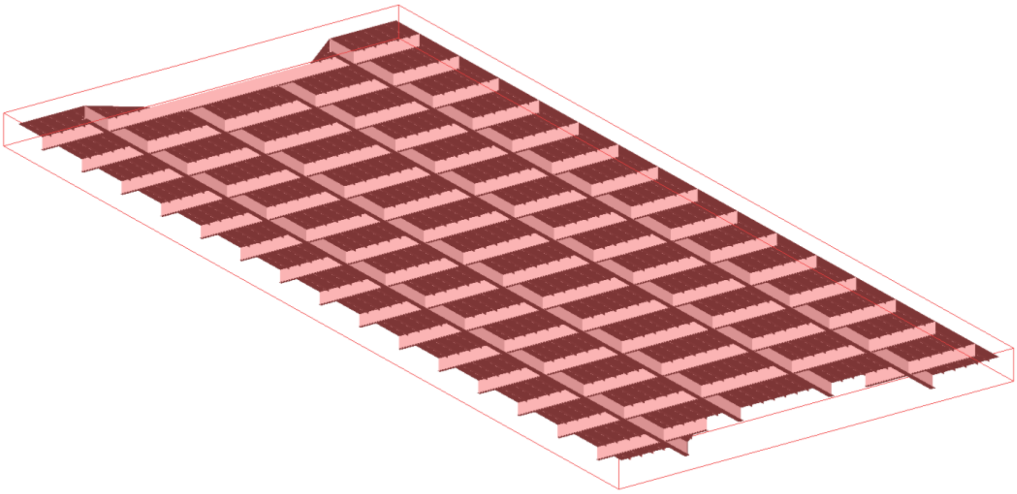

Figure 24 – Particular – 3D Passenger Deck

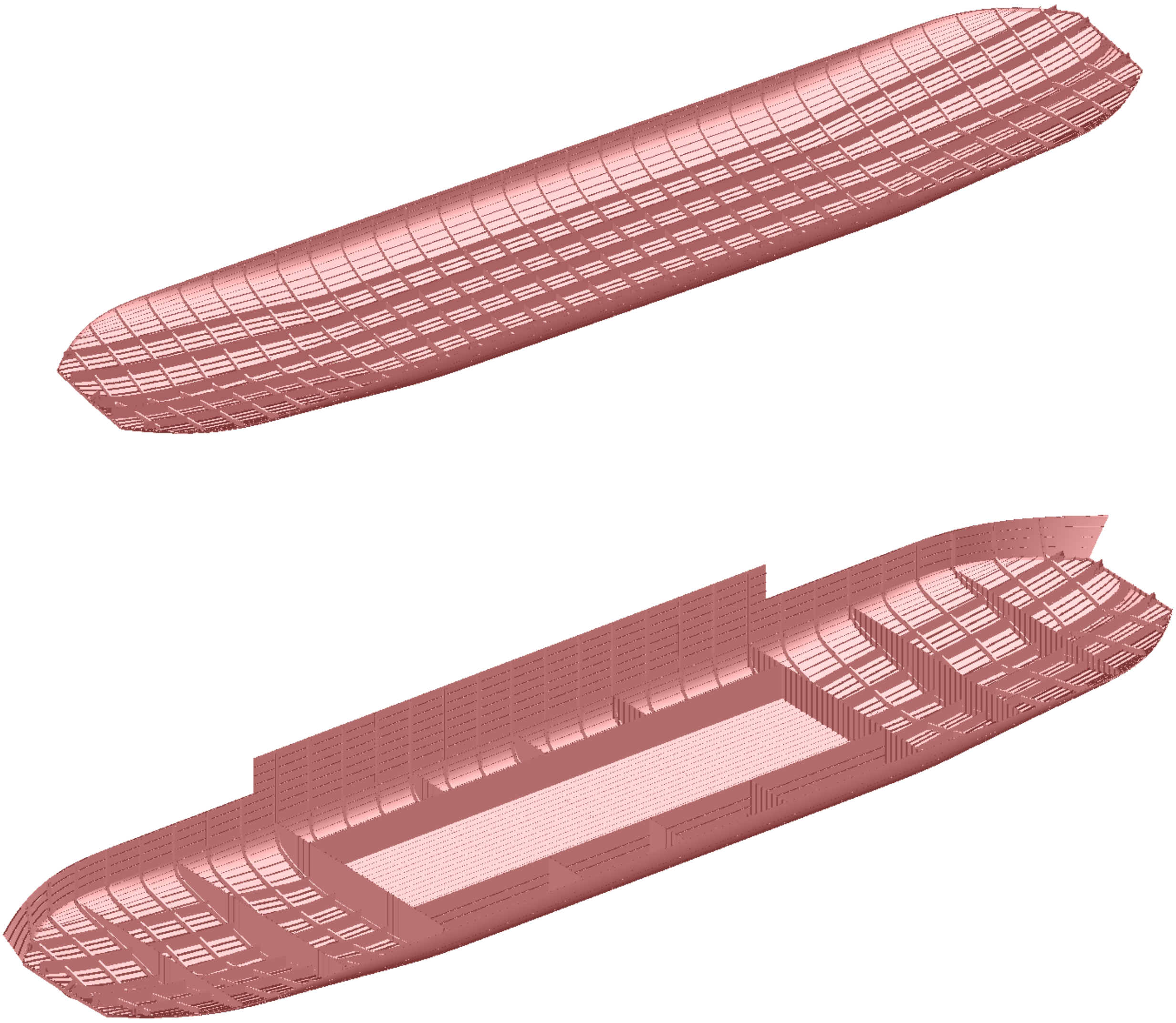

Figure 25 – Particular – Bottom's structural frame

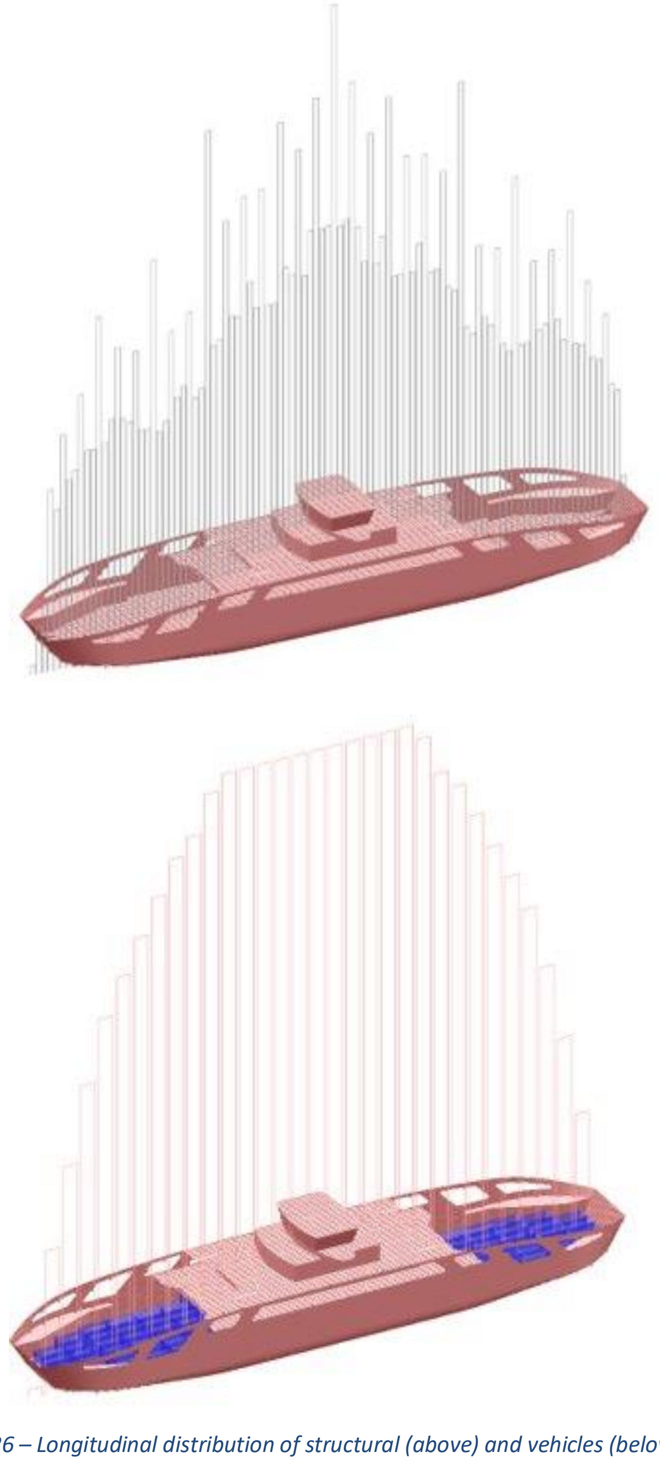

Figure 26 – Longitudinal distribution of structural (above) and vehicles (below) weight

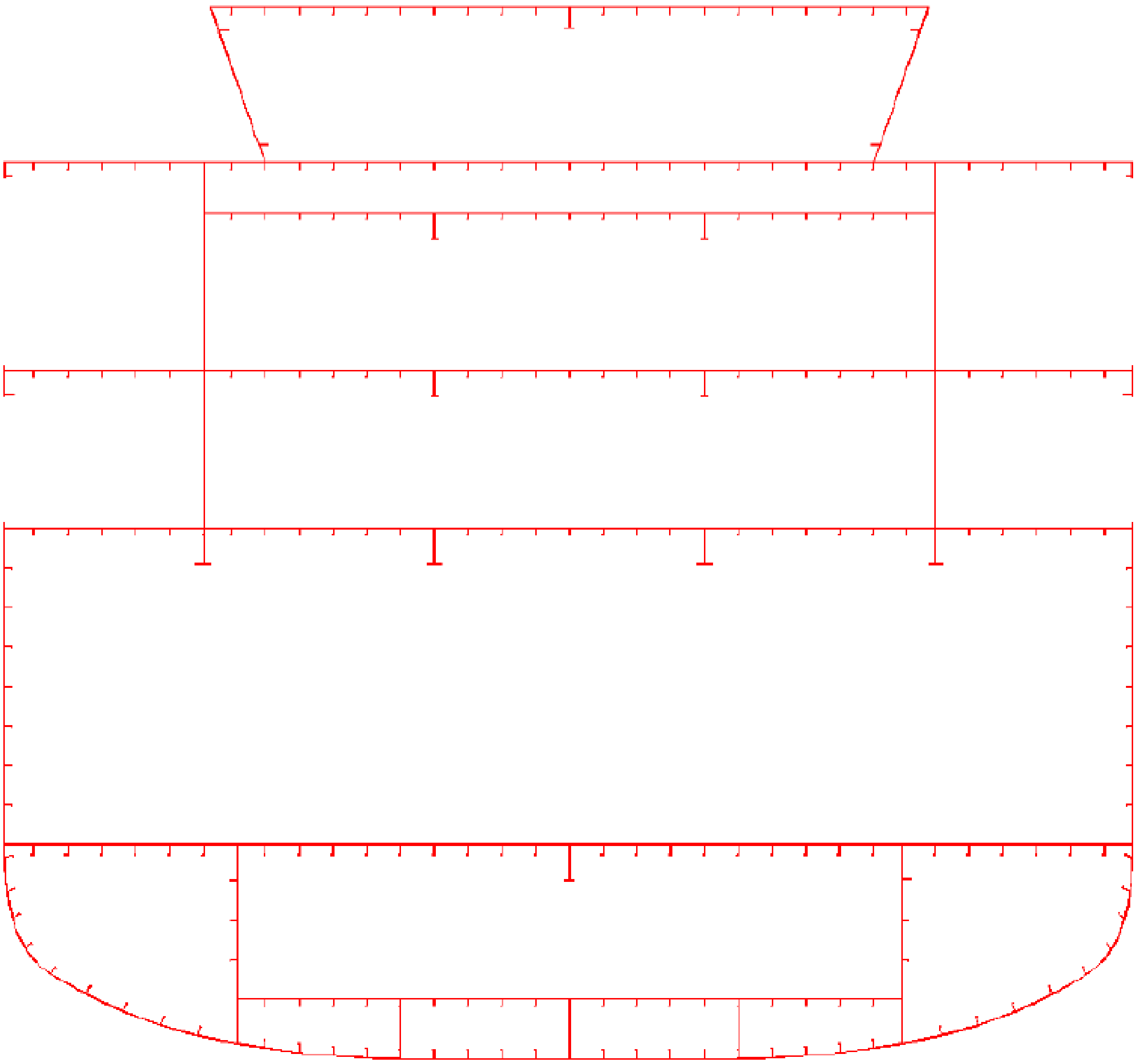

Figure 27 – Midship section

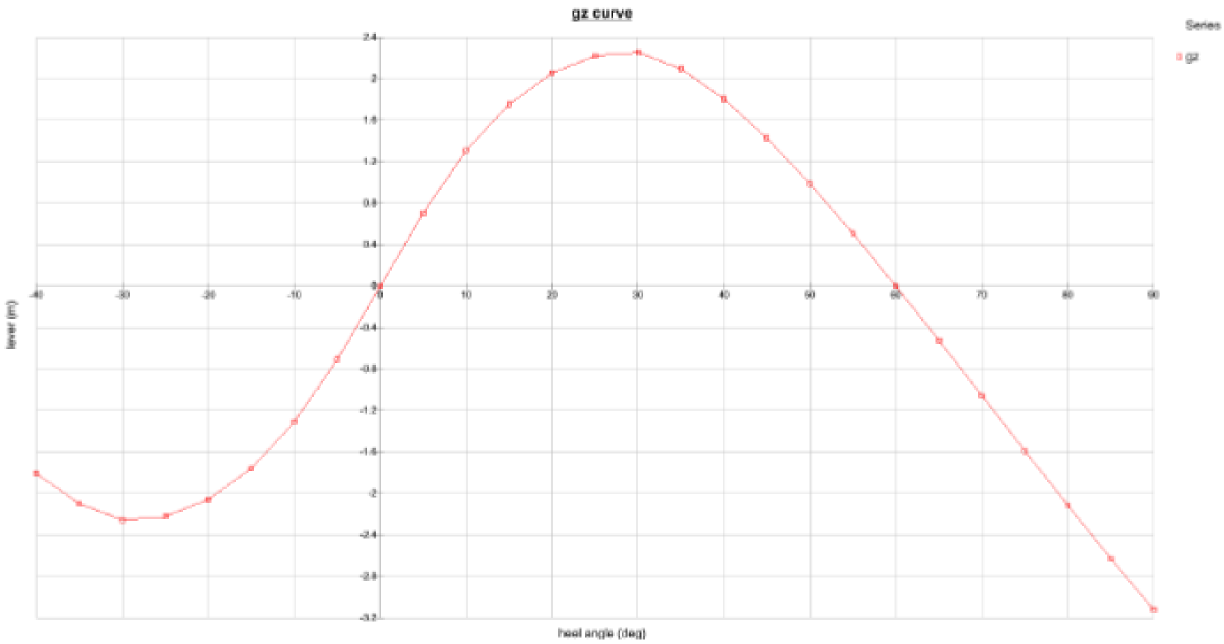

Figure 28 – GZ curve