COLOMBIAMAR PRESENTATION

Fluid-Structural Interaction Study of the Structural Arrangement of a Riverine Low-Draft Combat Boat for Coastal Transit Conditions

Estudio de Interacción Fluido-Estructural por Condiciones de Transito Costero en el Arreglo Estructural de un Bote de Combate Fluvial de Bajo Calado

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Introduction

In military river operations are important the availability of high-speed crafts capable of performing patrolling, offensive maneuvers and additional tasks related to homeland security and defense in shallow and harsh inland waters.

Taken from:
americamilitar.com/infanteria-de-marina/192-elementos-de-combate-fluvial-de-la-infamar-p2.html

Introduction

The Riverine low draft combat boats are aluminium-built crafts designed to operate exclusively in low-depth riverine environments.

Table 1. Riverine combat boat principal characteristics.

Principal particulars	Values
Length over all	8.68 m
Length at waterline	7.05 m
Beam	2.42 m
Amidship depth	1.03 m
Draught	0.34 m
Installed power	134 kW
Full load displacement	3650 kg

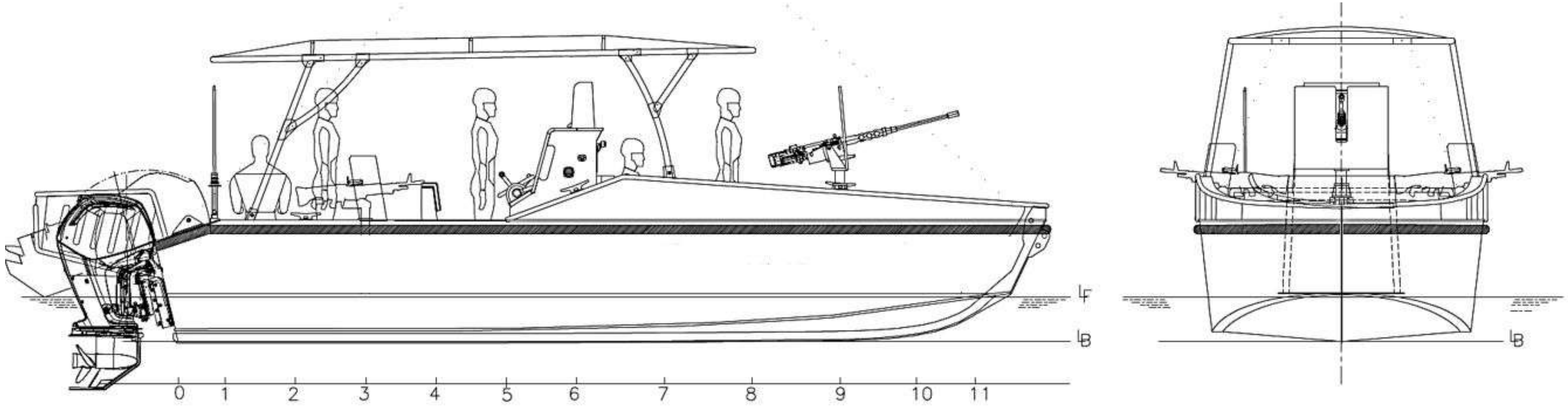
The scantling of the boat was performed according to:

- **ABS High- Speed Craft**; Hull Construction and Equipment”
- **ISO 12215** “Small craft – Hull construction and scantlings”

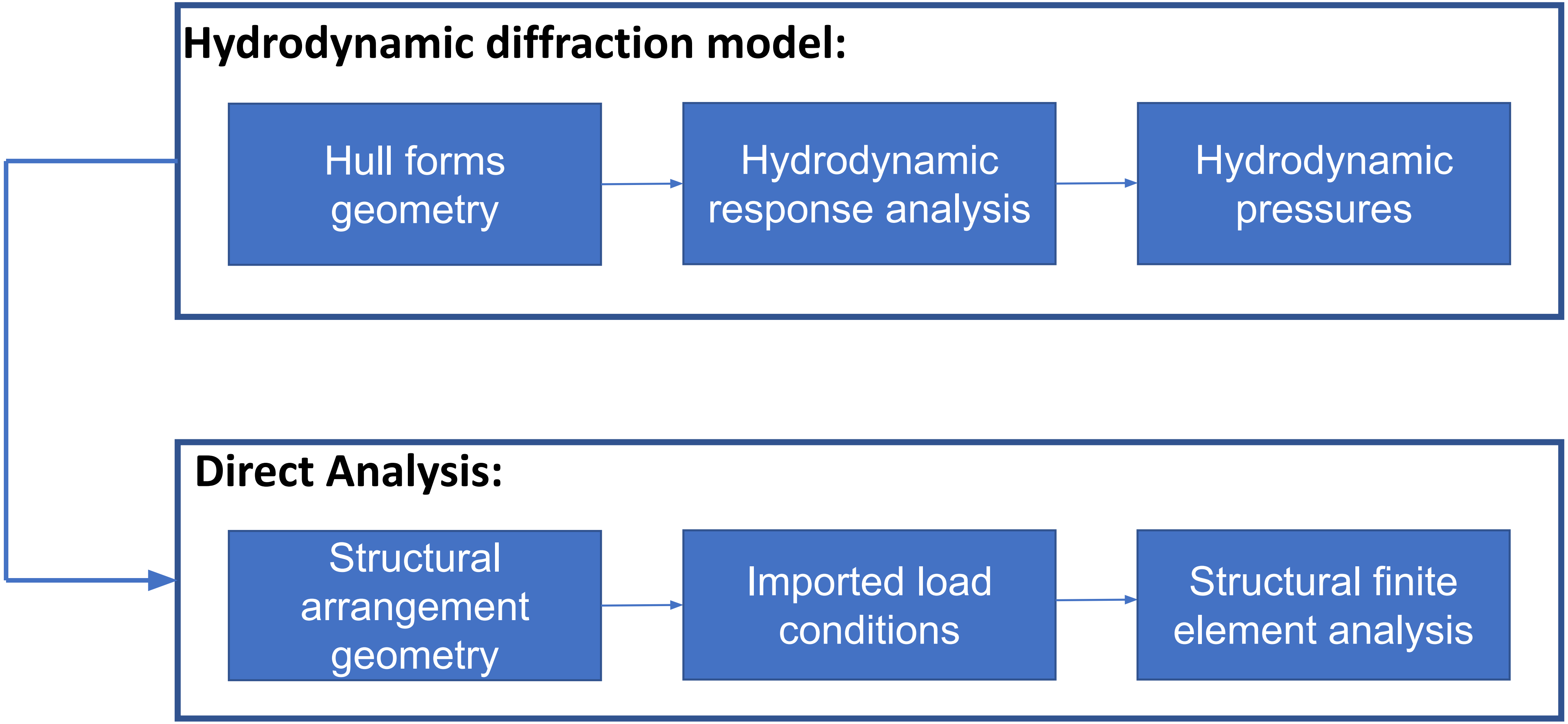
Definition of the engineering problem

Given the Colombian geography, riverine operations might be extended to estuaries or coastal transit conditions.

The main aim of this work is to evaluate the effects of hydrodynamic pressures on the hull's structural integrity at different headings and wave frequencies.



Methodology

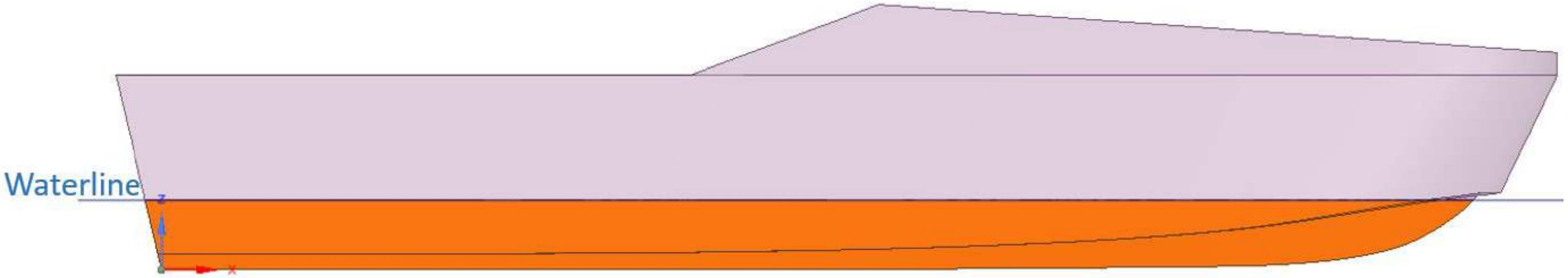


Methodology

Hydrodynamic diffraction model

Hull forms geometry:

Shell modeling was carried out by using ANSYS SpaceClaim 2022 software. Only external hull surfaces were included. These hull surfaces are divided by the waterline to perform analyses in the wet area.

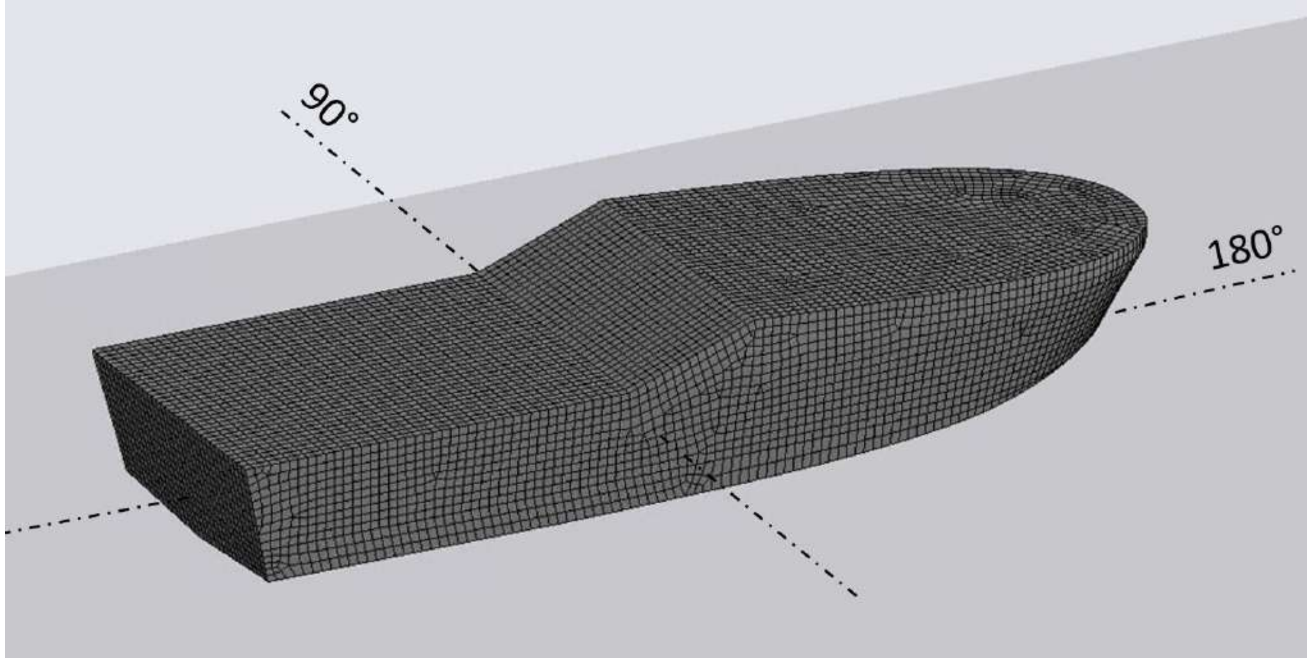


Methodology

Hydrodynamic diffraction model

Meshing:

- The surfaces were meshed with 10029 elements and a defeaturing tolerance of 5 mm.
- This element size allows a maximum frequency of 1.55 Hz for the analysis.



Methodology

Hydrodynamic Response Analysis

- Wave headings (β) were evaluated with increments of 15°, the wave encounter frequencies (ω_e) covers a range from 0.015 Hz to 1.2 Hz with increments of 0.1 Hz [2].
- The wave pattern was simplified with a regular wave with 0.5 m amplitude
- This analysis considers the operational profile at full load displacement.

Table 2: Mass properties for the model

Parameters	Value
Total mass	3650 kg
Longitudinal center of gravity	2.6 m
Transversal center of gravity	0.0 m
Vertical center of gravity	0.55 m
Radius of gyration –roll	0.82 m
Radius of gyration –pitch	1.76 m
Radius of gyration –yaw	1.84 m

Table 3: Environmental constants

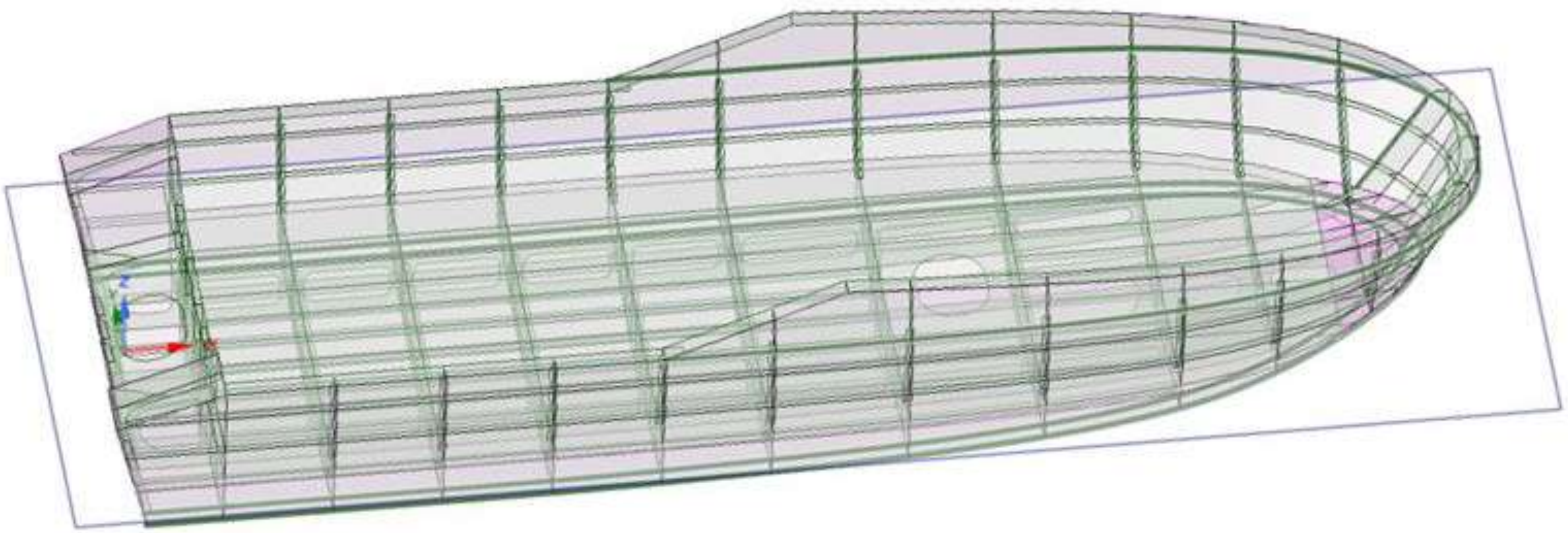
Characteristics	Value
Water Depth	4 m
Water density	1025 kg/m^3
Longitudinal water size	40 m
Transversal water size	25 m

Methodology

DIRECT ANALYSIS

Structural Model geometry:

- Shell modeling was carried out by using ANSYS SpaceClaim 2022 software
- *Bonded* contacts were used among structural elements given their welded connections.



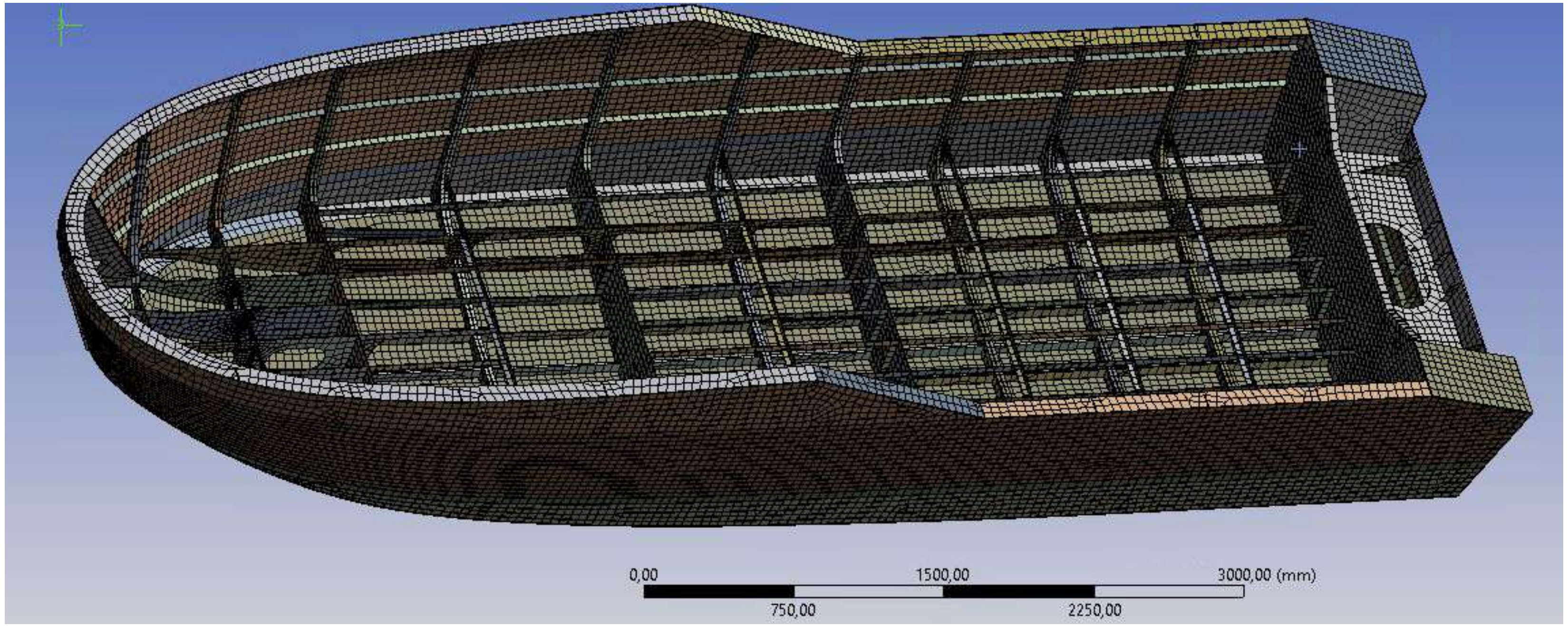
Methodology

DIRECT ANALYSIS

Meshing:

- In the structural analysis, the shell geometry is represented by *4 Node Linear Quadrilateral* elements; the *degenerate 3 Node Linear Triangular* option was only used as filler in mesh generation

- SHELL181 elements were used for meshing
- A 30 mm meshing element size was used



Methodology

DIRECT ANALYSIS

Boundary conditions:

- The boundary conditions for the global structural model should reflect simple supports that will avoid built-in stresses so the reaction forces in the boundaries are to be minimized.
- ANSYS Inertia relief option allows to exactly balance the force differences on the supports creating a state of static equilibrium.

Materials:

5083- H321 aluminum alloy mechanical properties were assigned to plates whereas aluminum alloy 6082 T6 properties were set to stiffeners.

Table 4: Aluminum alloys mechanical properties defined for the model

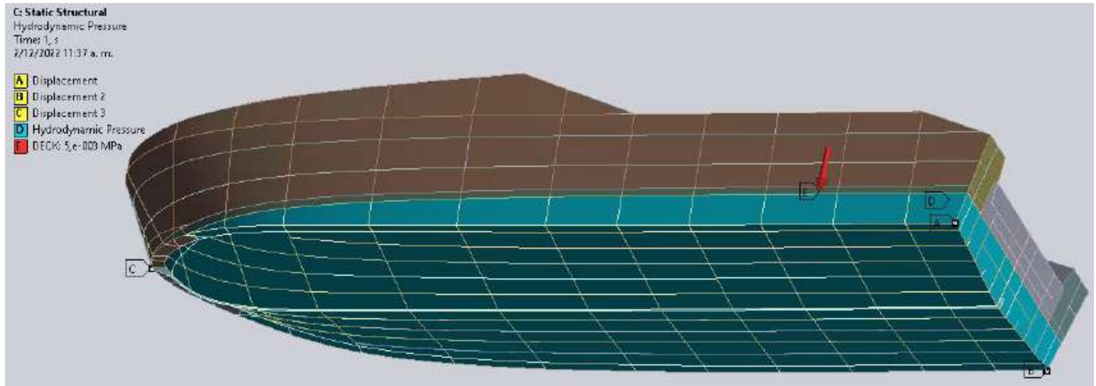
Properties	Al 5083-H321	Al 6082- T6
Density [g/ cm^3]	2.66	2.7
Poisson's ratio	0.33	0.33
Young's Modulus [GPa]	70	70
Tensile yield strength [MPa]	220	260
Tensile yield strength (welded) [MPa]	145	125
Tensile ultimate strength [MPa]	305	310
Tensile ultimate strength (welded) [MPa]	290	190

Methodology

DIRECT ANALYSIS

Load conditions:

- Hydrodynamic pressure, imported from the Ansys Aqwa software, was applied on the hull below de waterline.
- Design pressure calculations from class requirements was assigned on the deck with a value of 5 kN/m^2



Imported hydrodynamic pressures on the hull

Allowable stress:

- This analysis is carried out by using the Maximum-Distortion- Energy Criterion in order to assess the structure against failure.
- The maximum allowable stress for plates is 123 MPa and 106 MPa for stiffeners in heat-affected zones.

Table 5: Allowable stresses on structural members

Properties	Al 5083-H321	Al 6082- T6
Heat- affected zones	123 MPa	106 MPa
Non heat- affected zones	187 MPa	220 MPa

Results

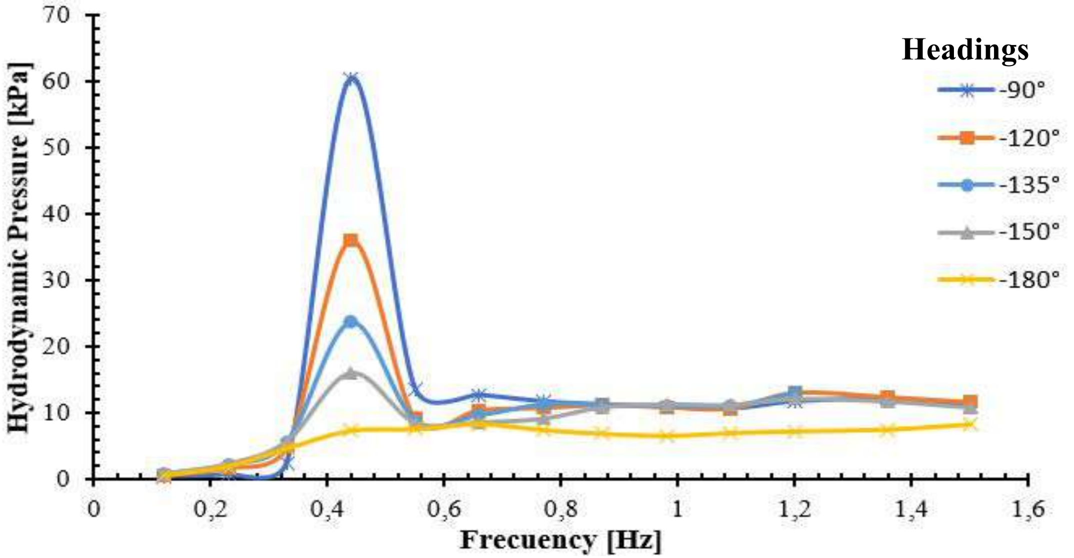
Hydrodynamic responses analysis

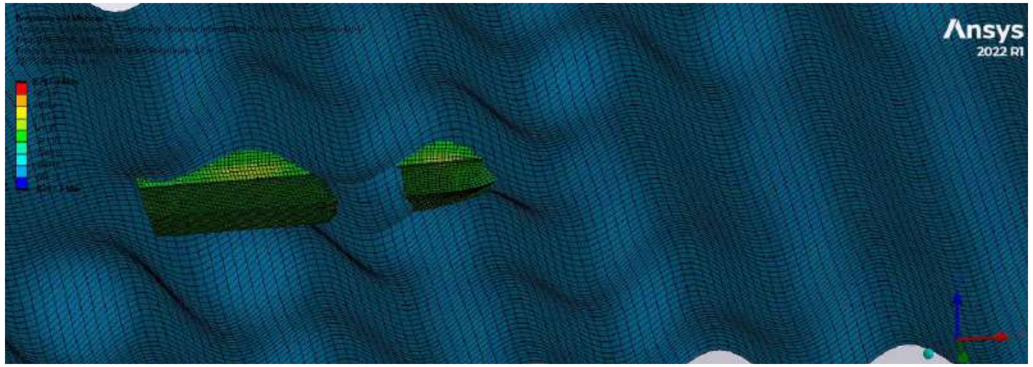
Hydrostatic Results:

The computations of the wave-induced motions were carried out by utilizing three- dimensional potential flow based on diffraction-radiation theory.

Characteristics	Value
Longitudinal center of gravity	2.6 m
Longitudinal center of Buoyancy	2.9 m
Actual volumetric displacement	3.78 m^3
Equivalent volumetric displacement	3.55 m^3
Cut water plane area	14.6 m^2

- **Hydrodynamic pressures:**





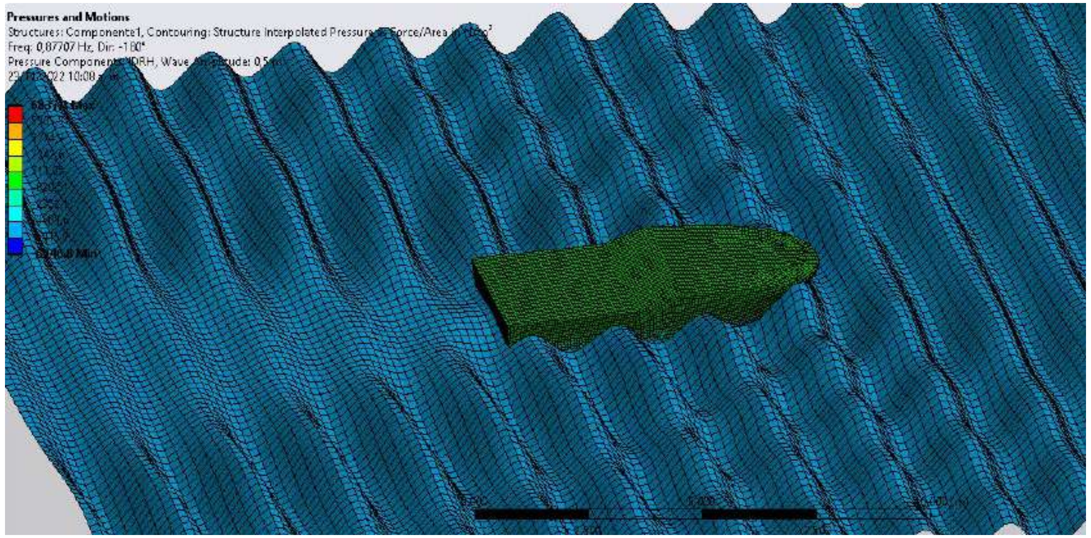
The wave frequency of 0.44 Hz produces the highest pressure levels with a wave amplitude of 0.5 m

Results

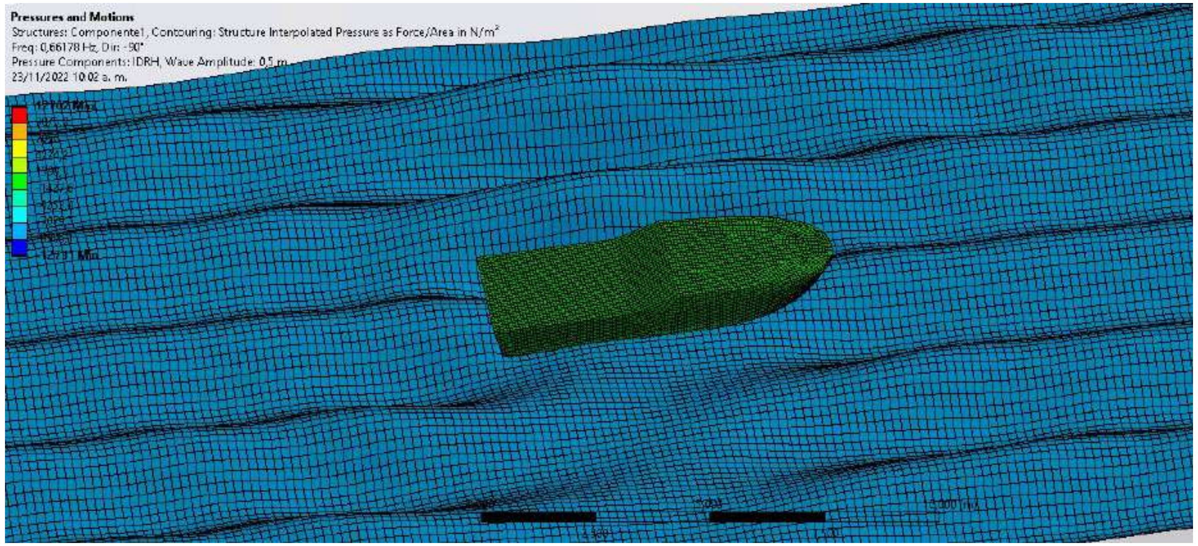
Hydrodynamic responses analysis

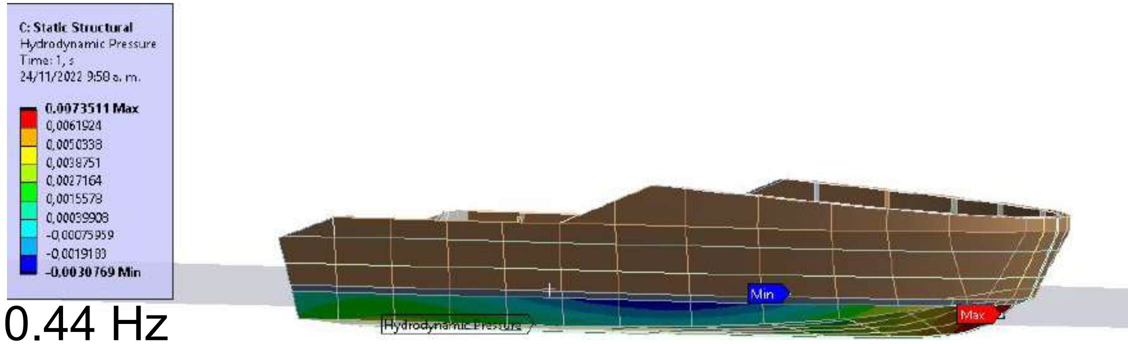
- **Hydrodynamic pressures:** the highest hull pressures were obtained with beam seas at a 0.44 Hz frequency and a wave height set in 0.5 m

90° heading– head seas

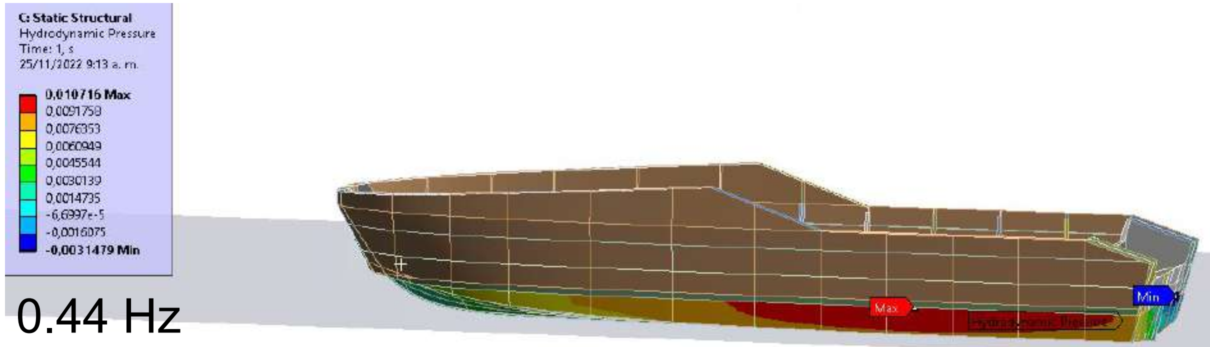


90° heading– beam seas





0.44 Hz

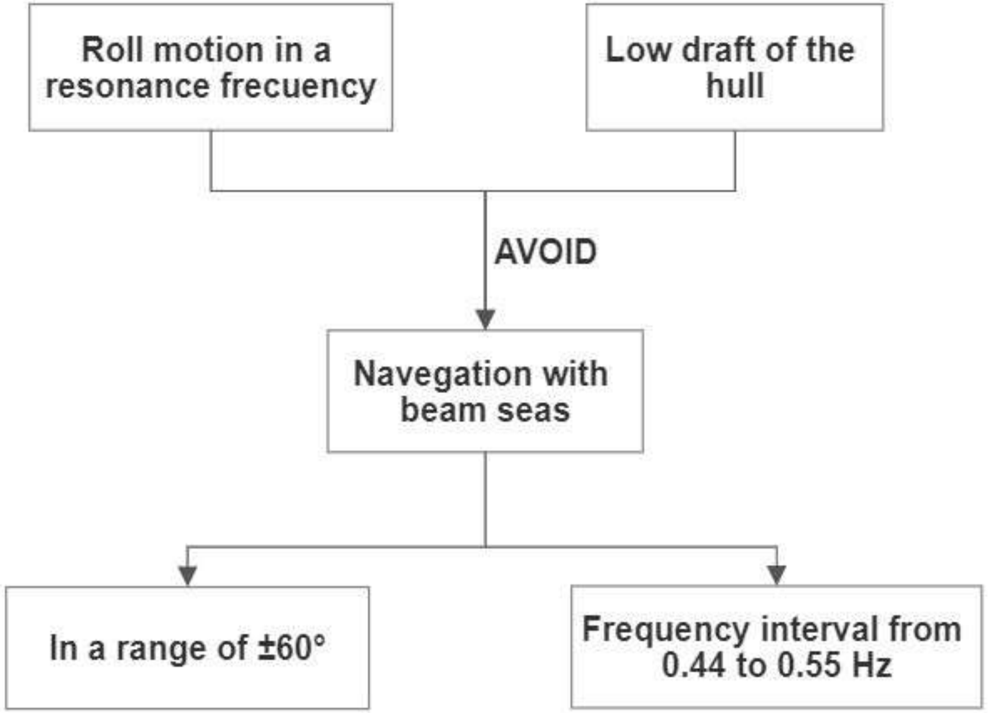


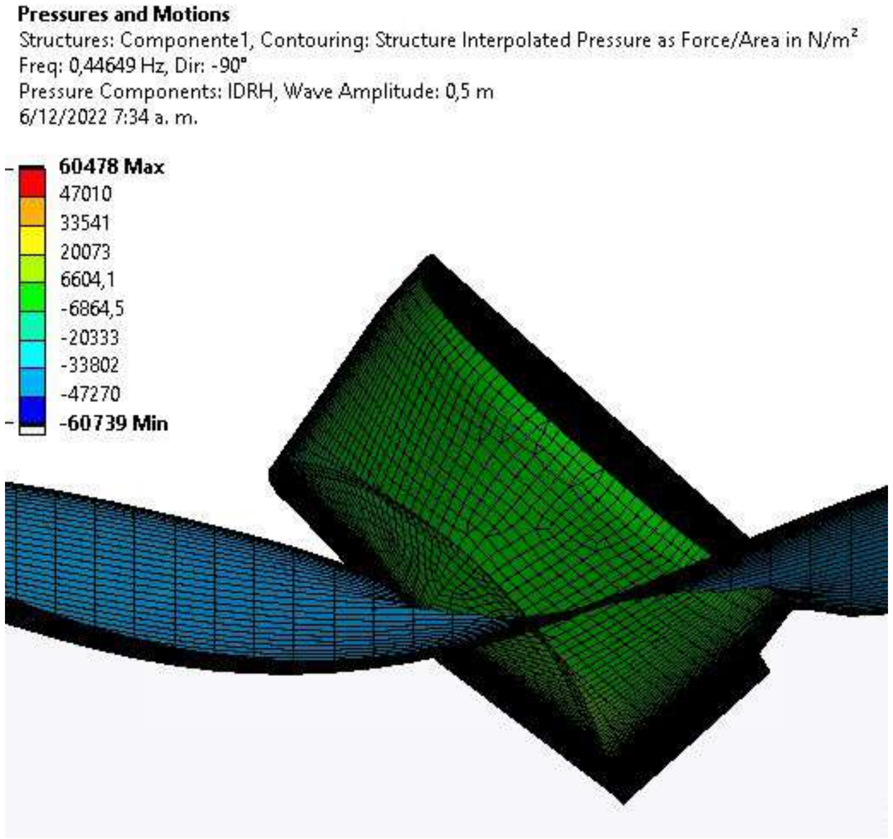
0.44 Hz

Results

Hydrodynamic responses analysis

- **Hydrodynamic pressures:** The obtained motions at different waves frequencies and headings showed that there are intervals in which the boat would present unsecure navigation in terms of stability.





Roll motion with beam seas (90°) at 0.44 Hz

Results

Hydrodynamic responses analysis

- **Hydrodynamic pressures:**

- The calculation of hydrodynamic wave pressures according to classification rules at head sea conditions and neglecting slamming pressure factors, present bottom pressures estimations as two times higher than obtained with the software.

Table 7: Hydrodynamic pressures on the bottom

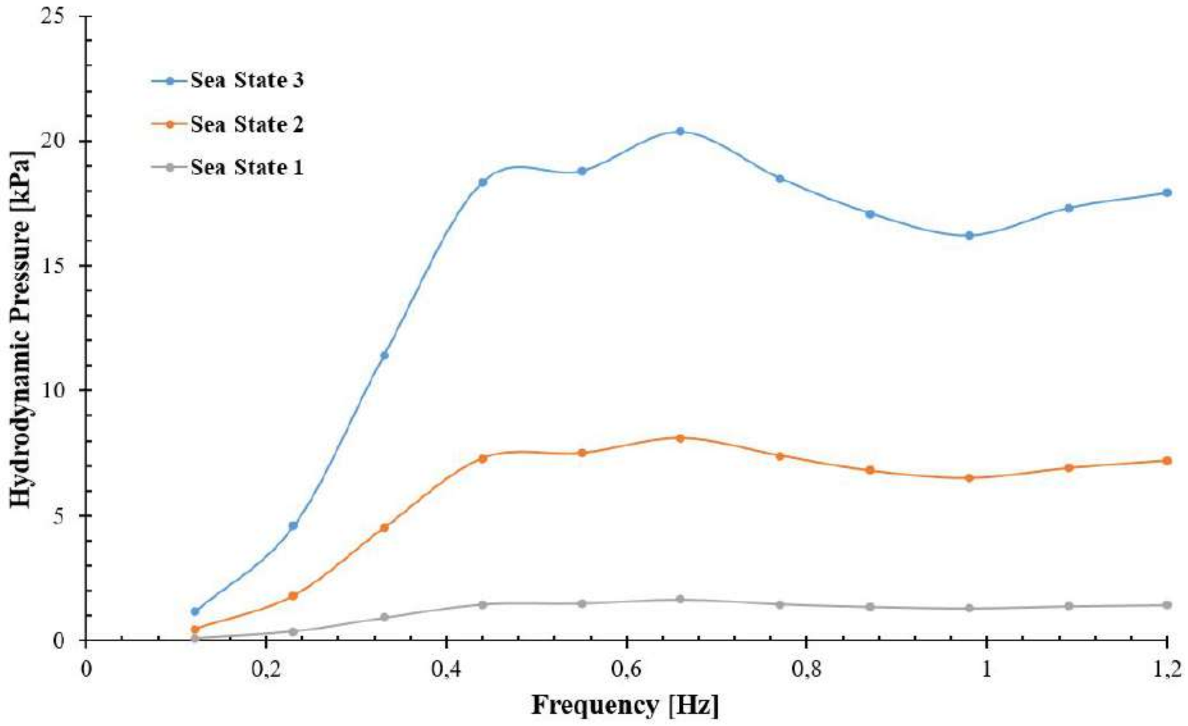
Method	Bottom Pressure	Difference [%]
Ansys AQWA	7.7 kPa	---
ABS "HSC"	16.7 kPa	116.8
LR "Special Service Craft"	10.3 kPa	33.76

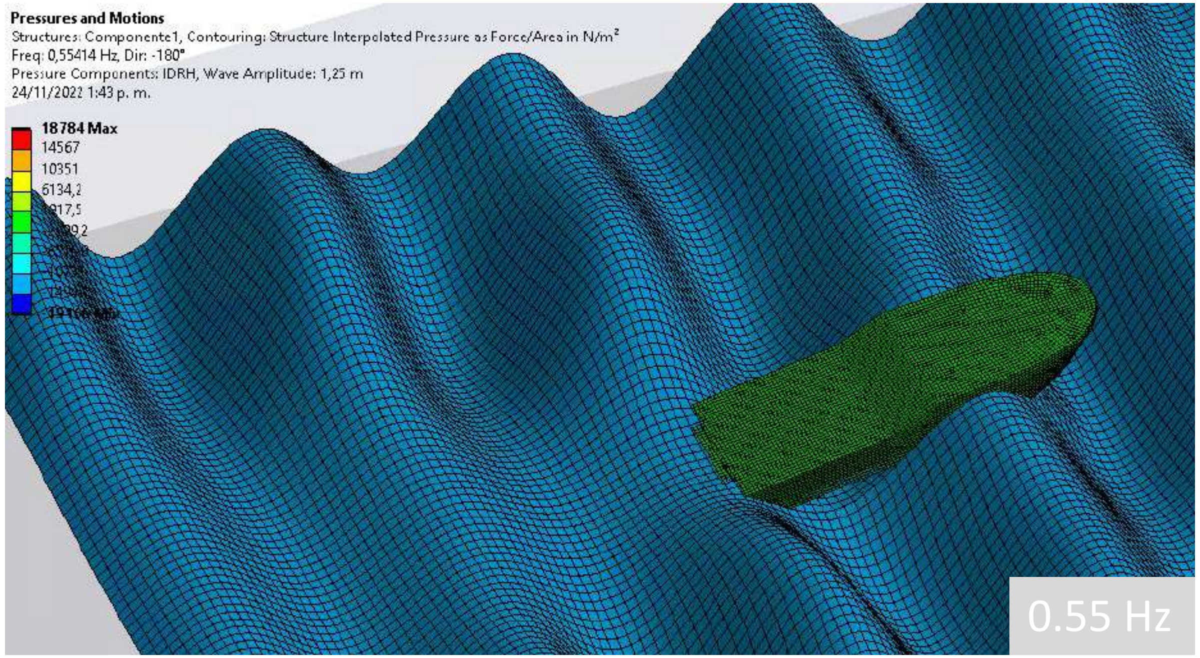
- Considering the slamming pressure in Classification Society rules calculation would imply a local increase in the hull pressure close to 70 kPa.

Results

Hydrodynamic responses analysis

- **Hydrodynamic pressures as function of sea state**



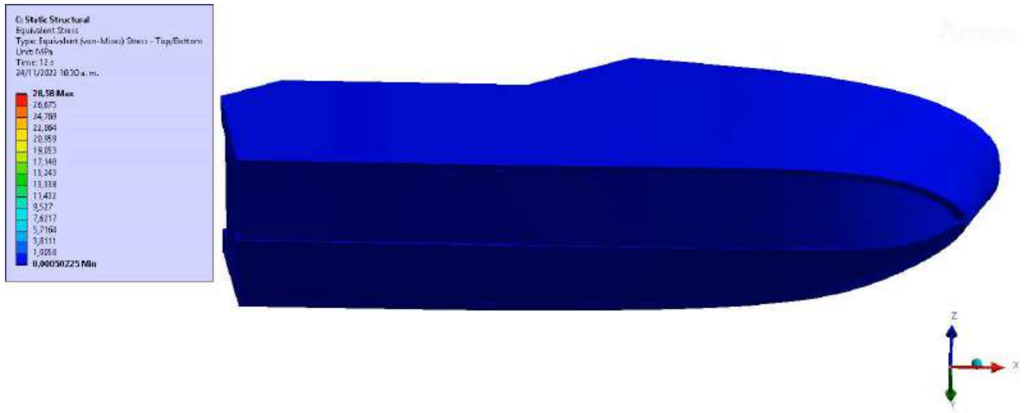


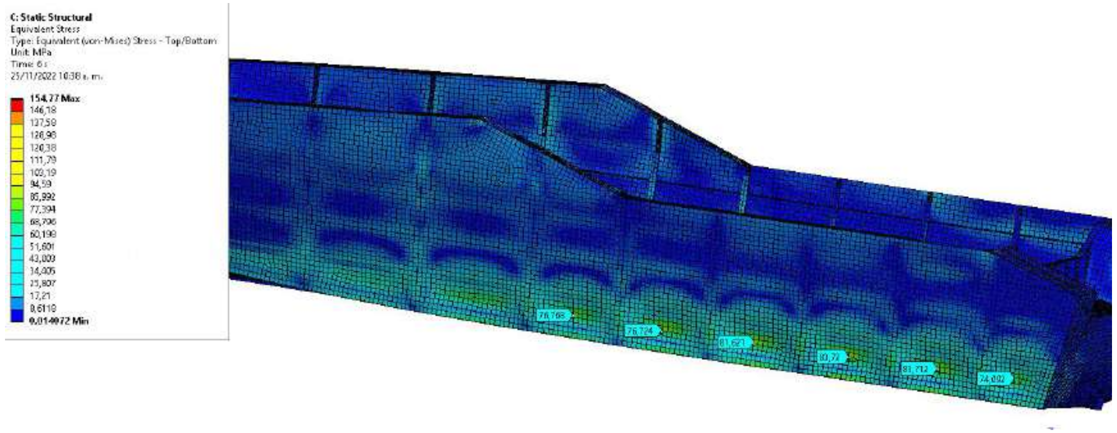
180° heading with a wave amplitude of 1.25m

Results

Direct analysis

Critical direct analysis was carried out with a heading of 90° and a frequency of 0.44 Hz.





At this load case:

- The highest pressures were found in the vicinity of the bottom – side connection.
- The side panels presented an equivalent maximum stress near to 84 MPa with a consequent 2.7 safety factor.

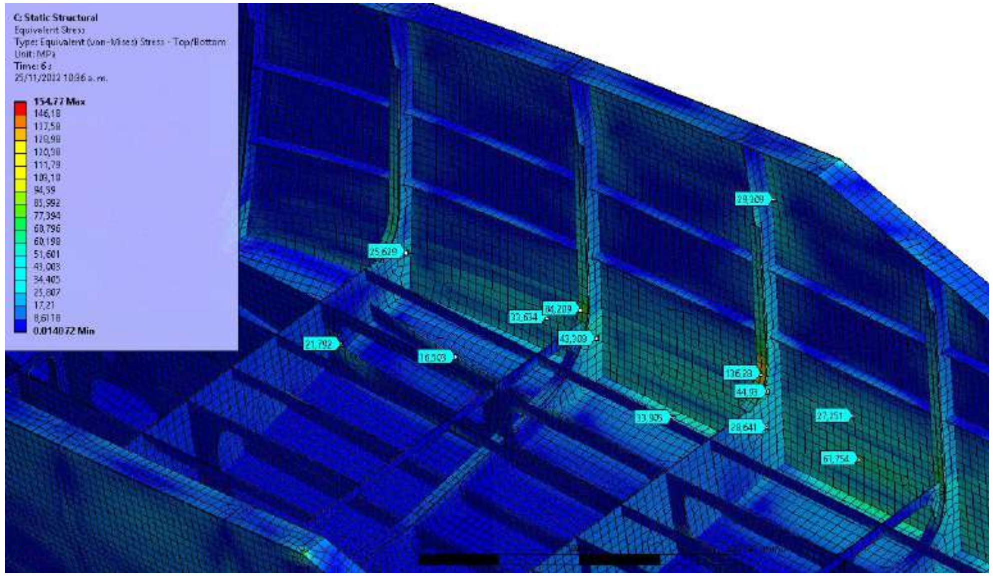
Results

Direct analysis

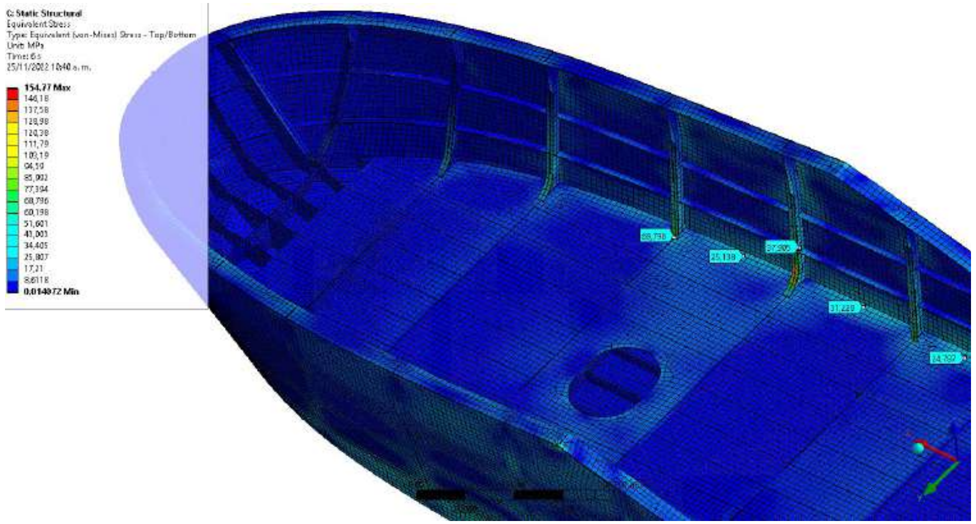
- Frames and bulkheads showed equivalent stress values between 25 MPa to 45 MPa in the hull pressure influence zone.

- There is a spot in the frame above deck in a bulkhead station with an equivalent stresses close to 140 MPa

- On deck, the assemble with the side frames bring as consequence maximum equivalent stress values under 80 MPa



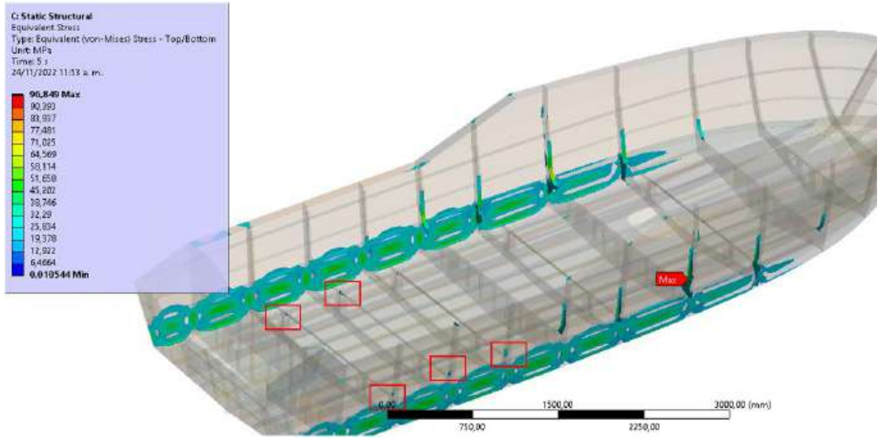
Stress distribution in the frames with beam seas



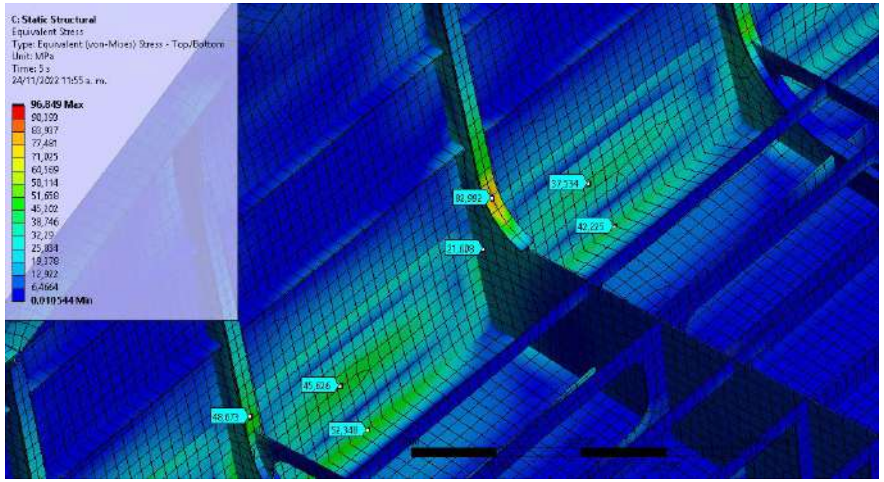
Stress distribution on deck

Results

At heading of 120°, stress levels increases towards the bow reaching values up to 97 MPa.

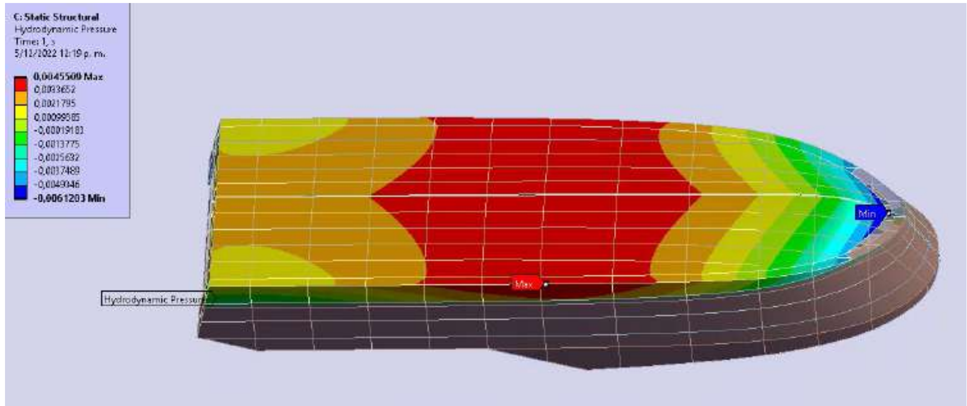


Stress distribution above 20 MPa with a 120° heading

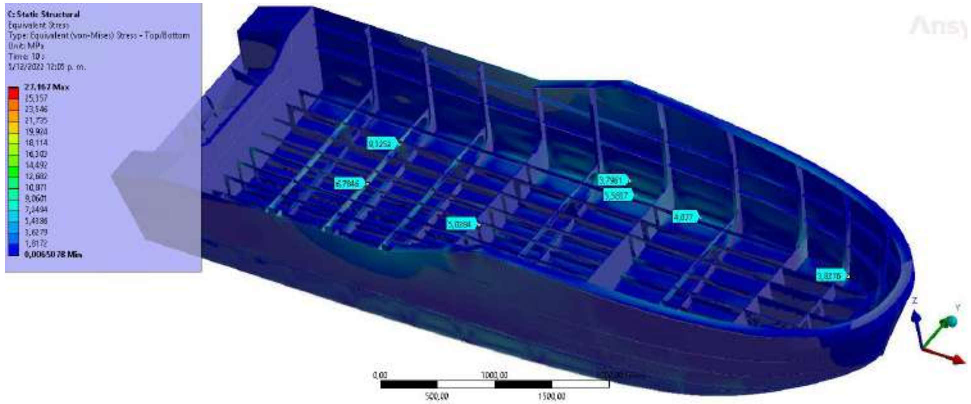


Stress distribution in side's plates and internals

- At head-seas conditions, the structural arrangement stress levels decrease.
- Higher stresses are reported in the bottom – side assembling



Hydrodynamic pressure distribution on the bottom at head seas conditions

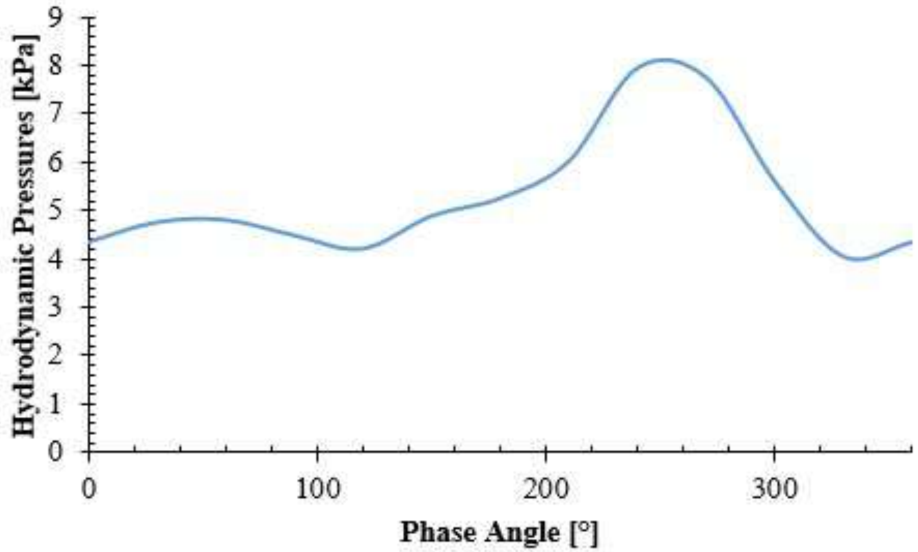


Stress distribution in internals below deck

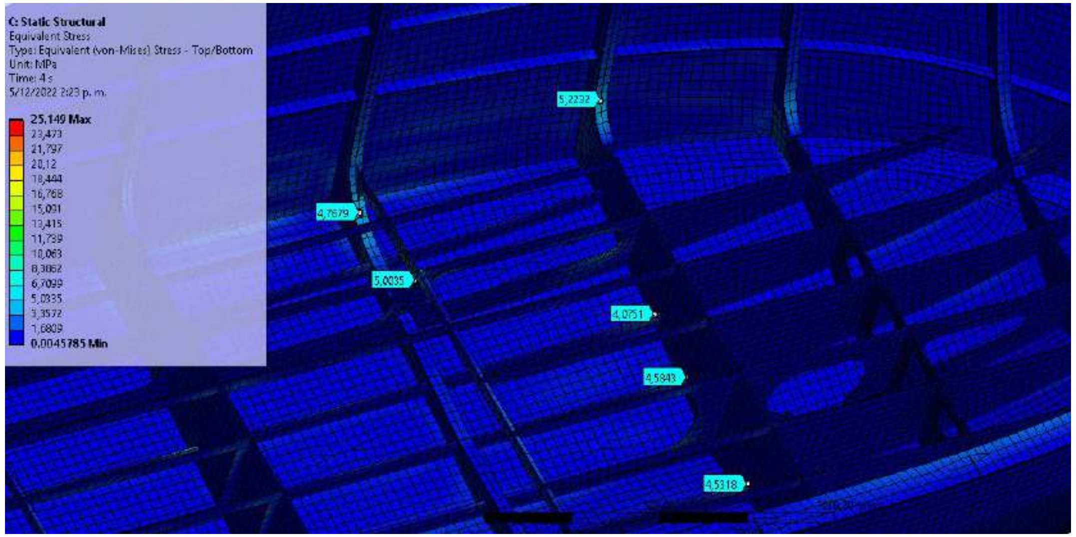
Results

With a different phase angle at the same heading and frequency, it was found a maximum hull pressure with a value of 7.7 kPa

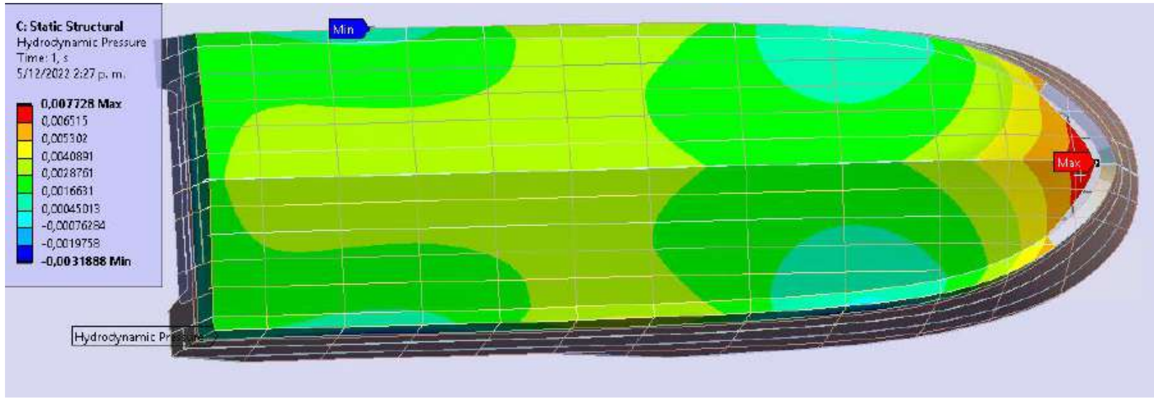
Given the reinforced structure at bow zone is designed to withstand slamming pressures and beaching maneuvers, the stress levels in the affected zone are up to 5 MPa.



Hydrodynamic pressures on the hull as a function of the wave phase angle



Stress levels at fore section of the boat

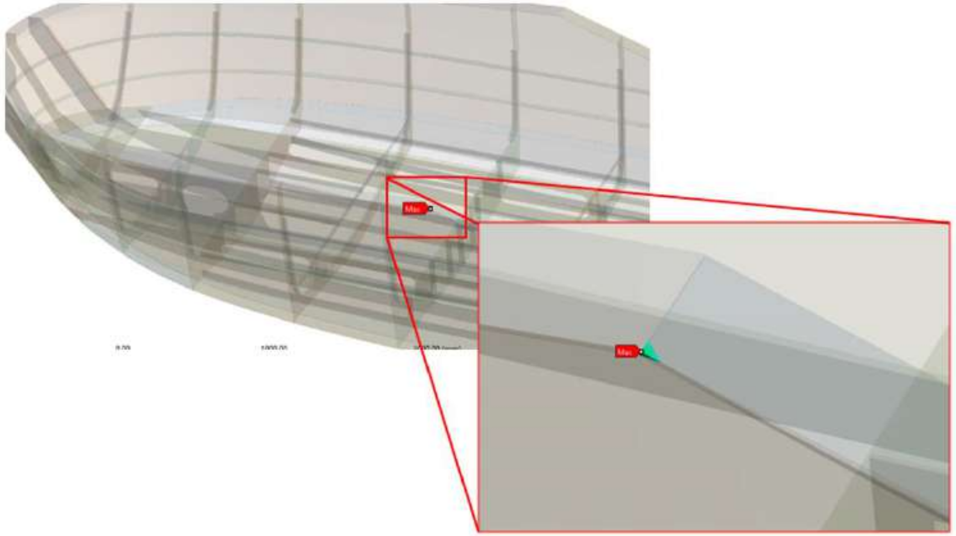


Location of the maximum hydrodynamic pressure on the bottom with a 260° wave phase angle

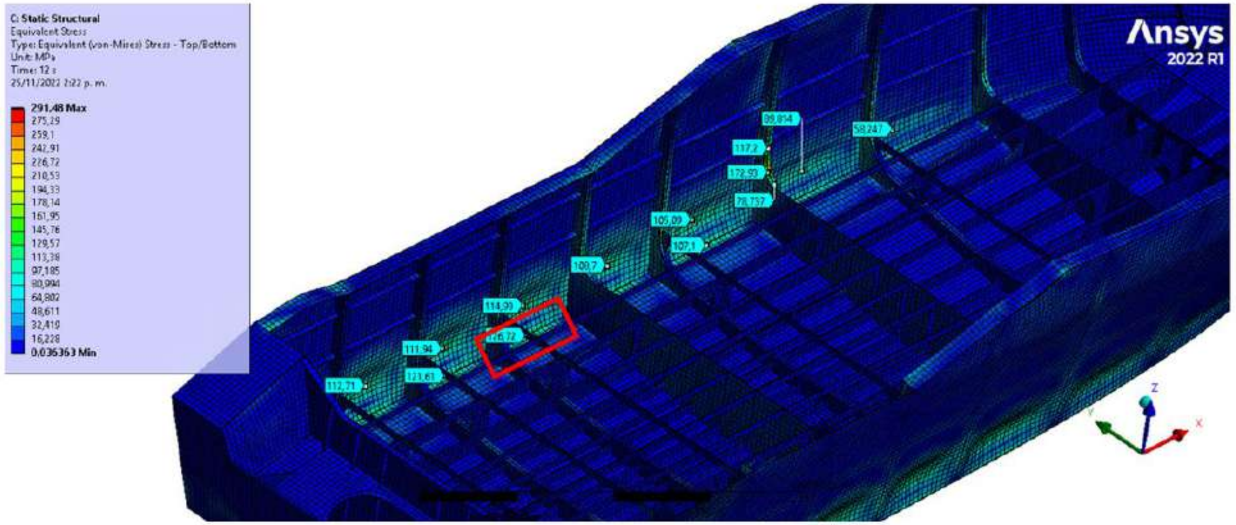
Results

Direct analysis

A high gradient stress zone was spotted at the portside gunwale, after mesh convergence was not reached; the reported high stress values are deemed as a singularity.



Stress singularities at gunwale



Stress levels at sea state 3 and 120° heading conditions

At sea state 3, with a frequency of 0.44 Hz, and a heading of 120°. Stress levels reach values up to 126 MPa in the chine and 115 MPa in the side plates.

Conclusions

- It can be concluded that the structure of the hull can withstand sea state 2 conditions. Nevertheless, the low draft of the vessel and its flat bottom might imply unsecure navigation specially under beam waves ± 60° conditions within frequencies from 0.44 Hz. to 0.55 Hz.
- According to the obtained hydrodynamic pressures on the hull, the Classification Societies Rules apply safety factors up to 2, this without having into account slamming pressures components.
- Sea state 3 present unsafe navigating conditions in a wide range of frequencies and headings because the boat motions. Additionally, at 120° of heading and with a resonance frequency of 0.44 Hz the structural arrangement strength of the side- bottom assembly is not enough to withstand the imported hydrodynamic pressures.

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THANKS.