Colombiamar 2021 DIGITAL

VII CONGRESO INTERNACIONAL DE DISEÑO E INGENIERIA NAVAL

Diseño y Validación por el Método de Elementos Finitos de la Estructura de un Bote de Bajo Calado para Reconocimiento Fluvial

Design and Validation by the Finite Element Method of the Structural Arrangement of a Riverine Low Draft Combat Boat

David R. Alvarado
Edison Flores
Edwin Paipa

COTECMAR

Table of contents

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, secluded and hard-to-reach harsh inland waters.

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

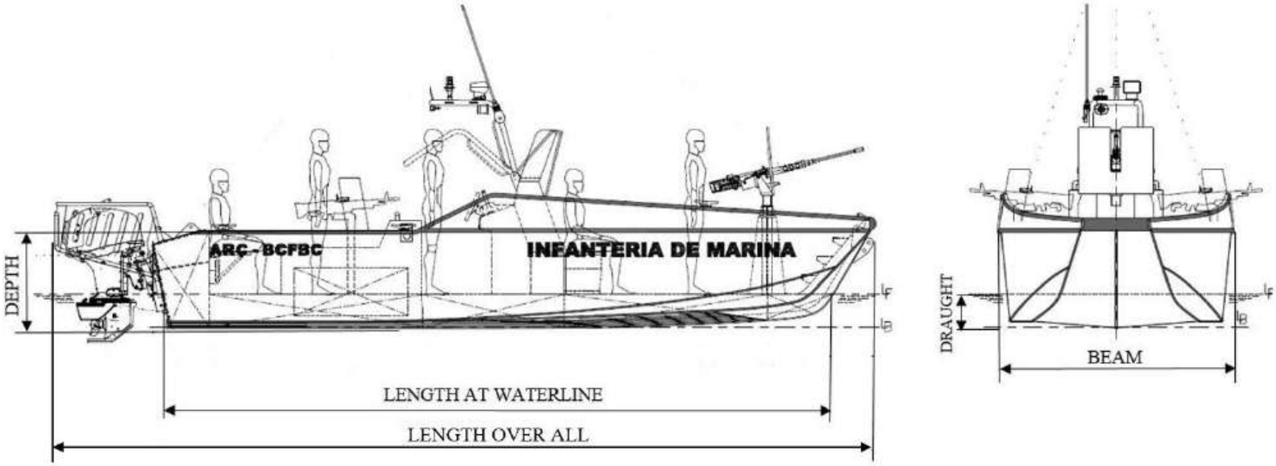
Introduction

The structural arrangement of the designed boat is intended to maintain a low weight while the security of the crew, the structural integrity of the hull and the boat performance remain preserved.

Tomado de:
www.infodefensa.com/latam/2021/07/28/noticia-armada-colombiana-incorpora-botes-combate-fluvial-calado-previstos.html

Definition of the Engineering problem

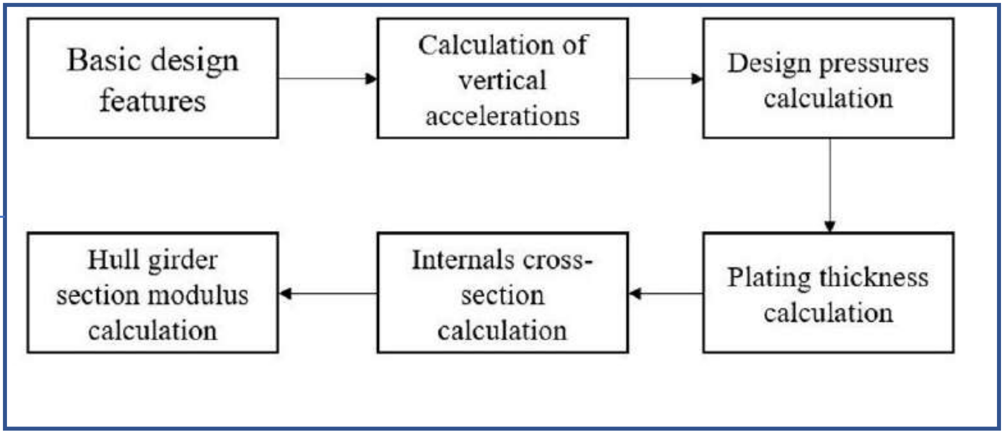
The aim of this work is to explain and to validate the boat scantling by guidelines of the classification societies and hence, improving and validating by direct analysis the hull structural arrangement.



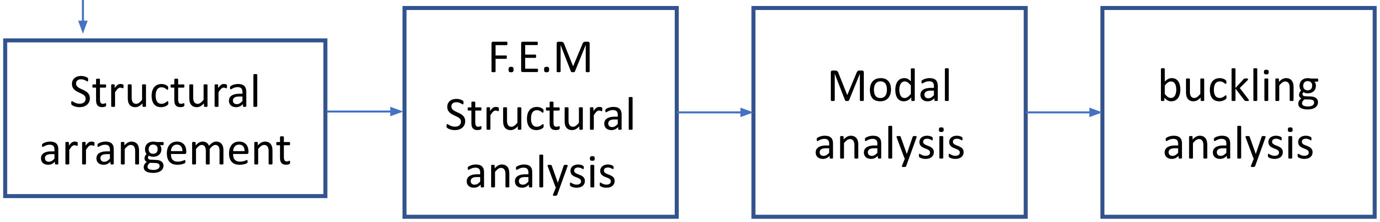
Characteristics	Value
Length over all	8.60 m
Length at waterline	7.05 m
Beam (molded)	2.42 m
Depth amidship (molded)	1.03 m
Draught	0.35 m
Installed power	120 hp (89 kW)
Fully loaded displacement	3650 kg

Methodology

Scantling:



Direct analysis:



Methodology

Materials:

mechanical properties of the aluminum alloys defined for the model

Properties	Al 5083- H116/ 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

- 5083- H116/ H321 aluminum alloy mechanical properties were assigned to plates whereas aluminum alloy 6082 T6 properties were set to stiffeners

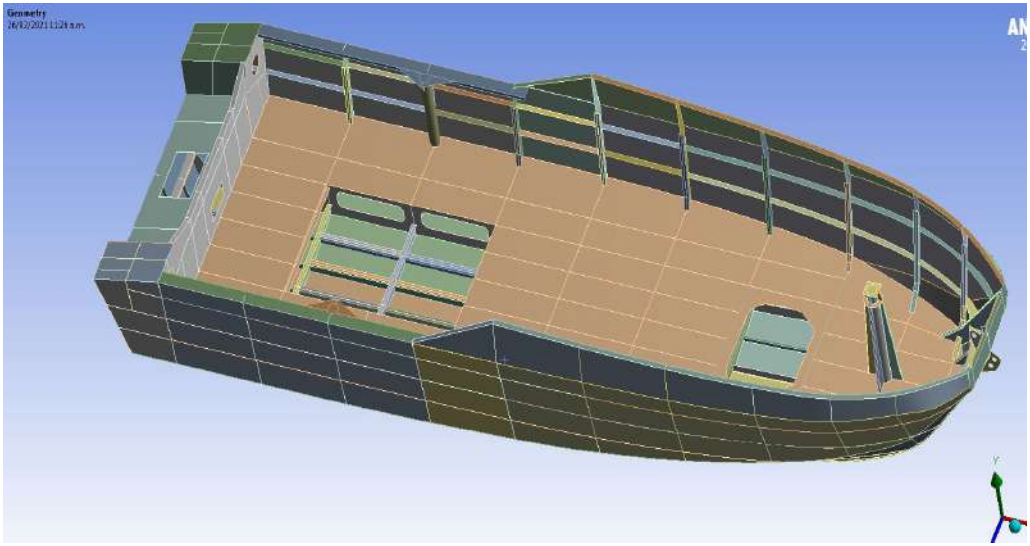
Methodology

Geometry:

- The whole structural arrangement was modeled including examples of critical connection details.

- Shell modeling was carried out by using ANSYS SpaceClaim 2019 software .

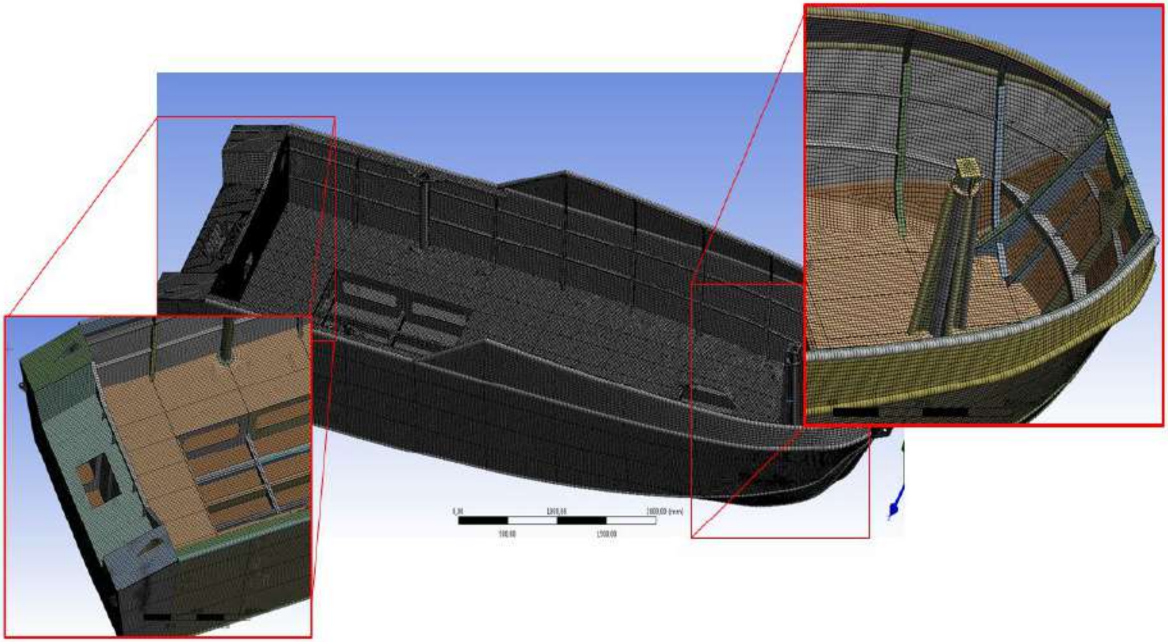
- *Bonded* contacts were used among structural elements given their welded connections.



Methodology

meshing:

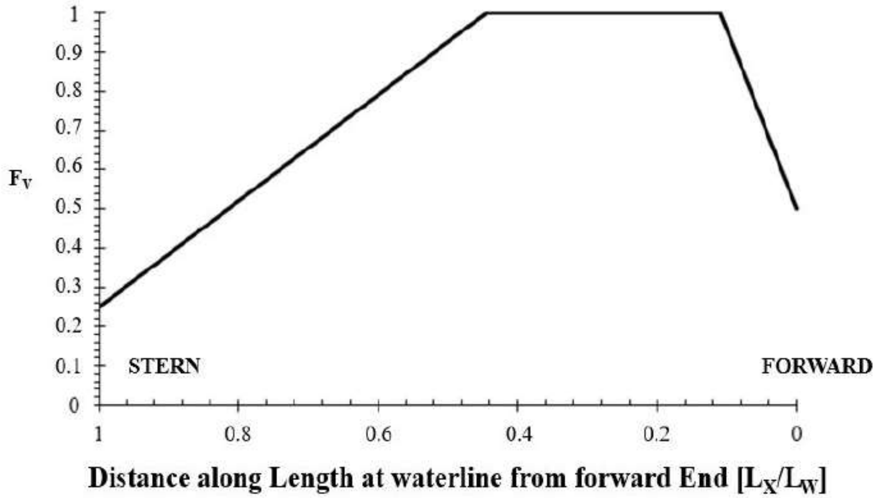
- SHELL181 elements were used for meshing
- The shell geometry is represented by *4 Node Linear Quadrilateral* elements; the *degenerate 4 Node Linear Triangular* option was only used as filler in mesh generation



Methodology

Load conditions:

- The boundary conditions for the global structural model should reflect simple supports that will avoid built-in stresses
- Design pressure calculations from class requirements of both classification societies.
- The maximum allowable stress for plates is 123 MPa and 106 MPa for stiffeners specifically in heat-affected zones.



Bottom slamming pressure distribution

Methodology

Modal Analysis:

- Then modal analysis is used to identify natural frequencies and vibration modes of the structural arrangement.

- A special emphasis was placed in transom due to the outboard motors effect on the structure; mass and inertial properties of these motors were considered.

Buckling Analysis:

- An eigenvalue buckling analysis was performed to ensure no structural elements failures by compressive loads

Results

SCANTLING:

Design pressures [wave height = 0.5 m]	HSC ABS [3] [kN/m^2]	ISO 12215-5 [4] [kN/m^2]
Bottom	79.9	72.7
Sides	18.4	17.0
Main deck	5.0	5.0
Watertight bulkheads	4.5	2.1

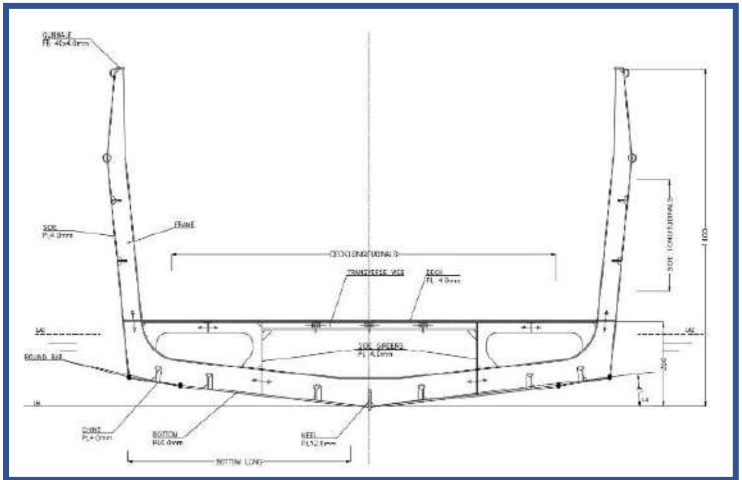
Design pressures

	ISO 12215-5 [mm]	HSC ABS [mm]	Plate thickness [mm]
Bottom	4.5	4.7	6.0
Sides	2.7	3.5	4.0
Decks	1.4	3.5	4.0
Bulkheads	1.7	3.5	4.0

Plates thickness

Internals dimensions

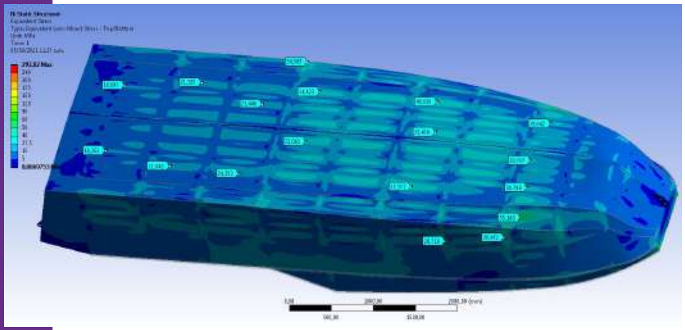
	ISO 12215		HSC ABS	
	SM req.	S.F	SM req.	S.F
Bottom longitudinal stiffeners	8.44	1.6	11.5	1.17
Sides longitudinal stiffeners	2.39	1.3	2.88	1.10
Deck longitudinal stiffeners	1.67	1.8	1.81	1.75
Deck transvers stiffeners	3.57	1.2	3.13	1.36
Floors	12.91	2.1	12.49	2.41
Frames	6.41	2.8	6.48	3.30

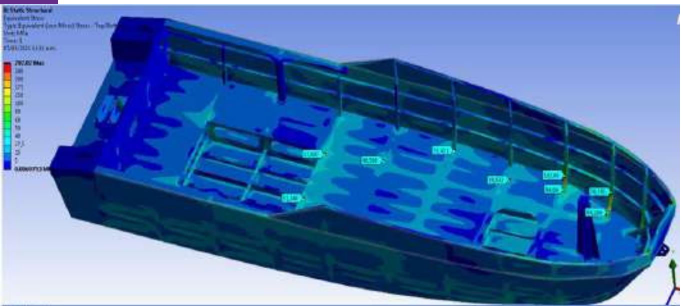


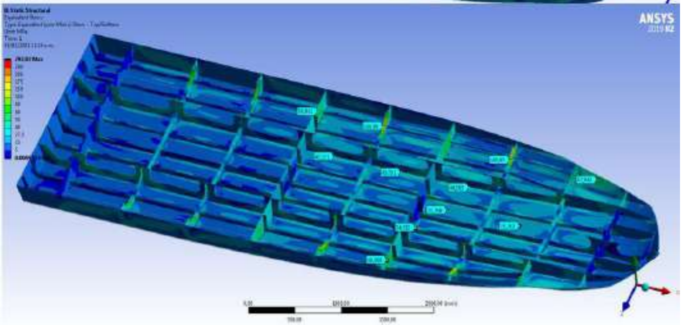
Typical frame

Results

Direct Analysis:





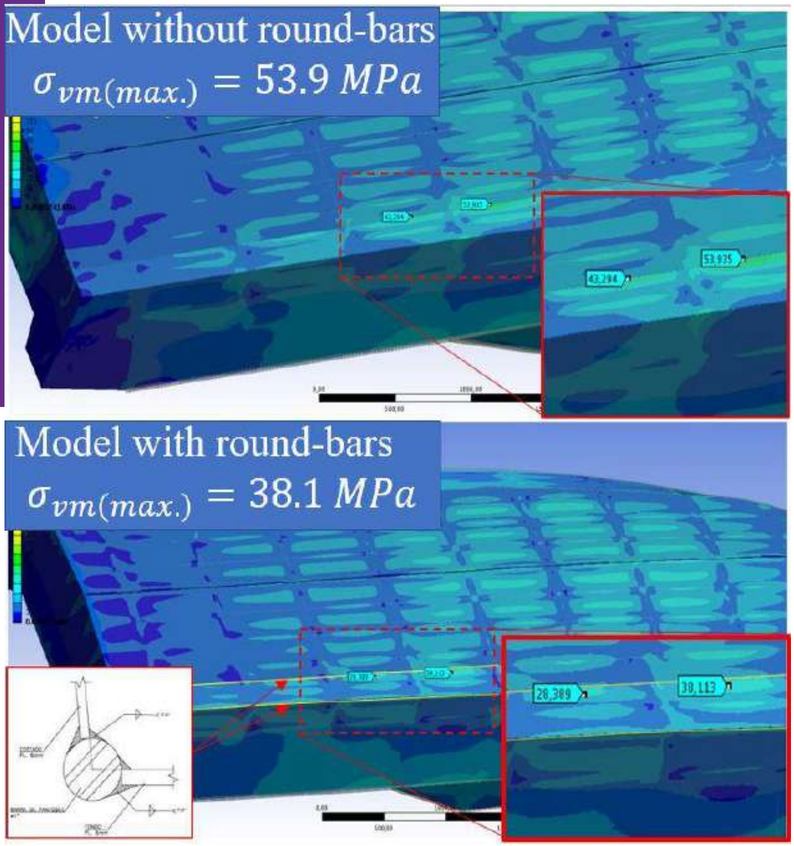


	Equivalent stress [MPa]	Allowable stress [MPa]	Safety factor	Scantling safety factor
Bottom longitudinals	63.9 MPa	106 MPa	1.66	1.17
Side longitudinals	42.0 MPa	106 MPa	2.50	1.10
Side girders	62.8 MPa	123 MPa	1.96	1.40
Floors	55.8 MPa	123 MPa	2.20	2.41
Frames	89.1 MPa	123 MPa	1.38	3.30
Transverse web	82.0 MPa	106 MPa	1.29	1.20
Deck longitudinals	82.1 MPa	106 MPa	1.29	1.75

- The highest stress level (close to 55.8 MPa) can be found in the bow between frames 9 and 10
- A 2.2 safety factor in the bottom plate is expected.
- When the obtained safety factor is compared to the scantling safety factor, it is discernible how conservative the scantling approach might be.

Results

Direct Analysis:

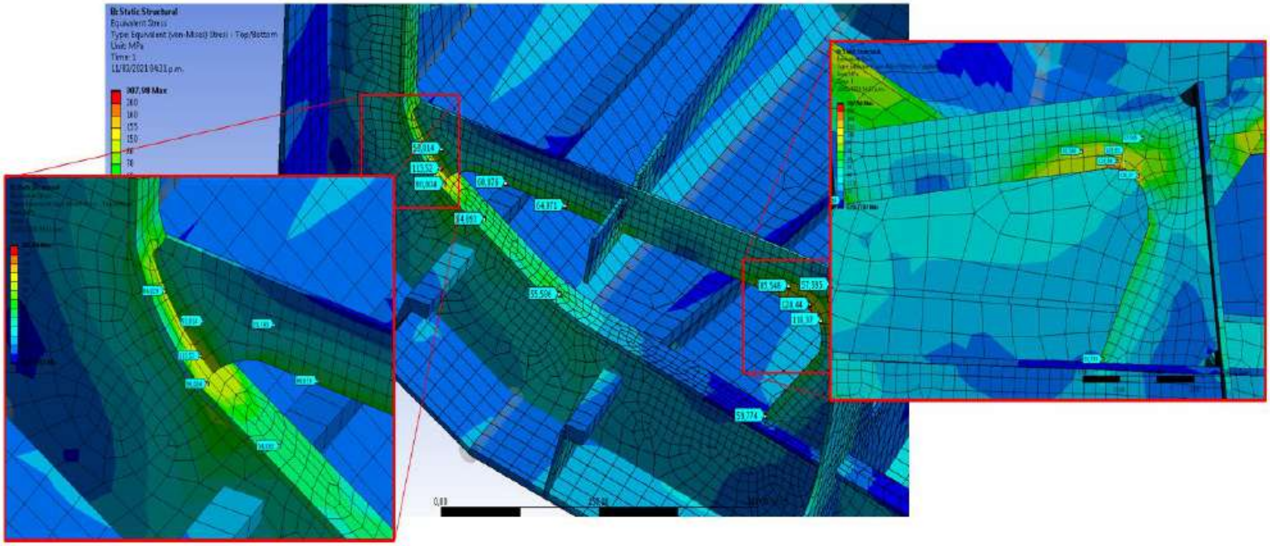


- The utility of these round bars is to improve the available welding surface area and raising stiffness.
- Beam type elements with cross section properties equivalent to the round-bars were added.
- it was found that chine stress levels showed a 30% stress level reduction

Results

Direct Analysis:

Structural details

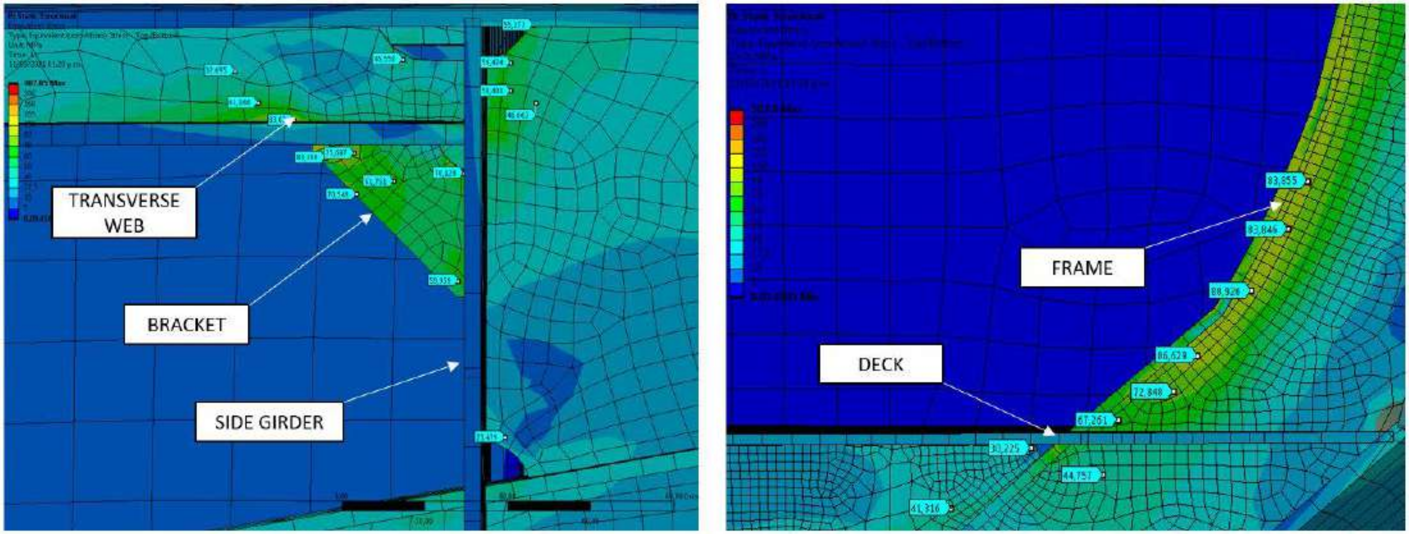


- Spotted stress concentration safety factors in deck longitudinals, floors, and frames are shown to be higher by the scantling approach
- This could be explained given the limitations of the scantling rules related to geometry and stress concentrations

Results

Direct Analysis:

Structural details

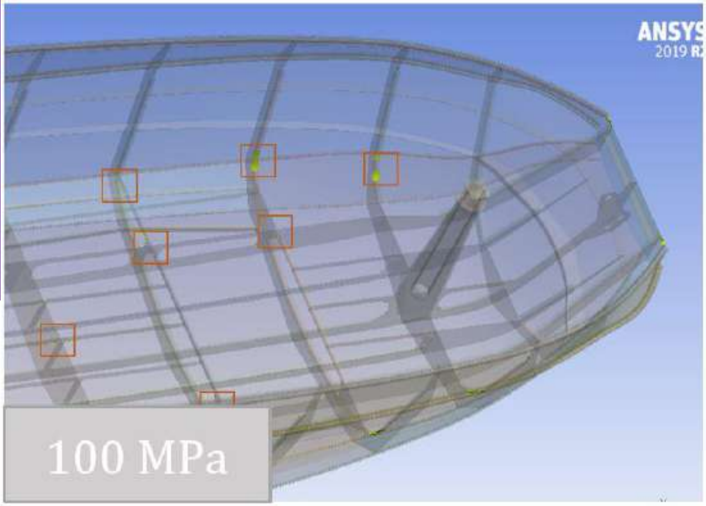


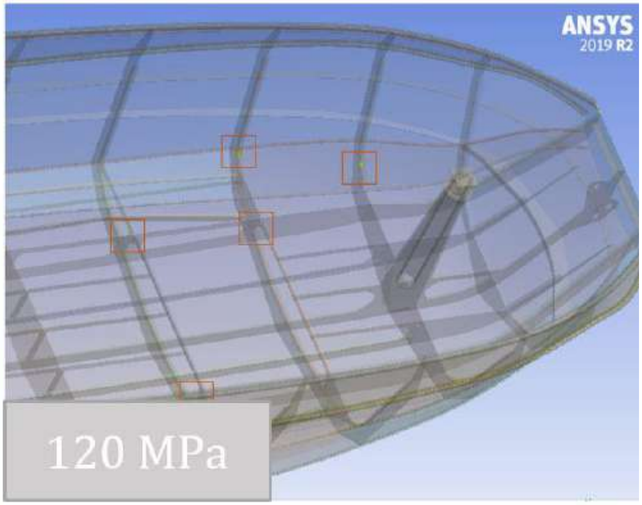
- In general, the stress is moderate and typically below 70 MPa but the upper bracket toe presents localized 125 MPa stress values due to stress concentration.
- Regarding the frame-deck intersection, typically below 90 MPa stresses were reported in frames due to their curvature near the deck.

Results

Direct Analysis:

Structural details



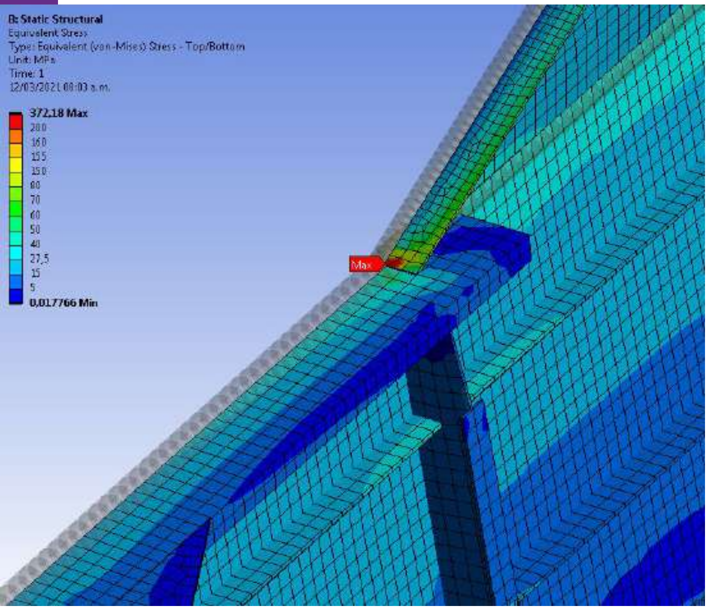


- localized plastic deformation would imply strain hardening and a slight loss of ductility.
- The spotted high stresses, which maximum value is close to 140 MPa, are remarkably below than aluminum tensile ultimate strength at heat-affected zones

Results

Direct Analysis:

Structural details

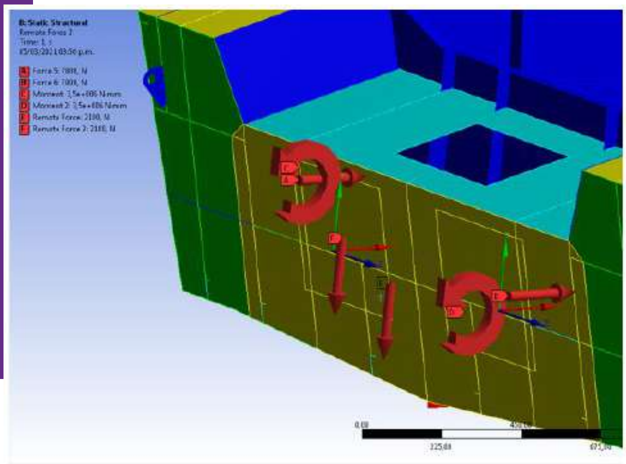


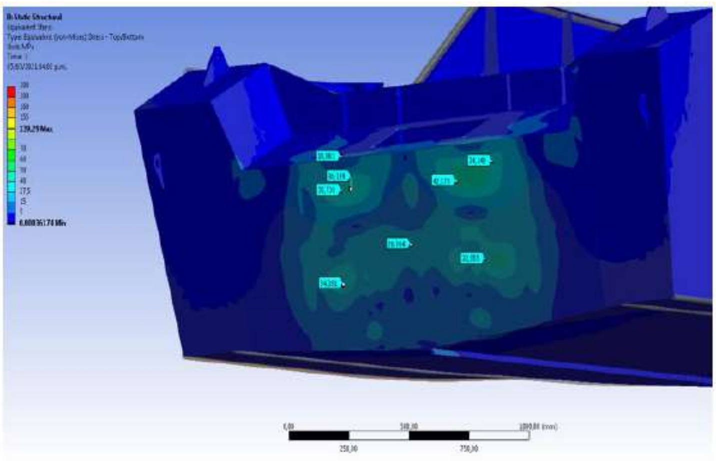
- A high gradient stress zone was spotted at the port gunwale, after mesh convergence was not reached; the reported high stress values are deemed as a singularity

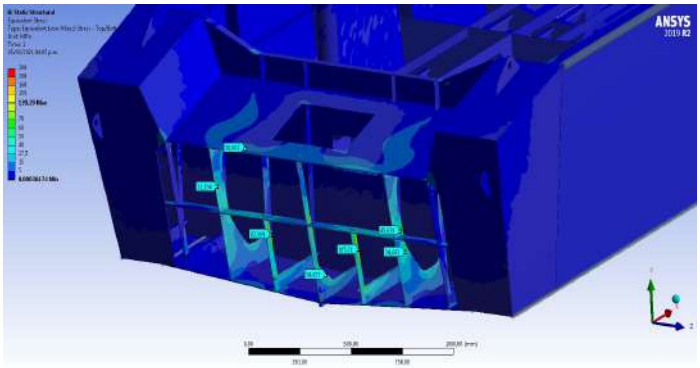
Results

Direct Analysis:

Structural details





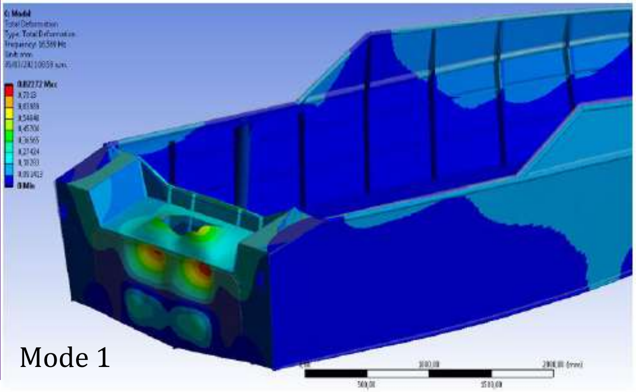


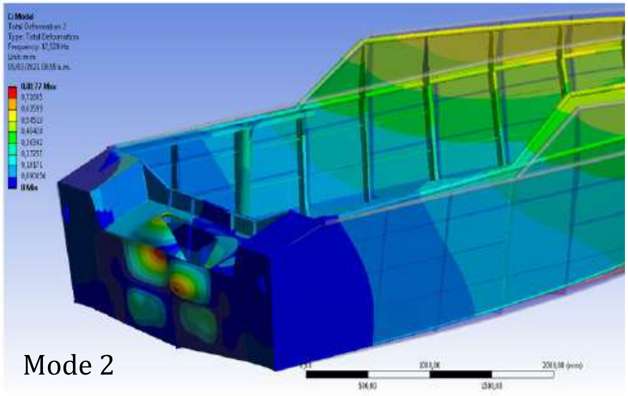
- Transom plate reinforcements present equivalent stress values below 50 MPa except for reinforcements at 250 mm from the centerline.
- These Al- 6082 -T6 profiles present local stress levels close to 140 Mpa and a 1.35 safety factor

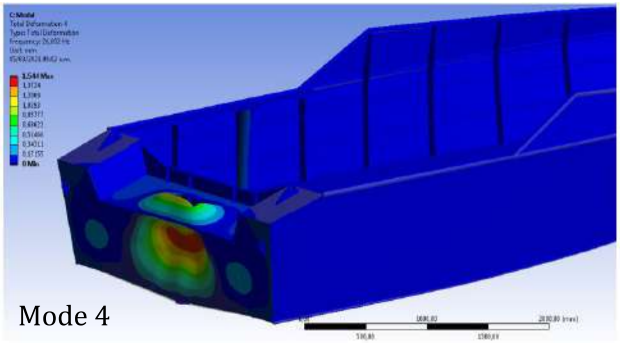
Results

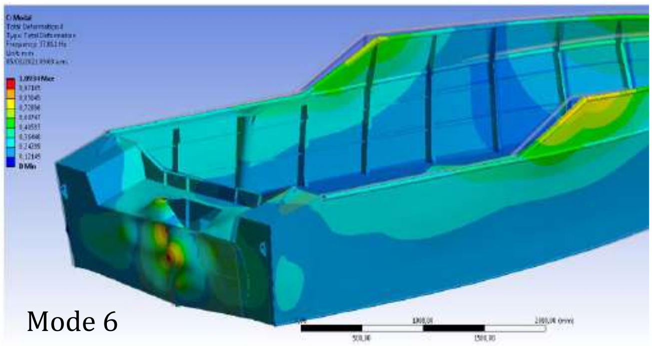
Direct Analysis:

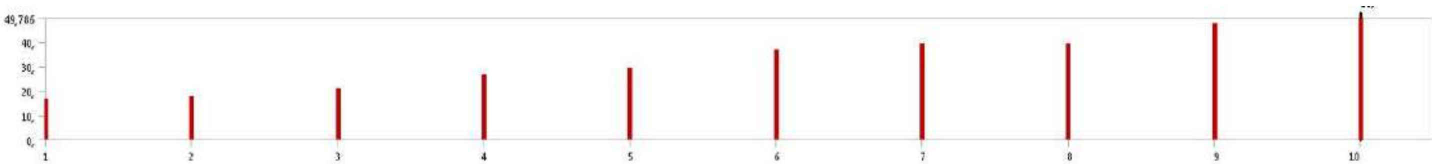
Modal Analysis







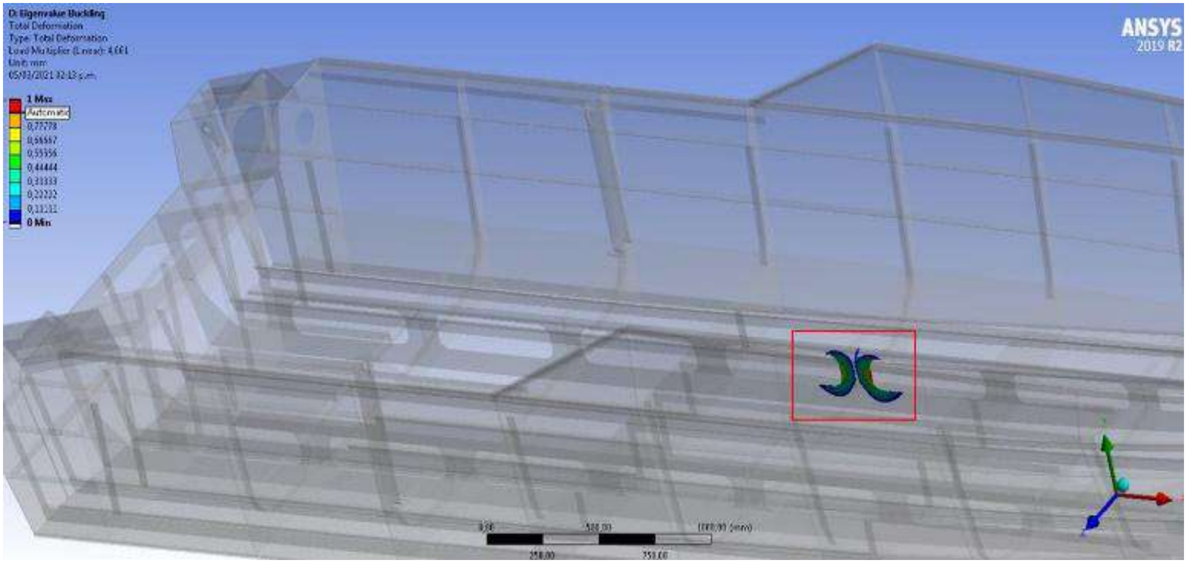




Results

Direct Analysis:

Buckling Analysis



- The analyzed modes found a load multiplier factor equal to 4.66; given a load multiplier factor higher than 1.0 this structure will not present failure by buckling.

Conclusions

- The designed structural arrangement for a riverine low-draft combat boat meets all requirements stipulated in both HSC- ABS and ISO 12215 scantling rules.

- In most of cases, scantling requirements are more conservatives in HSC-ABS rules than stipulated in ISO 12215.

- There are cases where direct analysis presents lower safety factors. This might be because of scantling rules limitations related to structure geometries and stress concentrations.

- The structural arrangement natural frequencies are out of range from operative outboard motors frequencies.

Conclusions

- The idle frequency is 15% lower than one of the transom vibration modes, but, due to deformation amplitude is below the maximum allowed, safety operations of the vessel are not deemed affected.

- From linear buckling analysis it can be shown that no structural elements will be failing by compressive loading instabilities.

References

[1] F. Alvarez y M. L. Medina, Guerra Fluvial Irregular: Fuerzas de Combate en los Rios de América, Madrid: IDS. Navantia, 2012.

[2] COTECMAR, «BCFBC. Manual de Usario,» Cartagena de Indias, 2020.

[3] A. B. o. S. ABS, Rules for building and classing. High-Speed craft. Part 3: Hull Construction and Equipment, Houston, TX. USA: ABS, 2020.

[4] International Organization for Standarization, Small Craft - Hull construction and Scantlings - Part 5: Design pressures for monohulls, design stresses, scantlings determinaion, ISO, 2014.

[5] Det Norske Veritas Germanischer Lloyd´s DNV-GL, DNV-GL-CG-027- Class Guideline- Finite Element Analysis, 2015.

[6] B. Yong y J. Wei-Liang , «Chapter 8 - Scantling of Ship's Hulls by Rule,» de Marine Structural Design , Butterworth-Heinemann, 2016, pp. 153-170.

[7] K. Anyfantis, «Ultimate strength of stiffened panels subjected to non-uniform thrust,» International Journal of Naval Architecture and Ocean Engineering, vol. 12, pp. 325-342, 2020.

[8] D. Van Tuyen , B. Liu, Y. Garbatov, W. Wu y C. Guedes Soares, «Strength assessment of aluminium and steel stiffened panels with openings on longitudinal girders,» Ocean Engineering, vol. 200, 2020.

[9] J. K. Paik, «Characteristics of welding induced initial deflections in welded aluminum plates,» Thin-walled Structures, vol. 45, pp. 493-501, 2007.

[10] Ship Structure Committe, SSC-218 Design Considerations for Alluminum Hull Structures, Washington D.C: Ship Structure Committe, 1971.

[11] R. Sielski, «Research needs in aluminum structure,» Ships and Offshore Structures, vol. 3, pp. 57-65, 2008.

[12] N. Nazemi, F. Ghrib y J. Sokolowski, «The HAZ in Aluminum Welding Revisited,» 3rd Specialty Conference on Engineering Mechanics and Materials, 2013.

References

[13] J. Paik, J. Lee, M. Ryu, Y. Jang, H. Renaud y P. Hess, «Mechanical buckling collapse testing on Aluminium stiffened plate structures for marine applications,» the World Maritime Technology Conference, 2006.

[14] M. Collette, «Strength and Reliability of Aluminium Stiffened Panels,» Ph.D submission School of Marine Science and Technology, Faculty of Science, Agriculture and Engineering, University of Newcastle, 2005.

[15] B. Chen y C. Guedes Soares, «A Simplified Model for the Effect of Weld-Induced Residual Stresses on the Axial Ultimate Strength of Stiffened Plates,» Journal of Marine Science and Application, vol. 17, pp. 57-67, 2018.

[16] P. Herrington y R. Latorre, «Development of an aluminum hull panel for high-speed craft,» Marine Structures, vol. 11, pp. 41-71, 1998.

[17] B. Liu, R. Villavicencio y G. S. Soares, «On the failure criterion of aluminum and steel plates subjected to low-velocity impact by a spherical indenter,» International Journal of Mechanical Sciences, vol. 80, pp. 1-15, 2014.

[18] B. Liu, S. Wang, R. Villavicencio y C. Guedes Soares, «Slamming load and hydroelastic structural reponse og bow flare areas of aluminium fast displacement crafts,» Ocean Engineering, 2020.

[19] B. Yong y J. Wei- Liang, «Chapter 8: Ship Hull Scantling Design by Analysis,» de Marine structural design, 2016, pp. 171-180.

[20] American Bureau of Shipping, Guidance notes on Structural Direct Analysis for High-Speed Craft, Houston: ABS, 2018.

[21] Lloyd´s Register, Rules for the manufacture, testing and certifications of materials, London: Lloyd's Register Group, July 2020.

[22] COTECMAR, «Cálculos de Escantillonado del Bote de Combate Fluvial de Bajo Calado - BCFBC,» Cartagena de Indias, 2020.

[23] E. Nieme, W. Frikle y S. Maddox, «Structural Hot- spot Stress Determination Using Finite Element Analysis,» de Structural Hot-Spot Stress Approach to Fatigue Analysis of Welded Components, IIW Collection, 2018.

[24] Lloyd´s Register, Rules and regulations for the classification of special service craft, London, July 2020.

Muchas Gracias