Structural Design of 38m Special Purpose Vessel in Aluminium Alloy

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Intermarine & Rodriquez Group

Fast Ferries

Mega Yachts

Military Vessels

Project Description

Main Dimensions

➢ Length overall	38,4 meters
➢ Breadth overall	8,6 meters
➢ Moulded depth	3,95 meters
➢ Gross Tonnage	295

Propulsion

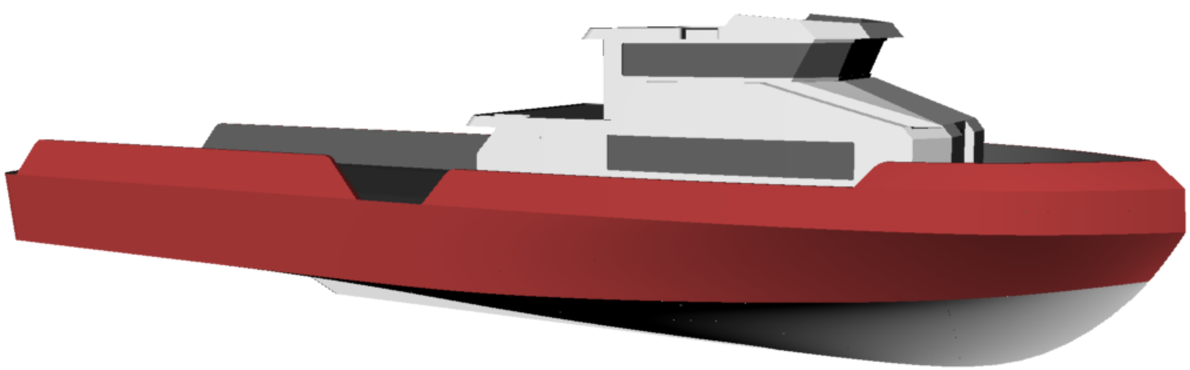
➢ Main Engines	3 x Cummins KTA 50 M2; 1343 Kw @ 1900 rpm
➢ Propellers	3 x 4 blade (fixed pitch)

Load Capacity

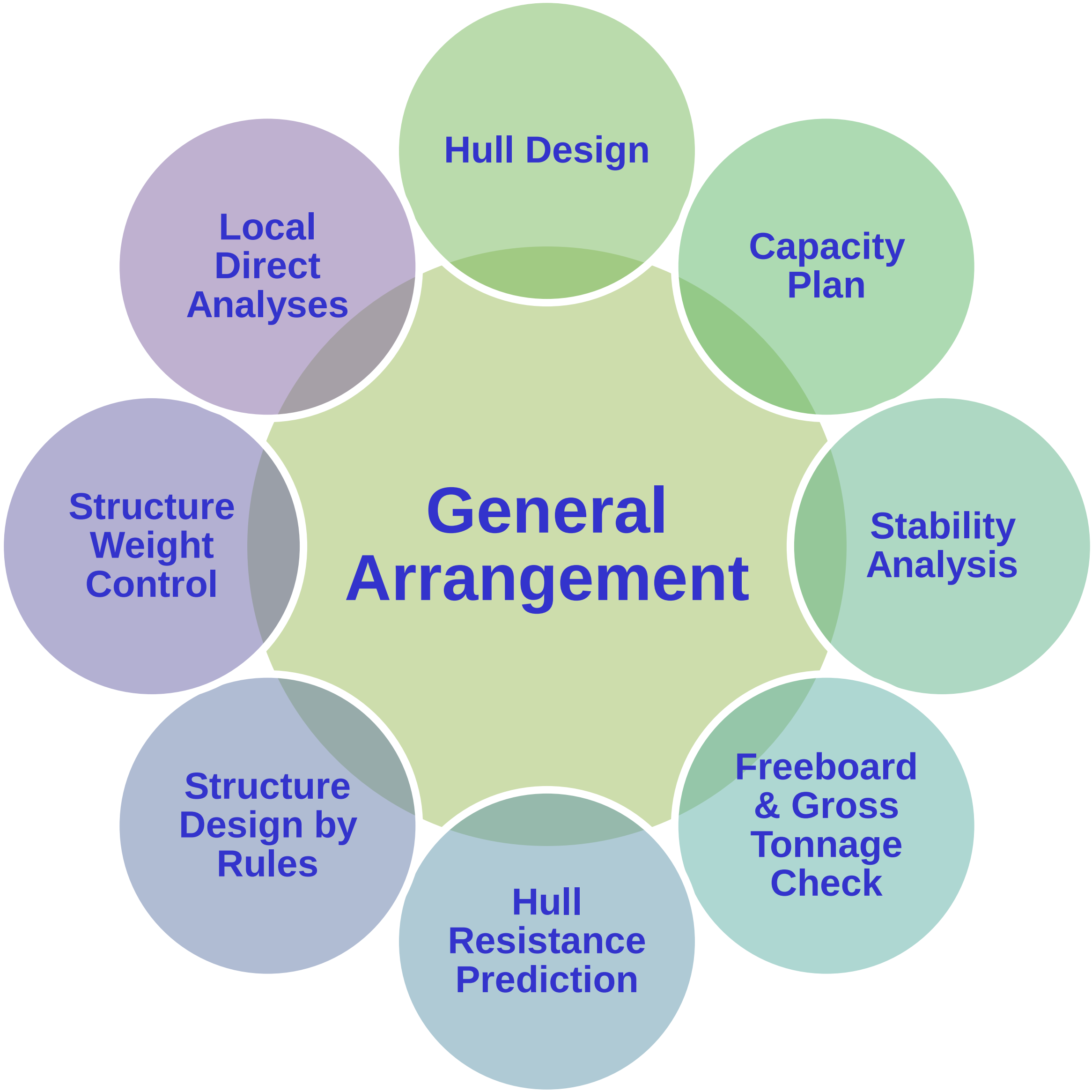
➢ Passengers	40 technical
➢ Deck cargo	40 t with a maximum height of the CG of 1,2 m from cargo deck
➢ Cargo area	60 m^2 (max 1,5 tonne/m^2)
➢ Weight distributed on deck	1,5 tonne/m^2 for loading area and 1,0 tonne/m^2 for remaining areas
➢ Deadweight	134 tonnes (difference between the displacement at full load and Lightship)

Service Performance

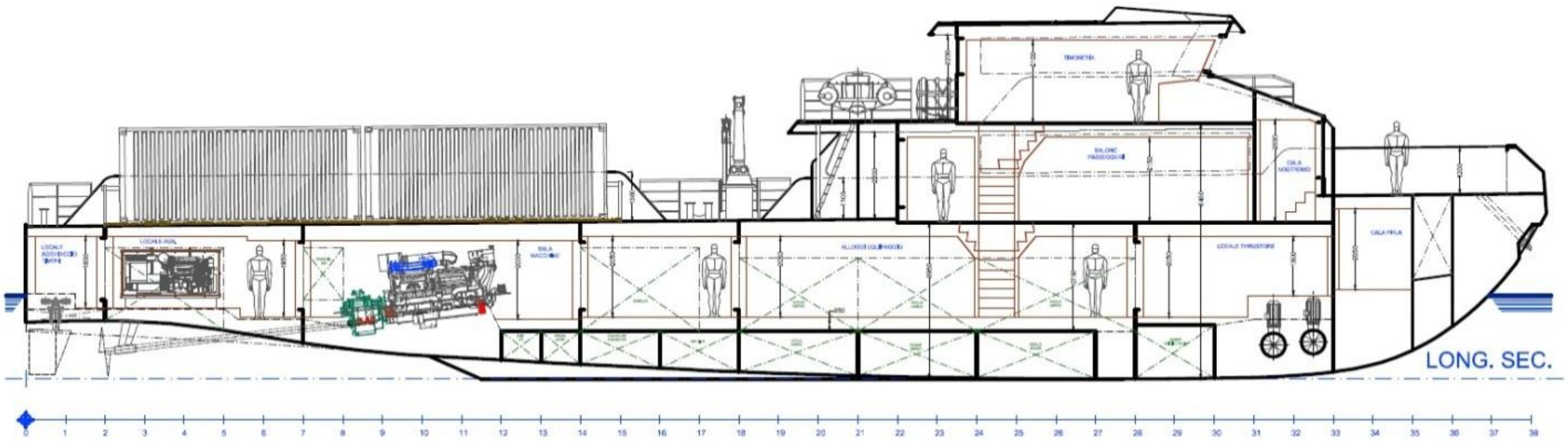
- Max. speed (@100% RPM)
  26 knots
- Min. speed (@90% RPM)
  23 knots

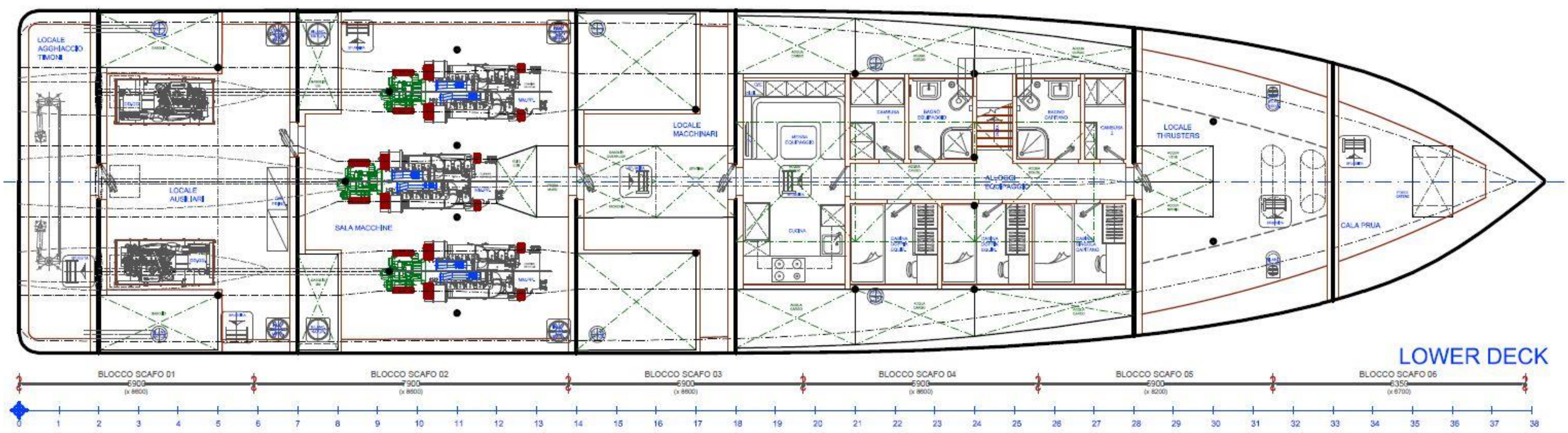


Preliminary Design Process



General Arrangement





Design by A. Battistini

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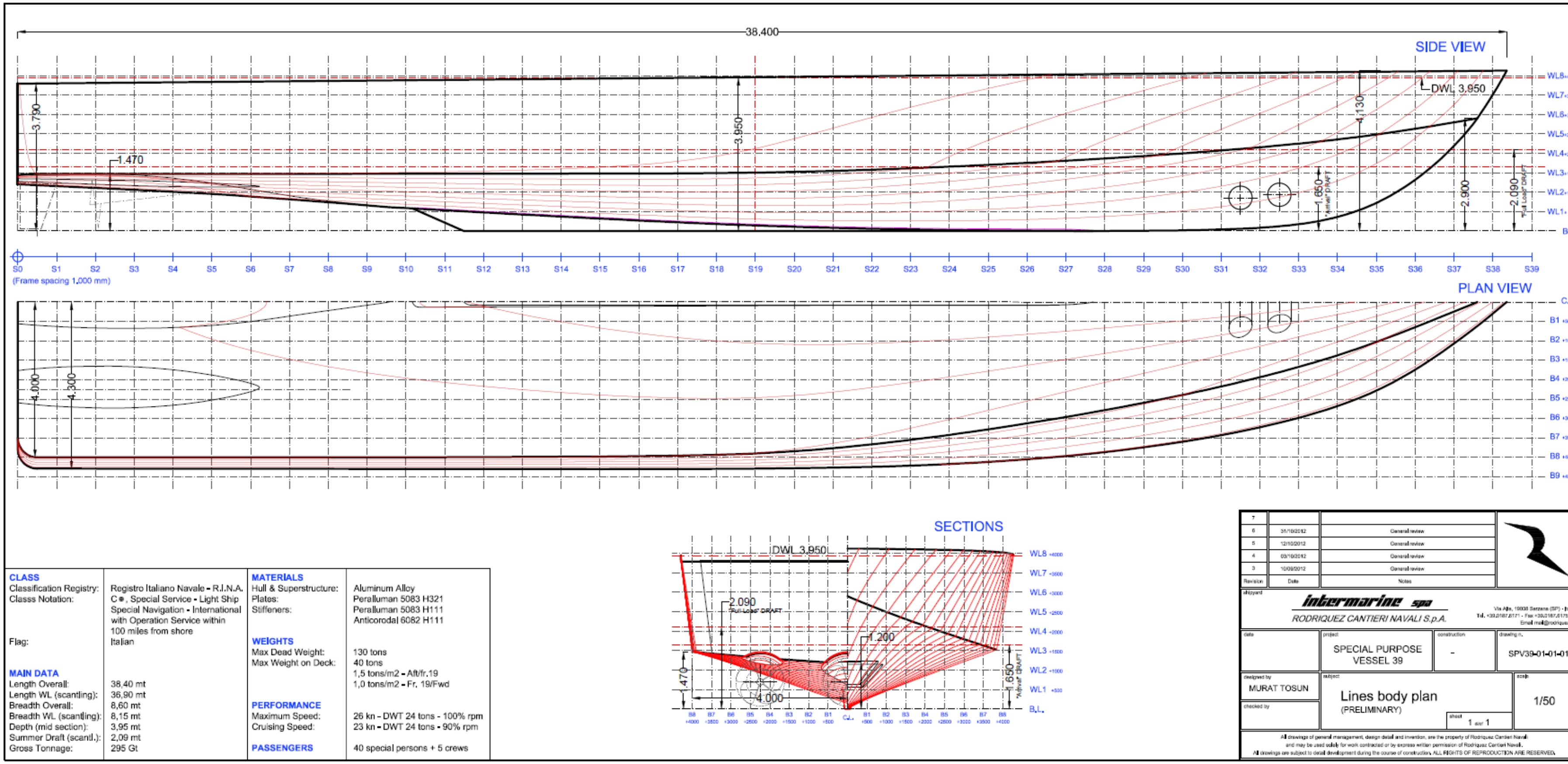
Lines Plan

- Classification Registry: Registro Italiano Navale – RINA
- Class Notation: RINA C ✠ , Special Service - Light Ship, Special Navigation - International Operations with Service within 100 miles from shore
- Flag: Italian



CLASS		**MATERIALS**	
Classification Registry:	Registro Italiano Navale - R.I.N.A.	Hull & Superstructure:	Aluminum Alloy
Classs Notation:	C ⊕ , Special Service - Light Ship Special Navigation - International with Operation Service within 100 miles from shore	Plates:	Peralluman 5083 H321
		Stiffeners:	Peralluman 5083 H111
			Anticorodal 6082 H111
Flag:	Italian	**WEIGHTS**	
		Max Dead Weight:	130 tons
		Max Weight on Deck:	40 tons
MAIN DATA			1,5 tons/m2 - Aft/fr.19
Length Overall:	38,40 mt		1,0 tons/m2 - Fr. 19/Fwd
Length WL (scantling):	36,90 mt		
Breadth Overall:	8,60 mt	**PERFORMANCE**	
Breadth WL (scantling):	8,15 mt	Maximum Speed:	26 kn - DWT 24 tons - 100% rpm
Depth (mid section):	3,95 mt	Cruising Speed:	23 kn - DWT 24 tons - 90% rpm
Summer Draft (scantl.):	2,09 mt		
Gross Tonnage:	295 Gt	**PASSENGERS**	40 special persons + 5 crews

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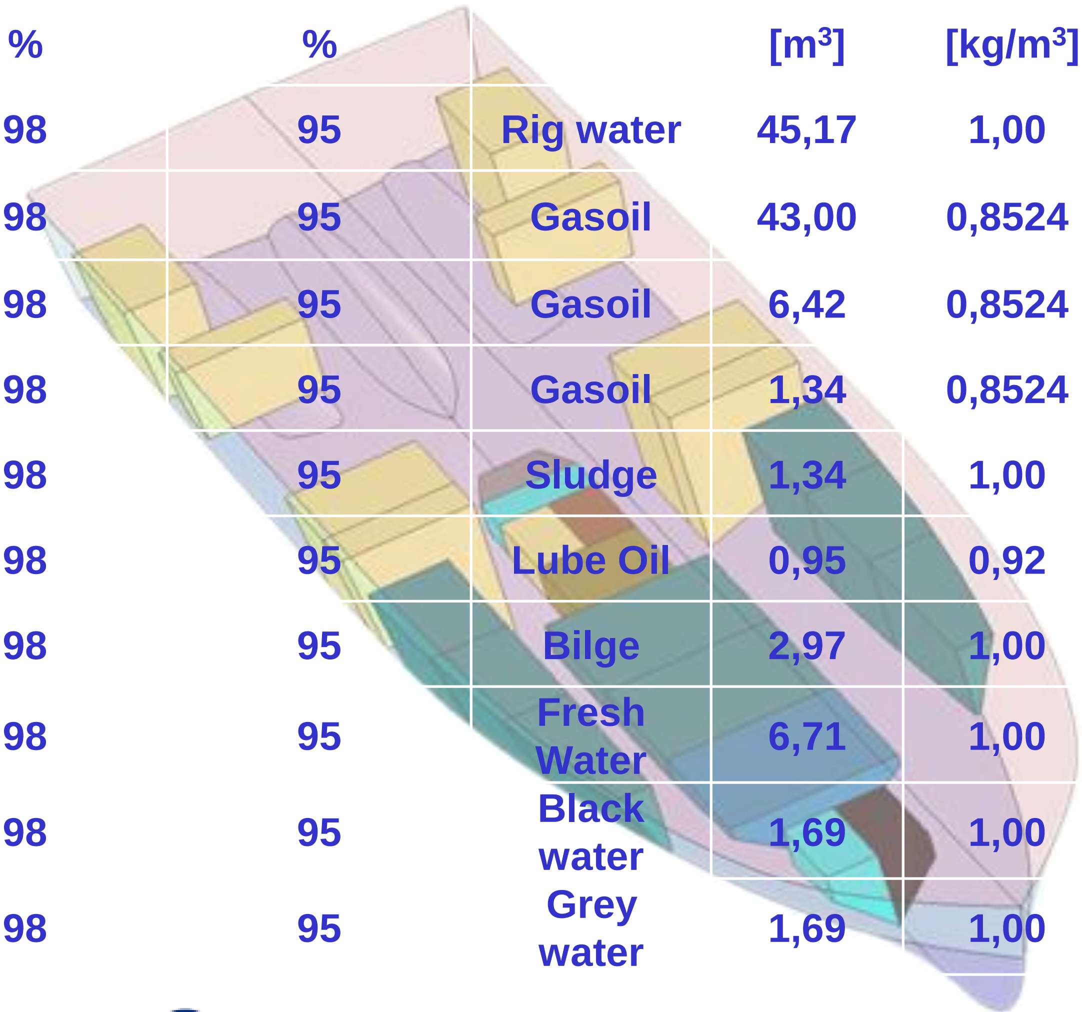
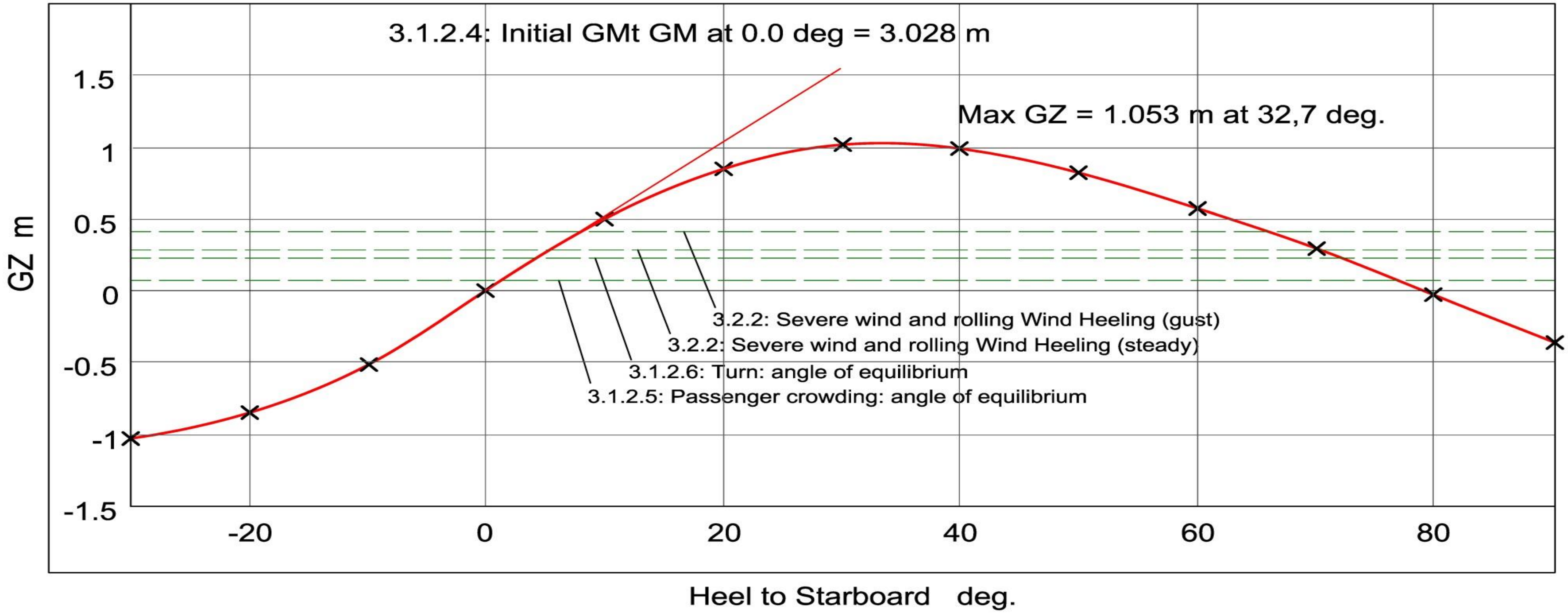
Tank Arrangement & Capacity Plan

Tank Name	Intact Permeability	Damage Permeability	Fluid Type	Volume	Specific Gravity	Weight
	%	%		[m³]	[kg/m³]	[kg]
Rig water	98	95	Rig water	45,17	1,00	45,17
Gasoil	98	95	Gasoil	43,00	0,8524	36,65
Daily oil	98	95	Gasoil	6,42	0,8524	5,47
Overflow	98	95	Gasoil	1,34	0,8524	1,14
Sludge	98	95	Sludge	1,34	1,00	1,34
Lubricating oil	98	95	Lube Oil	0,95	0,92	0,87
Bilge	98	95	Bilge	2,97	1,00	2,97
Fresh water	98	95	Fresh Water	6,71	1,00	6,71
Black water	98	95	Black water	1,69	1,00	1,69
Grey water	98	95	Grey water	1,69	1,00	1,69



Stability Design Criteria



Criteria (Full load condition)	Value	Units	Actual	Status	Margin %
3.1.2.1: Area 0 to 30 shall not be less than (>=)	0.055	m.rad	0.34	Pass	520.73
3.1.2.1: Area 0 to 40 shall not be less than (>=)	0.09	m.rad	0.52	Pass	481.10
3.1.2.1: Area 30 to 40 shall not be less than (>=)	0.03	m.rad	0.18	Pass	505.31
3.1.2.2: Max GZ at 30 or greater shall not be less than (>=)	0.20	m	1.05	Pass	426.27
3.1.2.3: Maximum GZ angle shall not be less than (>=)	25.00	deg	32.70	Pass	30.91
3.1.2.4: Initial GMt shall not be less than (>=)	0.15	m	3.03	Pass	1918.67
3.1.2.5: Passenger crowding angle of equilibrium shall not be greater than (<=)	10.00	deg	0.80	Pass	91.83
3.1.2.6: Turn angle of equilibrium shall not be greater than (<=)	10.00	deg	3.40	Pass	66.49
3.2.2: Severe wind and rolling criterion: Area 1 / Area 2 shall not be less than (>=)	100.00	%	158.03	Pass	58.03

Hull Resistance Prediction

- ✓ Hull shape: Hard chine hull in pre-planing regime ($1{,}0 < Fn_V < 3{,}0$). In this speed range the dynamic lift begins to have some effects, but has still a modest entity.
- ✓ Speed range: The resistance prediction algorithms are useful only within certain speed ranges; these limits are:

Algorithm	Low – speed limit	Actual (For trial condition)	High – speed limit
Savitsky (pre-planing)	$Fn_V = 1{,}0$	1,86	$Fn_V = 2{,}0$
Savitsky (planing)	$Fn_b = 1{,}0$	1,51	-
Lahtiharju (hard chine)	$Fn_V = 1{,}5$	1,86	$Fn_V = 5{,}0$
Holtrop	$Fn_L = 0{,}0$	0,70	$Fn_L = 0{,}8$

- ✓ Dimension limits for Savitsky algorithm:

Dimensions	Minimum	Actual (For trial condition)	Maximum
L/(V^1/3)	3,07	6,90	12,40
ie	3,70	15,78	28,60
L/B	2,52	4,53	28,26
B/T	1,70	4,94	9,80
At/Ax	0	0,37	1
LCG/L	-0,016	0,062	0,066

- ✓ Total resistance for Savitsky pre-planing method:

R_T	Total resistance; either expressed as: $R_T = R_R + R_F + R_{Cor} + R_{App} + R_{Air}$ or $R_T = R_W + R_V + R_{Cor} + R_{App} + R_{Air}$
R_{Cor}	Correlation allowance resistance; additional resistance for correlation from model to ship scale
R_{App}	Appendage resistance; resistance of appendages such as rudder, etc.
R_{Air}	Air resistance; wind resistance of above-water hull and superstructure

	Trial Condition		Arrival Condition		Half-Load Condition		Full-Load Condition	
Speed	Resistance	Power	Res.	Power	Res.	Power	Res.	Power
[kn]	[kN]	[kW]	[kN]	[kW]	[kN]	[kW]	[kN]	[kW]
23,0	114,10	2454,72	119,34	2567,34	154,31	3319,71	219,23	4716,34
26,0	127,92	3110,93	133,57	3248,42	171,24	4164,34	239,25	5818,44

Computational Fluid Dynamics Analysis

	Data from Savitsky Method			Data from CFD				Difference	
Speed	Trim	Disp.	RT	Aft draft	Trim	Disp.	RT	Disp.	RT
[kn]	[deg]	[tonnes]	[kN]	[m]	[deg]	[tonnes]	[kN]	[%]	[%]
26	0,4	157,3	127,92	1,55	0,25	171,37	133,81	8,21	4,40
26	0,4	157,3	127,92	1,50	0,25	153,23	112,86	-2,65	-13,35
26	0,4	157,3	127,92	1,53	0,28	155,32	111,84	-1,27	-14,38
26	0,4	157,3	127,92	1,52	0,30	153,62	110,35	-2,40	-15,92
26	0,4	157,3	127,92	1,53	0,30	154,88	110,09	-1,56	-16,19
26	0,4	157,3	127,92	1,55	0,40	165,90	127,24	5,19	-0,54
26	0,4	157,3	127,92	1,65	1,00	165,93	115,03	5,17	-11,25
26	0,4	157,3	127,92	1,63	1,00	162,10	113,01	2,93	-13,23
26	0,4	157,3	127,92	1,63	1,00	158,00	109,30	0,41	-17,07

Structure Design by Rules

1. Materials
2. Design Acceleration
3. Overall Loads
4. Local Loads

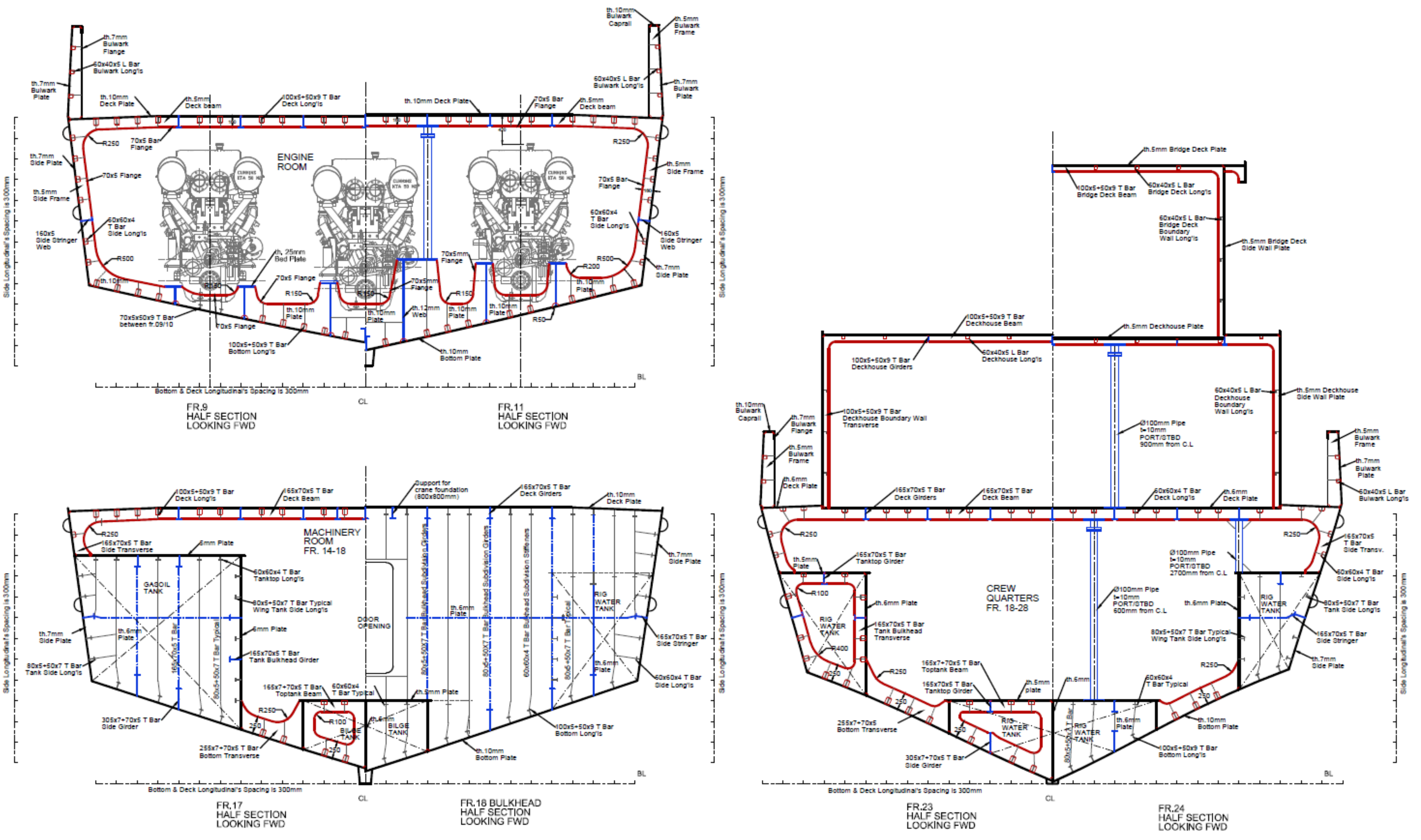
The structural elements of the vessel are determined with the rules and regulations of RINA Rules for the Classification of High-Speed Craft.

- Plates — 5083 series aluminum alloy
- Profiles — 5083 & 6082 series aluminum alloy
- Filler material — 5183 series aluminum alloy

Minimum Scanling Requirements
- Plating Thicknesses
- Ordinary Stiffeners
- Primary Supporting Members — Buckling Strength Control
- Pillars
- Main Machinery Seatings — Direct Analysis

Dimension	Value	Unit
L	36,91	m
B	8,60	m
B_W	8,15	m
D	3,95	m
T	2,09	m
Δ	263,8	tonnes
C_B	0,41	
V	26,00	knots
g	9,81	m/s^2
LCG	16,22	m

Structure Design by Rules



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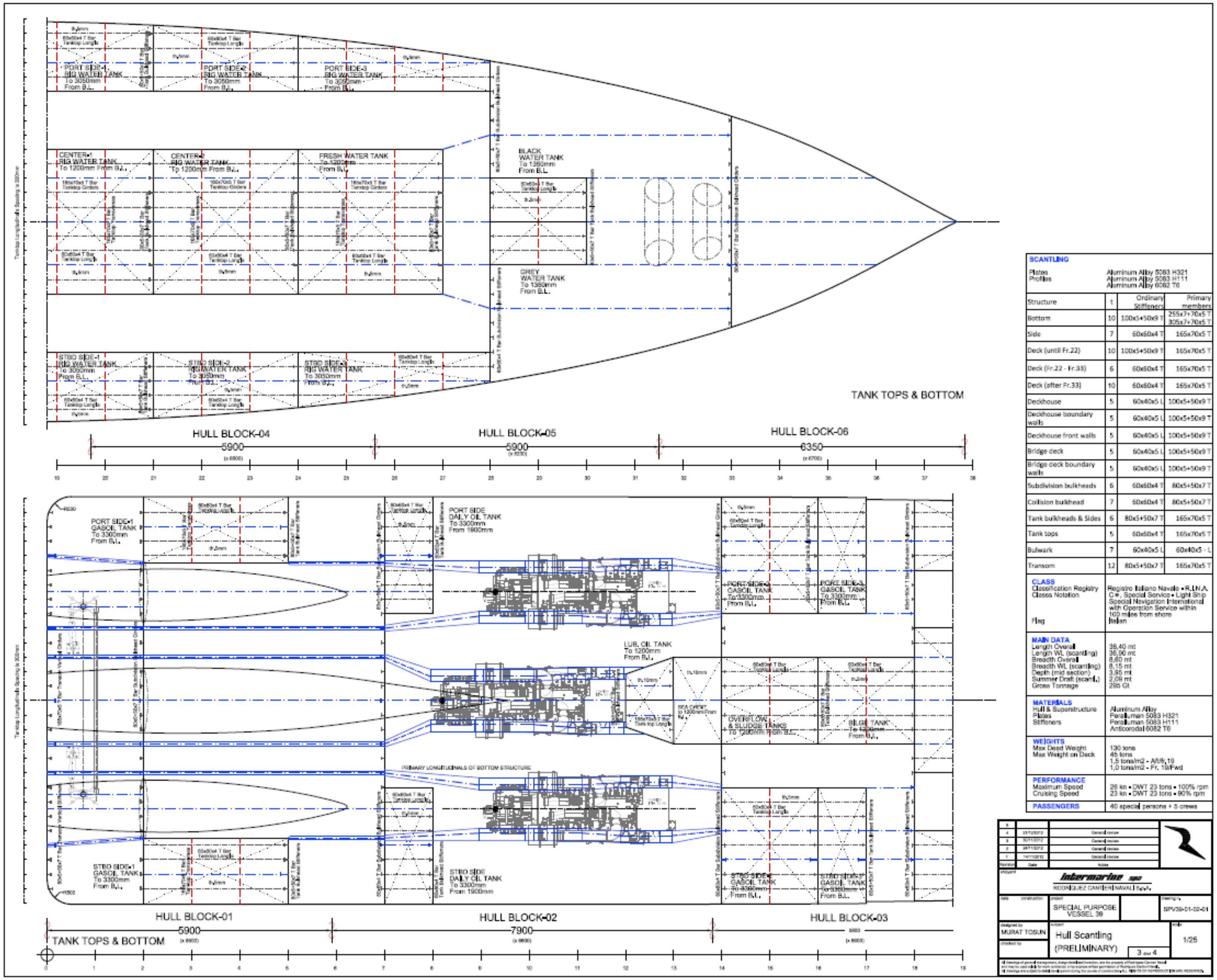
Structure Design by Rules



Structure	t	Ordinary Stiffeners	Primary members
Bottom	10	100x5+50x9 T	255x7+70x5 T 305x7+70x5 T
Side	7	60x60x4 T	165x70x5 T
Deck (until Fr.22)	10	100x5+50x9 T	165x70x5 T
Deck (Fr.22 - Fr.33)	6	60x60x4 T	165x70x5 T
Deck (after Fr.33)	10	60x60x4 T	165x70x5 T
Deckhouse	5	60x40x5 L	100x5+50x9 T
Deckhouse boundary walls	5	60x40x5 L	100x5+50x9 T
Deckhouse front walls	5	60x40x5 L	100x5+50x9 T
Bridge deck	5	60x40x5 L	100x5+50x9 T
Bridge deck boundary walls	5	60x40x5 L	100x5+50x9 T
Subdivision bulkheads	6	60x60x4 T	80x5+50x7 T
Collision bulkhead	7	60x60x4 T	80x5+50x7 T
Tank bulkheads & Sides	6	80x5+50x7 T	165x70x5 T
Tank tops	5	60x60x4 T	165x70x5 T
Bulwark	7	60x40x5 L	60x40x5 - L
Transom	12	80x5+50x7 T	165x70x5 T

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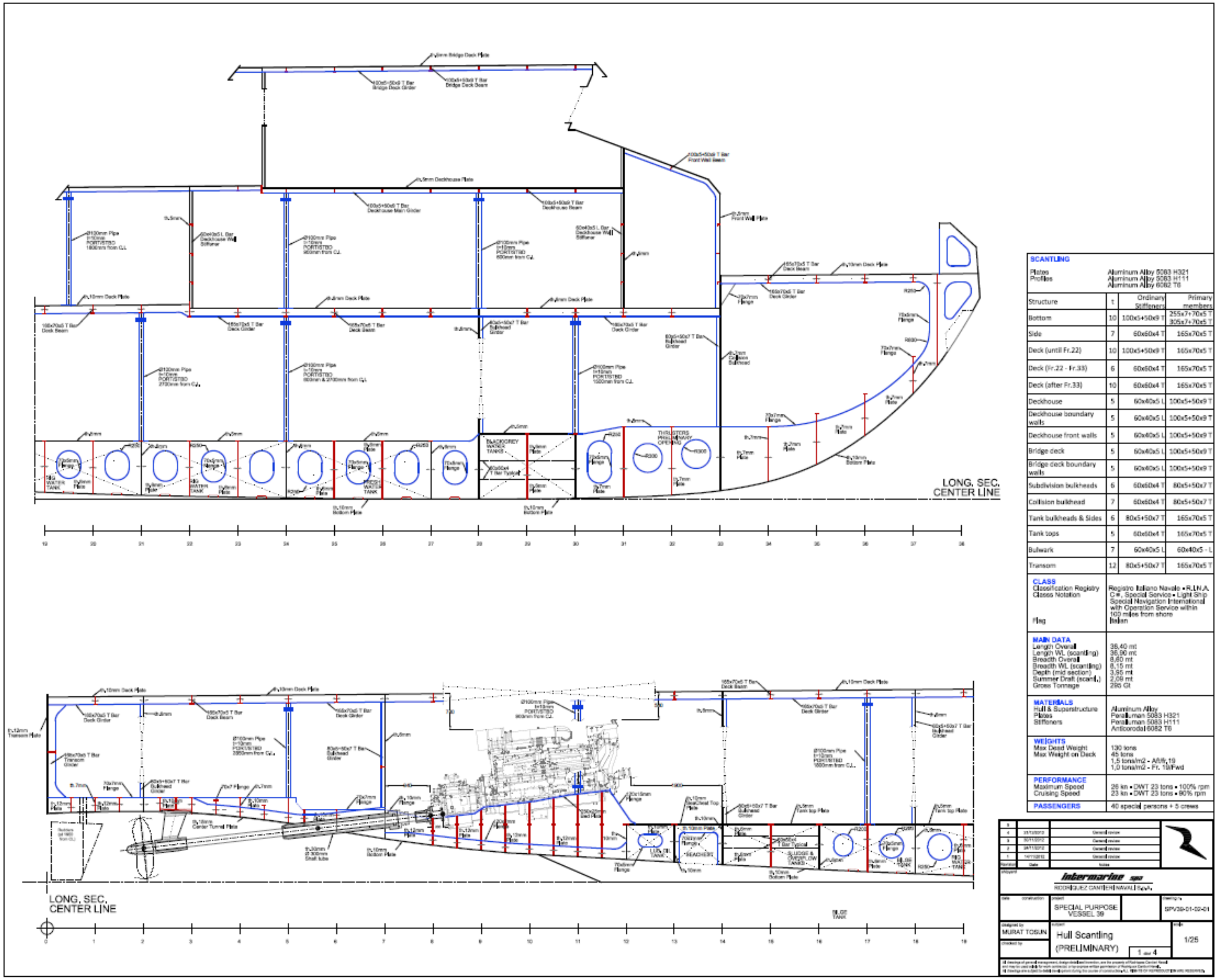
Structure Design by Rules



SCANTLING			
Plates Profiles	Aluminum Alloy 5083 H321 Aluminum Alloy 5083 H111 Aluminum Alloy 6082 T6		
Structure	t	Ordinary Stiffeners	Primary members
Bottom	10	100x5+50x9 T	255x7+70x5 T 305x7+70x5 T
Side	7	60x60x4 T	165x70x5 T
Deck (until Fr.22)	10	100x5+50x9 T	165x70x5 T
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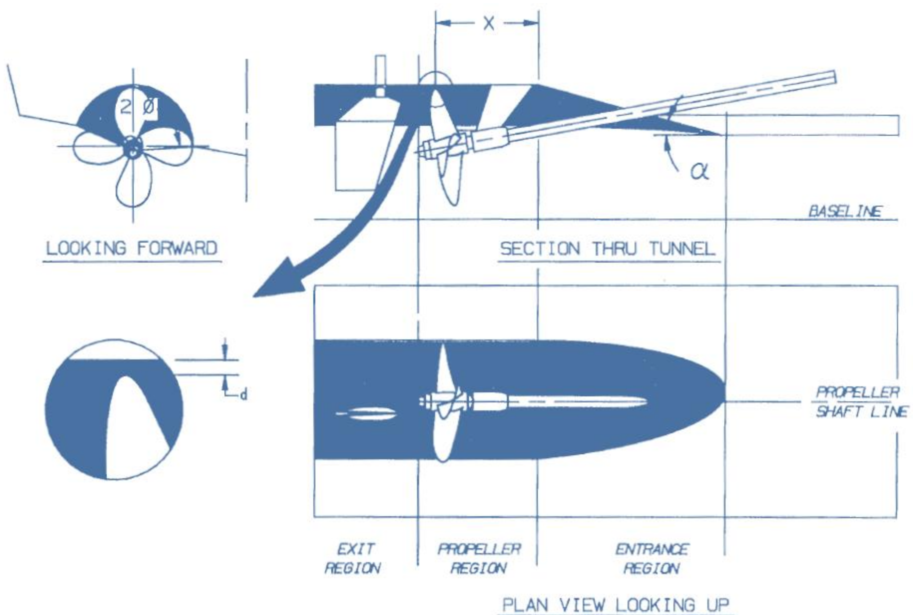
CLASS Classification Registry Classs Notation Flag	 Registro Italiano Navale • R.I.N.A. C ✠, Special Service • Light Ship Special Navigation International with Operation Service within 100 miles from shore Italian
MAIN DATA Length Overall Length WL (scantling) Breadth Overall Breadth WL (scantling) Depth (mid section) Summer Draft (scant.) Gross Tonnage	 38,40 mt 36,90 mt 8,60 mt 8,15 mt 3,95 mt 2,09 mt 295 Gt
MATERIALS Hull & Superstructure Plates Stiffeners	 Aluminum Alloy Peraluman 5083 H321 Peraluman 5083 H111 Anticorodal 6082 T6
WEIGHTS Max Dead Weight Max Weight on Deck	 130 tons 45 tons 1,5 tons/m2 - Aft/fr.19 1,0 tons/m2 - Fr. 19/Fwd
PERFORMANCE Maximum Speed Cruising Speed	 26 kn • DWT 23 tons • 100% rpm 23 kn • DWT 23 tons • 90% rpm
PASSENGERS	40 special persons + 5 crews

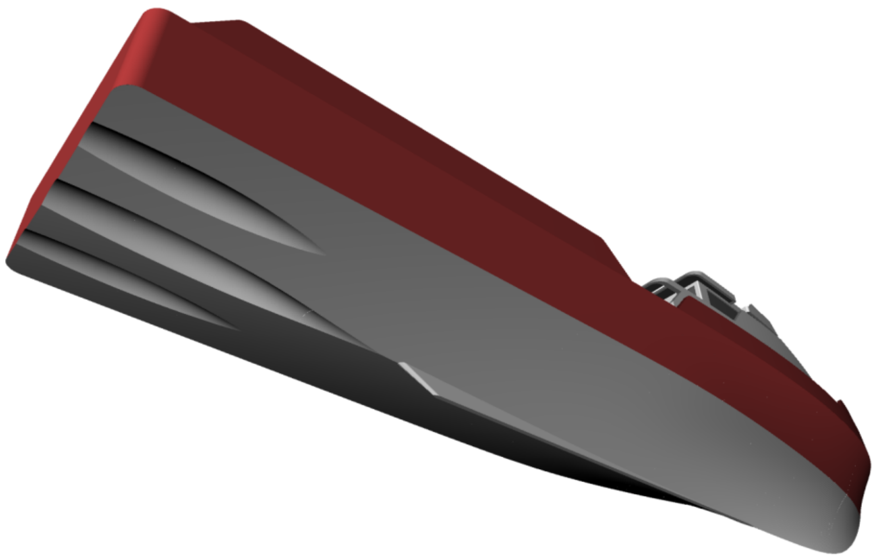
Propeller Pockets Design

Tunnels which are also called as "propeller pockets" are provided in ship hulls to accommodate propellers under reduced draught conditions, thereby avoiding reduction of propeller diameter and consequent loss of efficiency.

Main design parameters:

- Shaft angle (Target is to achieve 6° from 8-9°)
- Tunnel depth
- Propeller (1.28m diameter; 4-bladed) tip clearance
- Longitudinal placement of propeller within the tunnel
- Longitudinal distribution of cross-sectional area in the tunnel exit





Structure Weight

	Thickness [mm]	Plate area [m²]	Weight [kg]
PLATINGS	5 (H321-5083 series aluminum alloy)	880	11703
	6 (H321-5083 series aluminum alloy)	363	5793
	7 (H321-5083 series aluminum alloy)	394	7331
	10 (H321-5083 series aluminum alloy)	534	14215
	12 (H321-5083 series aluminum alloy)	44	1389
	15 (H321-5083 series aluminum alloy)	32	1261
	25 (H321-5083 series aluminum alloy)	6	399
	Typical Profile	Length [m]	Weight [kg]
PROFILES	60x40x5 (H111-5083 series aluminum alloy)	461	582
	60x60x4 (H111-5083 series aluminum alloy)	1040	1284
	80x5+50x7 (H111-5083 series aluminum alloy)	606	1153
	100x5+50x9 (H111-5083 series aluminum alloy)	1060	2552
	Ø100x10 (T6-6082 series aluminum alloy)	55	414
SUBTOTAL			48075
Welding	5183 series aluminum alloy	3%	1442
TOTAL			49517

Structural Strength Analysis by FEM

Objective & Scope

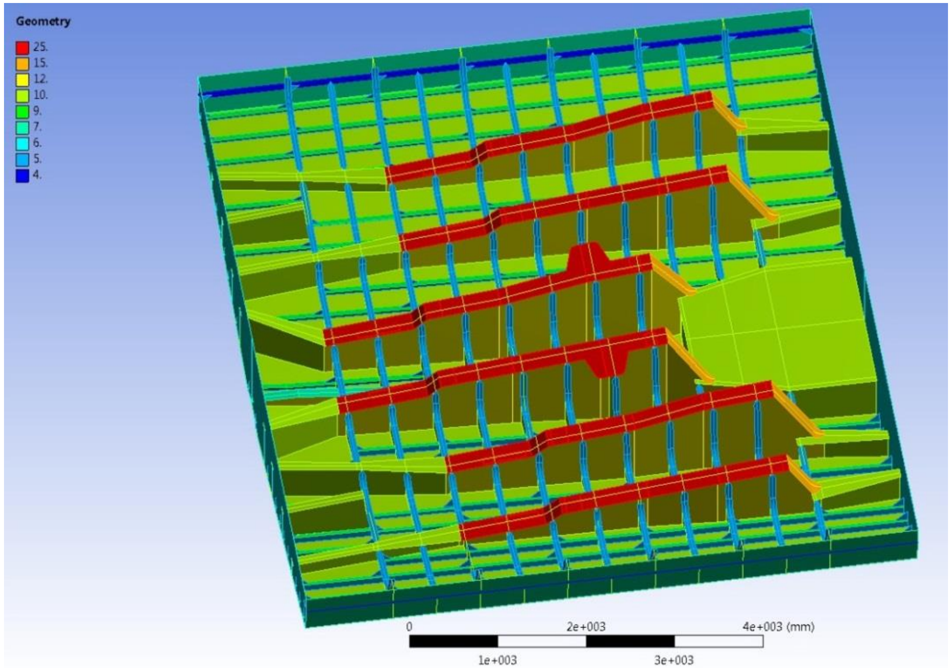
Main machinery foundations of the hull are investigated in detail for the structural analysis of the craft to ensure continuity of the reinforced elements

Finite Element Model

Below figure presents FE model with given different thicknesses. There are 6 main girders for 3 engines and center engine girders are connected to lubricating oil tank and this tank is situated by the side of sea chest

Direct Analysis Procedures

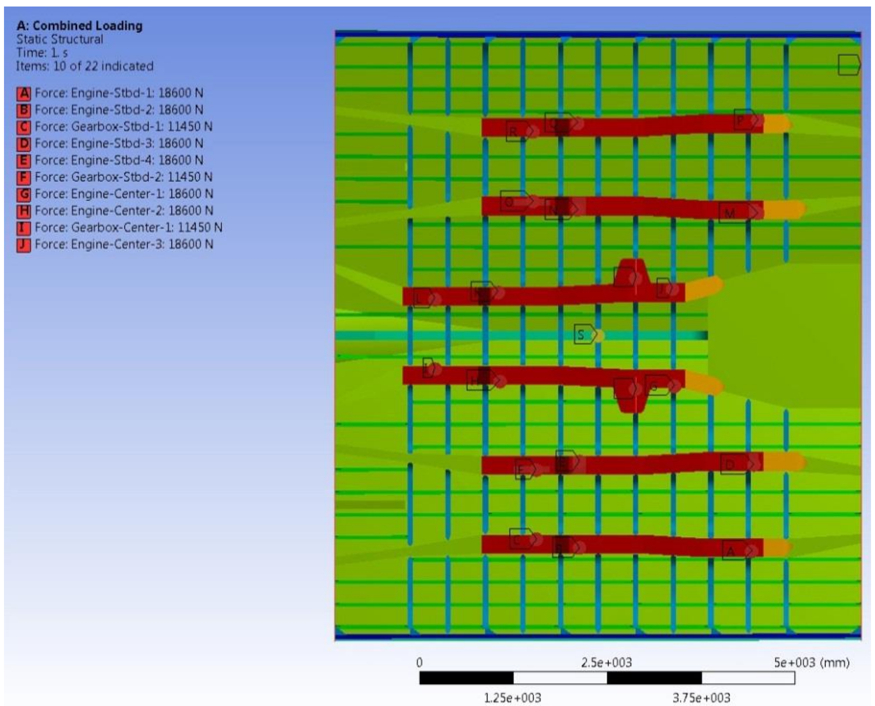
1. Structural finite element (FE) model development
2. Specification of the load cases
3. Determining of boundary conditions
4. Strength analysis
5. Application of the checking criteria



Structural Strength Analysis by FEM

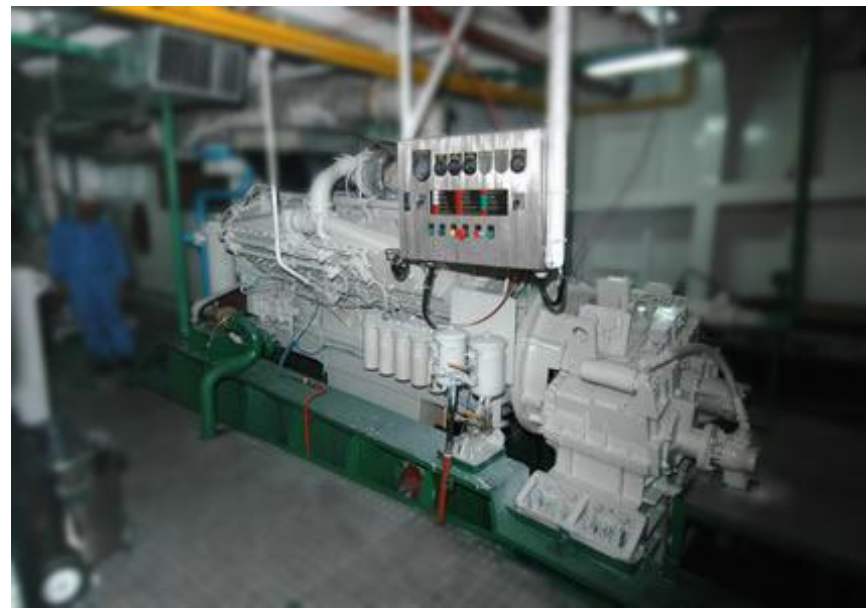
Loading Condition in Still Water

- Forces caused by engine weights and pillars through standard earth gravity
- Outer hydrostatic load in still water



Combined Loading Condition

- Forces of inertia due to the vertical acceleration a_v of the craft, considered in a downward direction
- Forces caused by engine weights and pillars through vertical acceleration

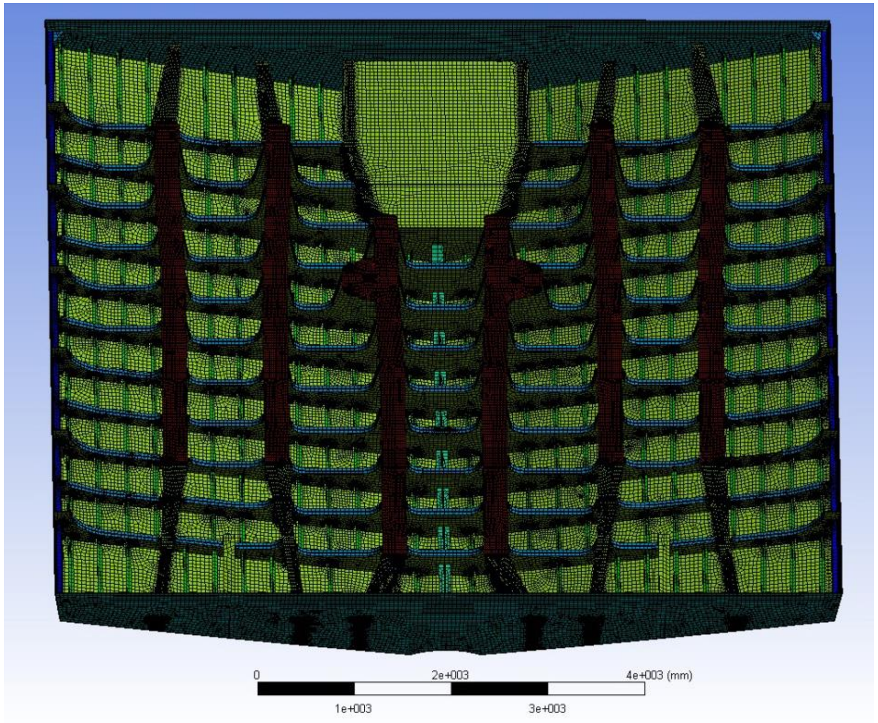


Structural Strength Analysis by FEM

Mesh Model

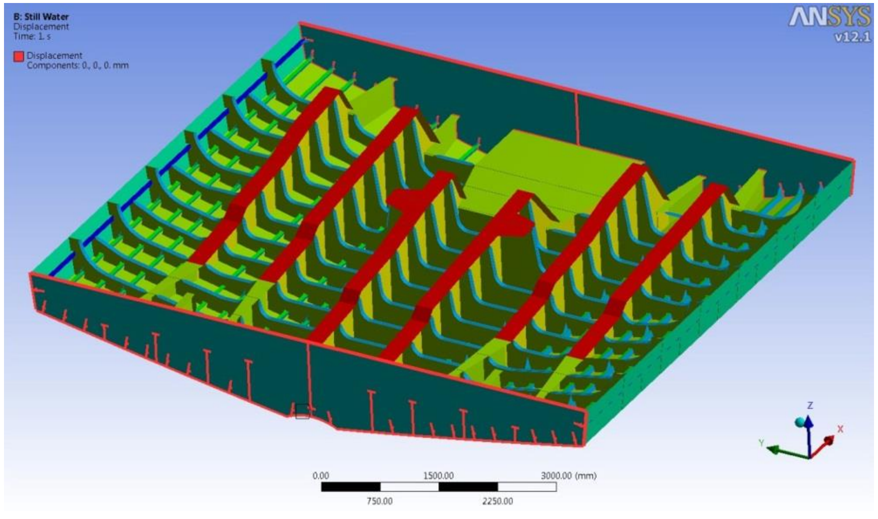
Global mesh is created with following features:

- Mesh element type: SHELL181
- Mesh method: Quadrilateral dominant
- Element size: 8,6 mm – 43 mm
- Number of elements: 384878



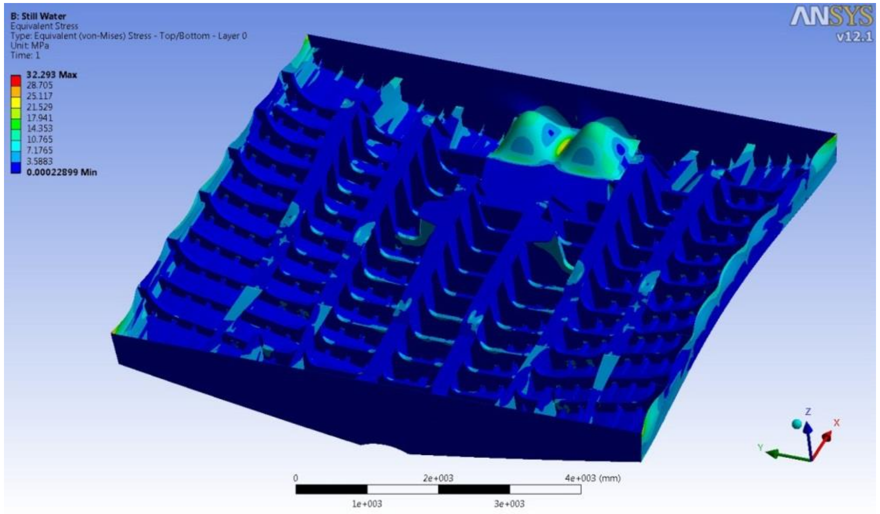
Boundary Conditions

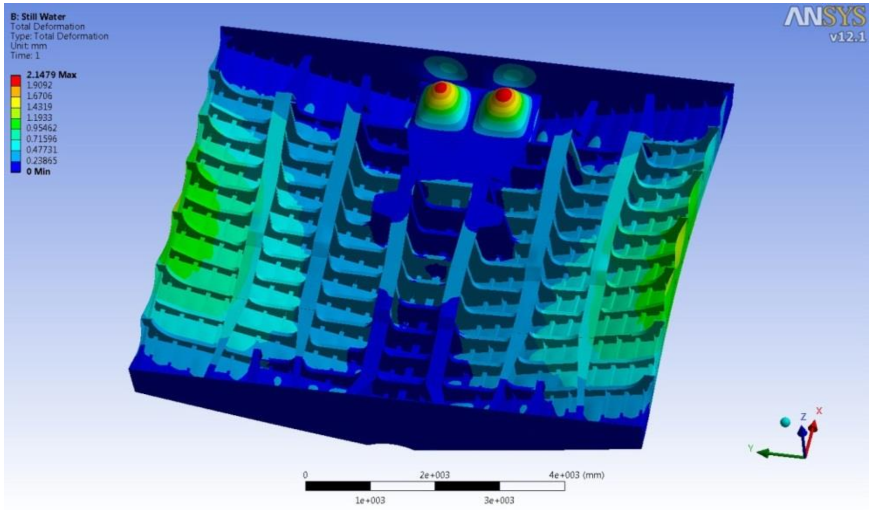
All longitudinal edges on bulkheads are fixed on X, Y and Z directions, rotations however are permitted



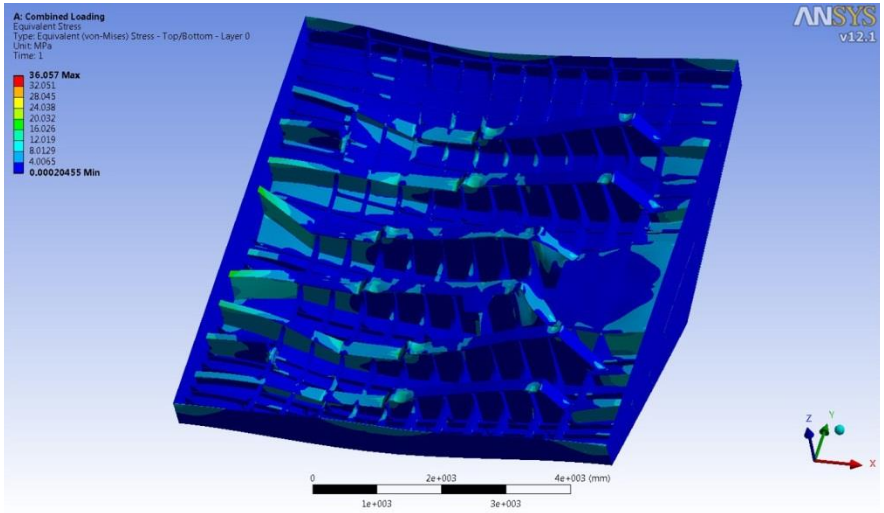
Structural Strength Analysis by FEM

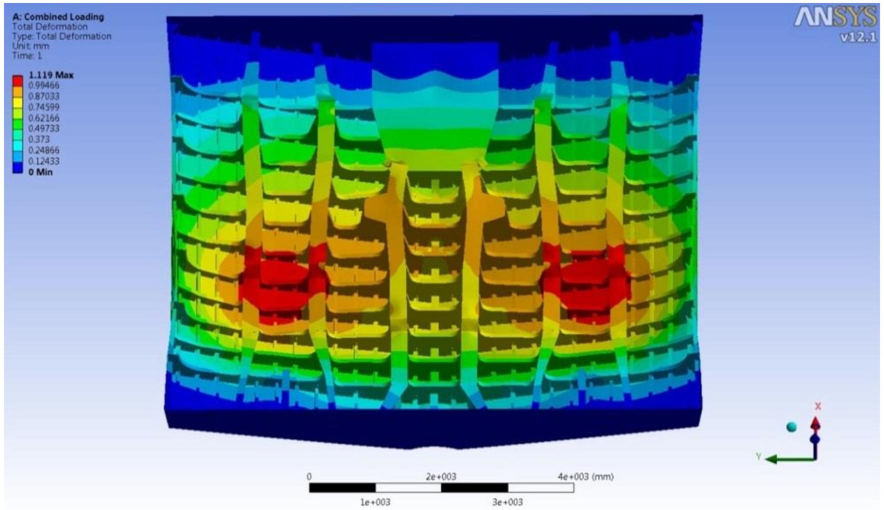
Loading Condition in Still Water





Combined Loading Condition

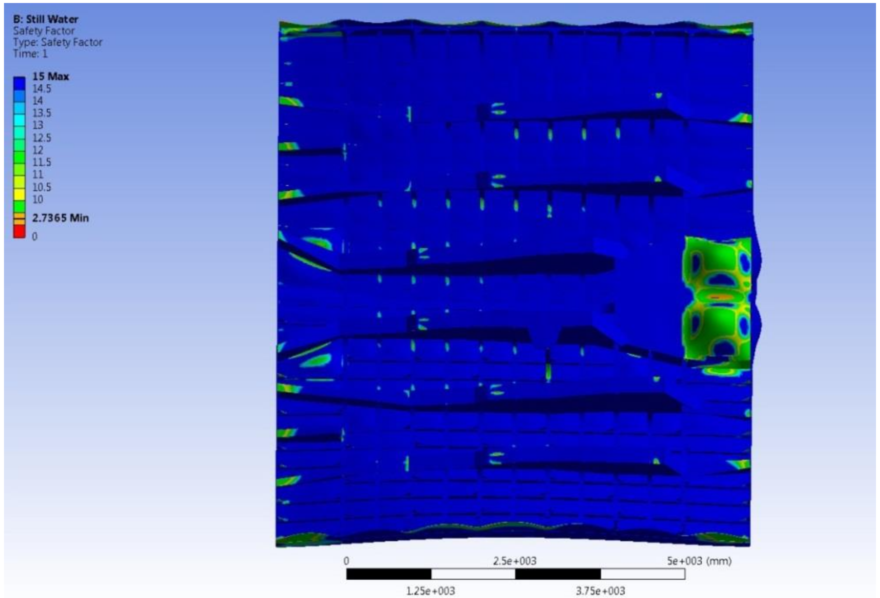


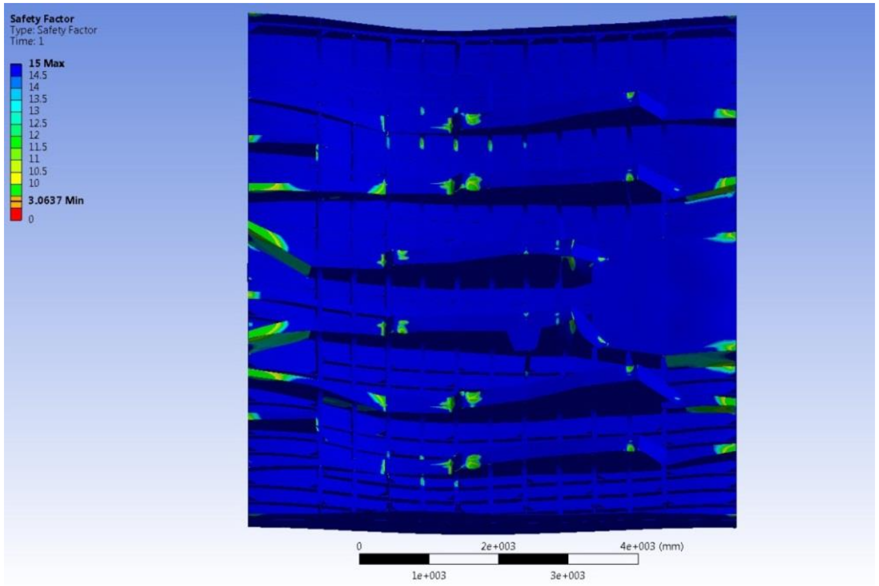


Structural Strength Analysis by FEM

Checking Criteria

Still water loading condition	Highest stress [N/mm²]	Check [N/mm²]	Safety factor
Normal stress	17,30	69,77	4,03
Shear stress	8,56	41,86	4,89
Von-Mises equivalent bending stress	32,29	88,37	2,74
Combined loading condition	**Highest stress [N/mm²]**	**Check [N/mm²]**	**Safety factor**
Normal stress	24,94	87,21	3,49
Shear stress	8,15	52,33	6,42
Von-Mises equivalent bending stress	36,06	110,47	3,06





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Conclusions

The hull resistance prediction is essentially momentous for developing hull lines at preliminary design stages. For this purpose Savitsky Method is applied primarily, then more accurate results are obtained by CFD applications and these results are compared with previous method. Meanwhile spray flow over the hull is observed even the resistance values are in a good range. To prevent this, using of “spray rails” under the chine is proposed.

Although the vessel is a high speed craft, it will work as a supply unit for offshore platforms to transport technical personnel, cargo on deck and liquid cargo. On the other hand, the structure design is developed according to High Speed Craft rules by directives of Classification Society.

In compliance with experiences of the shipyard, total structure weight, 50 tonnes, satisfied the predictions.

By considering experimental studies and recommendations of suppliers, partial tunnels are created under the hull and eventually shaft line angle is reduced 3° approximately.

Direct finite element analysis of engine foundations which have significant influence on structure is performed. Eventually high safety margins are gained for the scantling which is generated on the strength of previous projects of the shipyard.


Thank you for your attention!