Structural Analysis Report

Date: 09.05.2021

Boat: Tanaruz 7.5m – (Longitudinal Structure)

1- Input Data

This document includes the structural calculations of the Tanaruz-S 7.5 meters boat. To perform the calculations "Strength Model Tanaruz S 7.5m – Longitudinal Structure.3dm" file is used. In the calculations, three different cases are simulated as sea conditions, and analyses were performed following the same procedure for all calculations. Tanaruz S boat is 7.5 meters in length and wave function is created based on the length of the boat.

The sinusoidal wave assumption is used in the analysis as shown in Figure 1. The sinusoidal wave assumption allows creating wave crest and wave through conditions for a hull.

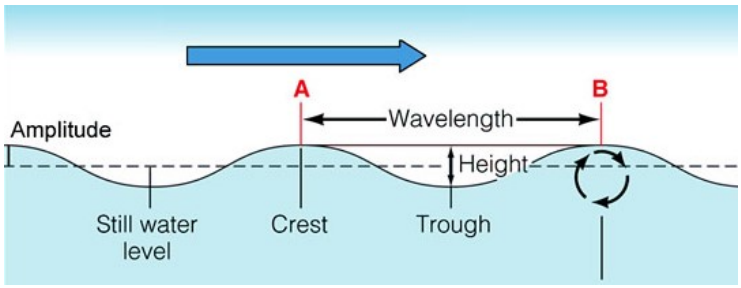


Figure 1 - Wave Assumption

For Tanaruz S which has 7.5-meter length, sinusoidal wave function creates 375mm wave height and 7500mm wavelength in order to provide the crest and trough conditions. In the following chapters, wave conditions are detailed.

FGF PP Glassfiber (30%) is used as material for the Tanaruz S structural analysis.

Material properties		
Description	**Testmethod**	**Typical value**
Specific gravity	ISO 1183	1,12 g/cc
MFI 230°C/2,16 kg	ISO 1133	13 g/10min
Tensile Strength at Yield	ISO 527	90 MPa
Elongation-Strain at Break	ISO 527	5%
Tensile modulus	ISO 527	7500 Mpa
Impact strength - Charpy method notched 23°C	ISO 179	10 kJ/m²
Impact strength – Izod method notched 23°C	ISO 180	10 kJ/m²
Flexural modulus	ISO 178	5900 MPa
Vicat softening temperature A	ISO 306	166°C
Vicat softening temperature B	ISO 306	140°C
Heat deflection temperature A 1,8 MPa	ISO 75	150°C
Heat deflection temperature B 0,45 MPa	ISO 75	161°C

Figure 2 - FGF PP Glassfiber Mechanical Properties

2- Model

The file “Strength Model Tanaruz S 7.5m – Longitudinal Structure.3dm” which is used to perform the structural analysis includes the 3D model of the boat. Figure 3 shows the 3D view of the Tanaruz-S file used for analysis.

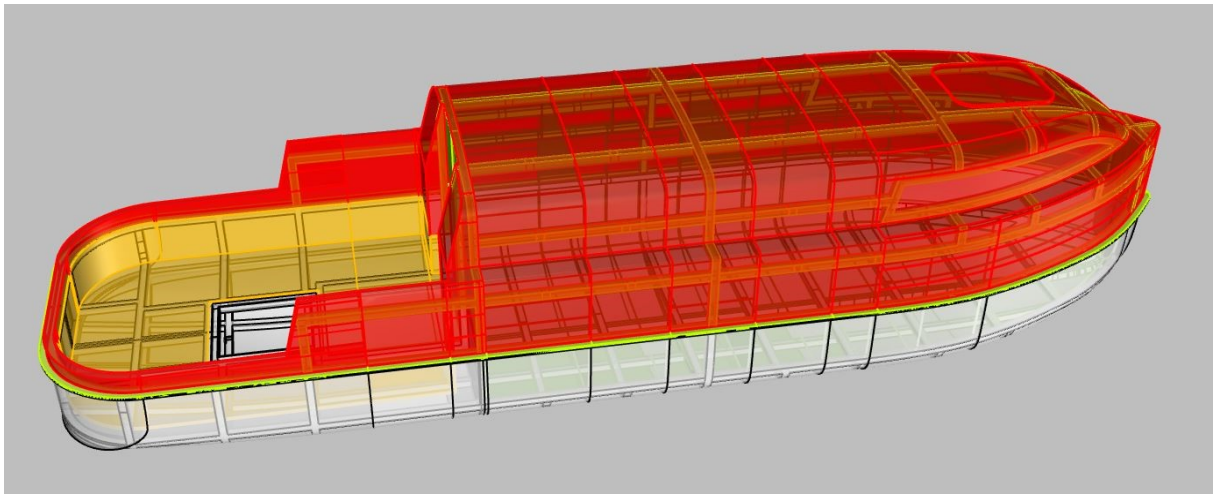


Figure 3 - 3D View of Tanaruz-S 7.5m

“Strength Model Tanaruz S 7.5m.3dm” file includes 7 poly-surfaces and the mentioned poly-surfaces are shown in Figure 4. All of the poly-surfaces are checked and noted that all of them are valid and acceptable to use in structural calculations. Tanaruz 7.5 meters model is created by extending the 4.5 meter model and transverse beams are removed from the geometry on the forward side of the bulkhead. Only one tranverse is kept on the hull and this tranverse works as a ring frame because one of the tranverse beam on the super-structure is also kept which is in the same section with the hull bottom transverse. Therefore, by connecting these transverse beams (hull transverse and super-structure beam), a whole ring frame is created.

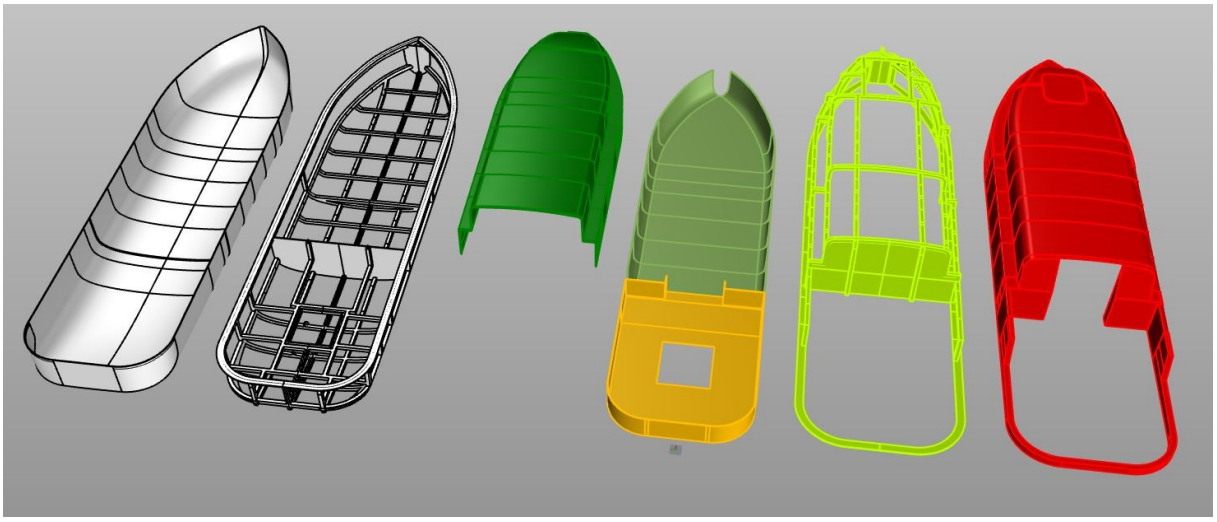


Figure 4 - Calculation Geometries

3- Calculation Method and Cases

In order to calculate the total weight value and to establish the loads on the boat, the "WeightDistribution Tanaruz S.xlsx" file is used. The file contains the weights of the components on the boat and the shared file shows the locations of the components additionally. Figure 5 shows a sample part of the weight distribution file. Tanaruz 4.5 m model was extended to 7.5 meters by keeping the thickness and longitudinal structure as mentioned. Additional boat weight is added into the total weight of Tanaruz4.5meters including all the extended surfaces which are hull, hull structure, deck and super structure of the boat.

							POSITION			comment
Basic equipment			optional equipment	pcs.	weight (kg)	Full weight	X (m)	Y (m)	Z (m)	
	2	BILGE PUMP		2	2	4	2	0	0.35	
	3	16A/230V RATIO SHOREPOWER CONNECTOR		1	0.5	0.5	-0.1	0.5	0.7	
	4	charging cable, 10 m		1	4	4	0.5	0.6	0.35	(in the str) PS
	6	Fusion MS-DAB100A DAB+ module, incl. antenne		1	2	2	2	0	1.8	
	7	Marine RADIO		1	0.3	0.3	2	0.6	1.4	
	8	WI-Fi Antenne (client choice)		0		0				
	9	Bluetoth Antenne (client choice)		0		0				
	10	GPS Antenne (client choice)		0		0				
	11	Anchoring rope 10mm		1	3	3	0.5	-0.6	0.35	(in the str) SB
	12	wheel (manual propeller)		0		0				
	13	ANCHOR 10kg		0		10	4	0	1.05	
	14	Anchor holding		1	1	1	4.5	0	1.25	
Exterior										
	15	Aluminium Side window		2	15	30	3	0	1.4	
	16	Companionway door		1	15	15	2	0	1	
	17	Escape top HATCH 50X60 CM		1	2	2	3.1	0	1.6	
	18	holding systems for access to fwd tanks		2	0.5	1	3.5	0	0.55	
	19	hatches (acess system) to the battery compartment		1	3	3	1.5	0	0.4	
	20	CHROMIUM HANDRAILS 32X1400mm		4	5	20	2	0	1.2	
	21	cleat (kikker) 30MM 55 X 200 X 70MM		4	0.7	2.8	3	0	1.2	
	22	TELESKOPIC ledder 4 steps SLF4A		0	3	0				
	23	*BLOWER (ventilation in & out)*		2	0.6	1.2	2	0	1	
	24	Audo signal system / whistles				0				
	25	Solar pannels		1	4	4	3.5	-0.6	1.2	
	26	solar panel cable, 5mtr		1	1.5	1.5	3	-0.6	1.2	
	27	solar panel control (see two options)		1	1	1	2	0.6	1.4	
Lamps										
	28	10-30V 7W Interior Lamp		4	0.2	0.8	3	0	1.5	
	29	External lamp spot light		2	0.2	0.4	3	0	1.5	
	30	12V - 112,5 red lamp external + green + white + 360 white		4	0.35	1.4	2.2	0	1.9	
Switches										
	31	(VICTRON ENERGY BLUE SMART IP67) CHARGER 12/25		1	1	1	2	-0.6	0.2	
	32	Schakelpaneel		1	0.4	0.4	2	0.6	0.8	

Figure 5 - Weight Distribution File

The total weight is 2070 kgs and this is equal to 2019.5 m_3 displacement volume for the defined load condition.

As shown in Figure 6, all of the weights are distributed on the boat in the 3D modeling software first. This method provides an opportunity to observe the weight distribution in the 3D model and to determine the loading surfaces of the weights on the boat.

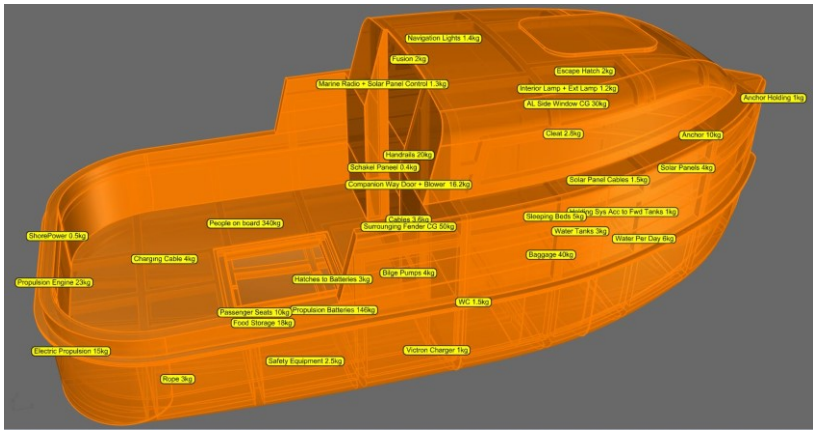


Figure 6 - 3D View of Weight Distribution

After calculating the total weight on the boat, displacement volume and water-plane are determined. Figure 7 shows the draught and displacement of Tanaruz S at the defined loading condition which equals to 2070kgs.

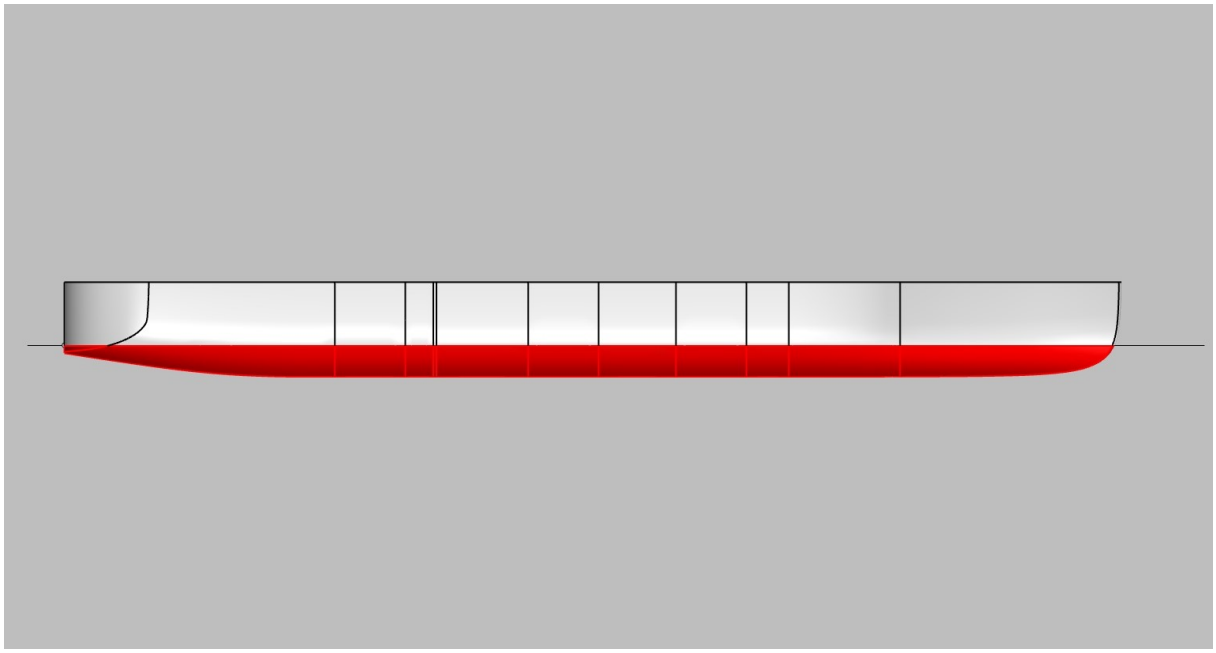


Figure 7 - Displacement of the Hull 2070kgs

To create the wave function and to calculate the hydrostatic pressure load on the hull, the Tanaruz S7.5 hull is split into 100 virtual sections which have 75mm spacing. Figure 8 shows the section spacing view defined on the hull.

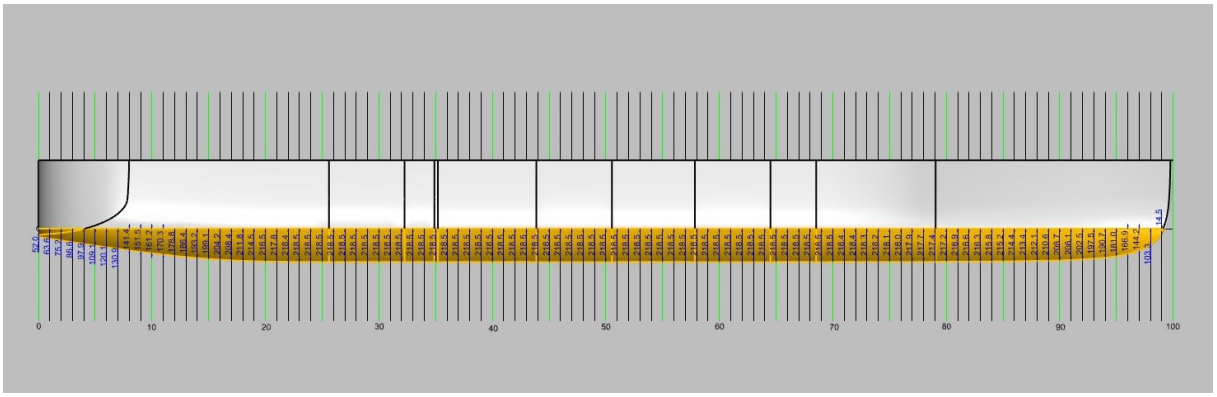


Figure 8 - Wave Function and Hydrostatic Pressure Spacing

Figure 9 shows the wave function as a curve for wave crest condition. The figure provides a visulation of the wave function which was used for the structural analysis.

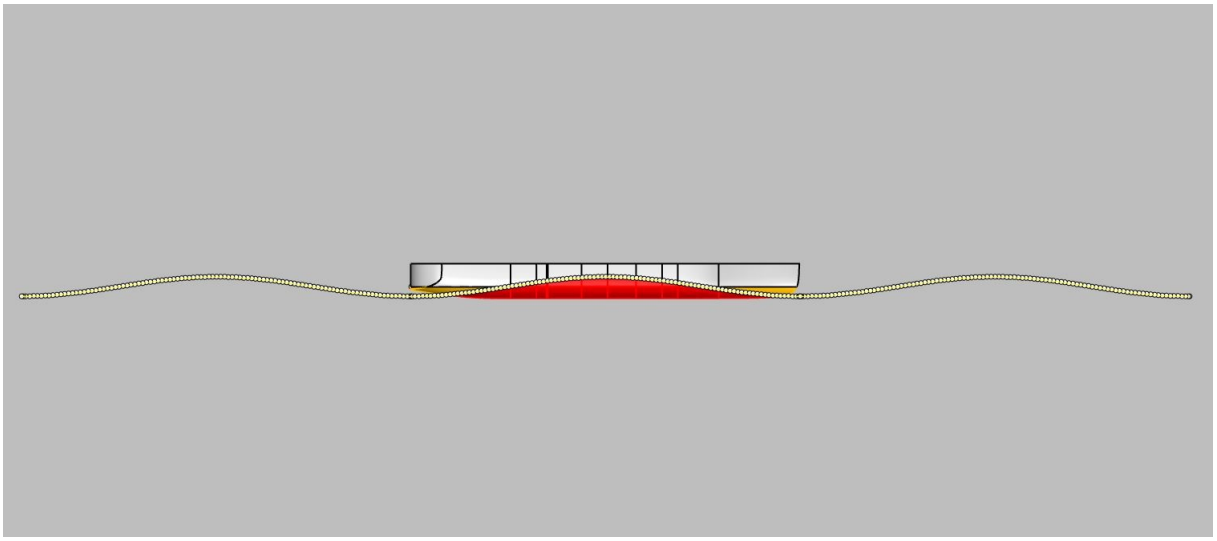


Figure 9 - Wave Function and Hydrostatic Pressure Spacing

Keel and still water level coordinates are determined and with the help of these values, still water hydrostatic pressures are calculated. By using the sinusoidal wave function, wave crest and wave trough distribution are determined for every 100 sections. Still water, wave trough, and wave crest pressure values and wave coordinates are shown in Figure 10 partially.

Hull Keel			Still Water				Wave Crest					Wave Trough					Still Water Load				Wave Crest Load			Wave Trough Load		
X	Y	Keel	s	x	keel-Z	Pressure	s	x	wave-Z	keel-Z	difference	Pressure	s		wave-Z	keel-Z	difference	Pressure									
0	0	-95.14	0	0	-95.1400	956.6565	0	0	-112.5000	-95.1400	-17.3600	0.0000	0	0	112.5000	-95.1400	207.6400	2087.8721	50	0	0	0	0	0	-112.5000	0	0	0	112.5000	0
50	0	-102.88	1	50	-102.8800	1034.4841	1	50	-112.2260	-102.8800	-9.3460	0.0000	1	50	112.2260	-102.8800	215.1060	2162.9442	100	0	0	0	100	0	-111.4052	0	100	0	111.4052	0
100	0	-110.59	2	100	-110.5900	1112.0101	2	100	-111.4052	-110.5900	-0.8152	0.0000	2	100	111.4052	-110.5900	221.9952	2232.2168	150	0	0	0	150	0	-110.0416	0	150	0	110.0416	0
150	0	-118.26	3	150	-118.2600	1189.1339	3	150	-110.0416	-118.2600	8.2184	82.6380	3	150	110.0416	-118.2600	228.3016	2295.6297	200	0	0	0	200	0	-108.1419	0	200	0	108.1419	0
200	0	-125.89	4	200	-125.8900	1265.8554	4	200	-108.1419	-125.8900	17.7481	178.4612	4	200	108.1419	-125.8900	234.0319	2353.2497	250	0	0	0	250	0	-105.7154	0	250	0	105.7154	0
250	0	-133.47	5	250	-133.4700	1342.0742	5	250	-105.7154	-133.4700	27.7546	279.0792	5	250	105.7154	-133.4700	239.1854	2405.0692	300	0	0	0	300	0	-102.7739	0	300	0	102.7739	0
300	0	-141.00	6	300	-141.0000	1417.7903	6	300	-102.7739	-141.0000	38.2261	384.3734	6	300	102.7739	-141.0000	243.7739	2451.2071	350	0	0	0	350	0	-99.3316	0	350	0	99.3316	0
350	0	-148.47	7	350	-148.4700	1492.9030	7	350	-99.3316	-148.4700	49.1384	494.0989	7	350	99.3316	-148.4700	247.8016	2491.7071	400	0	0	0	400	0	-95.4054	0	400	0	95.4054	0
400	0	-155.87	8	400	-155.8700	1567.3118	8	400	-95.4054	-155.8700	60.4646	607.9866	8	400	95.4054	-155.8700	251.2754	2526.6371	450	0	0	0	450	0	-91.0144	0	450	0	91.0144	0
450	0	-163.18	9	450	-163.1800	1640.8157	9	450	-91.0144	-163.1800	72.1656	725.6430	9	450	91.0144	-163.1800	254.1944	2555.9884	500	0	0	0	500	0	-86.1800	0	500	0	86.1800	0
500	0	-170.39	10	500	-170.3900	1713.3140	10	500	-86.1800	-170.3900	84.2100	846.7526	10	500	86.1800	-170.3900	256.5700	2579.8755	550	0	0	0	550	0	-80.9257	0	550	0	80.9257	0
550	0	-177.49	11	550	-177.4900	1784.7063	11	550	-80.9257	-177.4900	96.5643	970.9779	11	550	80.9257	-177.4900	258.4157	2598.4347	600	0	0	0	600	0	-75.2772	0	600	0	75.2772	0
600	0	-184.46	12	600	-184.4600	1854.7914	12	600	-75.2772	-184.4600	109.1828	1097.8604	12	600	75.2772	-184.4600	259.7372	2611.7224	650	0	0	0	650	0	-69.2619	0	650	0	69.2619	0
650	0	-191.26	13	650	-191.2600	1923.1671	13	650	-69.2619	-191.2600	121.9981	1226.7212	13	650	69.2619	-191.2600	260.5219	2619.6130	700	0	0	0	700	0	-62.9092	0	700	0	62.9092	0
700	0	-197.89	14	700	-197.8900	1989.8334	14	700	-62.9092	-197.8900	134.9808	1357.2657	14	700	62.9092	-197.8900	260.7992	2622.4012	750	0	0	0	750	0	-56.2500	0	750	0	56.2500	0
750	0	-204.30	15	750	-204.3000	2054.2876	15	750	-56.2500	-204.3000	148.0500	1488.6798	15	750	56.2500	-204.3000	260.5500	2619.8954	800	0	0	0	800	0	-49.3168	0	800	0	49.3168	0
800	0	-210.45	16	800	-210.4500	2116.1274	16	800	-49.3168	-210.4500	161.1332	1620.2351	16	800	49.3168	-210.4500	259.7668	2612.0197	850	0	0	0	850	0	-42.1432	0	850	0	42.1432	0
850	0	-216.32	17	850	-216.3200	2175.1517	17	850	-42.1432	-216.3200	174.1768	1751.3908	17	850	42.1432	-216.3200	258.4632	2598.9125	900	0	0	0	900	0	-34.7644	0	900	0	34.7644	0
900	0	-221.87	18	900	-221.8700	2230.9583	18	900	-34.7644	-221.8700	187.1056	1881.3935	18	900	34.7644	-221.8700	256.6344	2580.5232	950	0	0	0	950	0	-27.2162	0	950	0	27.2162	0
950	0	-227.06	19	950	-227.0600	2283.1451	19	950	-27.2162	-227.0600	199.8438	2009.4792	19	950	27.2162	-227.0600	254.2762	2556.8109	1000	0	0	0	1000	0	-19.5354	0	1000	0	19.5354	0
1000	0	-231.88	20	1000	-231.8800	2331.6114	20	1000	-19.5354	-231.8800	212.3446	2135.1778	20	1000	19.5354	-231.8800	251.4154	2528.0449	1050	0	0	0	1050	0	-11.7595	0	1050	0	11.7595	0
1050	0	-236.31	21	1050	-236.3100	2376.1561	21	1050	-11.7595	-236.3100	224.5505	2257.9119	21	1050	11.7595	-236.3100	248.0695	2494.4004	1100	0	0	0	1100	0	-3.9262	0	1100	0	3.9262	0
1100	0	-240.36	22	1100	-240.3600	2416.8799	22	1100	-3.9262	-240.3600	236.4338	2377.4010	22	1100	3.9262	-240.3600	244.2862	2456.3587	1150	0	0	0	1150	0	3.9262	0	1150	0	-3.9262	0
1150	0	-244.02	23	1150	-244.0200	2453.6821	23	1150	3.9262	-244.0200	247.9462	2493.1610	23	1150	-3.9262	-244.0200	240.0938	2414.2032	1200	0	0	0	1200	0	11.7595	0	1200	0	-11.7595	0
1200	0	-247.31	24	1200	-247.3100	2486.7639	24	1200	11.7595	-247.3100	259.0695	2605.0081	24	1200	-11.7595	-247.3100	235.5505	2368.5196	1250	0	0	0	1250	0	19.5354	0	1250	0	-19.5354	0
1250	0	-250.22	25	1250	-250.2200	2516.0247	25	1250	19.5354	-250.2200	269.7554	2712.4582	25	1250	-19.5354	-250.2200	230.6846	2319.5911	1300	0	0	0	1300	0	27.2162	0	1300	0	-27.2162	0
1300	0	-252.76	26	1300	-252.7600	2541.5650	26	1300	27.2162	-252.7600	279.9762	2815.2308	26	1300	-27.2162	-252.7600	225.5438	2267.8992	1350	0	0	0	1350	0	34.7644	0	1350	0	-34.7644	0
1350	0	-254.93	27	1350	-254.9300	2563.3849	27	1350	34.7644	-254.9300	289.6944	2912.9497	27	1350	-34.7644	-254.9300	220.1656	2213.8200	1400	0	0	0	1400	0	42.1432	0	1400	0	-42.1432	0
1400	0	-256.77	28	1400	-256.7700	2581.8865	28	1400	42.1432	-256.7700	298.9132	3005.6474	28	1400	-42.1432	-256.7700	214.6268	2158.1257	1450	0	0	0	1450	0	49.3168	0	1450	0	-49.3168	0
1450	0	-258.30	29	1450	-258.3000	2597.2711	29	1450	49.3168	-258.3000	307.6168	3093.1634	29	1450	-49.3168	-258.3000	208.9832	2101.3788	1500	0	0	0	1500	0	56.2500	0	1500	0	-56.2500	0
1500	0	-259.58	30	1500	-259.5800	2610.1418	30	1500	56.2500	-259.5800	315.8300	3175.7496	30	1500	-56.2500	-259.5800	203.3300	2044.5340	1550	0	0	0	1550	0	62.9092	0	1550	0	-62.9092	0
1550	0	-260.57	31	1550	-260.5700	2620.0965	31	1550	62.9092	-260.5700	323.4792	3252.6642	31	1550	-62.9092	-260.5700	197.6608	1987.5287	1600	0	0	0	1600	0	69.2619	0	1600	0	-69.2619	0
1600	0	-261.23	32	1600	-261.2300	2626.7330	32	1600	69.2619	-261.2300	330.4919	3323.1788	32	1600	-69.2619	-261.2300	191.9681	1930.2871	1650	0	0	0	1650	0	75.2772	0	1650	0	-75.2772	0
1650	0	-261.52	33	1650	-261.5200	2629.6490	33	1650	75.2772	-261.5200	336.7972	3386.5800	33	1650	-75.2772	-261.5200	186.2428	1872.7180	1700	0	0	0	1700	0	80.9257	0	1700	0	-80.9257	0
1700	0	-261.57	34	1700	-261.5700	2630.1517	34	1700	80.9257	-261.5700	342.4957	3443.8802	34	1700	-80.9257	-261.5700	180.6443	1816.4233	1750	0	0	0	1750	0	86.1800	0	1750	0	-86.1800	0
1750	0	-261.57	35	1750	-261.5700	2630.1517	35	1750	86.1800	-261.5700	347.7500	3496.7132	35	1750	-86.1800	-261.5700	175.3900	1763.5903	1800	0	0	0	1800	0	91.0144	0	1800	0	-91.0144	0
1800	0	-261.57	36	1800	-261.5700	2630.1517	36	1800	91.0144	-261.5700	352.5844	3545.3244	36	1800	-91.0144	-261.5700	170.5556	1714.9791	1850	0	0	0	1850	0	95.4054	0	1850	0	-95.4054	0
1850	0	-261.57	37	1850	-261.5700	2630.1517	37	1850	95.4054	-261.5700	356.9754	3589.4770	37	1850	-95.4054	-261.5700	166.1646	1670.8265	1900	0	0	0	1900	0	99.3316	0	1900	0	-99.3316	0
1900	0	-261.57	38	1900	-261.5700	2630.1517	38	1900	99.3316	-261.5700	360.9016	3628.9559	38	1900	-99.3316	-261.5700	162.2384	1631.3476	1950	0	0	0	1950	0	102.7739	0	1950	0	-102.7739	0

Figure 6 - A Partial View of the Wave Fuctions and Loads

Mesh is created in the structural analysis software as shown in Figure 11 and Figure 12. Mesh file includes 7 poly-surfaces which are meshed according to the mesh quality criteria of the software. All of the poly-surfaces mesh as a separate solid but in the calculations, these poly-surfaces are calculated as structurally bonded.

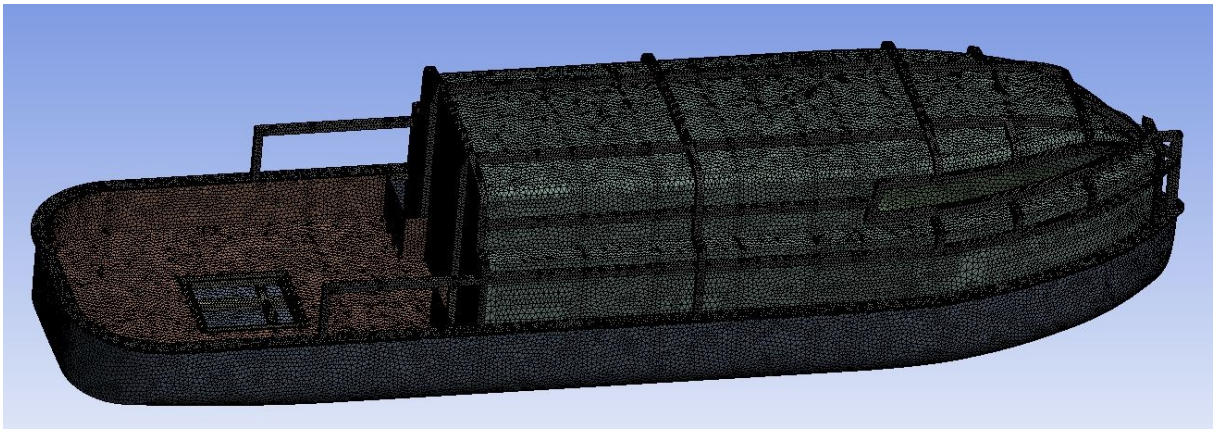


Figure 7 - Mesh View

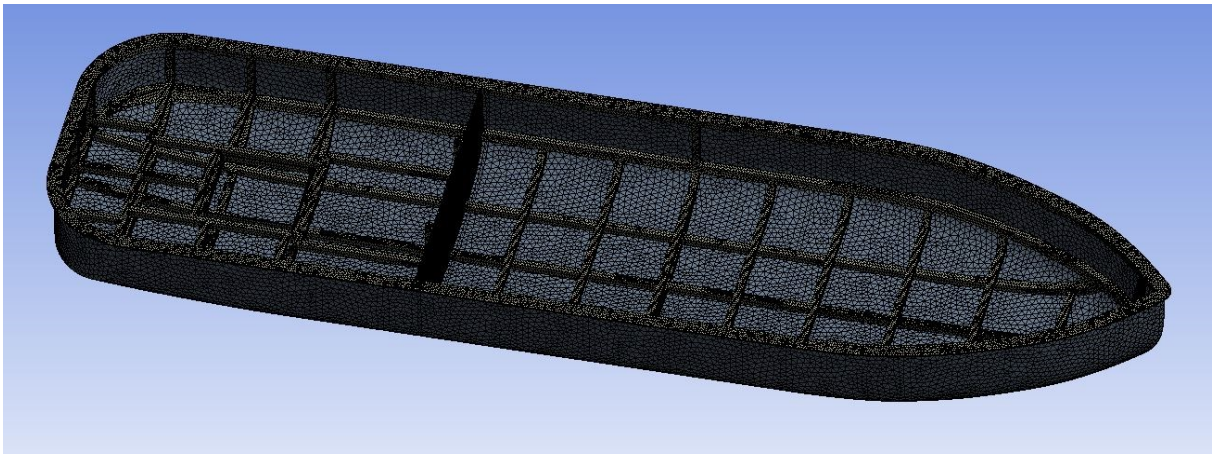
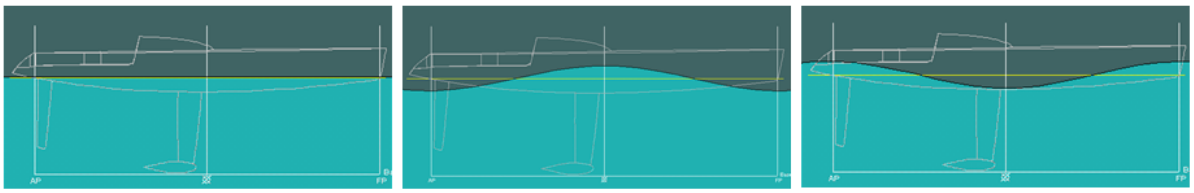


Figure 12 - Mesh View (Hull Structure)

Figures 13, 14, and 15 show the hydrostatic pressure distribution on the hull. There are three calculation cases mentioned in the “Input Data” section. Wave crest and wave trough are the worst cases for a conventional displacement hull. (There may be slamming cases for a boat in extreme weather conditions. The calculations which are detailed in this report do not include any dynamic and time-dependent cases such as slamming..etc.)



The figure above shows three cases as a sample and the following pictures show these cases as hydrostatic pressure distribution on Tanaruz S 7.5meters hull.

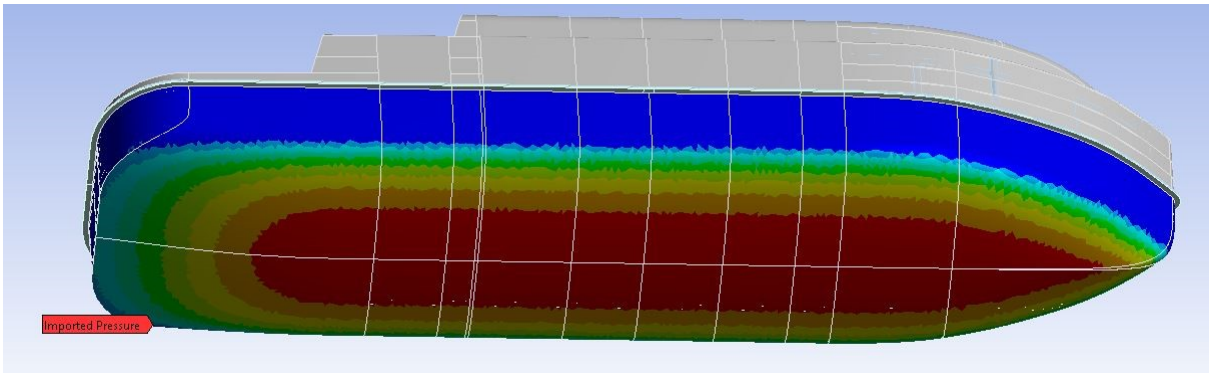


Figure 8 - Still Water Hydrostatic Pressure

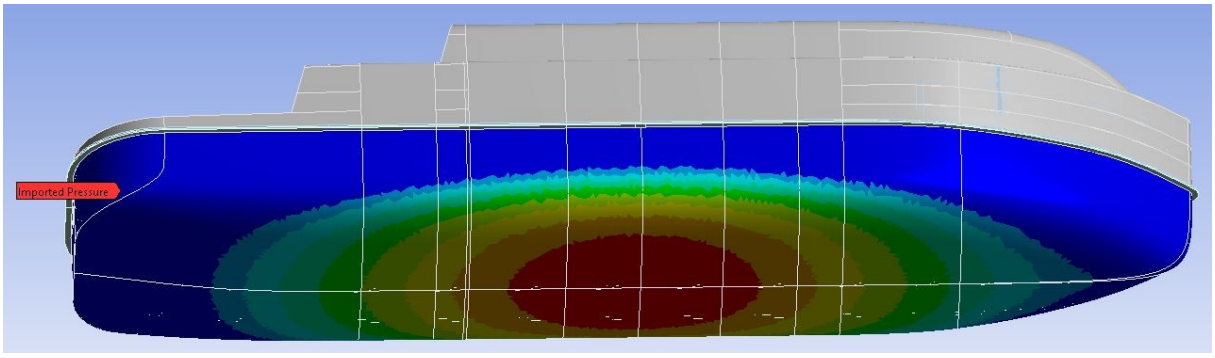


Figure 14 - Wave Crest Hydrostatic Pressure

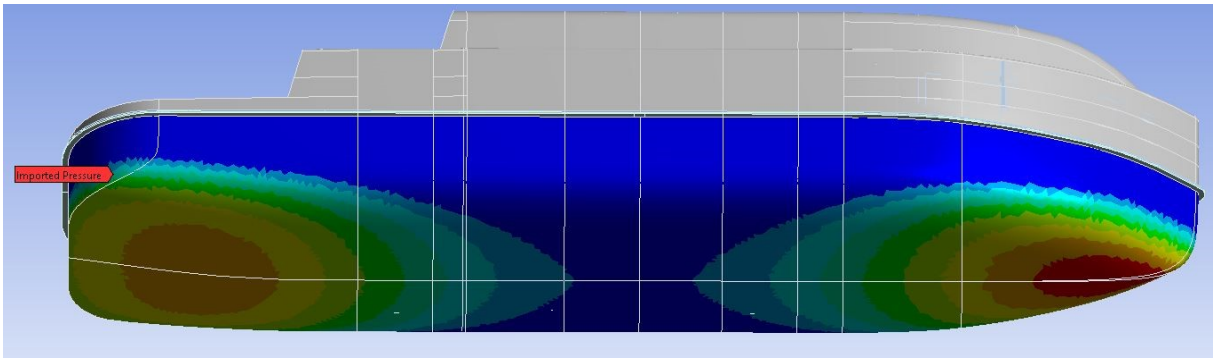


Figure 15 - Wave Trough Hydrostatic Pressure

Weights are defined as forces to the boat on the related surfaces which are shown in the previous section. Figure 16 shows the weight distribution applied to the structural model.

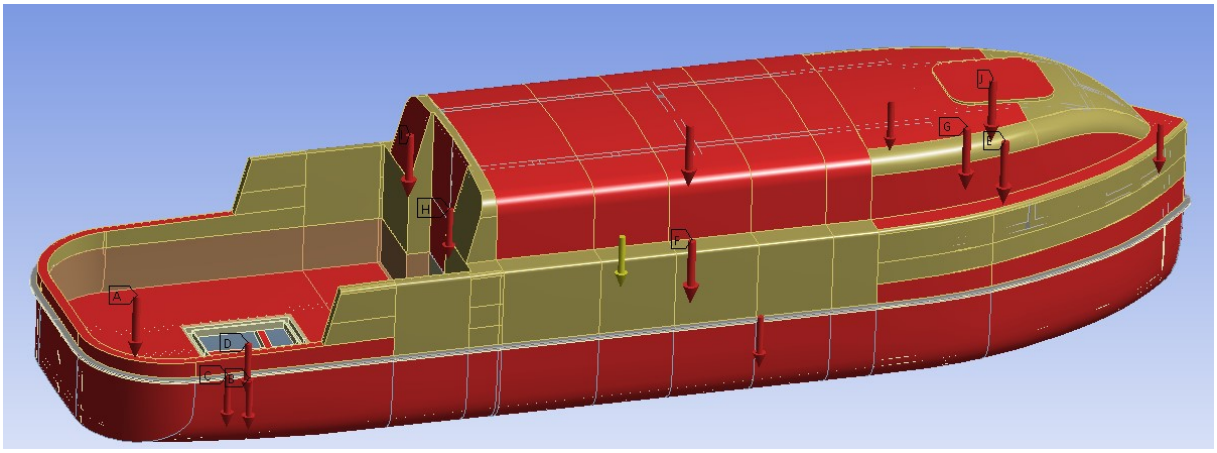


Figure 16 - Weigth Distribution on Structural Model

After defining all of the loads on the boat analyze can be solved. But there should be a fixed point to perform the analysis. In real conditions, ships have not a fixed point. Ships stay on the see free surface freely. In such cases “Inertia Relief” method is used. Water pressure acts as a support for the boat. The applied loads and hull weight which is simulated with gravity work against the hydrostatic pressure. The technique of inertia relief has been a well-known approach for the analysis of unsupported systems such as air vehicles in flight, sea vehicles on the sea, automotive in motion, or satellites in space.

4- Results

The following figures show the stress and deformation distribution on Tanaruz 7.5 meters for each condition defined. If all of the plots are inspected carefully, it can be stated that maximum stress value is observed at the wave trough condition which is 10.58Mpa. Maximum stress value on the hull structure is below the yield stress value of FGF PP Glass-fiber which is 90Mpa. But deflections on the boat structure is an important point that maximum deflection value should be below the allowable deflections.

Maximum deflection is observed on the hull bottom between the longitudinals. Maximum deflection is 7.32mm where the maximum allowable deflection is 8mm (2% of the panel span). It can be stated

that the created structure is in the safe zone stresswise but very close to deflection limit. In conclusion, Tanaruz 7.5 meters longitudinal based structure satisfies the stress and deflection requirements, and also structure is in a well-balanced point that as deflection values shows, boat structure in not a heavy design.

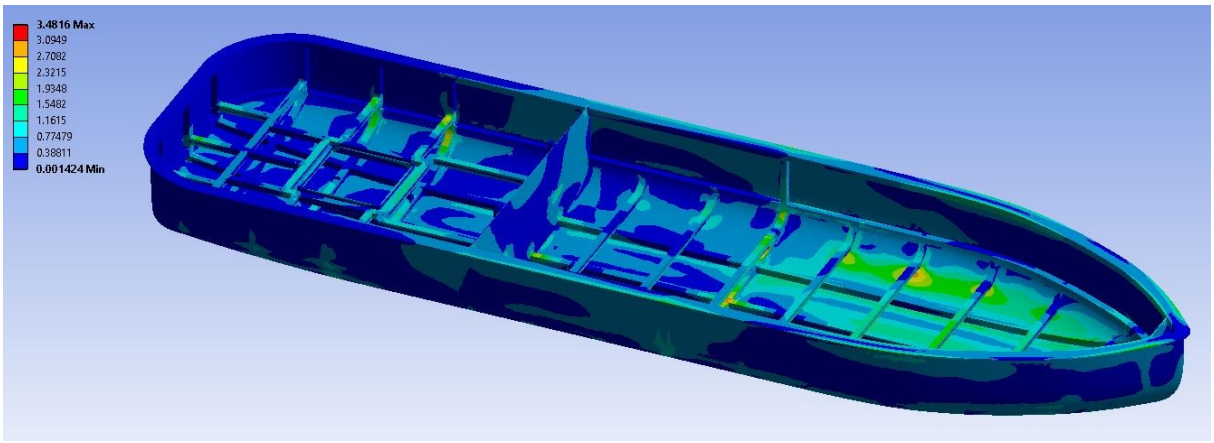


Figure 17 - Still Water Stress Plot Section View

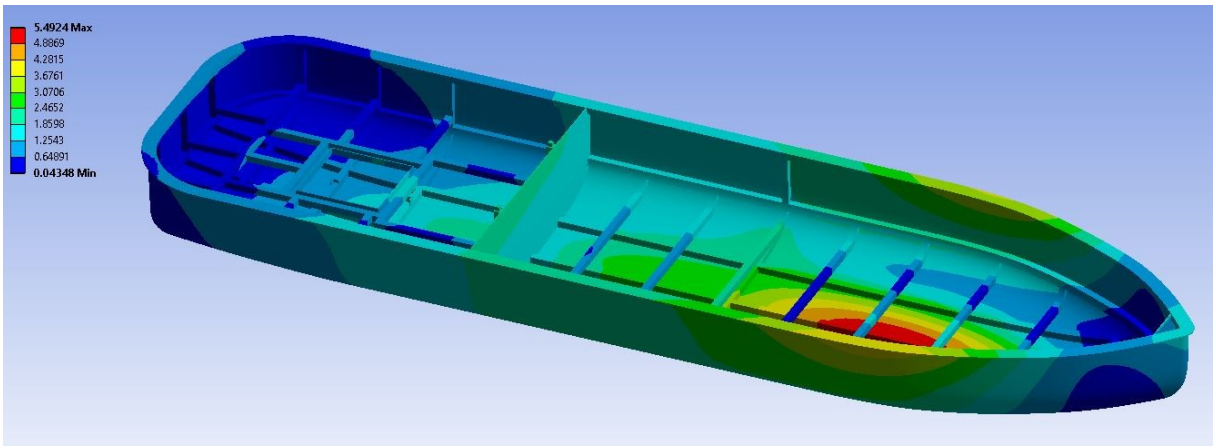


Figure 9 - Still Water Deformation Plot

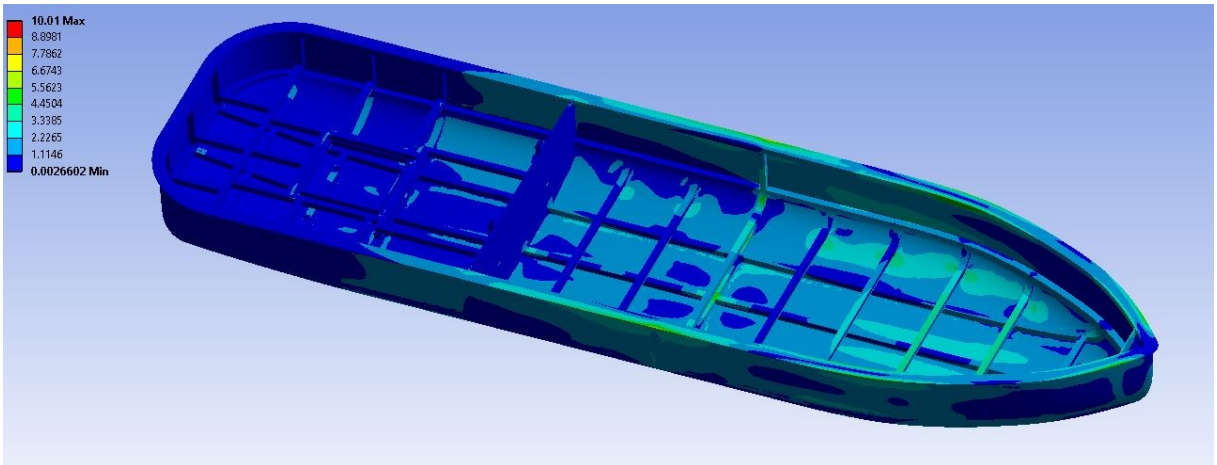


Figure 10 - Wave Crest Stress Plot Section View

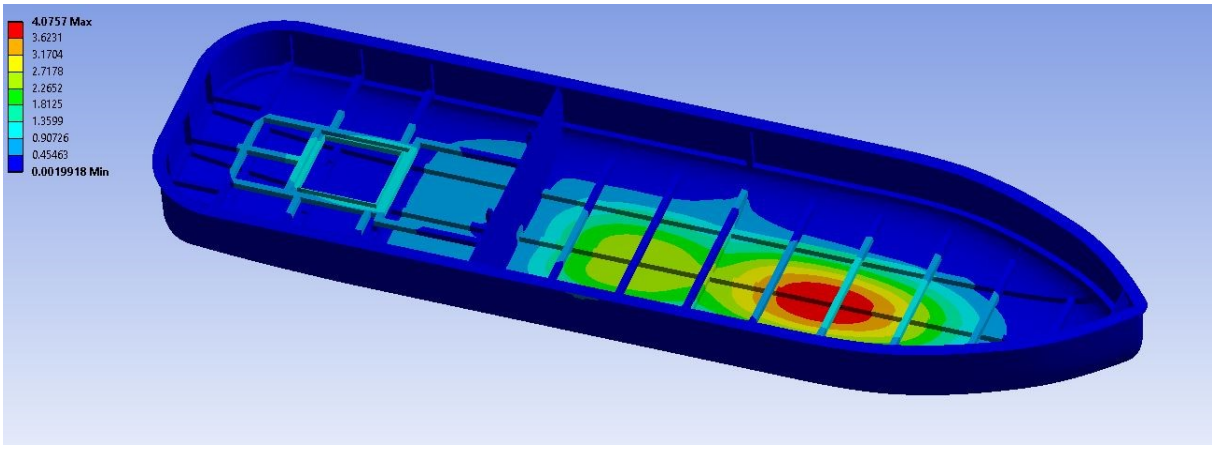


Figure 20 - Wave Crest Deformation Plot

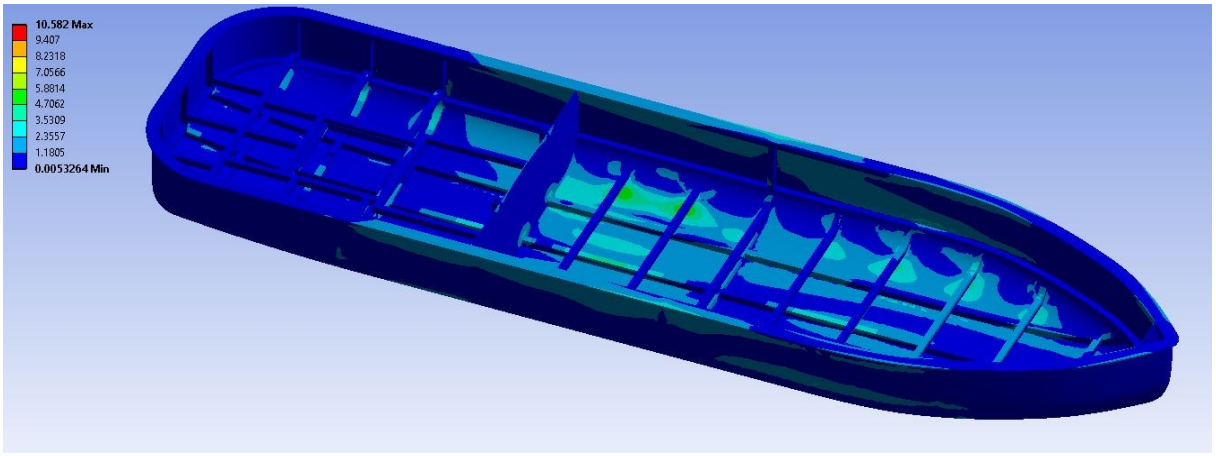


Figure 21 - Wave Trough Stress Plot Section View

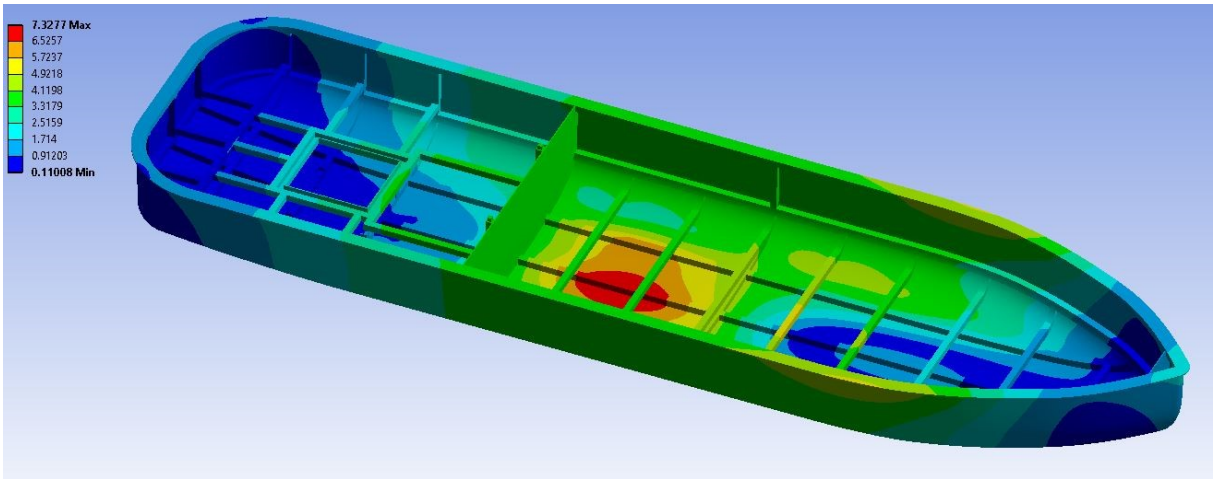


Figure 22 - Wave Trough Deformation Plot