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8th EMship cycle: October 2017 – February 2019

Master Thesis

Initial design of Rivera 780 Kabe motor yacht hull structure

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Contents:

1. INTRODUCTION

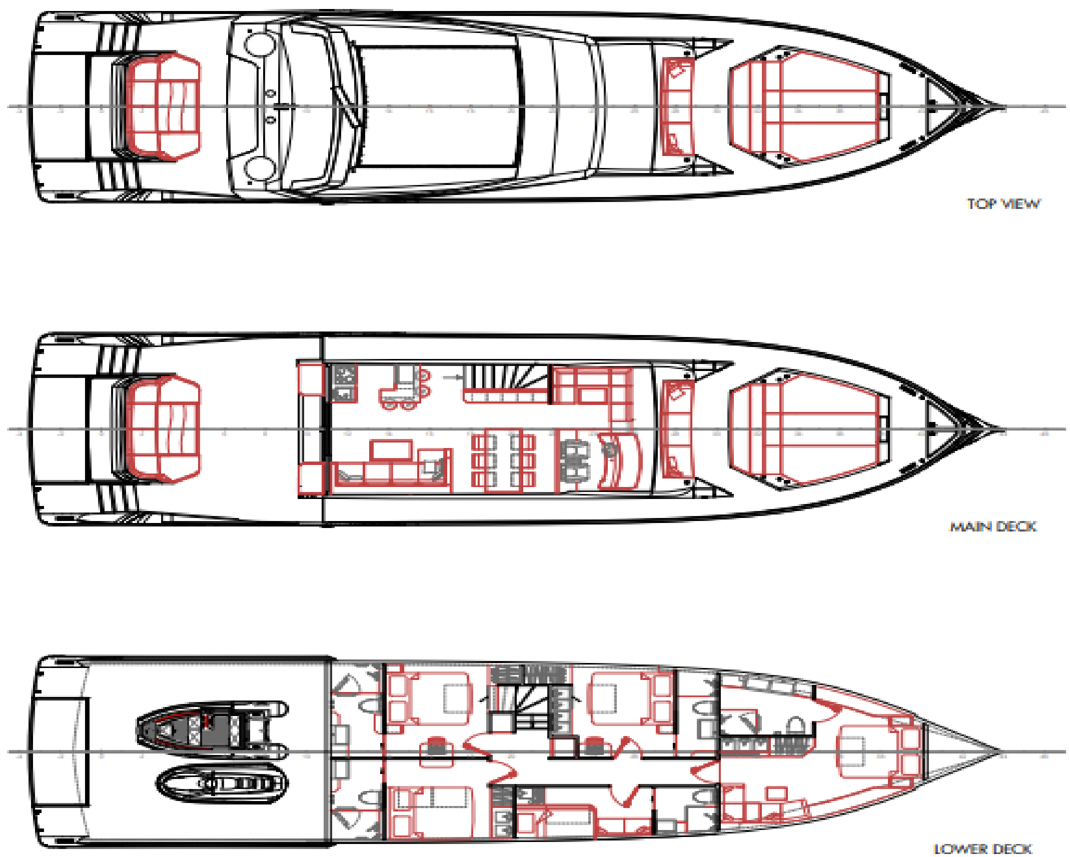
- The ‘yacht’ term was framed specifically for the sailing world, it has actually become an idea of going to the sea for pleasure and leisure purposes.

- These days, when talking about ‘yachts’, we can involve both terms of motor yacht and sailing yacht. We limit our discussion to motor yacht. In our case the motor yacht over which this work is done can be seen below

Some points

- The design drawing of Rivera kabe 780 motor yacht was provided by Nelton design , Szczecin on 9th of July 2018 with mutual agreement, to do scantling, weight estimation and FEM of engine foundation.
- This work have to be finished by time period of October 2019, but some complexities took time and the thesis part completed by December first week, 2018.
- The rules followed for entire Scantling is by DNVGL High speed Rules for Aluminum hull.
- The steps taken for completing this work is: Hull design on inputs provided by company in maxsurf modeler, Scantling calculations according to DNVGL High speed rule for aluminum hull in Excel, Structural three dimensional modelling in Maxsurf structure modeler and Finite Element Analysis by modelling aft portion of yacht structure in FEMAP software and later doing static analysis of engine foundation.

- The 2 D design provided by company as shown

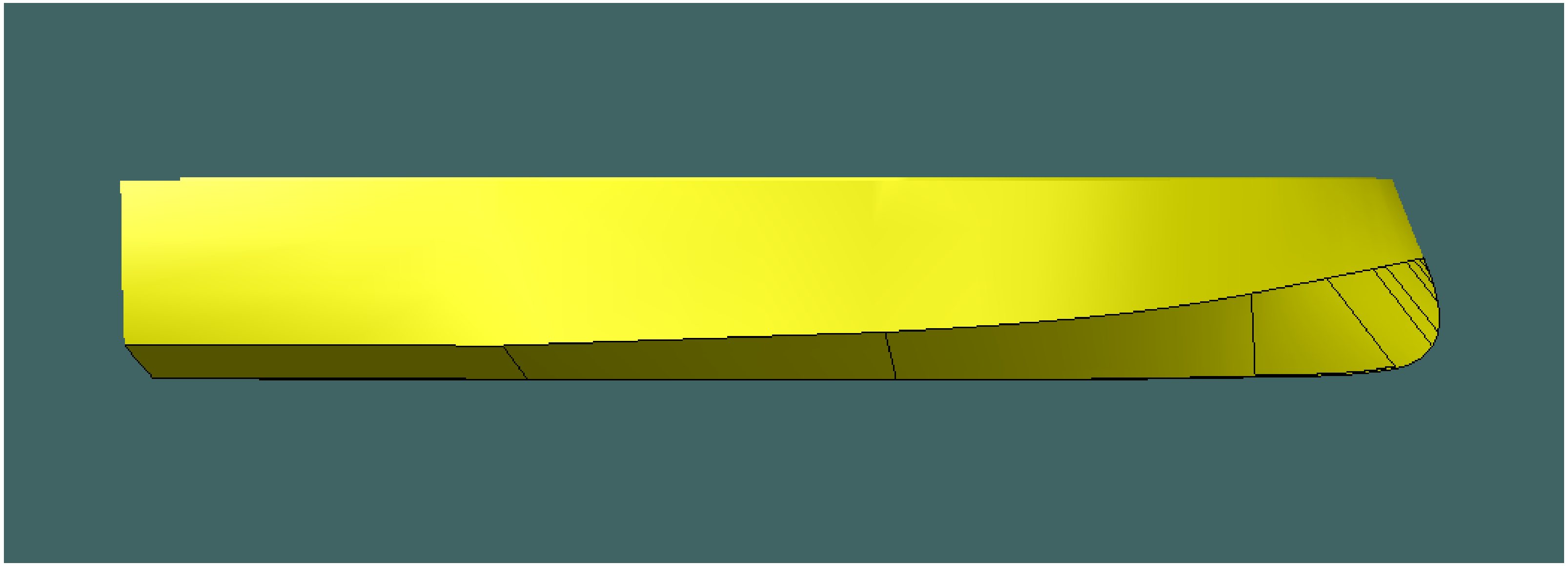


The Rivera Motor yacht Specialties

- It is a 23.8-meter concept yacht and is 6 meter wide
- Maximum speed of 30 knots
- 8 guest can spend time aboard accompanied by 2 crew members, Ejected part of the bow guarantees more space under deck, which make Rivera 780 more comfortable place and the engine used is Volvo Penta IPS D13 900

Hull shape

- The three dimensional hull is made in maxsurf structure modeler is shown
- Tools used were rhino and maxsurf structure modeler
- Issues faced: trimming problems and join surfaces, because of complex inverted u shape bow section.
- Modelling started in rhino module and finished in maxsurf modeler module



Hydrostatics of Rivera 780 Kabe hull

•The hydrostatics helps in knowing about displacement. Displacement depends over shape and size of hull and is linked with draft. The design draft is 1 meter. The waterline length is 22.3 meter. Lwl is length of boat at the point where it sits the water.it helps in determining how much water boat displaces.

•These two parameters play important role in scantling calculations of hull

Displacement	60.93	t
Volume (displaced)	59.44	m^3
Draft Amidships	1.00	m
Immersed depth	1.00	m
WL Length	22.30	m

Yachts Concepts

- Recreational craft or pleasure craft are used for pleasure or sport purposes. Recreational craft can be subdivided by three categories: propulsion system, construction material and speed.

Main Parts Yacht Hull is made of

•Stiffeners

•Girders

•Frames

•Shell plates

These are four basic elements responsible for overall all strength of hull structure. Plates subjected to lateral pressure. They cannot carry this load, thus transfer load to stiffeners. Stiffeners also need to be supported to prevent yielding and collapsing, thus girders are there to support stiffeners. Thus it makes strong overall Skelton to resist and face static and dynamic loads faced during voyage.

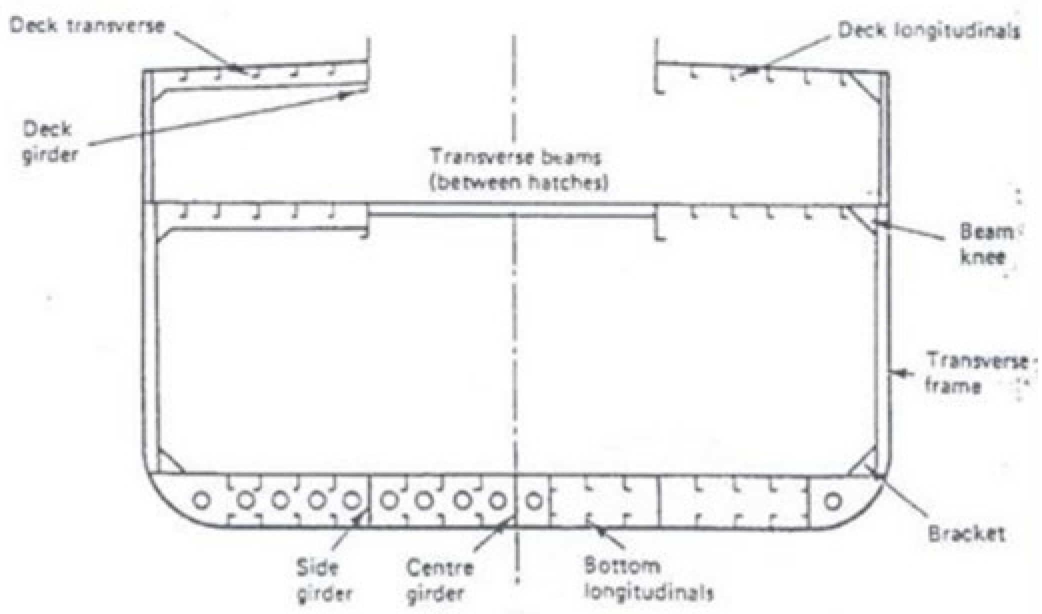
Framing System used

•Mixed framing system used

•Frame spacing is 0.5 meters with total 44 frames

•Stiffener spacing is 0.245 meter on both bottom and side part of hull

•Two side girders used on bottom plate



2. YACHT TYPOLOGIES

•Runabout: small boat with limited autonomy, for short cruises

•Day cruiser: more advanced version of runabout with closed living spaces

•Cruisers (Flying bridge): continuous deck, with bigger space area and comfort

•Cruisers (Hard Top): when the yacht is not provided with accessible flying bridge

•Sports fisherman: a high bow, a large aft cockpit completely open with short sides

•Trawlers: commercial fishing boats and she is characterized by a large central deckhouse and a large cockpit astern

•Open yachts: Yacht without superstructures and with a wide-open area astern

•Offshore yachts: open yachts with smaller dimensions but with speeds similar to those of offshore racing powerboats.

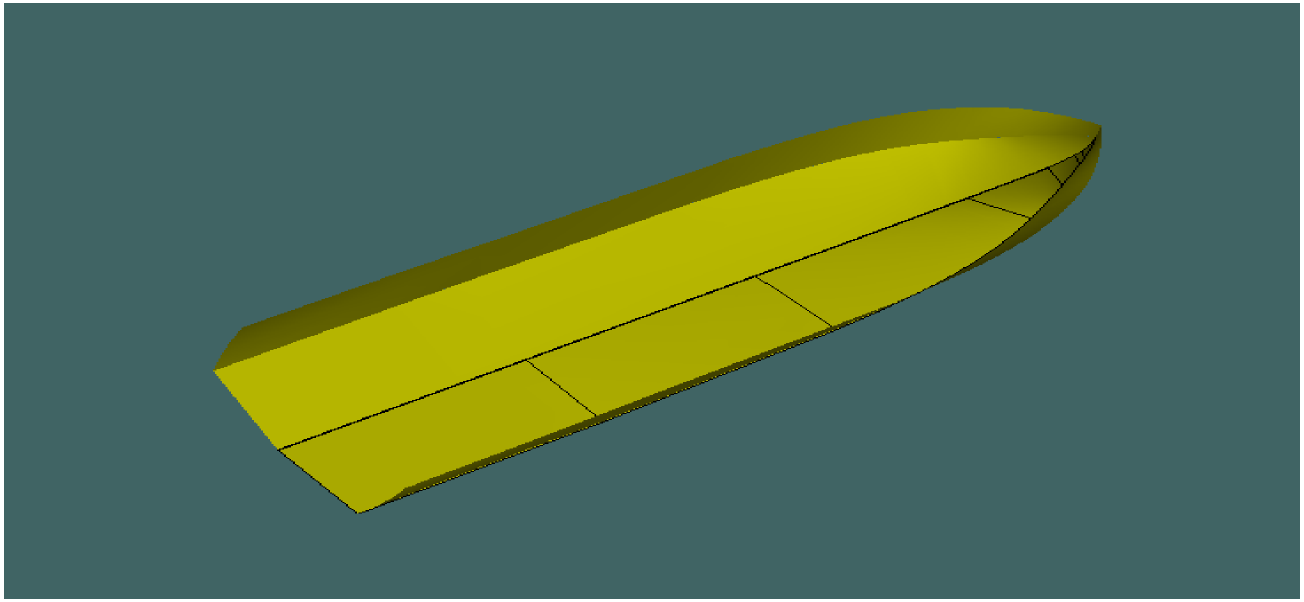
•Super yachts:

Different type of yachts in one frame

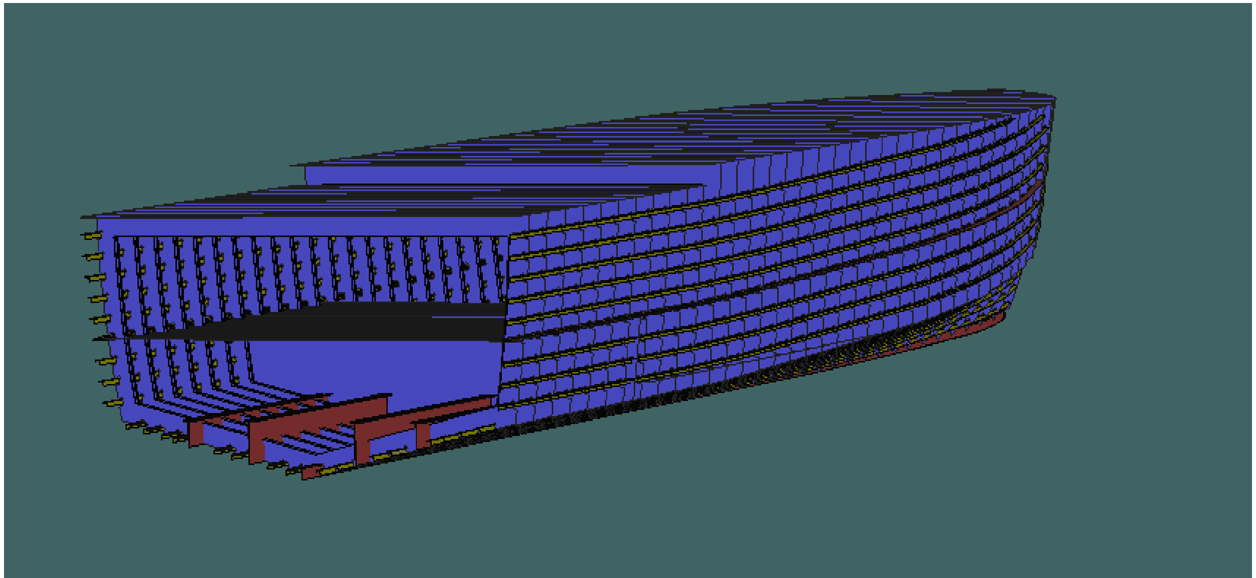
3. MODELLING

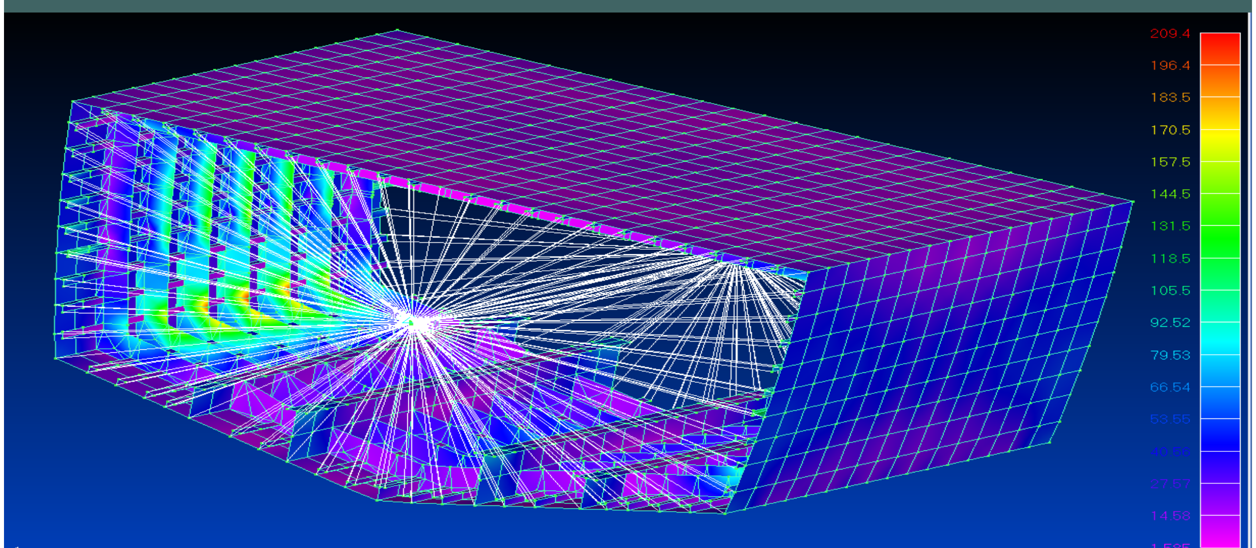
Software Used – Maxsurf modeler, Maxsurf structure advanced and FEMAP

- First modelling was done for Hull of yacht in maxsurf modeler
- Second mas Structure making modelling in maxsurf structure advanced for 3d representation of structure, computed through excel calculations of scantling
- And last modelling was to do modelling of aft section of hull in FEMAP for further Static analysis.



Maxsurf structure advanced and FEMAP modelling





4.DNVGL HIGH SPEED RULES CALCULATIONS

- Vertical acceleration

When $V_i/\sqrt{L} \geq 3$:

$$a_{cgi} = \frac{k_h g_0}{1650}\left(\frac{H_{si}}{B_{WL2}} + 0.084\right)\left(50 - \beta_{cg}\right)\left(\frac{V_i}{\sqrt{L}}\right)^2 \frac{L B_{WL2}^2}{\Delta} \ (\mathrm{m/s^2})$$

- Horizontal acceleration

$$a_{li} = \frac{a_{cg}}{6} \ (\mathrm{m/s^2})$$

- Transverse acceleration

$$T_R = \frac{\sqrt{L}}{1.05 + 0.175\frac{V}{\sqrt{L}}} \ (\mathrm{s})$$

- Combined acceleration

$$a_c = \sqrt{a_v^2 + a_l^2 + a_t^2} \ (\mathrm{m/s^2})$$

- Slamming pressure on bottom

concept taken here below in this formula is elemental area. The elemental area is calculated as span x spacing. And there is some restriction for choosing elemental area.

$$p_{sl} = \frac{a_{CG} \cdot \Delta}{0.14 \cdot A_{ref}} \cdot K_{red} \cdot K_l \cdot K_\beta \text{ (kN/m}^2\text{)}$$

- Pitching Slamming pressure on bottom

The pitching slamming pressure formula Tfp. The Tfp is draft value which will be different as we go from aft to fore section. In my case, for our yacht case in light ship condition, the yacht has trim and thus corresponding draft for every section longitudinally.

$$p_{sl} = \frac{21}{\tan(\beta_x)} k_a k_b C_w \left(1 - \frac{20 T_{FP}}{L}\right) \left(\frac{0.3}{A}\right)^{0.3} \text{ (kN/m}^2\text{)}$$

- Forebody Side and Bow impact Pressure

important factor here which is cause of lot of calculations for this pressure is Ch, because it indirectly depends over $h0$, which is vertical distance in meter from water line at draft T to the load point.

$$p_{sl} = \frac{0.7LC_LC_H}{A^{0.3}}\left(0.6 + 0.4\frac{V}{\sqrt{L}}\sin(\gamma)\cos(90^\circ - \alpha) + \frac{2.1a_0}{C_B}\sin(90^\circ - \alpha)\left(\frac{x}{L} - 0.4\right)\sqrt{0.4\frac{V}{\sqrt{L}} + 0.6}\right)^2 \ (\mathrm{kN/m^2})$$

- Sea Pressure

The sea pressure here given is have different magnitude for above design waterline and below design waterline. These sea pressure depends over h0, which is distance of measurement from waterline to element considered, the element can be stiffener, girder and plate.

Pressure acting on craft bottom, side, superstructure side, deckhouse side and weather deck shall be taken as

for load point below design waterline:

$$p = a\left(10h_0 + \left(k_s - 1.5\frac{h_0}{T}\right)C_w\right) \ (\mathrm{kN/m^2})$$

for load point above design waterline:

$$p = a\,k_s\left(C_w - 0.67\,h_0\right) \ (\mathrm{kN/m^2})$$

- Hogging and Sagging Bending moment

1.5.1 Longitudinal hull bending moments (still water + wave) shall not be taken smaller than:

$$M_{tot} = M_{sw} + M_w \text{ (kNm)}$$

M_{sw} = still water bending moment in the most unfavourable loading condition in kNm
M_w = wave bending moment amidships in kNm.

The most unfavourable still water conditions shall be given.

If the still water moment is a hogging moment, 50% of this moment can be deducted where the design sagging moment is calculated.

Additional correction may be required added to the wave sagging moment for craft with large flare in the fore ship.

For monohull craft:

M_{sw} = $0.11\ C_W L^2 B C_B$ (kNm) in hogging if not known
= 0 in sagging if not known.
M_w = $0.19\ C_W L^2 B C_B$ (kNm) in hogging
= $0.14\ C_W L^2 B\ (C_B + 0.7)$ (kNm) in sagging.

- Minimum Plate thickness calculation

The thickness of structures shall in general not be less than

$$t = \frac{t_0 + kL}{\sqrt{f}} \frac{s}{s_R} \text{ (mm)}$$

- Stiffener and girder thickness and section modulus calculations

3.1.1 The section modulus of longitudinals, beams, frames and other stiffeners subjected to lateral pressu
is not to be less than:

$$Z = \frac{ml^2 sp}{\sigma} \left(\text{cm}^3\right) \quad (4)$$

$$Z = \frac{mS^2 bp}{\sigma} \left(\text{cm}^3\right)$$

σ	121.6	160 f1	(maximum)					
m			bending moment factor,m-values in accordance with [2.4.3] may be ap					
S	let	0.5	girder span in m. The web height of in-plane girders may be deducted					
b		0.2745	breadth of load area in m (plate flange) b may be determined from Table					
p (bottom)		103.00	design pressure in kN/M2 according to Ch.1 Sec.3					
p(side)		29.72						
p(deck)		11.37						

- Material chosen for plate and stiffener

There are two materials chosen in designing the yacht for plates and shell, the material used is VL 5083 H321 Aluminum, whose f value is 0.9 and for members like stiffener and girder and frames, we used 6061 T5 Aluminum, whose f factor basically a material factor, its value is 0.76.

- Section modulus and thickness summary

PRESSURES

PLATES LOADS	KN/m2	KN/m2	KN/m2	KN/m2	KN/m2	KN/m2
	Slamming load bottom	Sea load on bottom	Sea load on side	pitching slamming load bottom	forebody side and bow impact pressure on bottom	forebody side and bow impact pressure on side
AP to 0.4	92.94	20.5	12.77	18.87	0	0
0.4 to 0.75	103.27	22.82	14.98	34.27	12.09	12.51
0.75 to FP	69.95	24.96	17.02	54.44	14	14.56
STIFFNERS LOADS	103.27	24.43	17.67	54.44	13.61	29.72
GIRDERS LOADS 1st	20.01	21.36	13.28	NA	1.9	1.05
2nd	11.44	21.36	13.28	23.8	1.1	

DECK LOADS	SEA LOAD KN/m2
3260(Weather deck fwd)	2.16
3020(Weather deck aft)	3.23
1600(Accomodation Deck)	10.37
800(Accomodation Deck)	20.77
collision bulkhead	19.61
Aftpeak bulkhead	8.65
Engine bulkhead	8.65

PLATE THICKNESS(Side & bottom):		Minimum Thickness(mm)	Thickness(mm)	Bending Thickness(mm)	slamming formula thickness
AP to 0.4	**bottom**	4.93	6	3.94	2.84
	above wL	4.17	6	1.54	
0.4 to 0.75	**bottom**	4.93	6	4.16	3
	above wL	4.17	6	1.67	
0.75 to FP	**bottom**	4.93	6	3.42	2.46
	above wL	4.17	6	1.78	

DECK PLATE & BULKHEAD PLATE THICKNESS

Deck	Minimum Thickness(mm)	**Thickness(mm)**	Bending Thickness(mm)	
3260(Weather deck fwd)	3.87	**5**	0.63	
3020(Weather deck aft)	3.11	**5**	0.77	
1600(Accomodation Deck)	4.93	**6**	1.39	car deck
800(Accomodation Deck)	2.58	**5**	1.97	

Bulkhead	Minimum Thickness(mm)	**Thickness(mm)**	Bending Thickness(mm)	
Collision	3.87	**5**	1.91	free board deck is main deck
Aft	3.64	**5**	1.15	accomodation deck is not main deck
Engine	3.64	**5**	1.27	

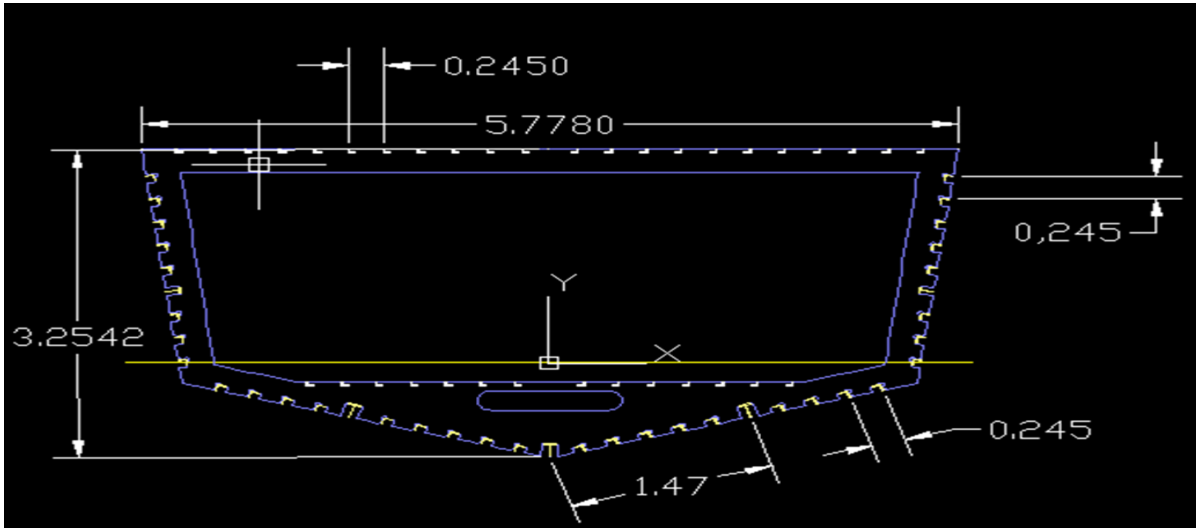
Initial design of Rivera 780 Kabe motor yacht hull structure

MEMBERS	DIMENSIONS	minimum thickness	**Obtained Z(cm3)**	lateral pressure)Min Z(cm3)	Z(cz of slamming)
Continuous longitudnal stiffnerof bottom & side	60x60x6	4.22	5.45	3.93	3.93
Deck 3260 mm(longi)Stiff	40x40x6	4.22	2.32	0.1	
Deck3020 mm(Longi)stiff	40x40x6	4.22	2.32	0.1	
Deck 1600 mm(Longi)stiff	40x40x6	4.22	2.32	0.4	
Deck 800 mm(Longi)stiff	40x40x6	4.22	2.32	0.9	
AftpeakWatertight bulkhead, simpy supported(Verical or longitudnal)stiffner	40x40x6	4.22	2.32	1.74	
AftpeakWatertight bulkhead, simpy supported(Horizontal girder or transverse)	300x5/100x8	4.22	116.07	92.34	
Collison Watertight bulkhead, simpy supported(Verical) stiffner	60x60x6	4.22	5.45	4.94	
Collison Watertight bulkhead, simpy supported(Horizontal girder)	106x5/100x6	4.22	28.45	28.45	
Engine bulkhead vertical stiffner	40x40x6	4.22	2.32	1.1	
Engine bulkhead Transverse girder	350x5/100x8	4.22	153.4	129.04	
Keel girder	139x5/90x8	4.73	27.9	18.82	
bottom side girder	139x5/90x8	4.22	27.9	18.82	
Side girder	100x5/45x8	4.22	14.17	6.11	
Webframe upper	250x5/100x6		28.45	27.5	
Webframe lower	250x5/100x6		28.45	11.74	
Web frame bottom	250x5/100x6		79	77.29	

5. RESULTS

•Global Hull girder Strength of Hull

The minimum section modulus requirement of hull given by (DNVGL/RU-HSLC/2018) in hull girder strength section and the value is 6411.5 cm3 by table 18.21 and the section modulus calculated for midship value is 132381.405 cm3 in Table 18.20. So calculated midship section modulus passes the criteria of minimum section modulus value. And the stresses calculated in keel main deck and inner bottom are 5.52 MPa, 6.44 MPa and 2.77 MPa, which are under limit and very less than yield limit of aluminum alloy. Thus, the calculations done for knowing the Minimum section modulus criteria for midship section of hull is finished. And the structural design that is members and plates and material which we choose at initial design stage in constructing the structural arrangement of aluminum hull is correct and thus we can further move with this design data and finish the further steps which are required in completing the hull structural design of hull.



- Weight Estimation of hull structure

The weight estimation is done automatically by Maxsurf structure advanced software. It only cannot estimate weight of bulkhead members and deck members. So for that we have provided the estimated weight calculation by excel software.

Structure weight	11.89	tonnes

Total weight	32.22	Tonnes

- Weight comparison/optimization by comparing altered frame spaces

- For spacing of 500mm: 11.89 t, with weight per volume: 0.198 t/m3

- For spacing of 600mm: 11.57 t, with weight per volume: 0.193 t/m3

Structure weight	11.89	Tonnes	0.5
Structure weight	11.57	Tonnes	0.6

The changes from 0.5 to 0.6 frame spacing has significant only on section modulus, that is mainly of longitudinal stiffeners of bottom and side and keel girder and bottom side girder,

The comparison of weight estimated by 2 different frames spacing of 0.5 and 0.6 yield a benefit of weight reduction in choosing 0.6 frame spacing over 0.5

- Finite Element Analysis of Engine foundation

Finite Element Analysis yield results which shows the engine girder which we designed in initial phase for our yacht in maxsurf structure advanced module, is safe and is of enough strength to face static and dynamic load conditions a long with high slamming pressure which was calculated by Load Excel according to DNVGL rule.

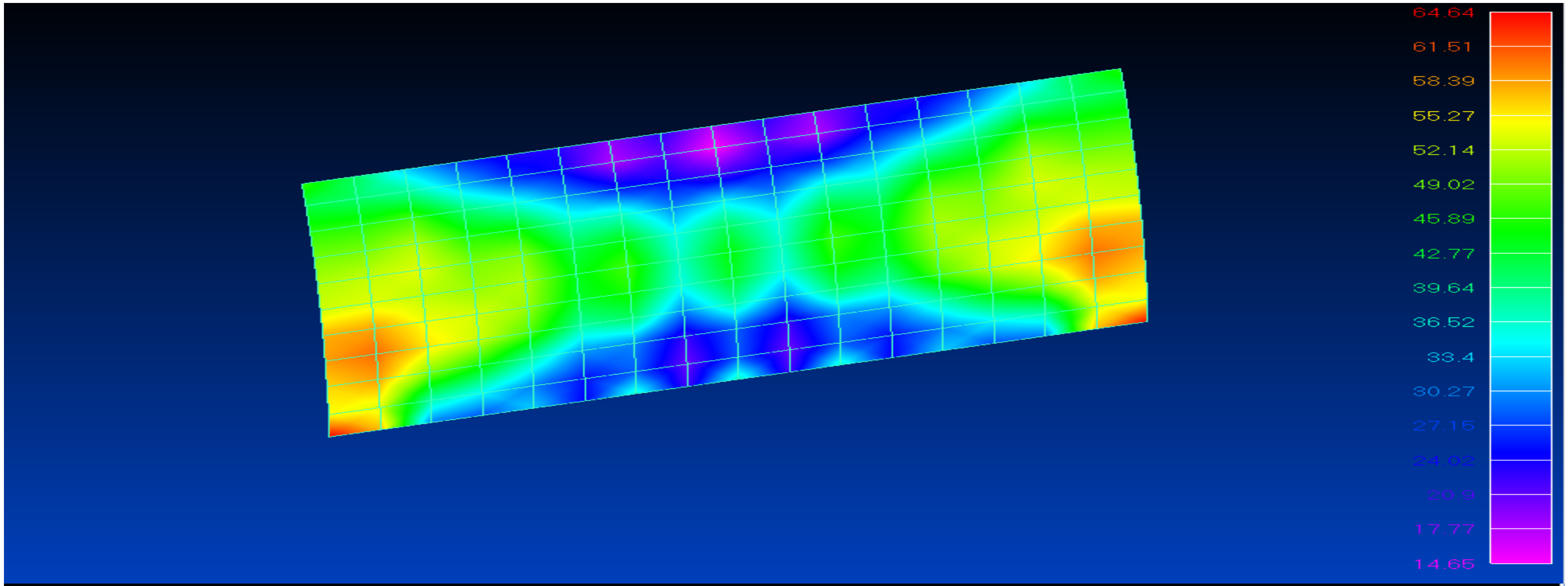
Conventionally, If there is no full model available, the idea is to apply the local loads separately and the resulting stresses are added to the hull girder stresses. The methodology followed in this case is explained as follows,

Since the model is not full (spanwise), the application of local loads along the length of the model does no give the evaluated bending moment value. The only possibility is to adjust the weight of the model (by changing the density/acceleration due to gravity) to make it up to the calculated value of bending moment. Here, the density of the model has been changed to obtain the design bending moment value.

In order to calculate the new densities, the actual weight of the structure and the model's weight have to be obtained. The actual weight is provided in the technical specifications and the weight of the model is obtained by getting the volume in Femap.

$$\Delta_{model} = \rho_{Aluminium} \text{ x } \nabla_{model}$$

$$\rho_{calibration} = \rho_{Aluminium} \text{ x } \frac{\Delta_{actual}}{\Delta_{model}}$$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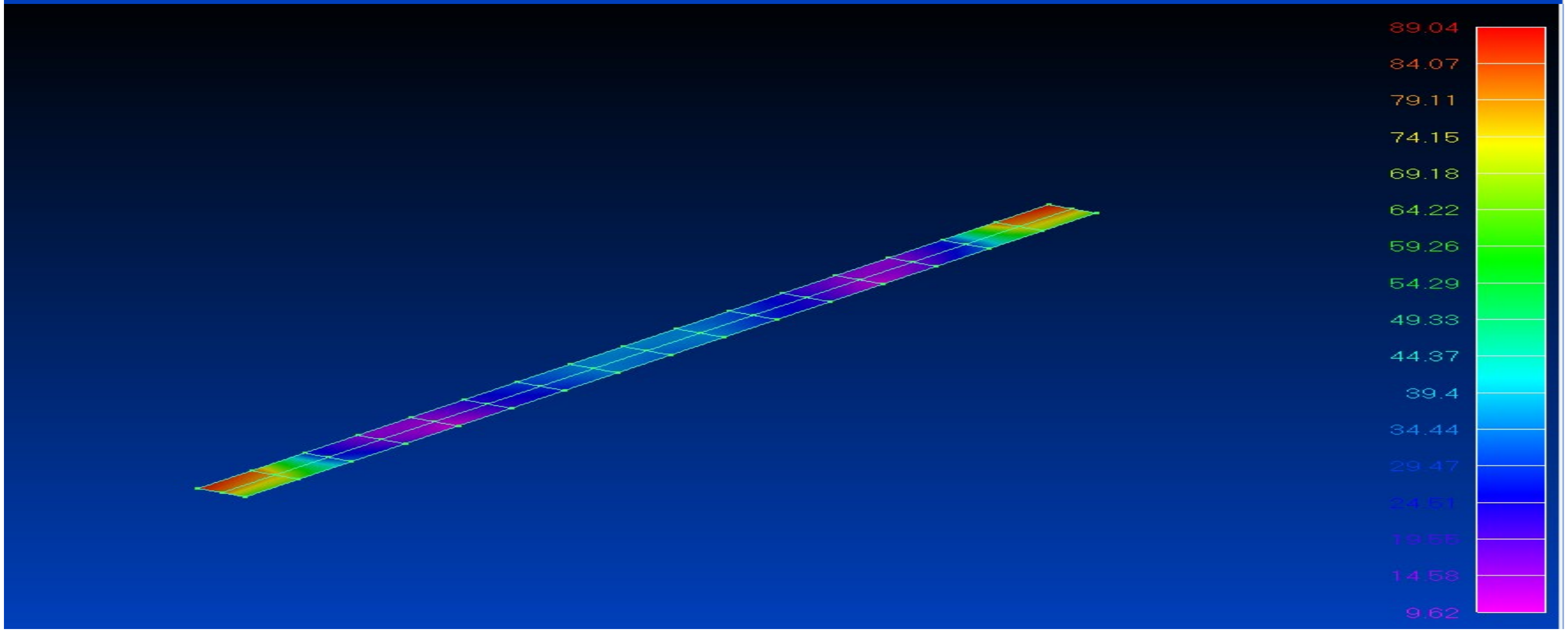
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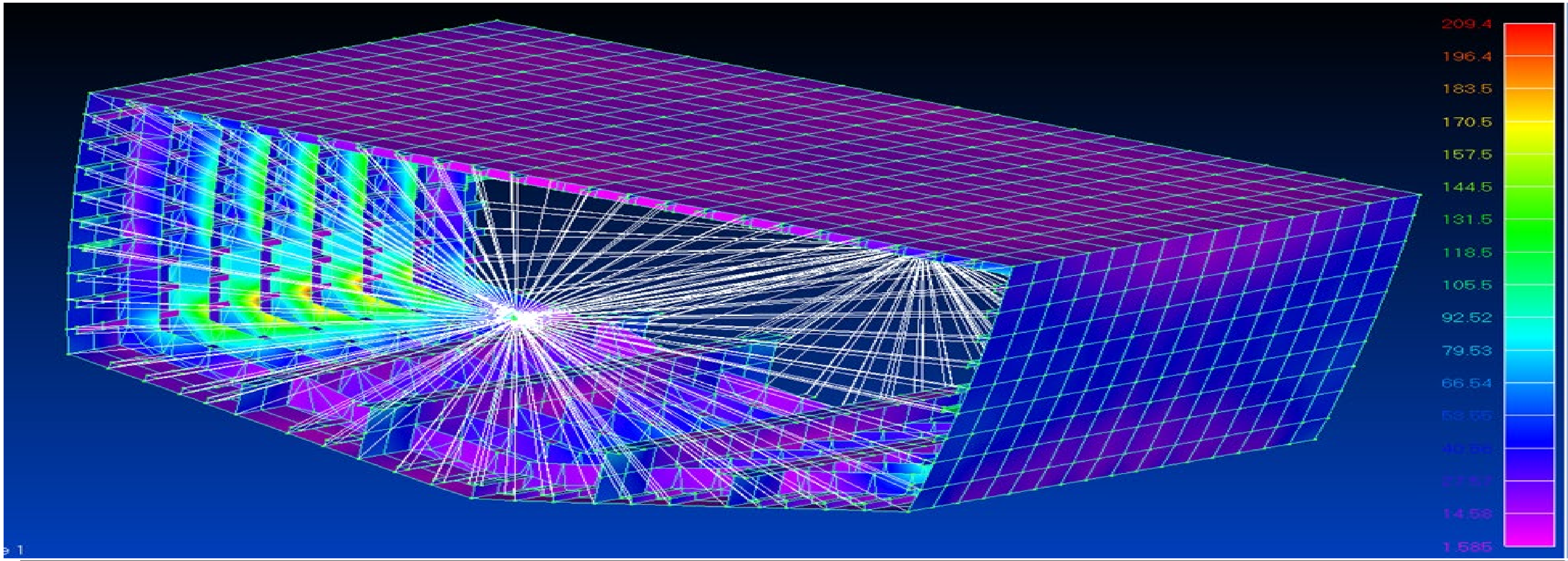
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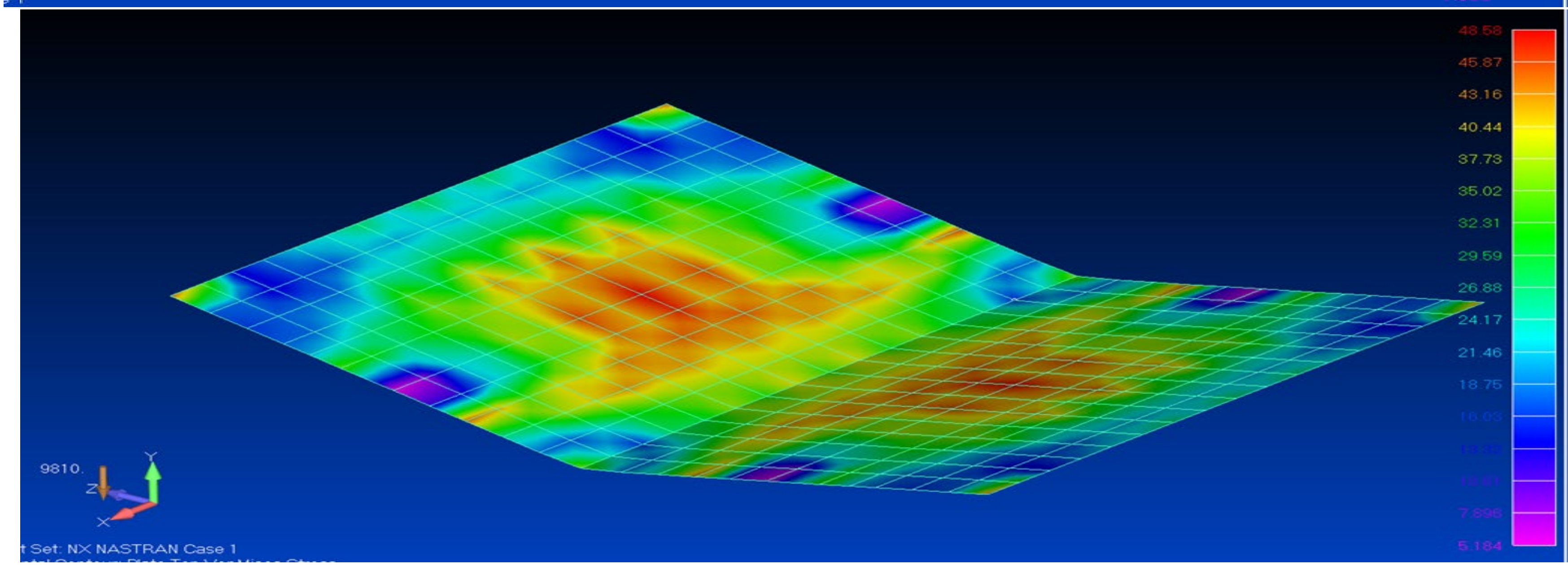
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6. CONCLUSIONS

•Tackling trimming surfaces problem while doing initial hull design in maxsurf modeler and later part of three dimensional structure development by using software named maxsurf structure advanced and its help in estimating weight of structure was quite brilliant.

The work over DNVGL rules over high speed yacht also tells that mostly for high speed cases, stiffener spacing remains very less. We have not tried to alter or reduce stiffener spacing further and then do the weight comparison, because there was limitation of Engine girders. Engine girder conflict or collision with normal longitudinal stiffeners can be the possibility, already by weight optimization point of view it is not beneficial.

•There is some limitation of Maxsurf structure advanced module, so we cannot get complete three dimensional perfect structure of it.

•There is not complete weight estimation of lightship weight, because of limited data provided by company.

•There is one another important results we found is the deck which is at distance 1.6 meter from baseline of hull, is not at enough height, and thus can lead to problem while doing engine installation, because of very less clearance between engine head and platform deck (1.6 meter)

•The Finite Element part done to check the engine foundation strength in facing the stresses due to inertial and self-weight along with the loading of static and dynamic sea pressure was also safe, the stresses value came under limits in respect to yield values of aluminum alloys.

•The use of FEMAP manual meshing to construct meshed portion of aft portion of yacht hull by quad and triangular elements by satisfying the jacobian criteria and its analysis by Nastran solver to get the stresses value is beneficial for our thesis work by estimating that given section modulus of engine foundation is enough to face stresses developed by loads namely static sea load, dynamic sea load, inertial load and self-weight all in together.

•There is some limitation also for choosing minimum elemental area(elemental area as by definition according to DNVGL Rule for high speed yacht is spacing x span), so it also limits in further reducing the product of two parameters, that is span and spacing for elemental area, in other words, we cannot further reduce spacing or span especially in cases where we compare weight of structure for different cases for either stiffener spacing or frame spacing or for both.

•As this work of report did comparison for two cases, 0.6m and 0.5m frame spacing on same stiffener spacing, that is 0.245 m, we found that we cannot reduce further frame spacing beyond 0.5 m on same stiffener spacing. The work by rule of DNVGL high speed also limit stiffener spacing by 0.245, we cannot increase stiffener spacing

Spacing 0.245 meter for case of high-speed yacht, so it is the maximum stiffener spacing we can use for our structural calculation.

- we preferred and used this spacing of 0.245 further reduction of stiffener spacing we didn’t try, because of risk of engine foundation collision with longitudinal stiffeners of bottom plate, as distance between two girder of engine foundation is 0.810 m


Thank you!
http://www.wildoceanfilm.com/marketing/images/photos/marinelife/Big%20Ship.jpg