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An Integrated Framework for Conceptual Design Stage Structural Optimisation of RoRo & RoPax Vessels

Master Thesis
EMSHIP WEEK 2018, La Spezia

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EMSHIP 7th Cohort (2016-2018)

Motivation & Scope

•**Conceptual Design Phase** :

- Rule based Structural analysis with emphasis on reducing lightship weight

•**Structural Optimisation of midship section** : mainly involve rule based determination of optimum scantlings for main transverse frames, plates, longitudinal stiffeners etc.

- Plates, longitudinal stiffeners (BV MARS Loop) – by University of Liege
- Main transverse frames (BV STEEL Loop) – Within the scope of Thesis

- **To establish Optimisation loop integrating different tools utilizing Response Surface Methodology**

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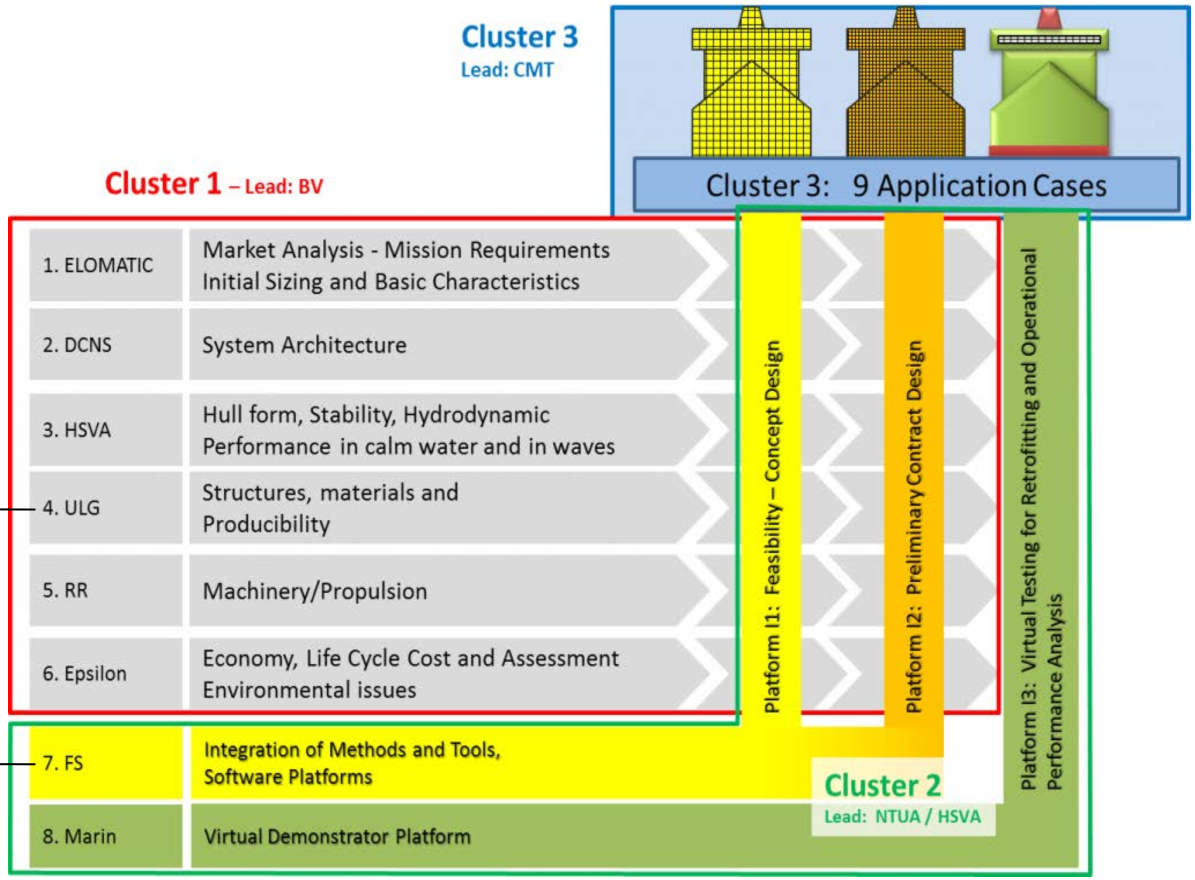
HOLISHIP (HOLIstic optimisation of SHIP design and operation for life-cycle) - Overview

Work Package 4 (WP4) ← 4. ULG

Work Package 7 (WP7) ← 7. FS



Source :- http://www.holiship.eu/

Workflow - Different Steps Involved

Step 1: Analysing the 'BV STEEL' model of RoRo hull

Step 2: Coupling BV STEEL & 'modeFRONTIER' tools with 4 design variables. **(STEEL_modeFRONTIER Loop 1)**

Step 3: Extending STEEL-modeFRONTIER loop with 8 Design Variables **(STEEL-modeFRONTIER Loop 2)**

Step 4: Establishing Surrogate models using Response Surface Methodology **(RSM)**

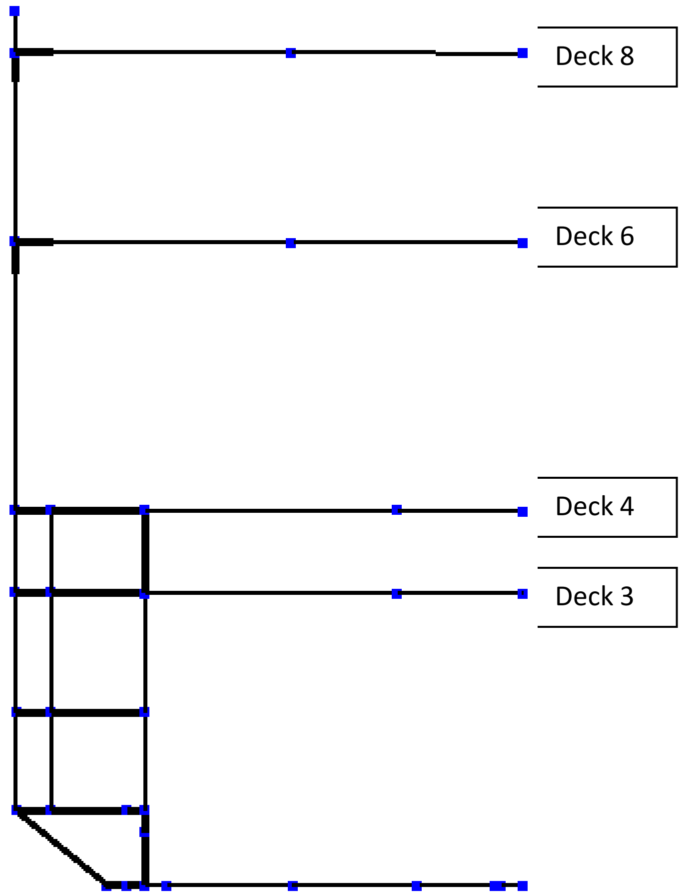
Step 5: Coupling BV STEEL with 'CAESES' tool **(STEEL - CAESES loop)**

Step 6: Structural & Load Modeling of RoPax Hull using BV STEEL.

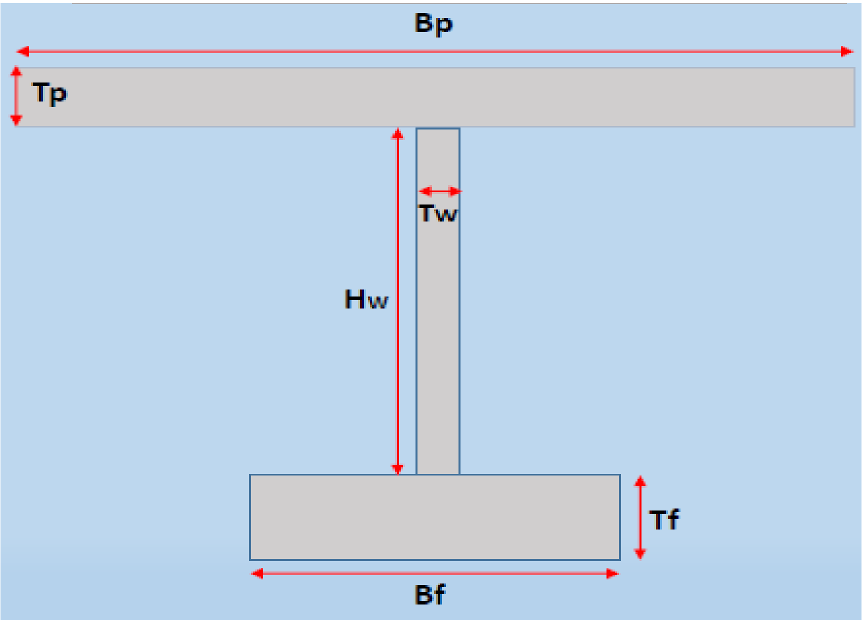
Step 7: Establishing STEEL - CAESES loop for RoPax hull

Step 8: Coupling STEEL-CAESES loop with RoPax Parametric hull loop to enable integrated hull and structural optimisation. **(STEEL - CAESES Parametric Hull Loop)**

RoRo STEEL Model for Main Transverse Frame



Basic Vessel Data – RoRo Hull	
L_{PP}	~ 196 m
B_{mld}	~ 32.2 m
Scantling Draft, T	~ 8.2 m
Material of Construction	Steel AH36



Typical Representation of a Beam Section Considered

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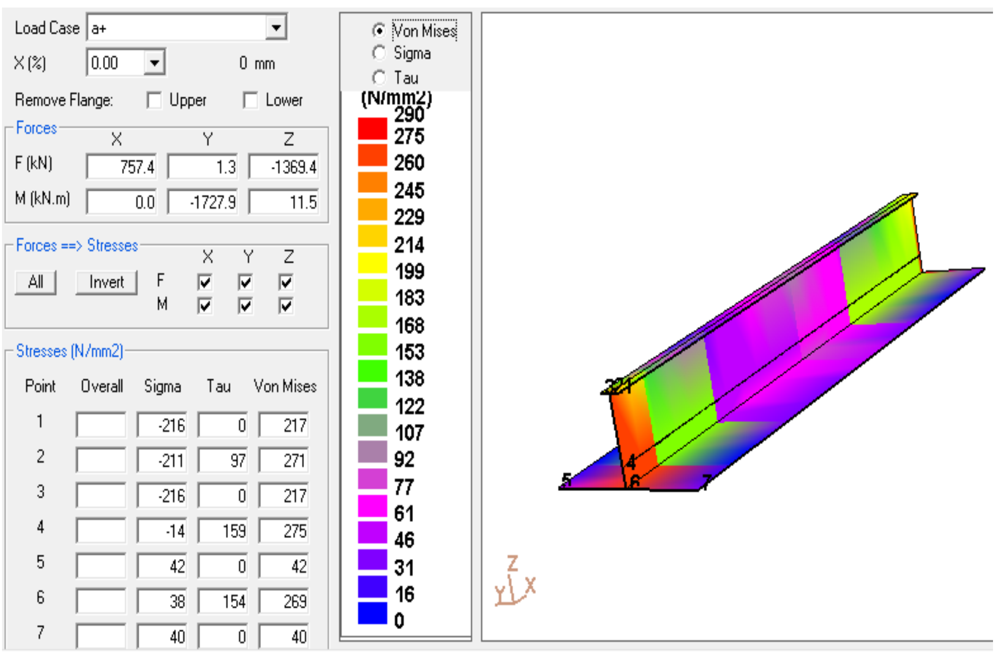
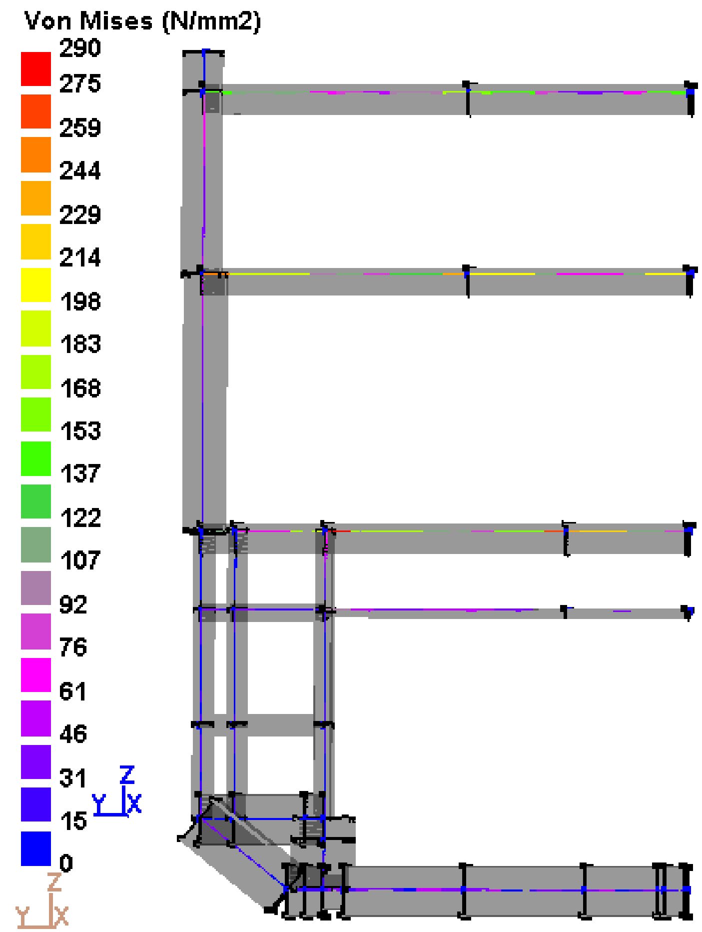
Von mises Stress Distribution- From STEEL tool





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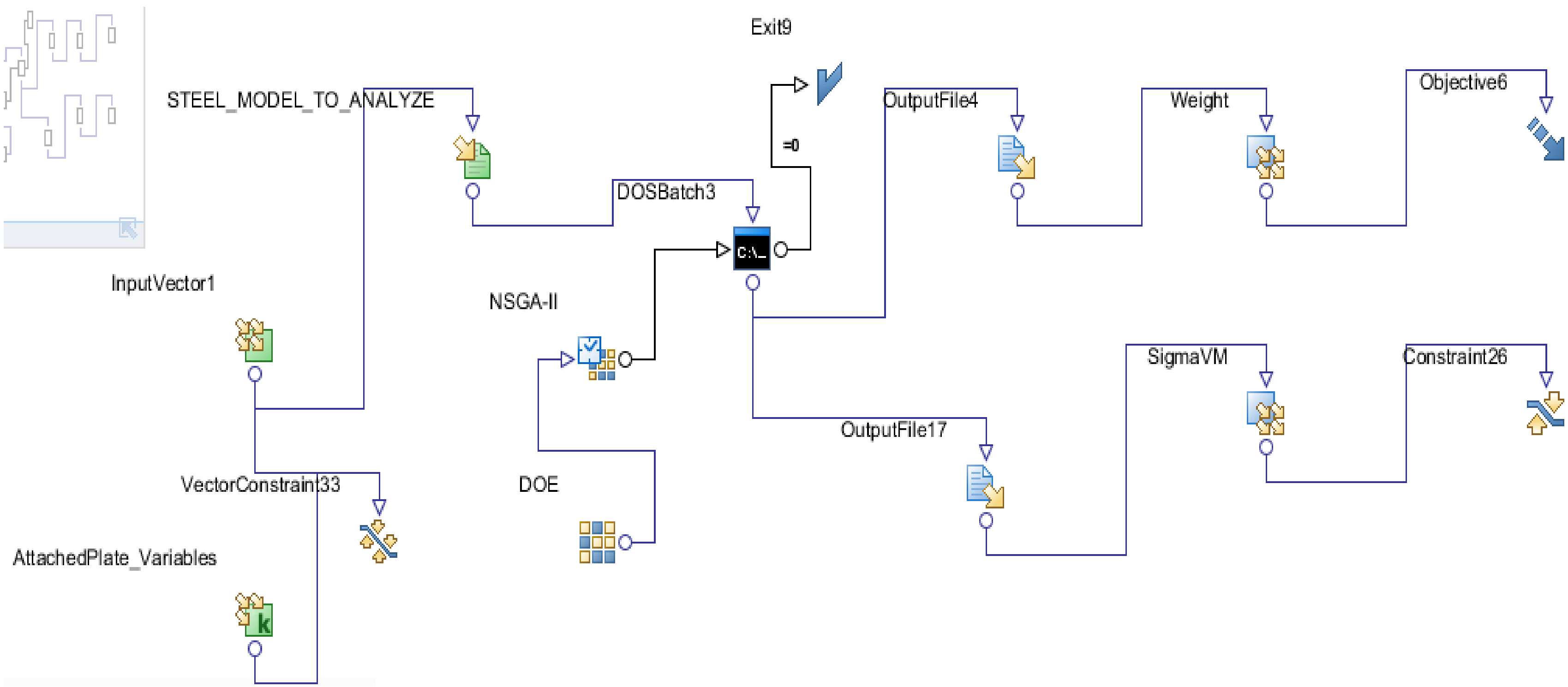
STEEL – modeFRONTIER Loop For RoRo Hull



σ_{VM}

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Defining Objective Function and Constraints for Optimization

35	8.79	297
36	3.19	47
43	3.89	61
44	2.69	42
45	3.89	57
46	2.69	40
47	3.89	57
48	1.12	17
49	3.00	44
50	1.12	17
51	3.00	44
[Total_Weight]		4476

- Criteria for the Von mises Stress (σ_{VM}) - Yield Check

  $\sigma_{VM} \leq 290$ MPa (BV Rules NR 467, Pt.B, Ch7, App.1)

- Criteria for Geometrical Properties (BV Rules NR 467,Pt B, Ch4, Sec3,[4])

[Beam_Stress] Beam Detailed Stress (N/mm2)

*N°	Sig_1	Tau_1	Sig_2	Tau_2	Sig_3	Tau_3	Sig_4	Tau_4	Sig_5	Tau_5	Sig_6	Tau_6	Sig_7	Tau_7
1	-2	0	-2	7	-2	0	0	7	2	0	2	7	2	0
1	-1	0	-1	0	-1	0	0	0	1	0	1	0	1	0
1	-2	0	-2	8	-2	0	0	8	2	0	2	7	2	0
2	-8	0	-8	35	-8	0	0	39	9	0	9	35	9	0
2	5	0	4	0	5	0	0	0	-5	0	-5	0	-5	0
2	-9	0	-8	36	-9	0	0	39	10	0	9	35	10	0
3	-8	0	-8	36	-8	0	0	39	10	0	9	35	10	0
3	5	0	4	0	5	0	0	0	-5	0	-5	0	-5	0
3	-8	0	-8	36	-8	0	0	39	9	0	9	35	9	0
4	-2	0	-2	8	-2	0	0	8	2	0	2	7	2	0
4	-1	0	-1	0	-1	0	0	0	2	0	1	0	2	0
4	-2	0	-2	7	-2	0	0	8	2	0	2	7	2	0
5	-2	0	-2	49	-2	0	0	54	2	0	2	48	2	0
5	23	0	23	3	24	0	0	4	-26	0	-26	3	-27	0
5	-8	0	-7	49	-5	0	0	53	9	0	8	48	6	0
6	-39	0	-38	22	-39	0	0	46	16	0	13	43	10	0
6	-99	0	-97	29	-99	0	0	61	35	0	32	58	32	0

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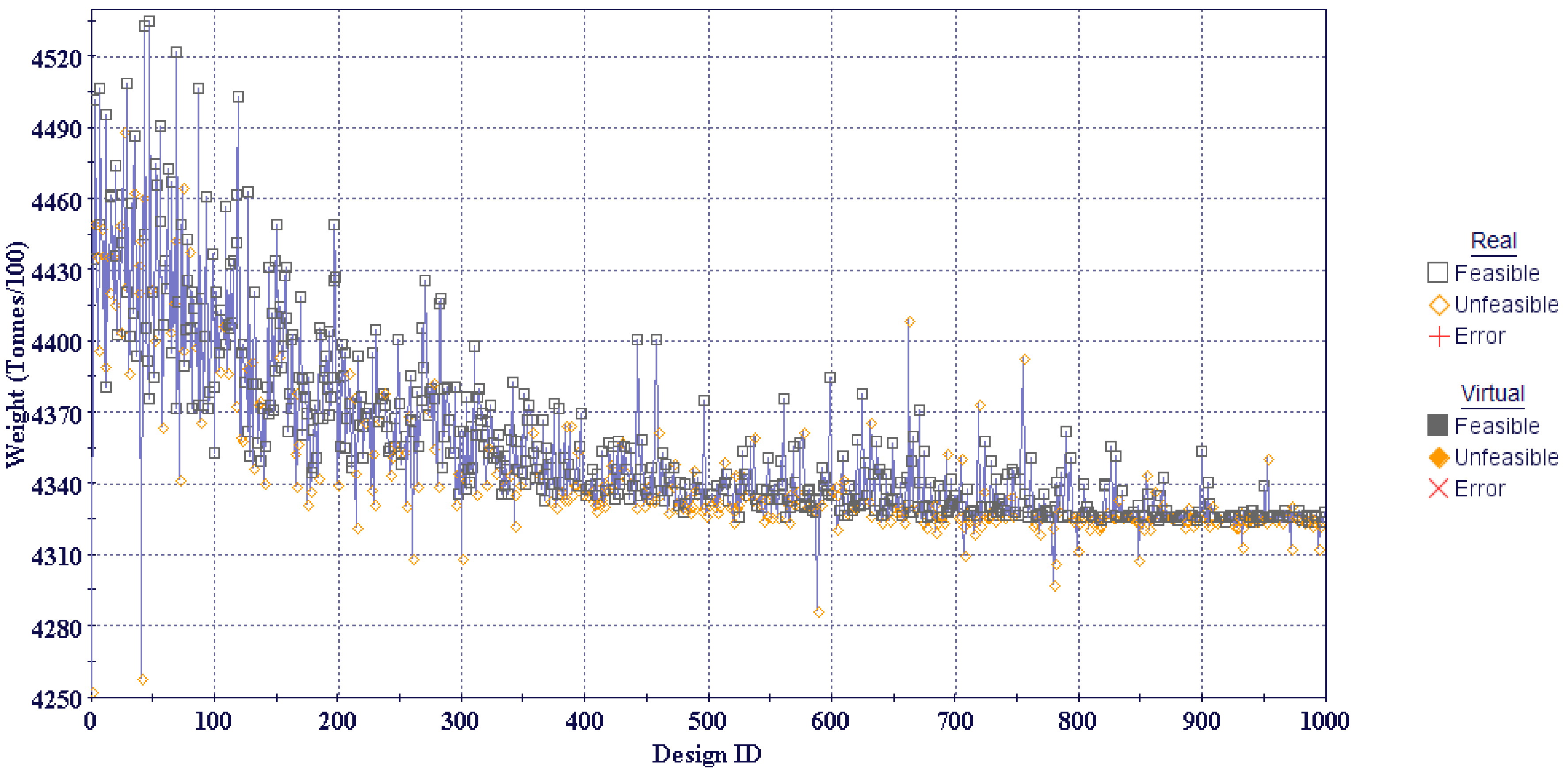
History Chart-Weight with 8 Variables from STEEL-modeFRONTIER loop : RoRo Hull



Establishing Surrogate Models using Response Surface Method (RSM)

- **Response Surface Methodology**

- **Applicability**

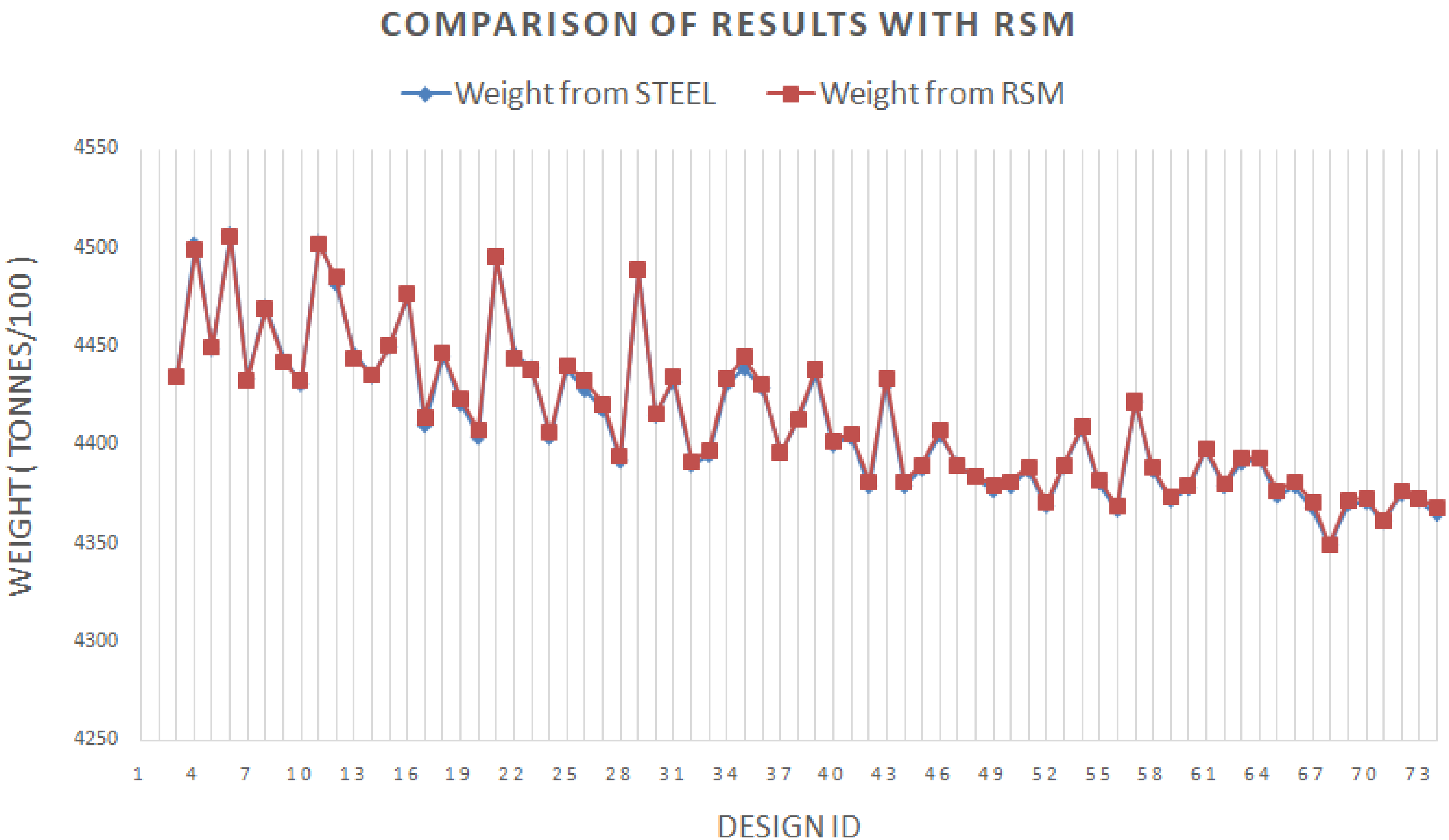
RSM With R Tool & CAESES – Using Polynomial Quadratic Surrogate Model

Weight, W = $4205.65 - 3.864 * x_1 + 5.874 * x_1^2 + 12.461 * x_1 x_2 + 6.480 * x_1 x_3 - 0.5429 * x_1 x_4 + 0.1929 * x_2 + 0.0003 * x_2^2 + 0.4970 * x_3 + 0.0031 * x_3^2 + 1.798 * x_3 x_4 + 0.1127 x_4 + 0.0007 * x_4^2$

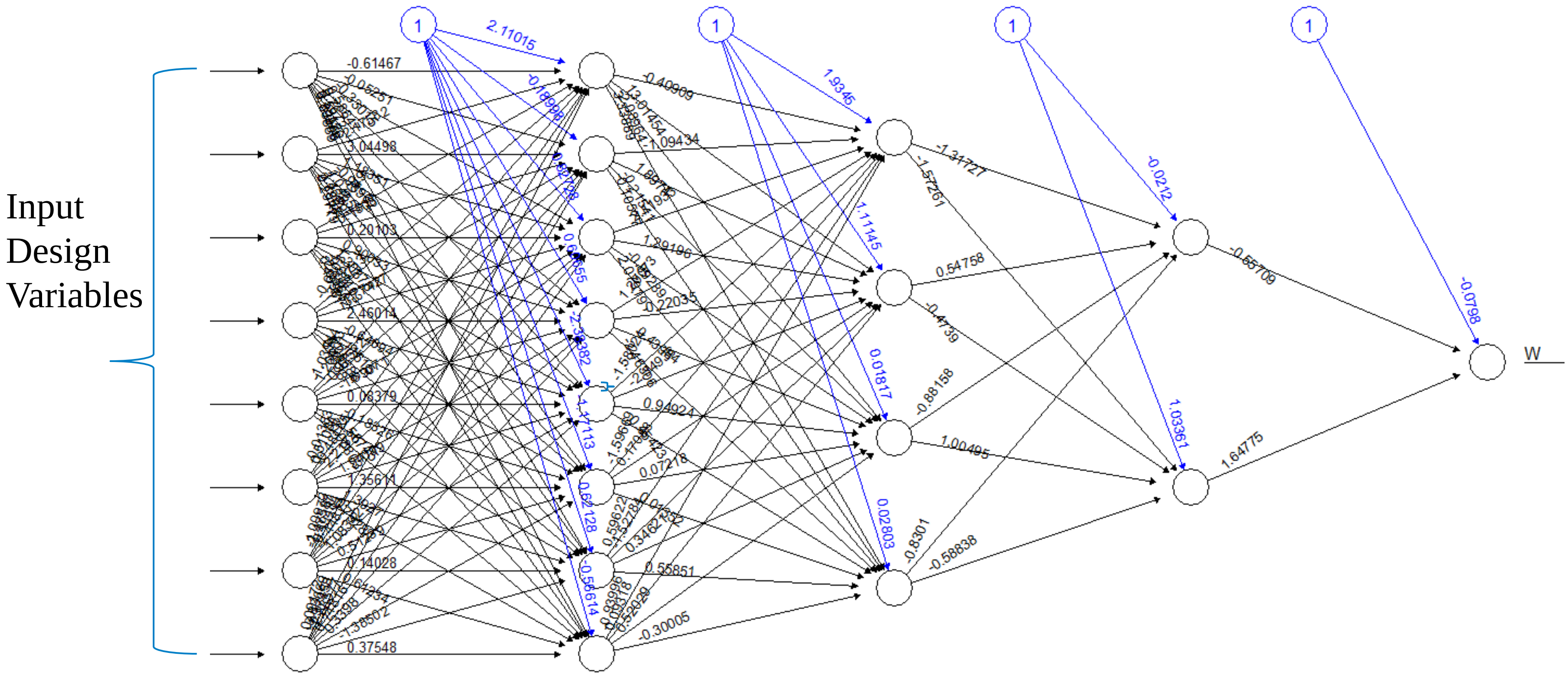
$$x_1 = H_W,\ x_2 = T_W,\ x_3 = B_f,\ x_4 = T_f$$

Relative difference as low as .002%.

RSM – Using Polynomial Regression



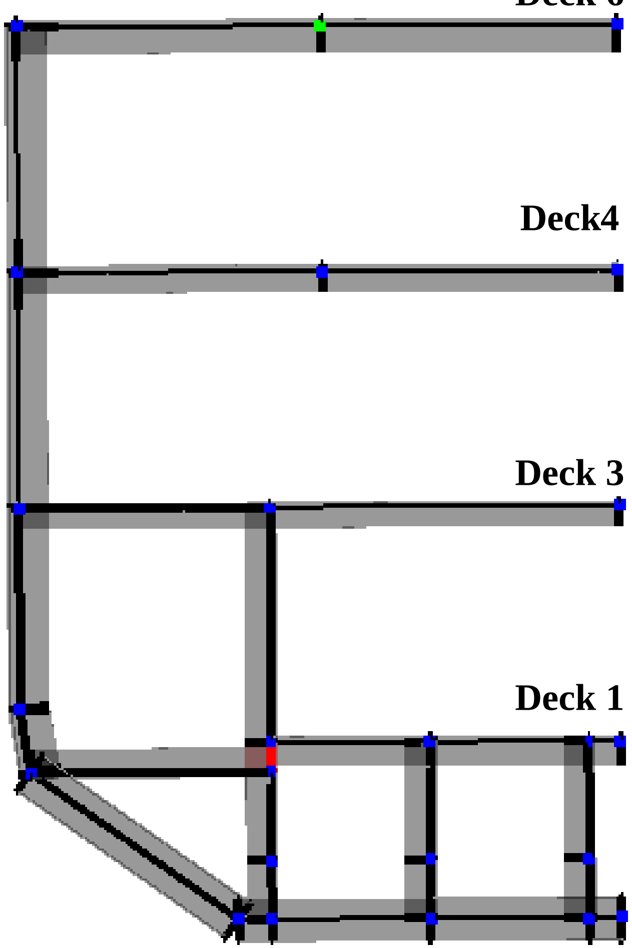
RSM - Using Artificial Neural Network



•Using neuralnet Package available in ‘R’

• The percentage of relative error was found to be within acceptable limits (maximum around 0.2 %).

Structural & Load Modeling of RoPax Hull for WP7 Application



Basic Vessel Data – RoPax Hull	
Scantling Length	162.845 m
B_{mld}	27.6 m
Scantling Draft, T	7.1 m
Material of Construction	Steel AH36

•Load cases a ,b for Upright conditions & Load cases c ,d for Inclined loading conditions

•Only local loads are considered as per the BV Class rules applicable.

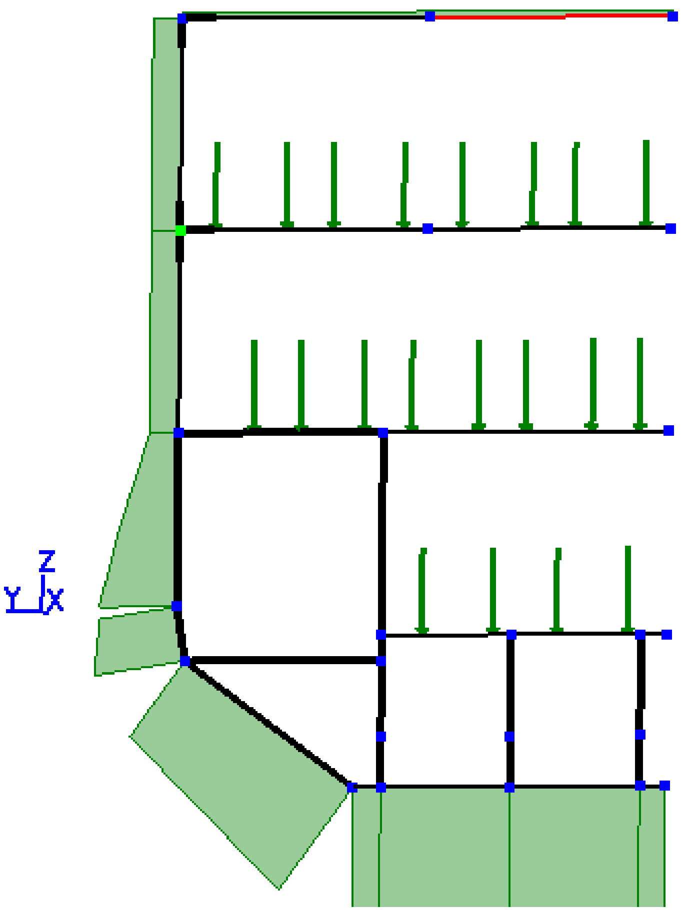
•Sea Pressure loads are acting on the outer shell

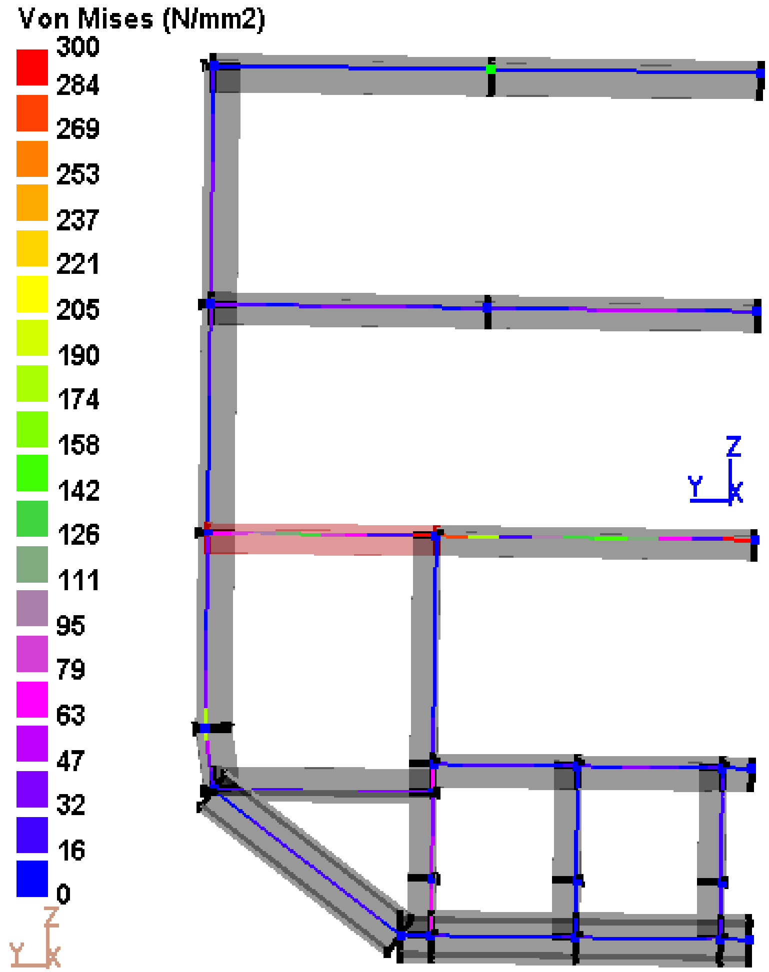
•Wheeled cargo are placed at Deck1,Deck3& Deck 4

•Passenger spaces at Deck 6

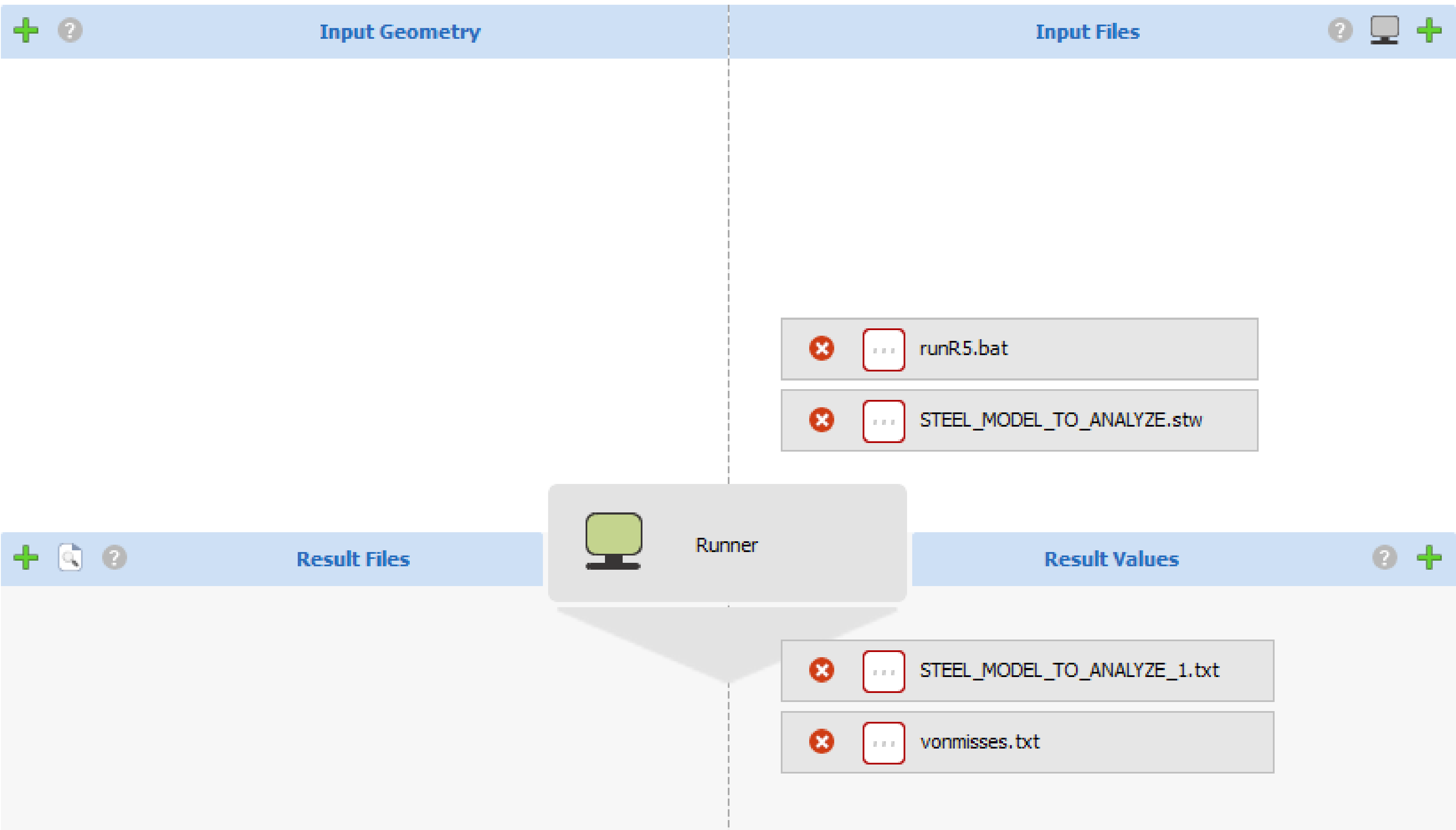
•Load Case a+ represent one of the critical load cases.

Stress Distribution : RoPax Hull

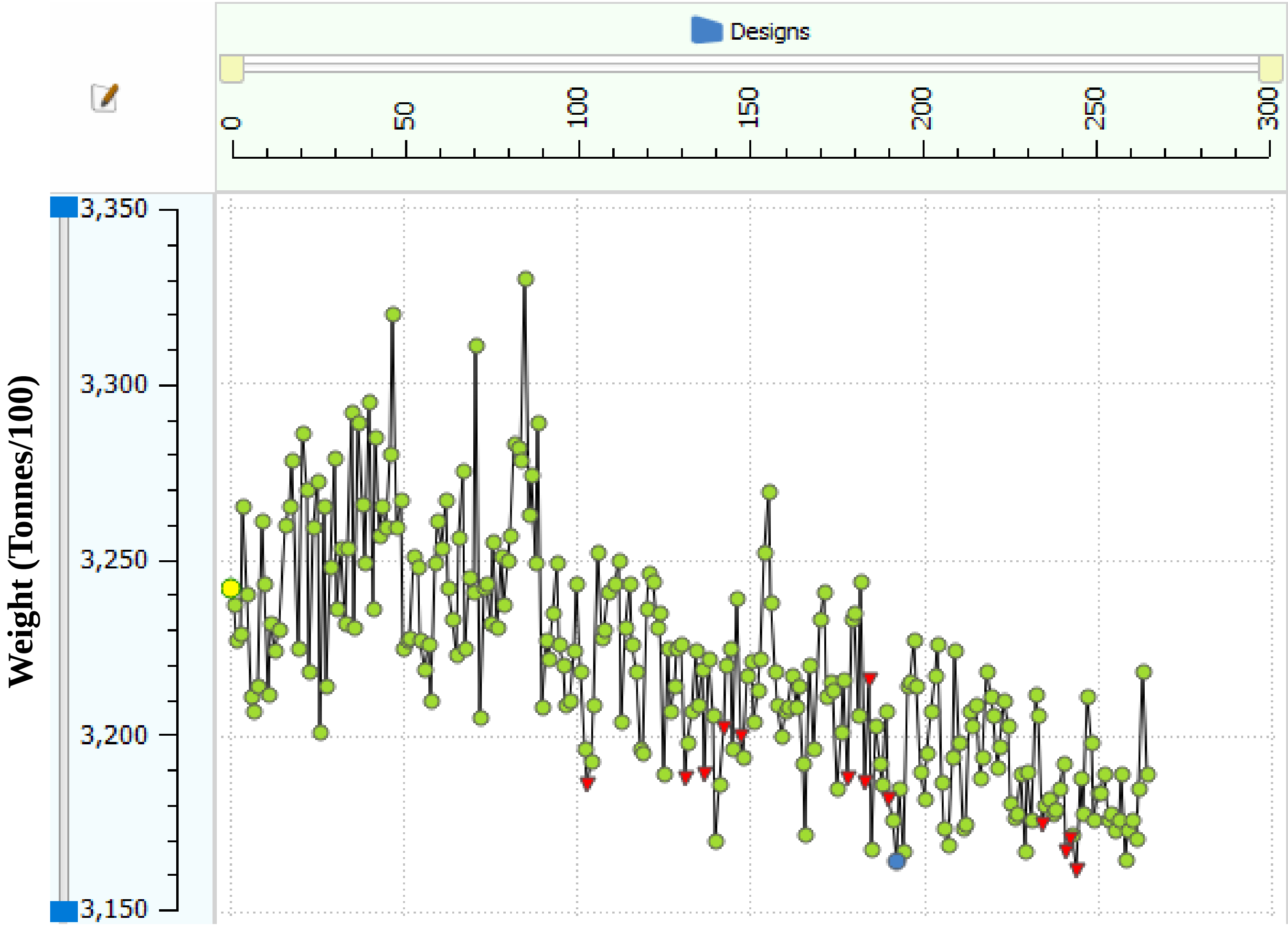




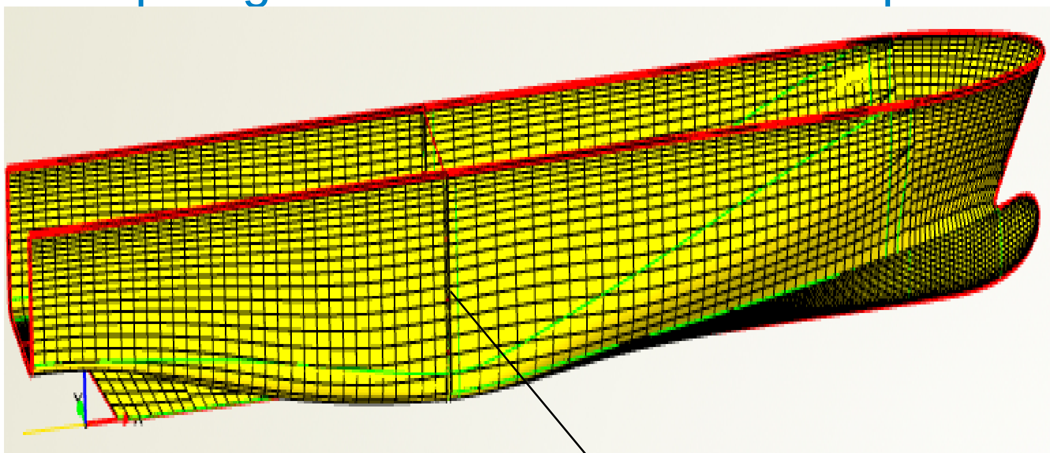
STEEL-CASES Loop for RoPax Hull : WP7 Application



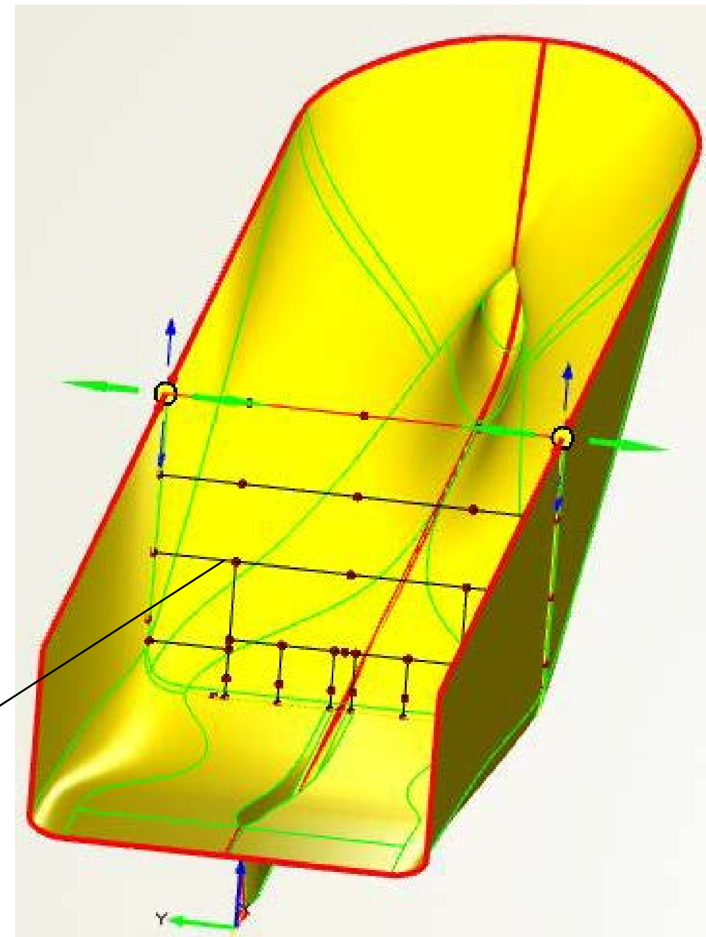
Variation of Weight - RoPax hull



Coupling STEEL- CAESES Loop with RoPax Parametric Hull

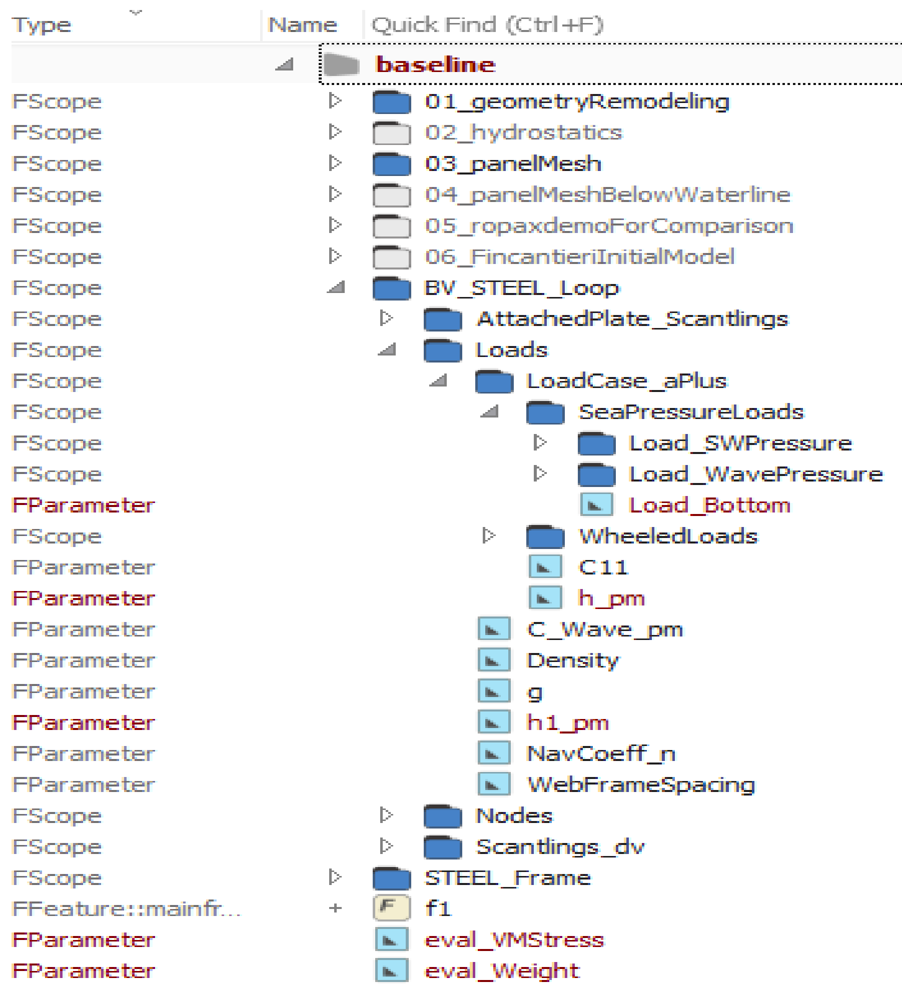


Mainframe Curve in RoPax Hull



Web Transverse Frame Modelled in CAESES

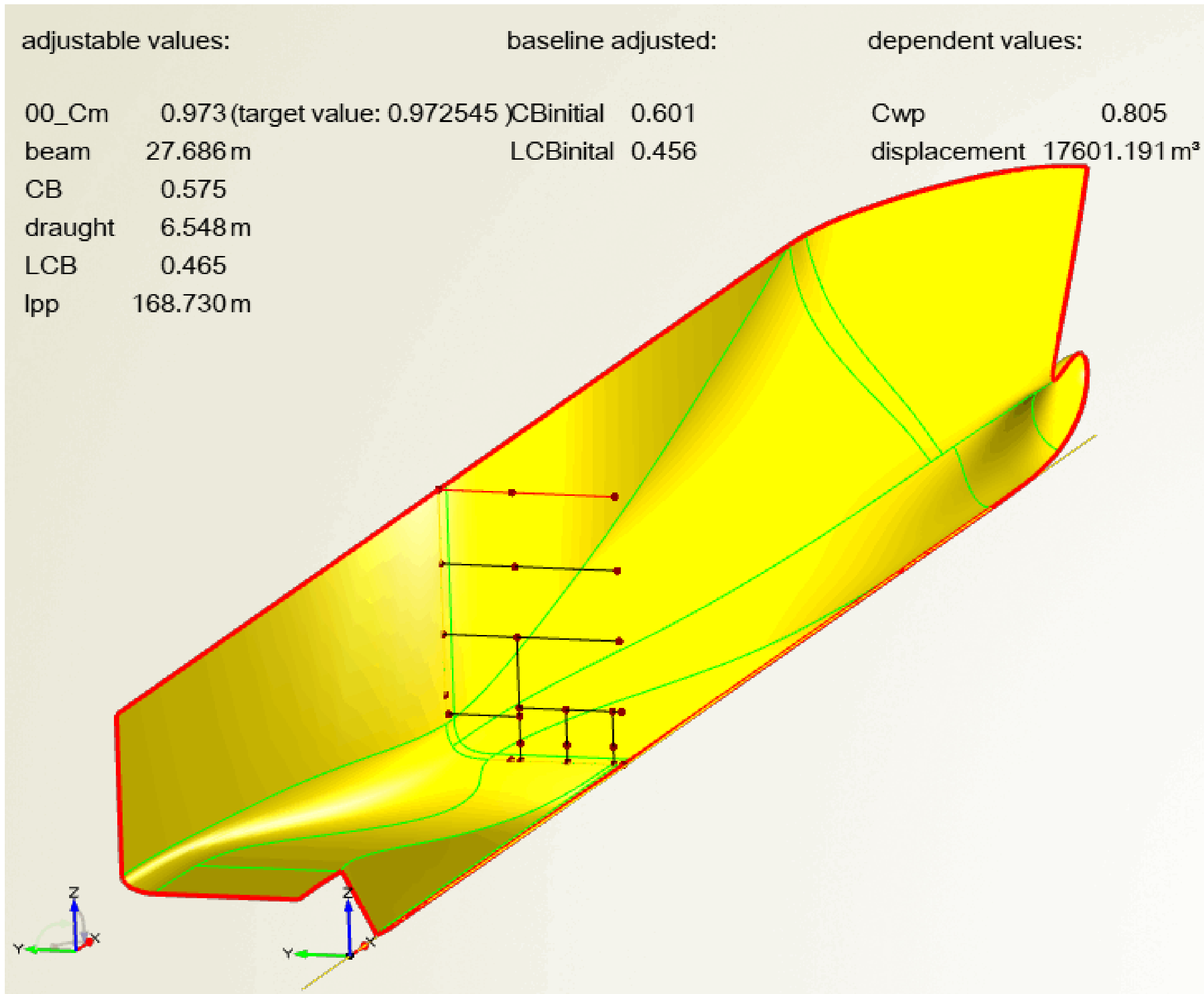
Parameterization of Loads in CAESES



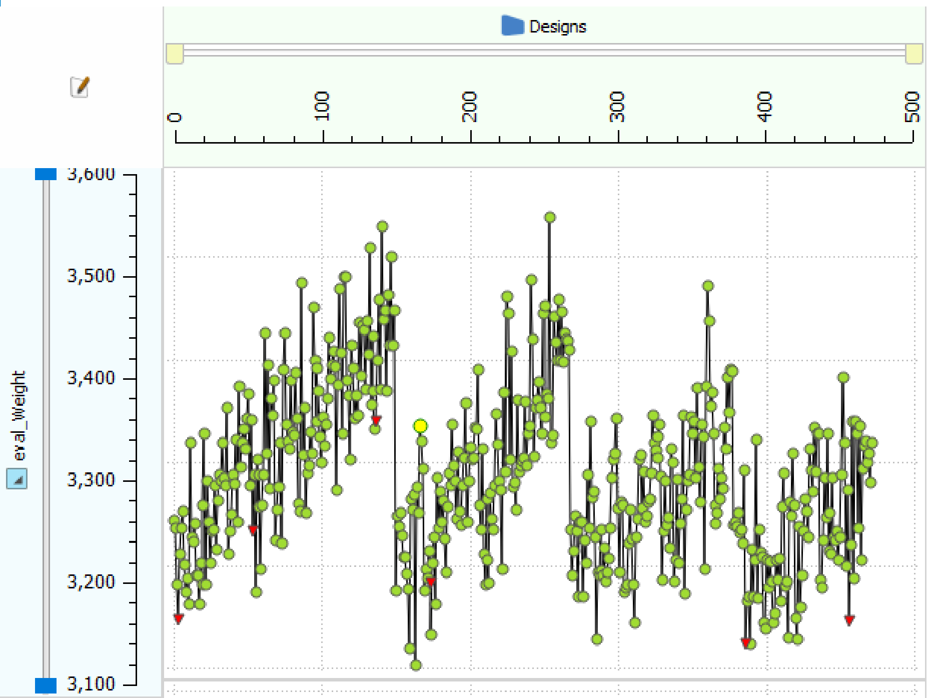
Design Variables

	DOE	Design Engine
Chosen Type	DAKOTA Sensitivity Analysis	DAKOTA Global Optimisation
Total No. of Iterations	~500	

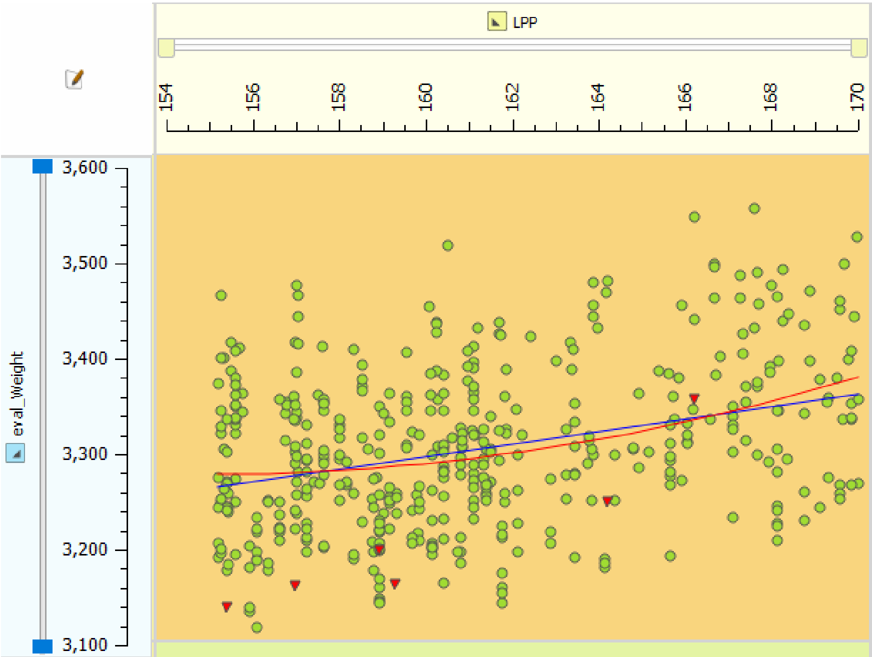
Design Variable	Description	Min. Value	Max. Value
Hw_Deck4	Web Height of Deck4 Beam section	0.550 m	0,850 m
Tw_Deck4	Web Thickness of Deck4 Beam Section	8 mm	12 mm
Bf_Deck4	Flange Width of Deck4 Beam Section	0.200 m	0.400 m
Tf_Deck4	Flange Thickness of Deck4 Beam Section	15 mm	25 mm
Hw_Deck3	Web Height of Deck3 Beam section	0.550 m	0,850 m
Tw_Deck3	Web Thickness of Deck3 Beam Section	8 mm	12 mm
Bf_Deck3	Flange Width of Deck3 Beam Section	0.200 m	0.400 m
Tf_Deck3	Flange Thickness of Deck3 Beam Section	15 mm	25 mm
L_{PP}	Length b/w Perpendiculars	155	180
L_{cb}	Long. centre of buoyancy (in % of L_{PP})	0.44	0.47
B	Breadth	27,6	30,6
Draft	Design draft	6,5	7,1
Height Factor	Scale factor for height	0.95	1.02
C_B	Block Coefficient	0.56	0.58
C_M	Midship section coefficient	0.965	0.985


adjustable values:
baseline adjusted:
dependent values:
00_Cm 0.973 (target value: 0.972545)
beam 27.686 m
CB 0.575
draught 6.548 m
LCB 0.465
lpp 168.730 m
CBinitial 0.601
LCBinital 0.456
Cwp 0.805
displacement 17601.191 m³
Z
Y
X

Results from Integrated Loop



Designs x Weight (Tonnes/100)



L_{PP} (m) x Weight (Tonnes/100)

Summary

•Structural weight can be significantly reduced for the entire vessel if optimum scantlings are chosen – Could be useful in the Conceptual design phase to save lightship weight.

•RSM - a reliable solution to replace existing optimization loops in later stages when more tools, methods or design components will need to be integrated together.

•Integrated Optimization loops increase design flexibility during conceptual phase

Recommendations for Future Work

•BV MARS can be integrated with to enable complete structural optimisation of midship section. Global loads can be considered as well.

•When MARS, STEEL loops are coupled, combined loop may be run as inner loop within the parametric hull loop.

Thanks !