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8th EMship cycle: September 2017 – February 2019

Master Thesis

Structural Optimisation of Midship Region for Ro-Pax Vessel in Early Design Stage using FEA

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Hamburg, February 2019

Contents

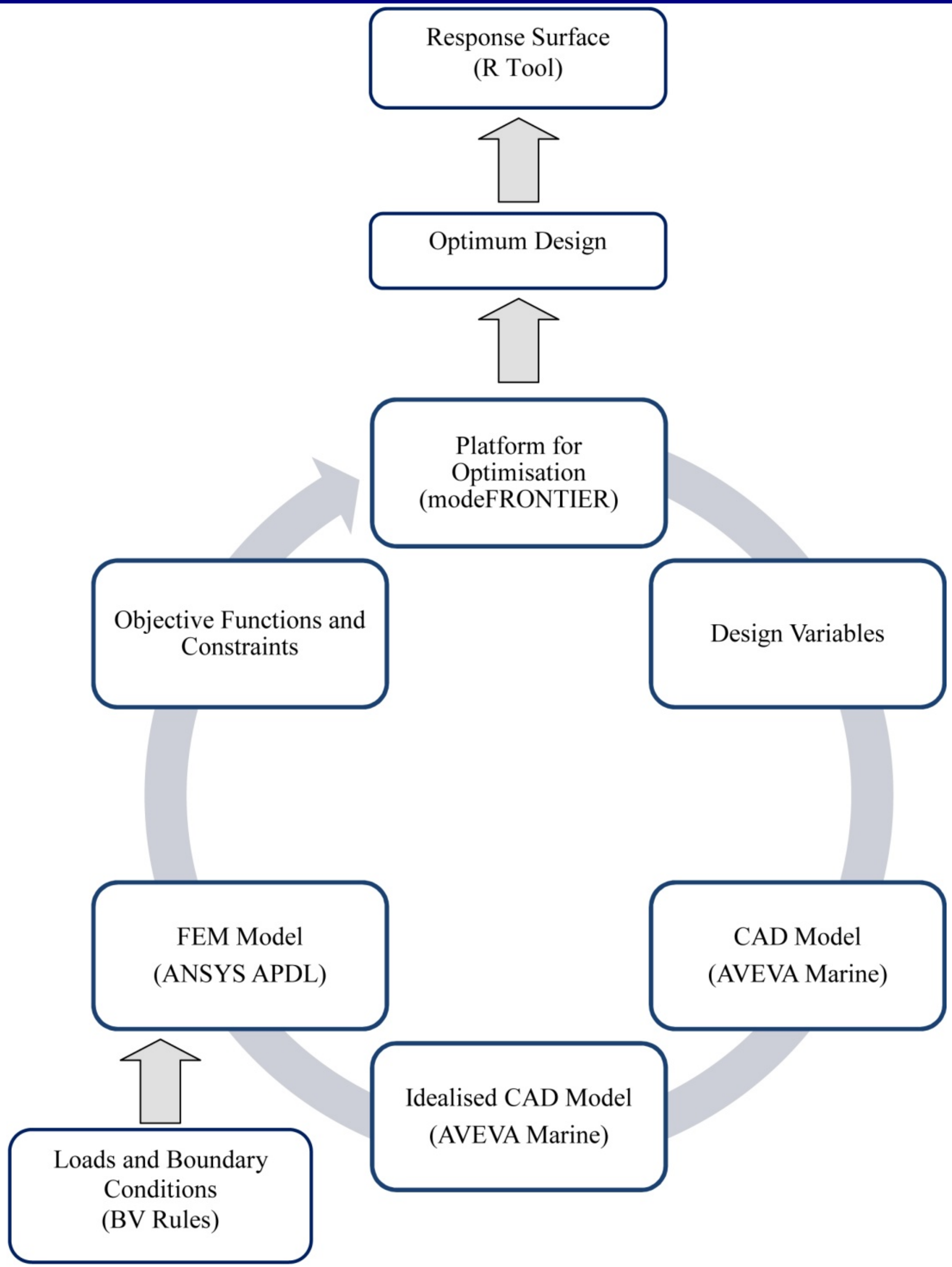
- **Optimisation**
  - the process of decision making when a number of alternative choices are available
  - an optimal solution has to be determined with regard to specific criteria
  - taking into account the restrictions and constraints set by the environment

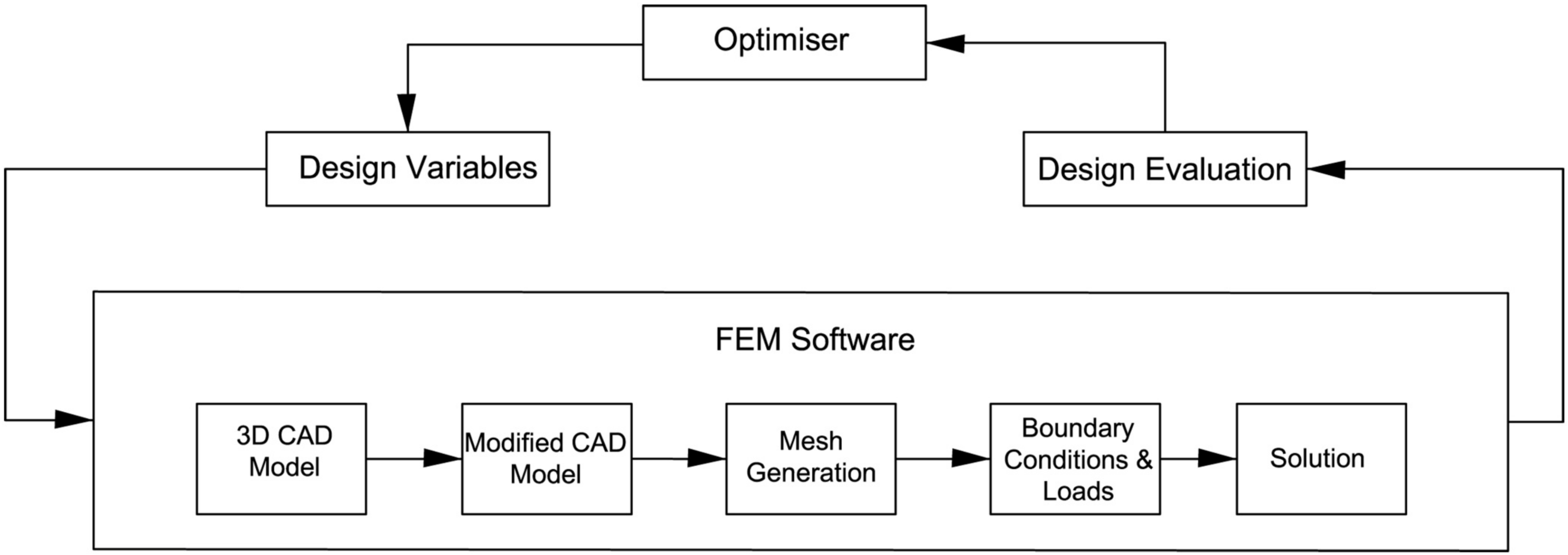
- **Ship design** – a typical optimisation problem **involving multiple** and frequently contradictory **objective functions** and **constraints**

- Ships need to be optimised for
  - cost effectiveness
  - highest operational efficiency or lowest required freight rate
  - passenger and crew comfort and safety
  - minimum environmental impact, etc.

- Optimisation often requires **minimization** or **maximization** of property(ies) of the structure under given load cases and constraints

- Development of an **integrated platform** for the **optimisation of midship region of Ro-Pax vessel** using **ANSYS® APDL**, *as finite element tool* and **modeFRONTIER®**,*as optimisation tool*
- **No manual intervention** in the GUI of the integrated platform
- Determination of **optimum scantlings** and thereby the **minimum weight** (*objective*) of the midship region of Ro-Pax vessel
- Developing **polynomial response surfaces** (*RSM*) to replace the FEM package to reduce calculation time

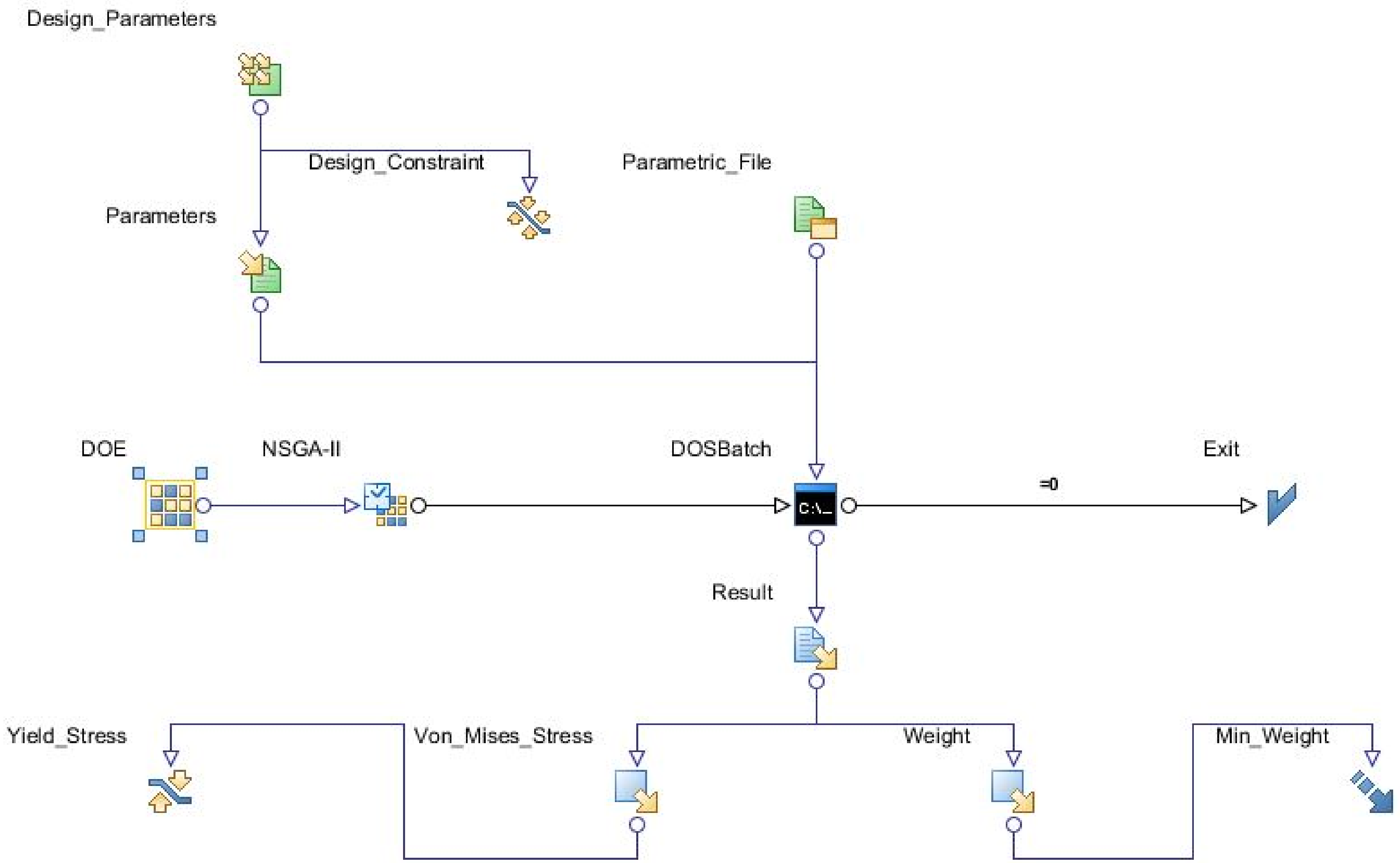

Response Surface
(R Tool)
Optimum Design
Platform for
Optimisation
(modeFRONTIER)
Objective Functions and
Constraints
Design Variables
FEM Model
(ANSYS APDL)
CAD Model
(AVEVA Marine)
Idealised CAD Model
(AVEVA Marine)
Loads and Boundary
Conditions
(BV Rules)


Optimiser
Design Variables
Design Evaluation
FEM Software
3D CAD Model
Modified CAD Model
Mesh Generation
Boundary Conditions & Loads
Solution

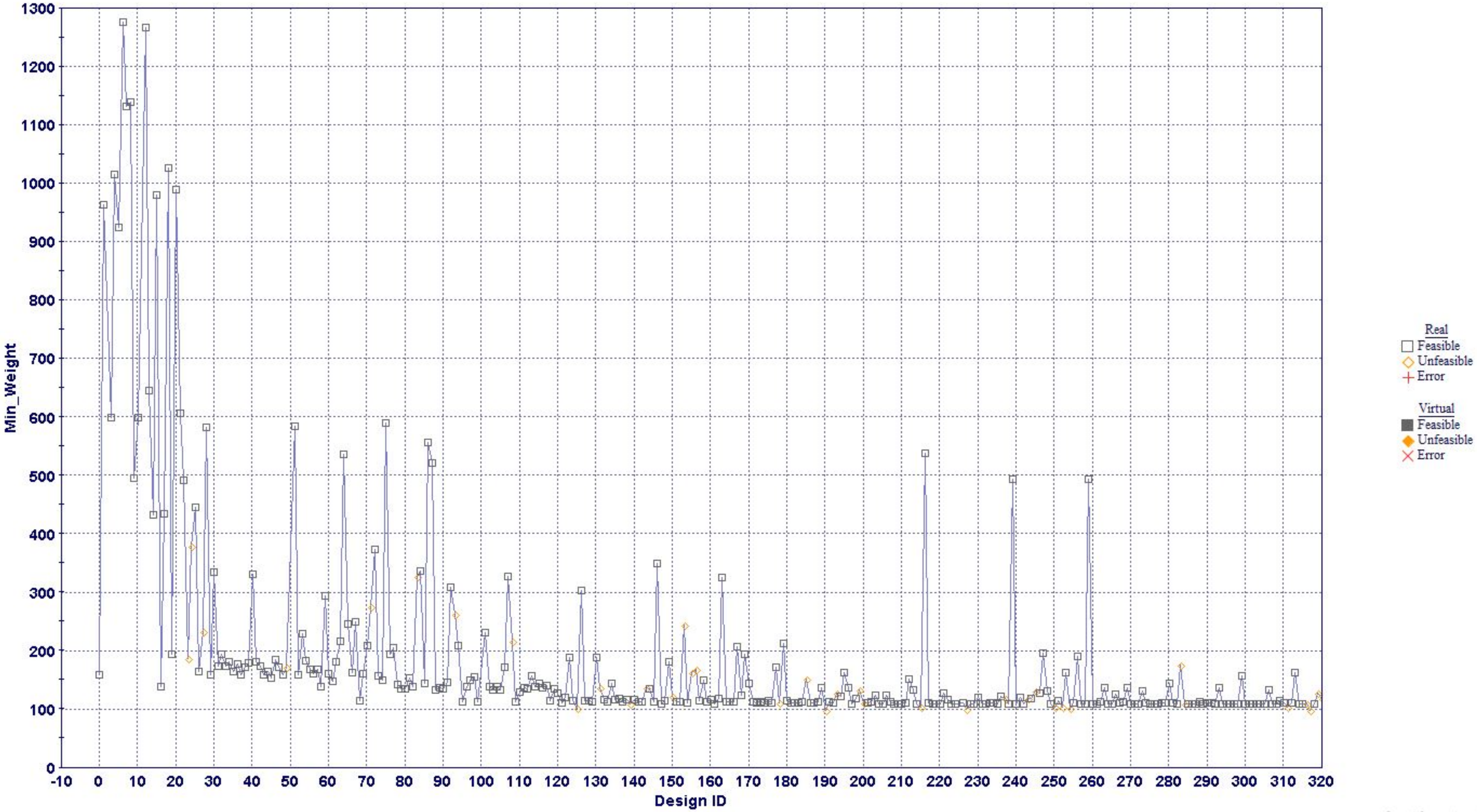
- **Stiffened Panels**

- basic building blocks in ships and marine structures
- also find applications in box girder bridges, nuclear power plants, etc.
- *reduction in stiffened panel weight* without losing their structural integrity yields *reduction in ship's weight*
- optimisation process to test the codes developed in ANSYS® APDL and understand the working of ANSYS® and modeFRONTIER® coupled loop
- **Seven design variables**
  - plate thickness
  - number of longitudinal stiffeners
  - number of transverse stiffeners
  - longitudinal stiffener web height and web thickness
  - transverse stiffener web height and web thickness
- **Weight – Objective function**

– Optimisation loop using ANSYS® APDL



− Convergence history for **Objective** function (**Weight** of the stiffened panel)



- **Response Surface Method (RSM)**

− Response surface using second order polynomial regression model

$$W = 836.09904 + 233.42986*Y_1 + 168.72417*Y_2 + 116.81434*Y_3 + 155.13404*Y_4 + 114.26292*Y_5 + 190.34547*Y_6 + 136.51625*Y_7 - 19.93504*Y_1*Y_2 + 12.16043*Y_1*Y_3 - 32.46640*Y_1*Y_4 + 16.12237*Y_1*Y_5 + 5.33439*Y_1*Y_6 - 13.15543*Y_2*Y_3 + 114.30040*Y_2*Y_4 + 90.76182*Y_2*Y_6 - 10.15464*Y_2*Y_7 + 76.85179*Y_3*Y_5 - 16.71419*Y_3*Y_6 + 41.21212*Y_3*Y_7 - 54.10183*Y4*Y_5 + 70.96034*Y_4*Y_6 + 19.71127*Y_4*Y_7 + 58.45976*Y_5*Y_7 - 11.18839*Y_2^2 + 21.54268*Y_4^2 + 3.36939*Y_7^2$$

− **Relative difference in the weight** between FEM and RSM is less than **4%**

− Time taken for one calculation in a machine with Intel® Core i3, 2.0 GHz CPU and 4GB RAM

  - FEM – 30 seconds
  - RSM – milliseconds

- **Ro-Pax Vessels**

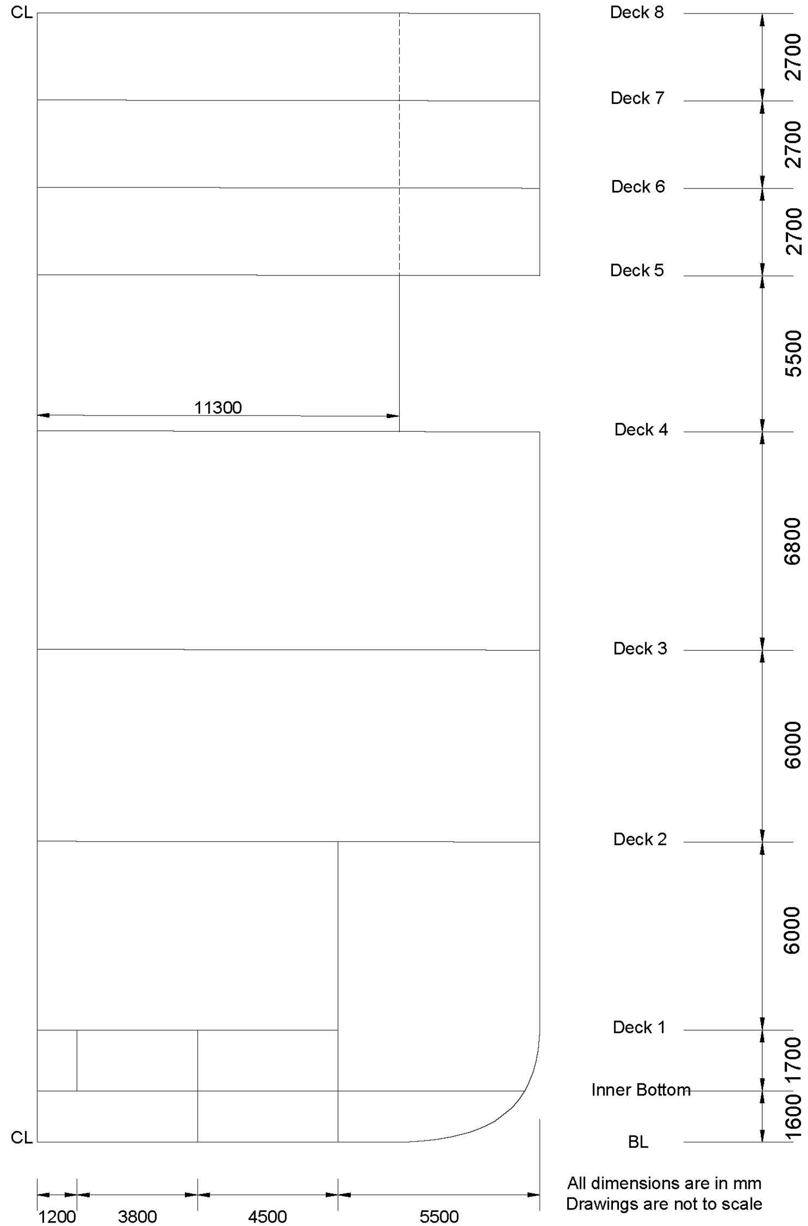
– designed to transport vehicles and passengers efficiently

– midship structural design can be considered as a basic structural problem

– the major part of hull follows the pattern of midship section

– provides an approximate estimation of hull weight

Length overall	220.00 m
Length between perpendiculars	210.00 m
Breadth	30.00 m
Depth	9.0 m
Draft	6.50 m
Block coefficient	0.629
Displacement	28000.00 t

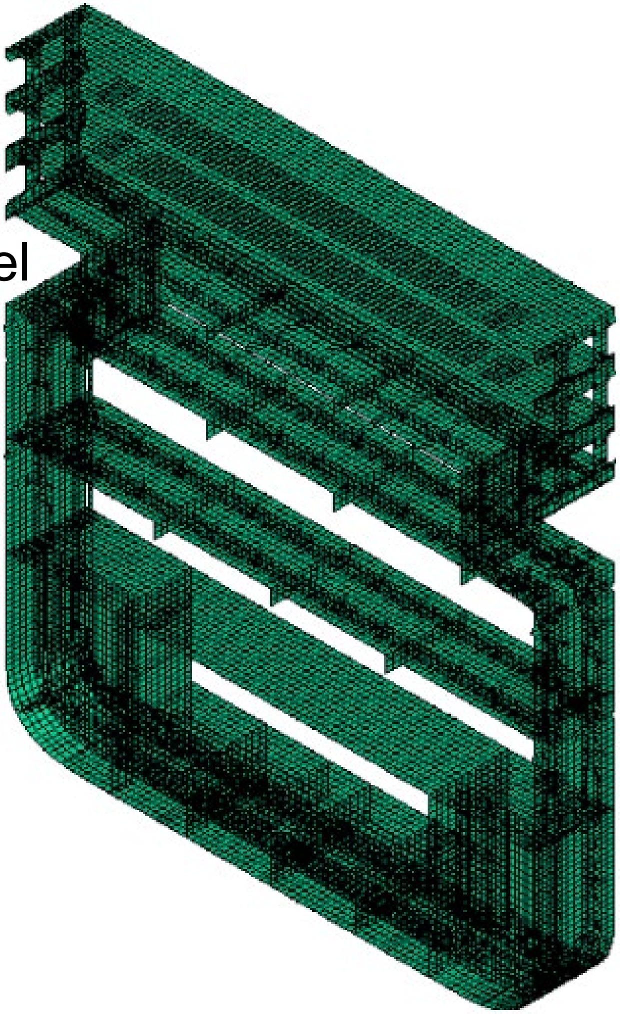

CL
Deck 8
Deck 7
Deck 6
Deck 5
Deck 4
Deck 3
Deck 2
Deck 1
Inner Bottom
BL
2700
2700
2700
5500
6800
6000
6000
1700
1600
11300
1200
3800
4500
5500
All dimensions are in mm
Drawings are not to scale

– Load cases based on BV Rules

Load Conditions	Description
1	Full load on decks + (a+) + Sagging
2	**Full load on decks + (a+) + Hogging**
3	Full load on decks + (a-) + Sagging
4	Full load on decks + (a-) + Hogging
5	Full load on decks + (b) + Sagging
6	Full load on decks + (b) + Hogging
7	Full load on decks + (c+) + Sagging
8	Full load on decks + (c+) + Hogging
9	Full load on decks + (d+) + Sagging
10	Full load on decks + (d+) + Hogging
11	Ballast Condition + (a+) + Hogging

- Finite element model of midship region selected between two main frames, 4.8m extension.
- SHELL181 elements for plates
- BEAM188 elements for stiffeners
- Load case 2 considered
- RIGID elements are employed on ends of the model
- 2 Materials are available (Mild Steel and HSS)

Material	Young's modulus (MPa)	Yield Strength (MPa)
Mild Steel	206000	235
High Strength Steel	206000	355



- **Midship Region Optimisation**

- 58 Design variables in total
  - 30 for representing plate thicknesses
  - 10 for stiffener geometry
  - 18 for stiffener spacing
- Constraints imposed

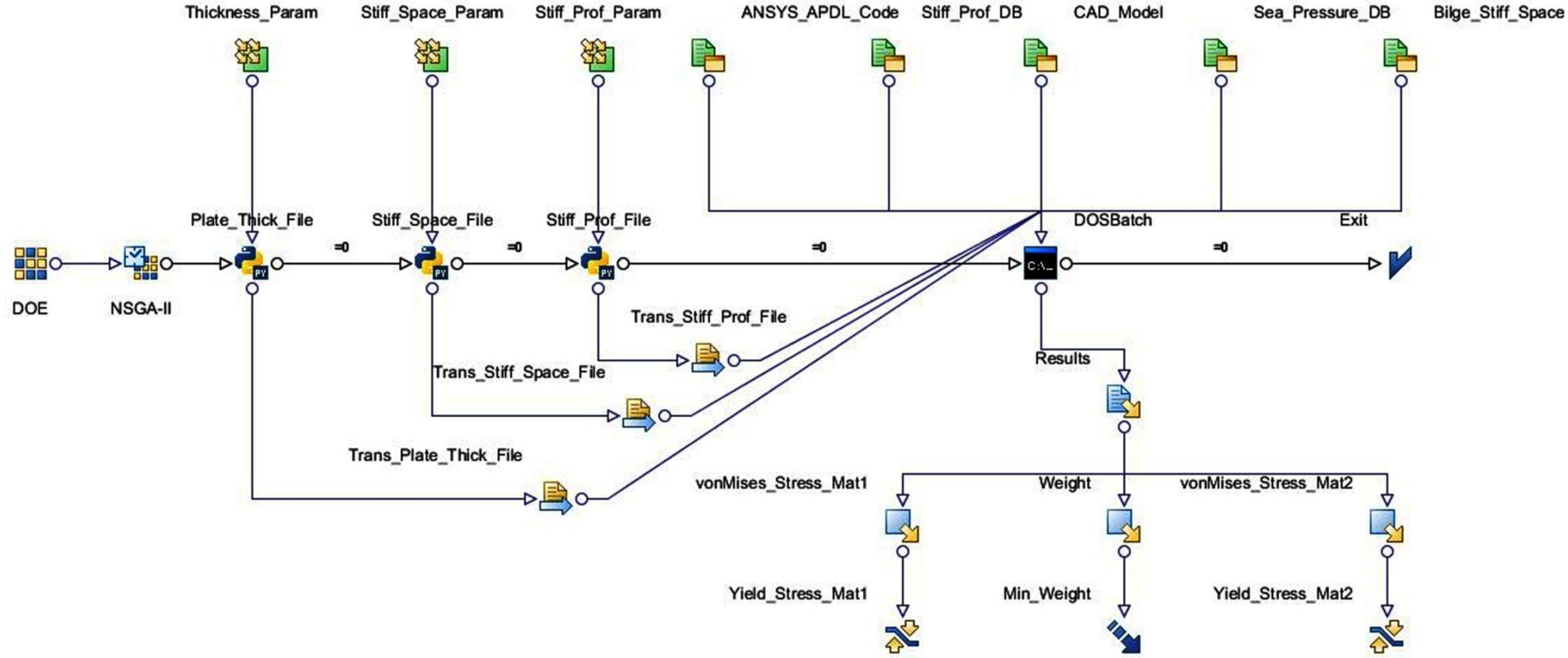
$$\begin{cases} 6\ mm \leq t_p \leq 17\ mm \\ 400\ mm \leq S_s \leq 700\ mm \end{cases}$$

- Stiffener geometry database available from shipyard
- Allowable stress values for the materials are calculated using the below equation (BV Rules NR467, Part B, Chapter 7, Section 3)

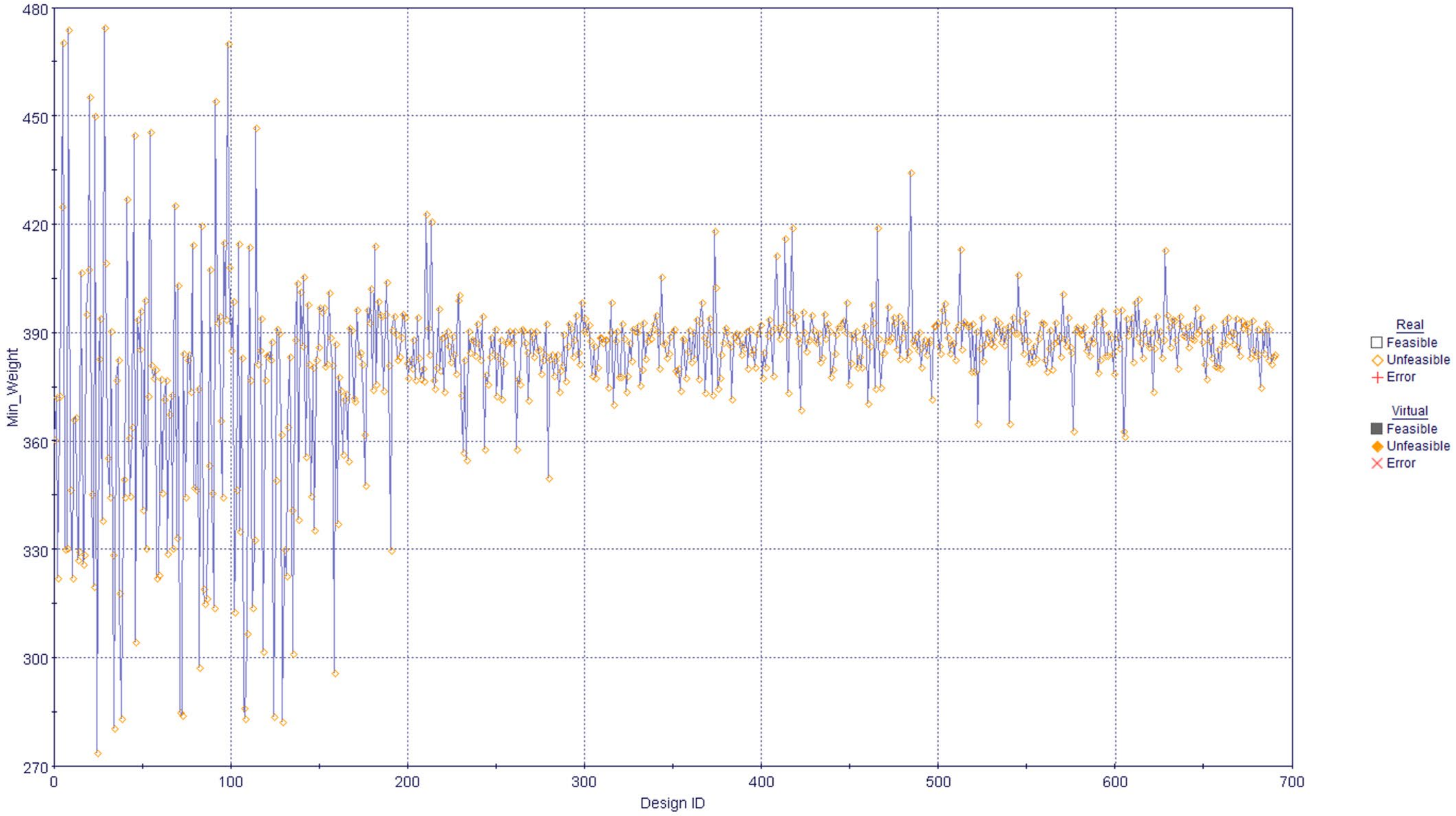
$$\sigma_{VM} = \frac{R_y}{\gamma_R \gamma_M}$$

- Resistance partial safety factor, $\gamma_R = 1.2$
- Material partial safety factor, $\gamma_M = 1.02$

- Midship structural optimisation loop

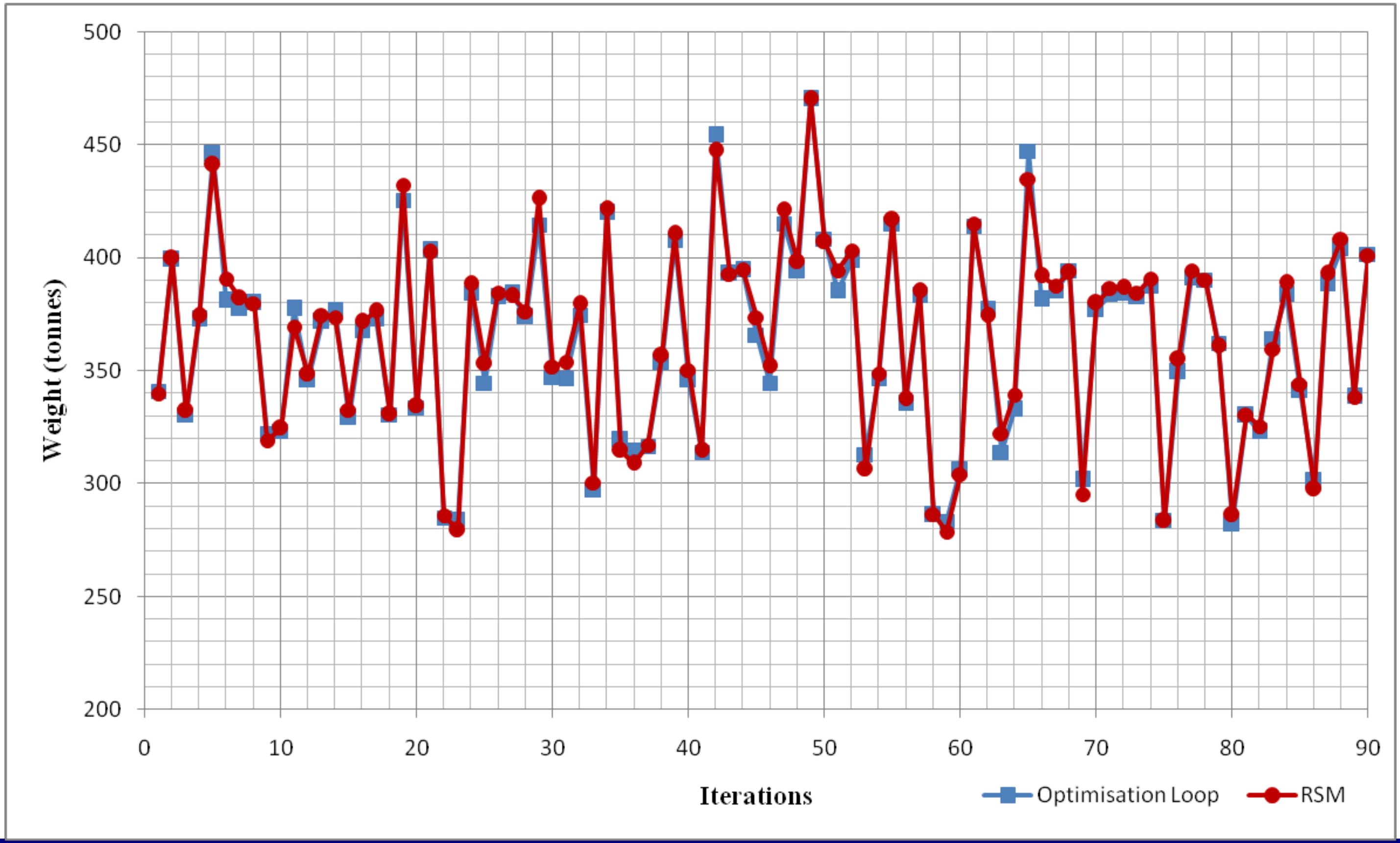


– Convergence history for **Objective** function (**Weight** of the midship region of Ro-Pax vessel)



Comparison of Results with RSM

$$W = 365.9242 + 4.3065*Y_1 + 8.4978*Y_3 + 18.1669*Y_5 + 2.3236*Y_6 + 21.1239*Y_8 + 3.3606*Y_{10} + 7.6034*Y_{11} - 2.3262*Y_{12} + 9.8896*Y_{13} + 3.5447*Y_{14} - 2.2277*Y_{15} + 3.8099*Y_{18} + 8.3646*Y_{19} + 4.6476*Y_{20} + 4.1471*Y_{23} - 4.007*Y_{24} + 24.7047*Y_{25} + 8.0861*Y_{26} - 2.3731*Y_{28} + 9.2455*Y_{31} + 1.9007*Y_{32} + 2.4002*Y_{33} + 16.3632*Y_{34} + 5.0619*Y_{35} + 7.6309*Y_{37} + 17.3196*Y_{38} + 10.2807*Y_{39} + 31.5779*Y_{40} - 29.7439*Y_{41}$$



- Optimisation convergence history shows the ability to couple ANSYS® and modeFRONTIER® for structural optimisation.
- Feasibility of an automated structural optimisation loop achieved.
- Significant reduction of structural weight is possible through the optimisation in early design stage.
- Parametric code developed using ANSYS® APDL can be applied to different kind of ships with slight modifications.
- Response surface method is a reliable tool to replace the existing optimisation loops to reduce the calculation time.

- Frame spacing can be considered as design variable
- A coupled tool between CAD, FEA and optimisation software
- Loads from CFD analyses instead of rule based loads
- Load case 2 considered. All identified load cases have to be included.


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