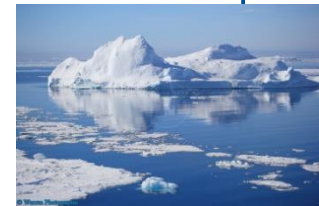


Structural Design and Optimization of an Ice Breaking Platform Supply Vessel

Juncheng Wang

Supervisor: Prof. Patrick Kaeding

- ▶ Opportunity
 - Territorial waters disputes
 - New business route
 - Energy treasure
- ▶ Challenge
 - Multi-year ice load
 - Low temperature
 - Economical efficiency
 - Lighter
 - Cheaper
 - ...

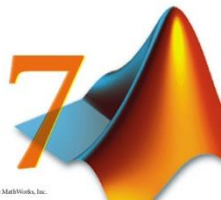


- ▶ Rule-based structural design, polar class PC2, PC4 and PC6
- ▶ Structural optimization considering weight
- ▶ Structural optimization taking production into account
- ▶ Weight assessment for proposal design
- ▶ Rules Calc approval
- ▶ FEM approval

Lloyd's
Register



MATLAB®
The Language of Technical Computing

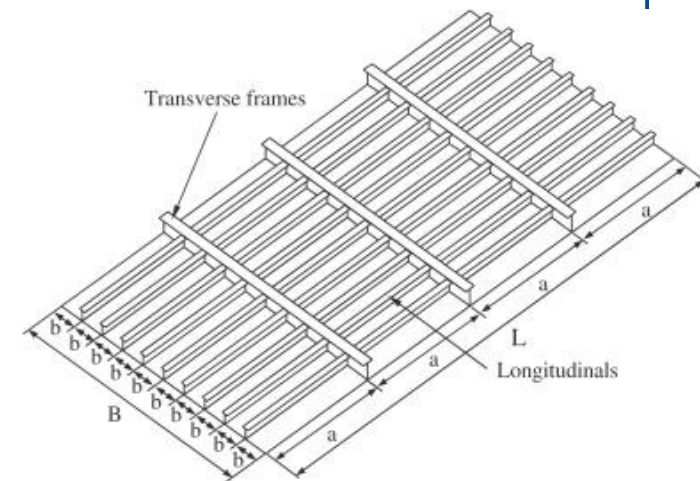
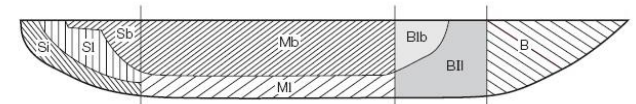
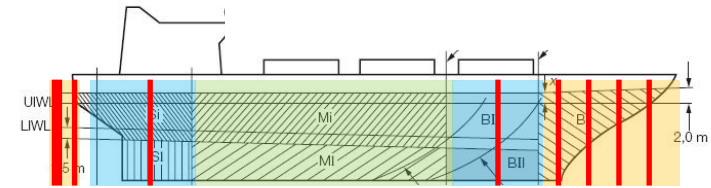


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ANSYS®

Process for polar class ships design

- ▶ Rules
 - Ship structures (General)
 - General cargo ships
 - Offshore supply vessels
 - Polar class
- ▶ Ice load patch & Ice belt
- ▶ Other structure
- ▶ Global strength
- ▶ Corrosion and material
- ▶ Additional:
 - Analytical method (buckling)
 - Plastic design theory (FEM)



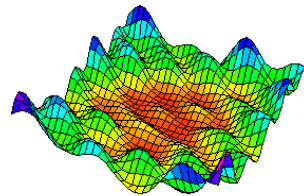
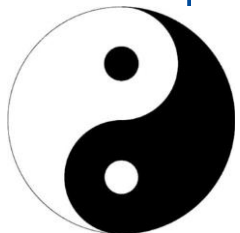
4C Optimization method for panel

4C method

- ▶ **C**riteria
Average thickness, t_{ave}
- ▶ **C**onstraints
Rules + experience
- ▶ **C**onnection
Stiffeners + Primary elements
- ▶ **C**atalog
Rules + Shipyard documents

Advantages

- ▶ Practical
- ▶ Flexible
- ▶ Modularized
- ▶ Globally arrival



Optimization process



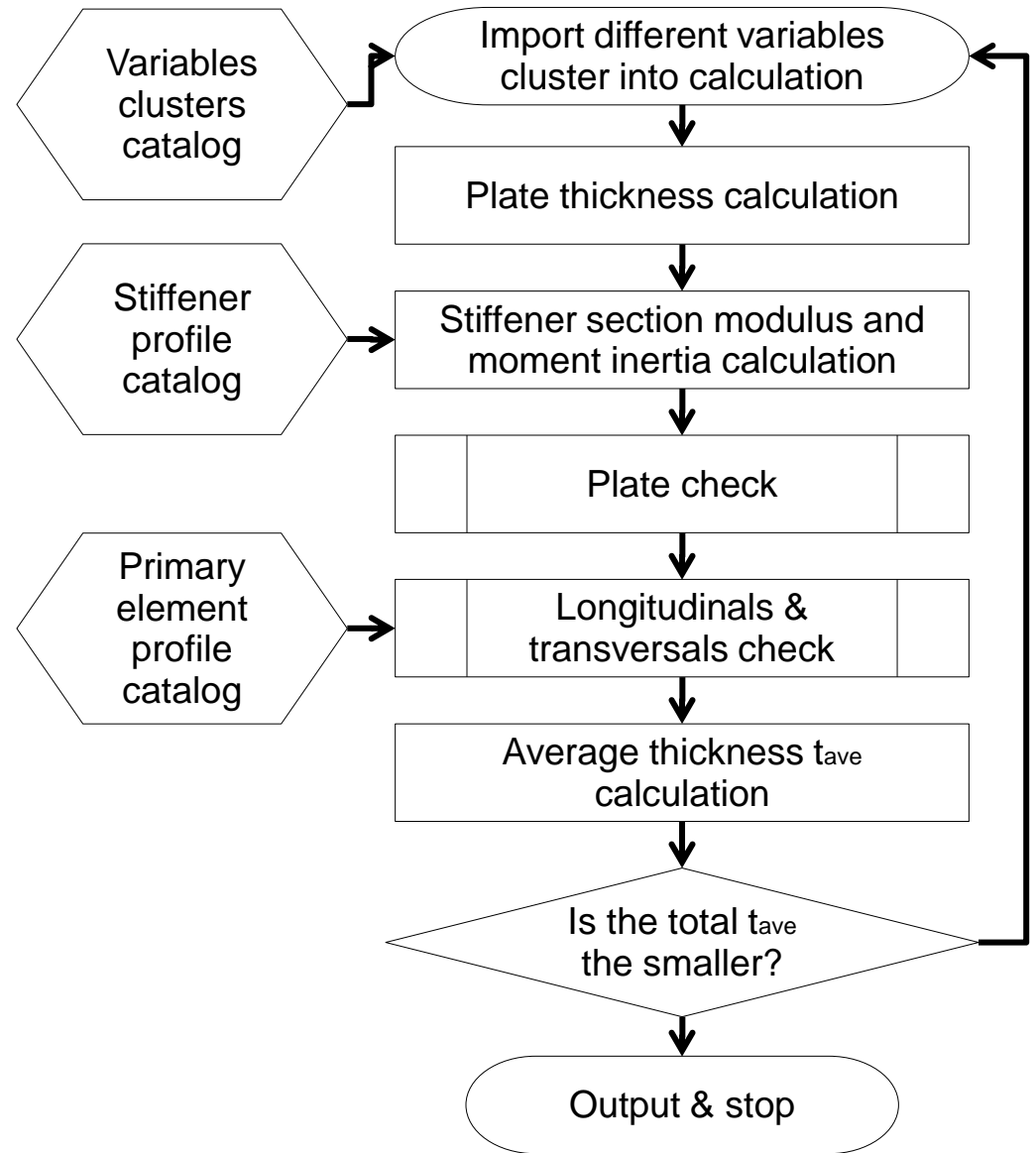
Find main parameters

Define primary variables & constrains

Analyze the effect of variables

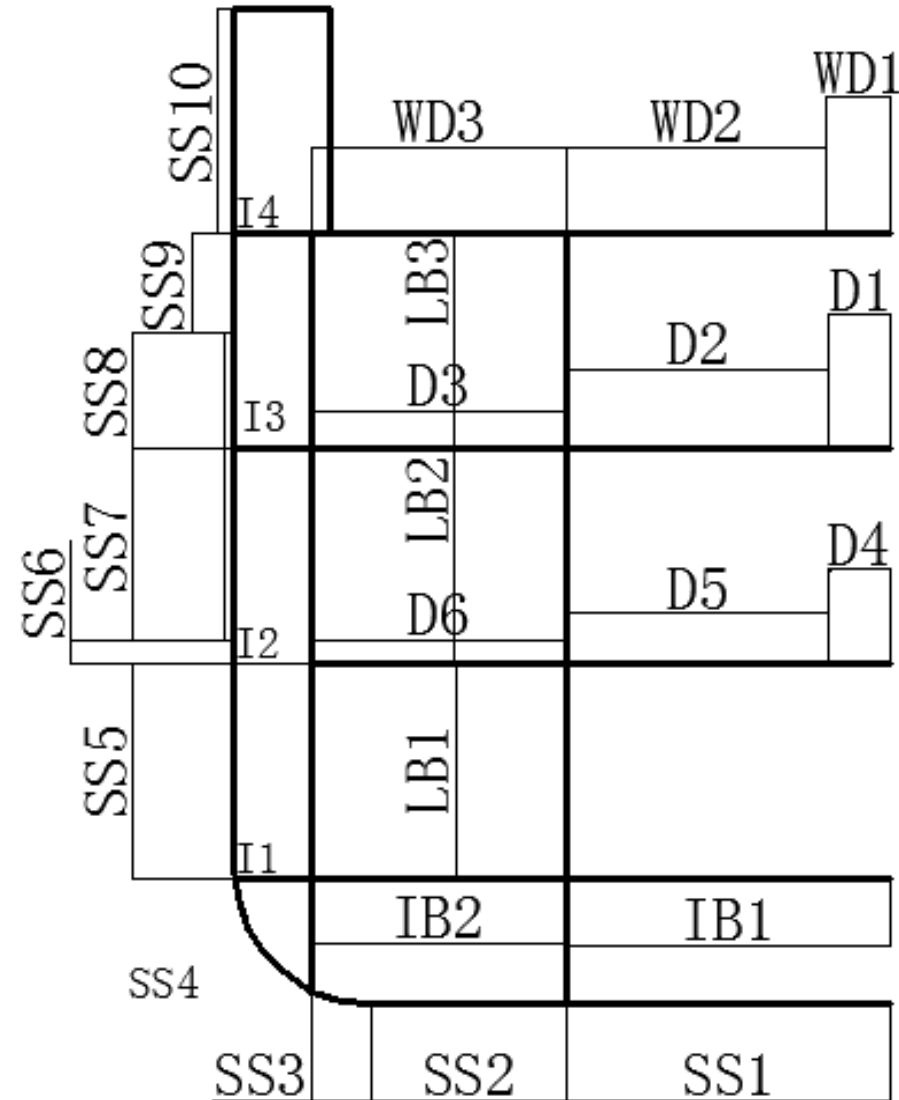
Select reasonable variable range

Global bending moment



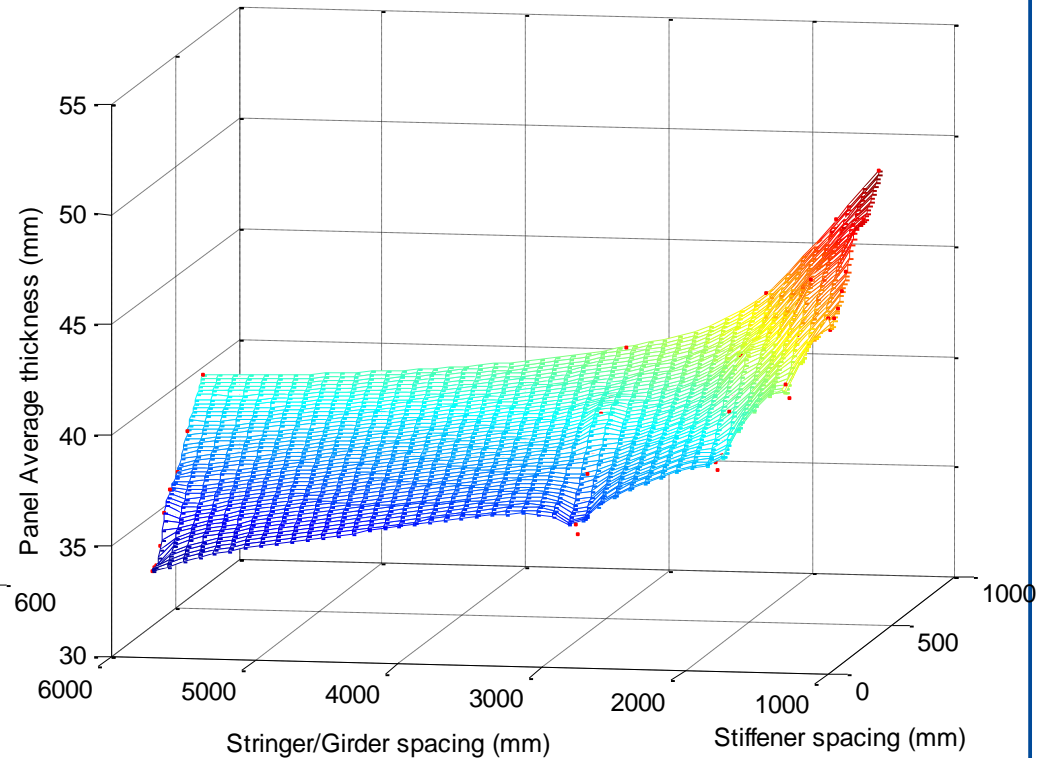
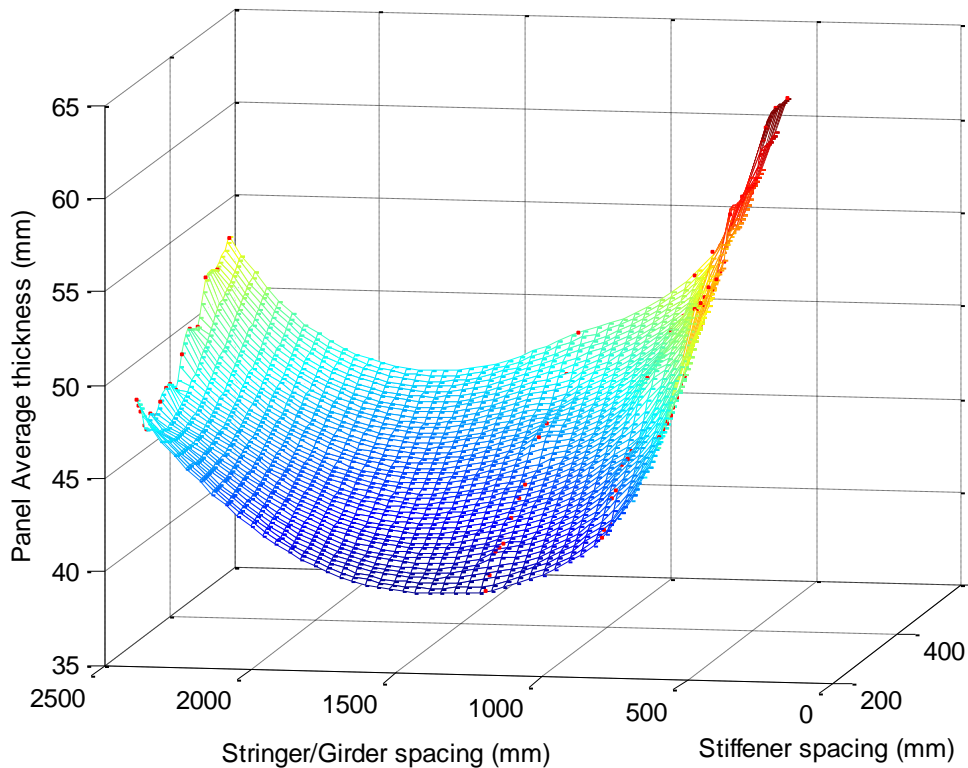
Panel based optimization

- ▶ Midbody & Intermediate
- ▶ Sort of panels
 - Shell
 - Deck
 - Longitudinal bulkhead
 - Transversal bulkhead
- ▶ Primary parameters Opt.
- ▶ Secondary parameters Opt
 - Plate
 - Stiffener
 - Bracket



Stiffening method

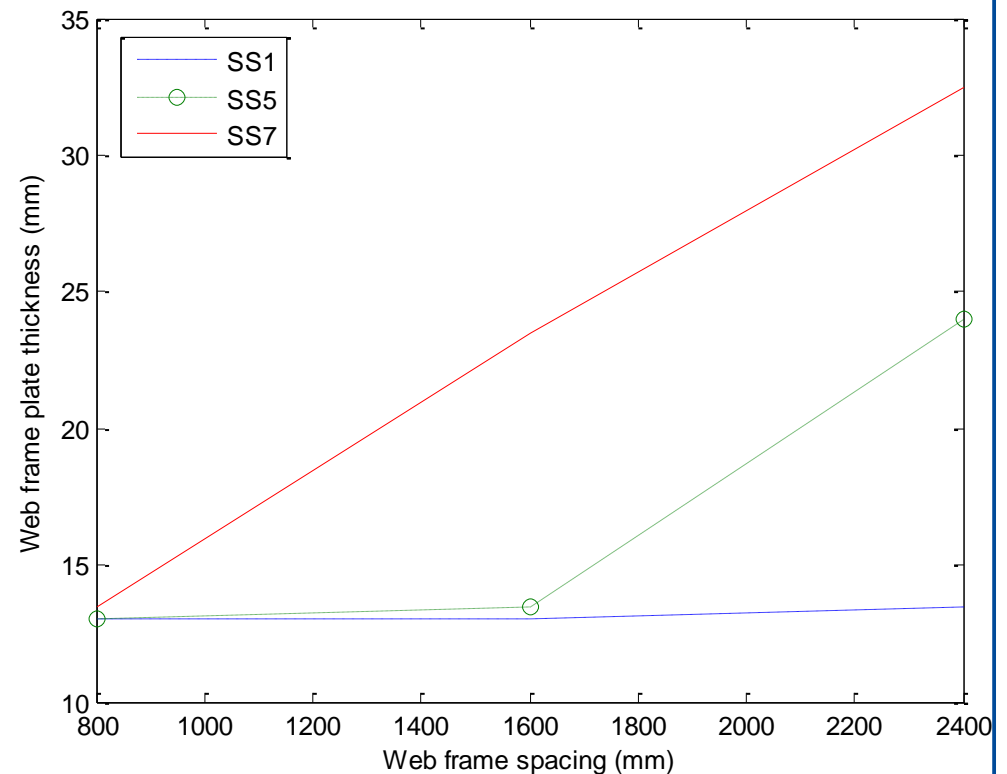
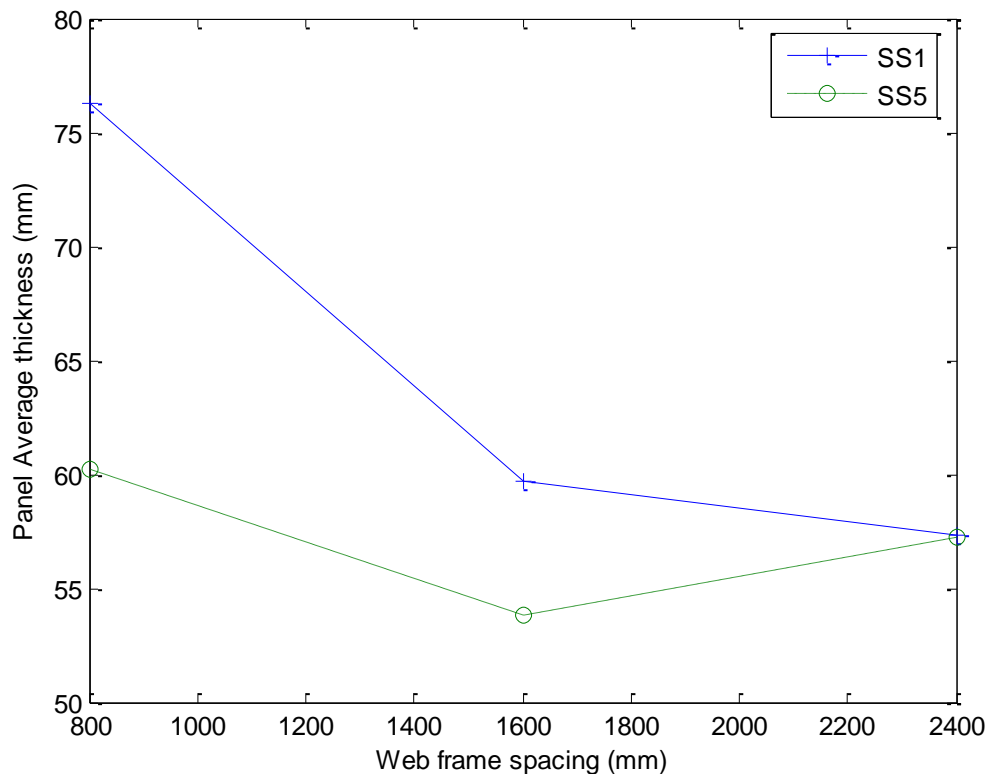
- ▶ Transversal stiffening is more weight effective
 - Compressive load
 - Shape of ice load patch



Web frame spacing

Bigger web frame spacing

- ▶ Bottom: effective
- ▶ Side shell: higher t_{ave} and welding complexity

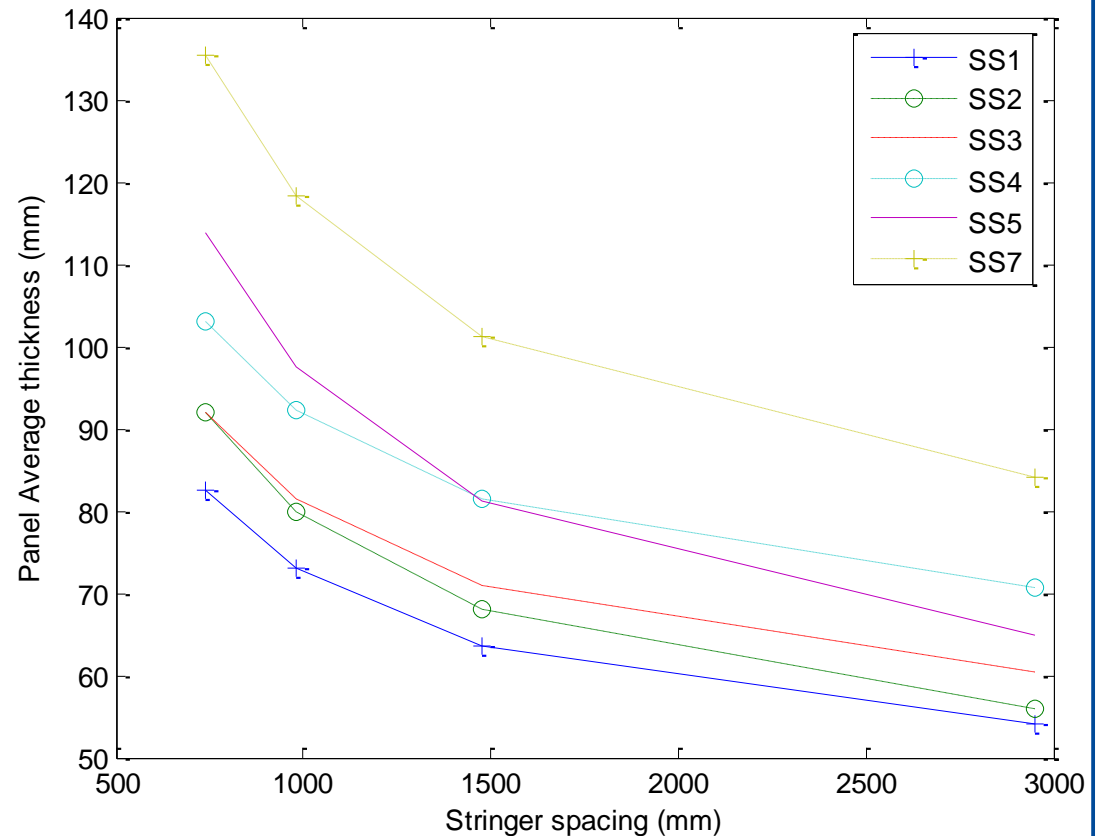


Stringer spacing

- ▶ Bigger spacing is more effective
 - Shape of ice load patch
 - Geometrical limitation due to GA



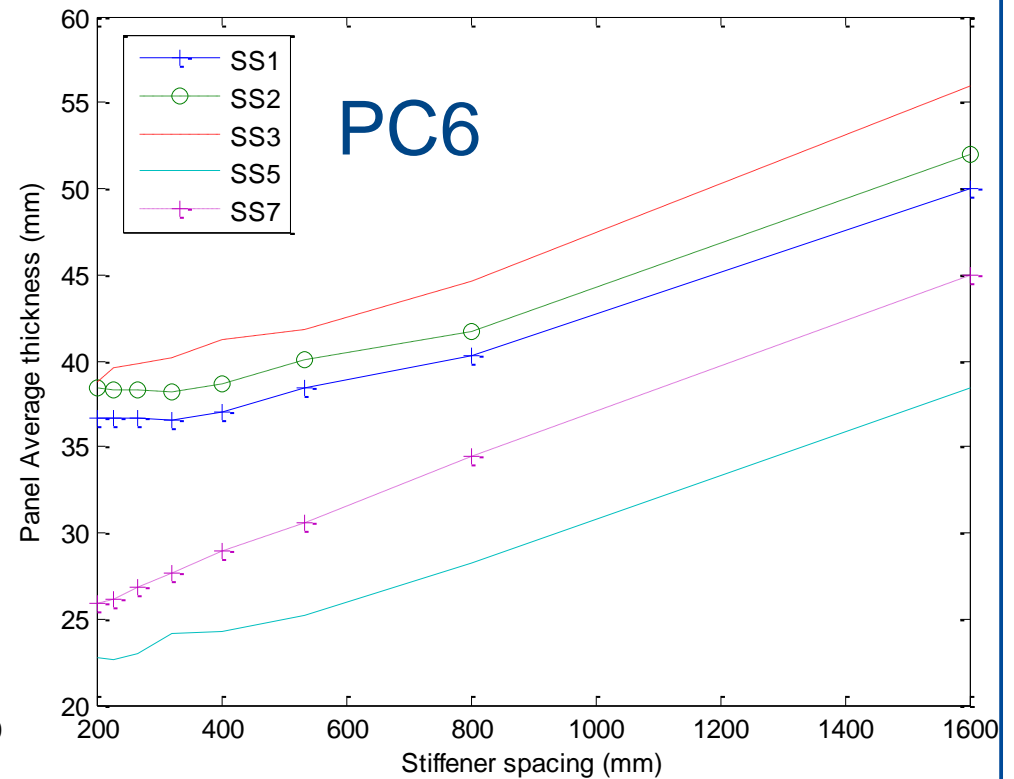
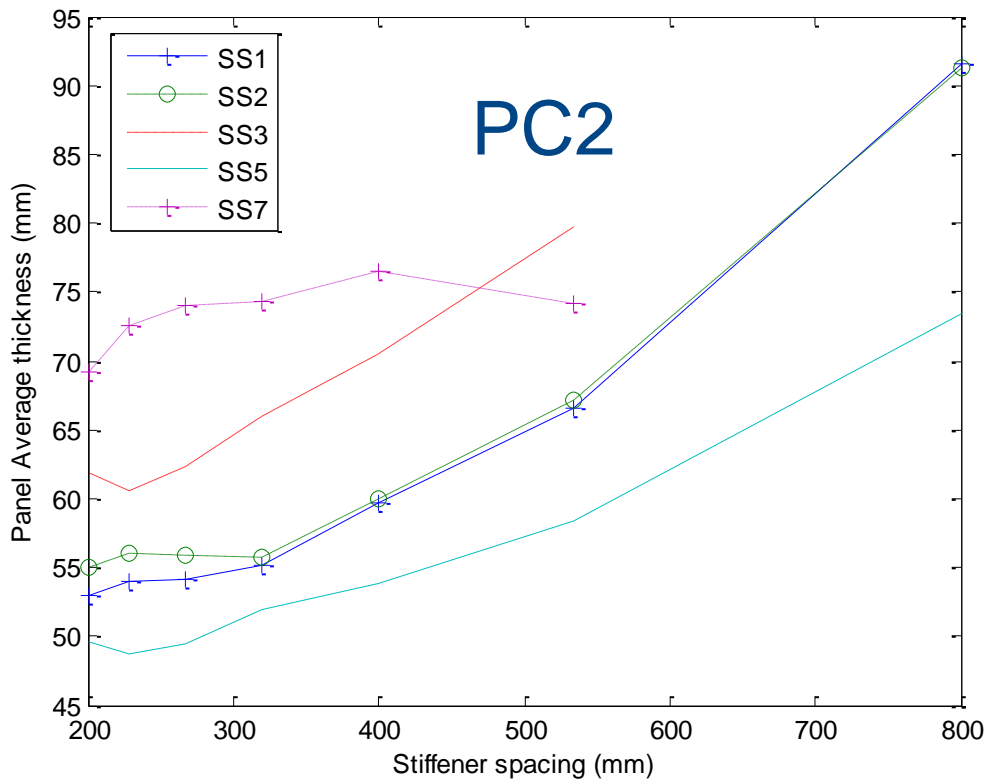
PC2: 3.12 * 0.86 m



Stiffener spacing (1/3)

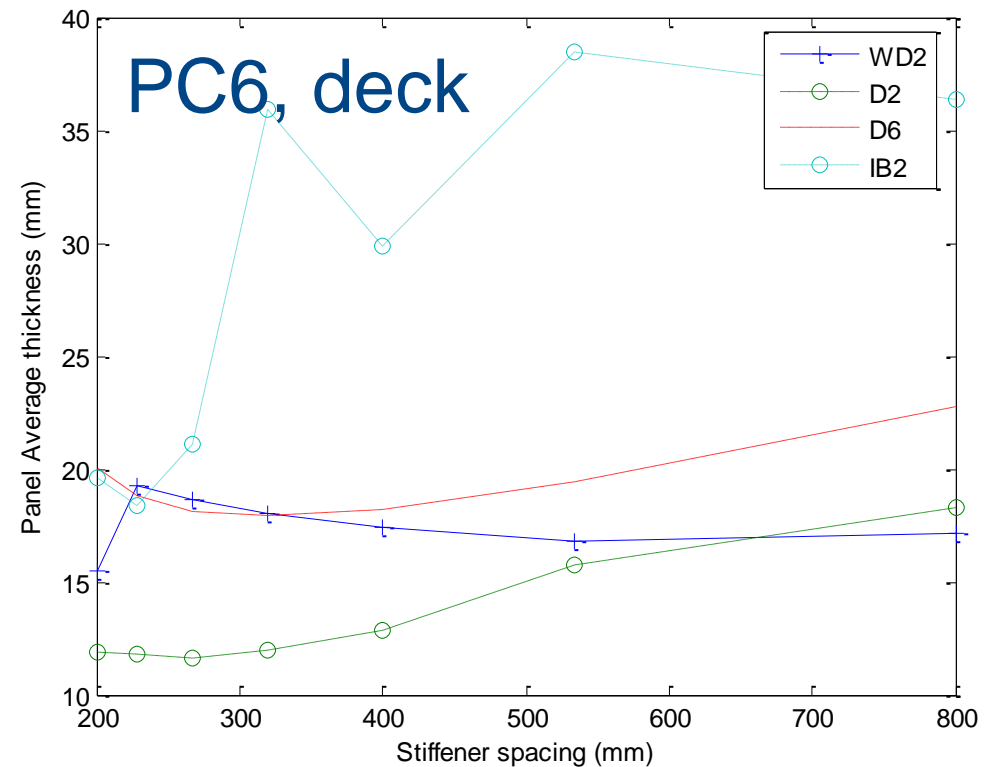
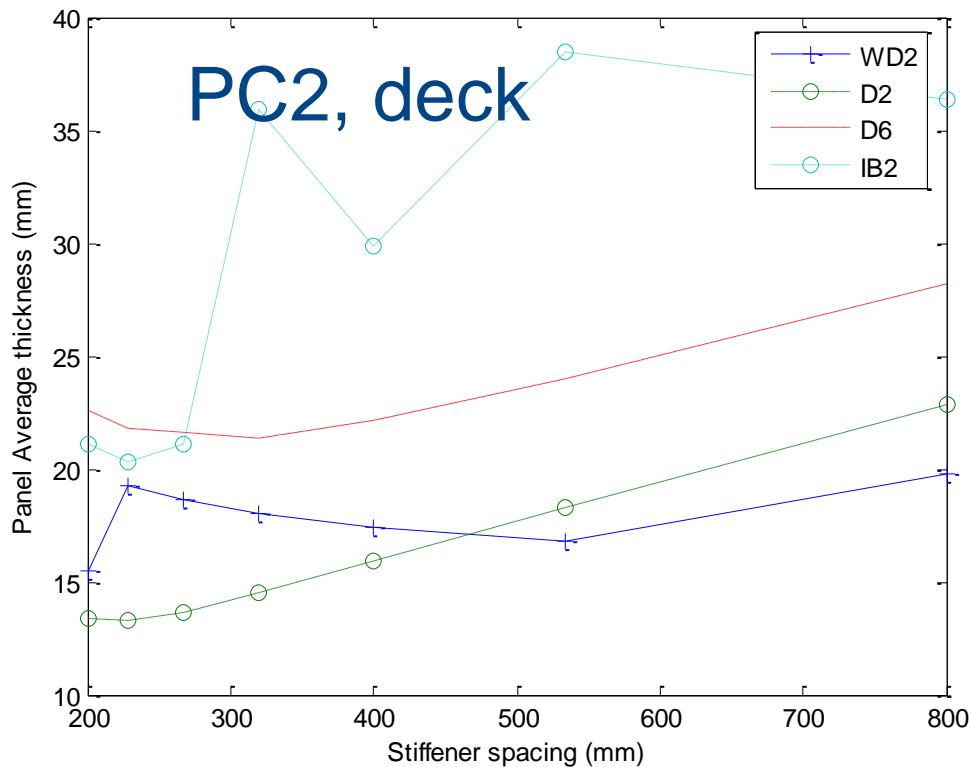
► Panels at shell

- PC2-6: Smaller spacing, smaller t_{ave} , bigger peak pressure
- PC2→6: Milder tendency, lower weight



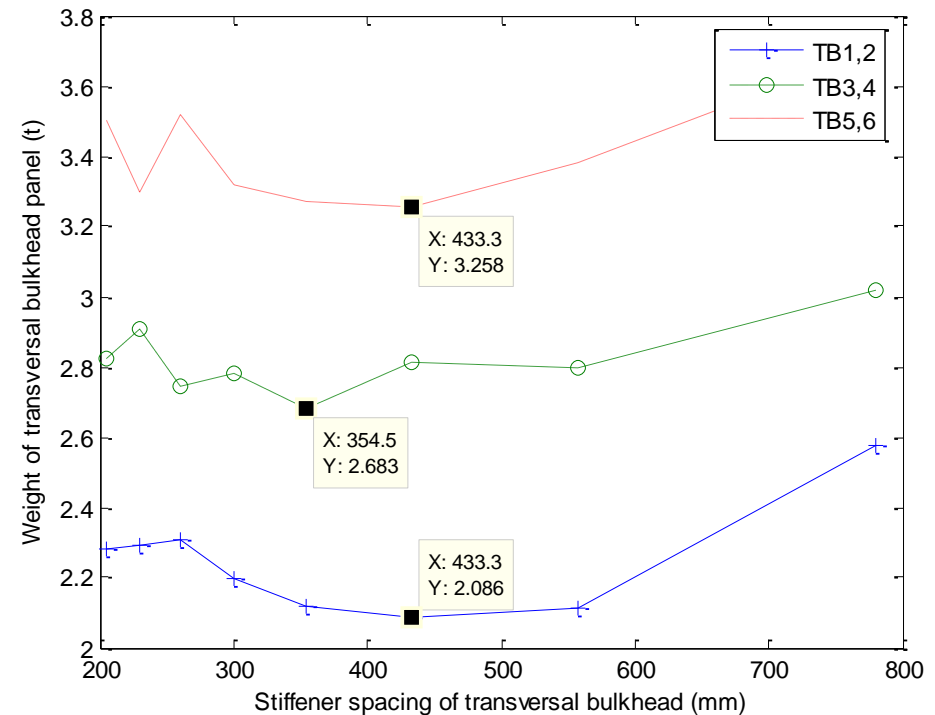
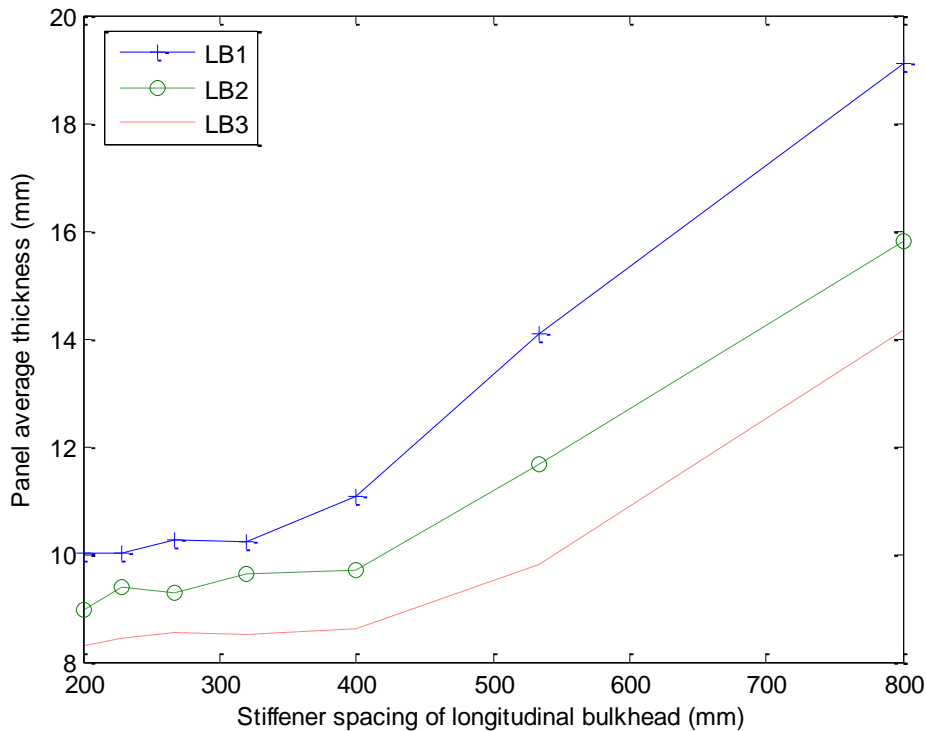
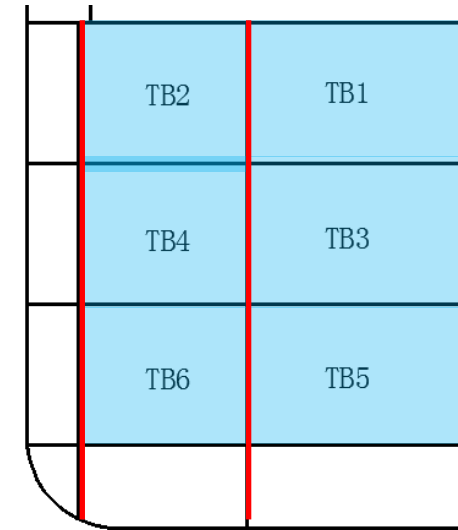
Stiffener spacing (2/3)

- ▶ Panels at deck
 - Compressive load is critical sometimes
 - Plate thickness is more sensitive
 - Minimum solution various



Stiffener spacing (3/3)

- ▶ Longitudinal bulkhead
 - Similar with shell panels
- ▶ Transversal bulkhead
 - Minimum in the middle



► Factors/Modulus

- Total part number – Each panel
- Total welding length – Each panel
- Other customized parameter

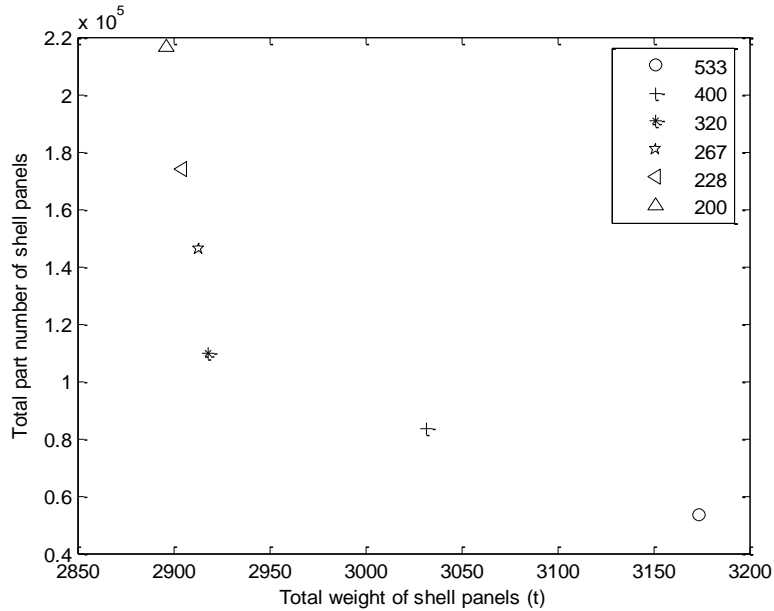
► Criteria

- Pareto Frontier diagram
- Weight of cost (vertical coordinate)& structural weight (horizontal coordinate)

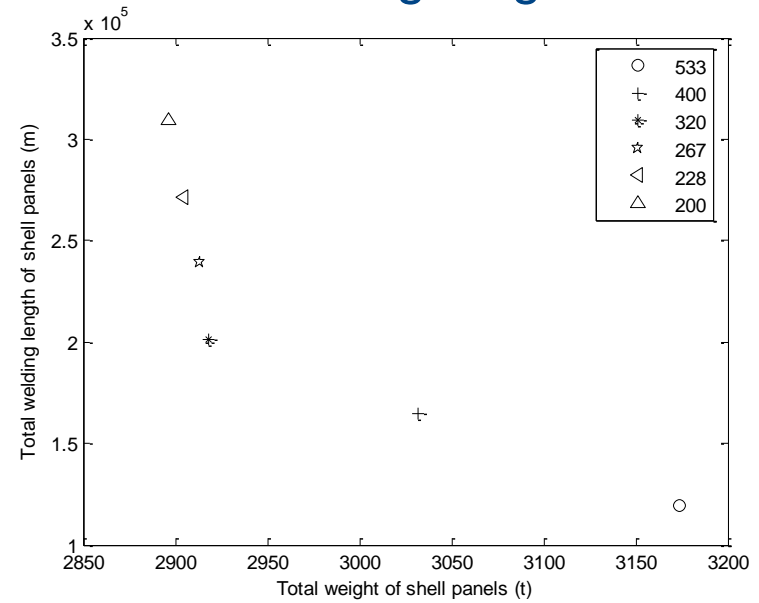
Cost optimization – Midbody

Shell

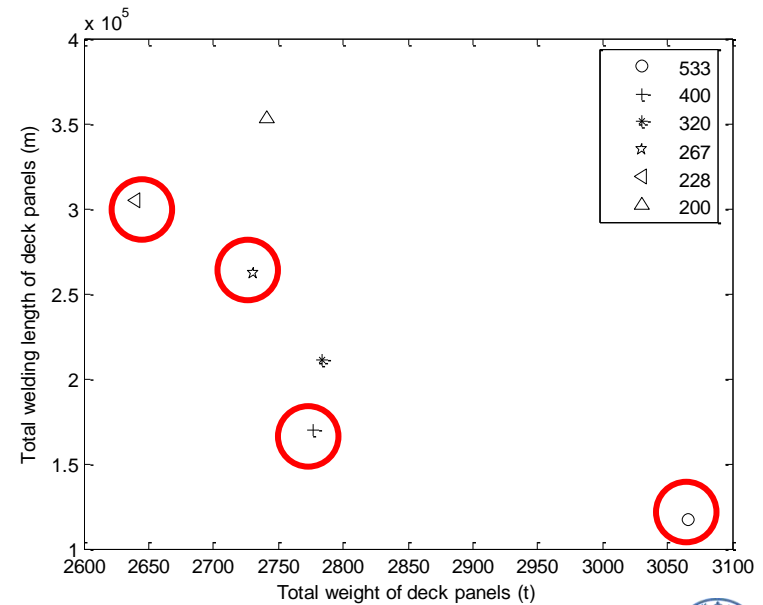
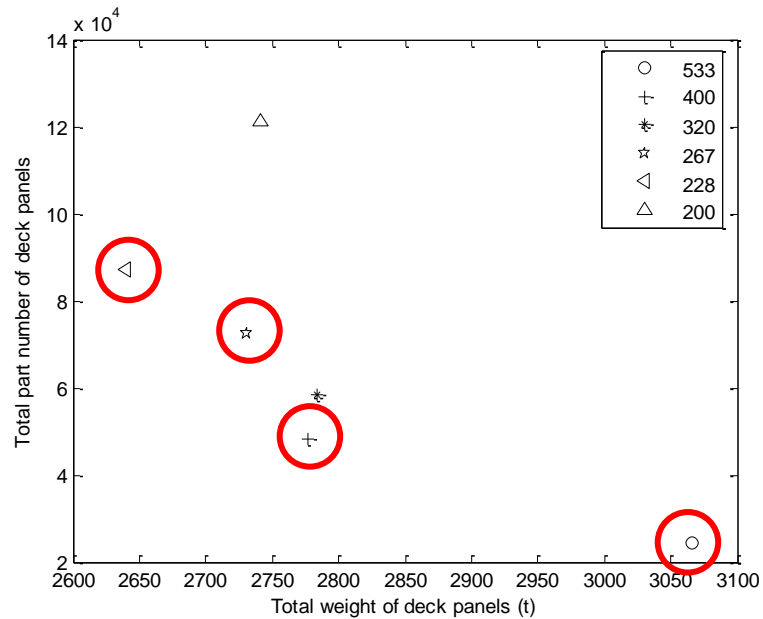
Part number



Welding length

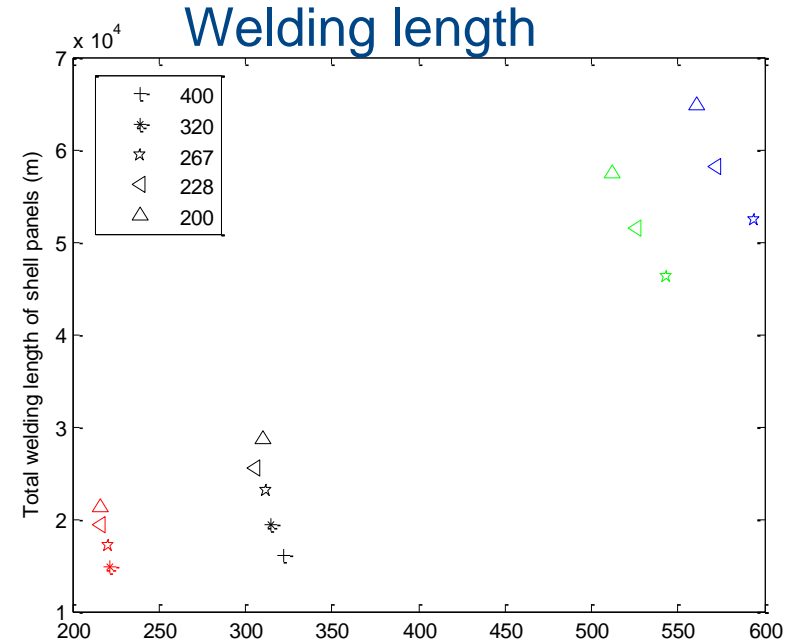
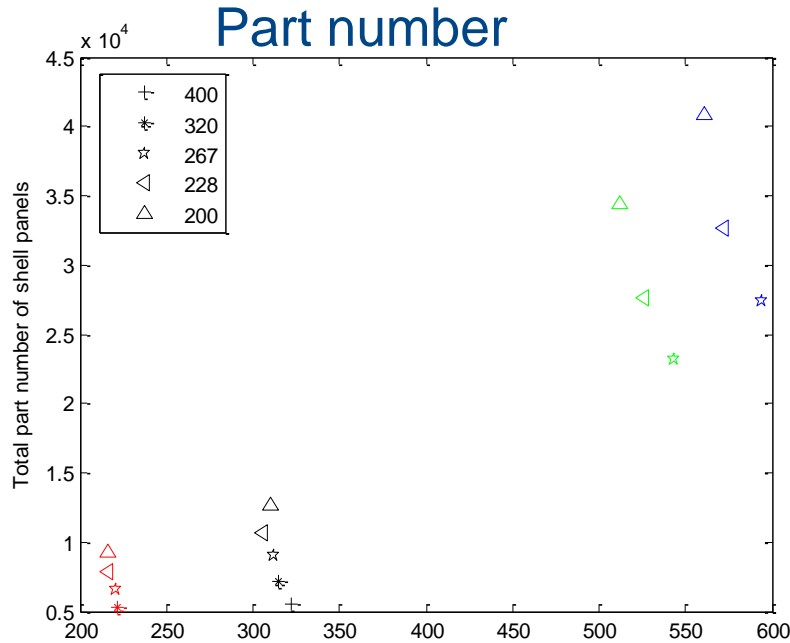


Deck

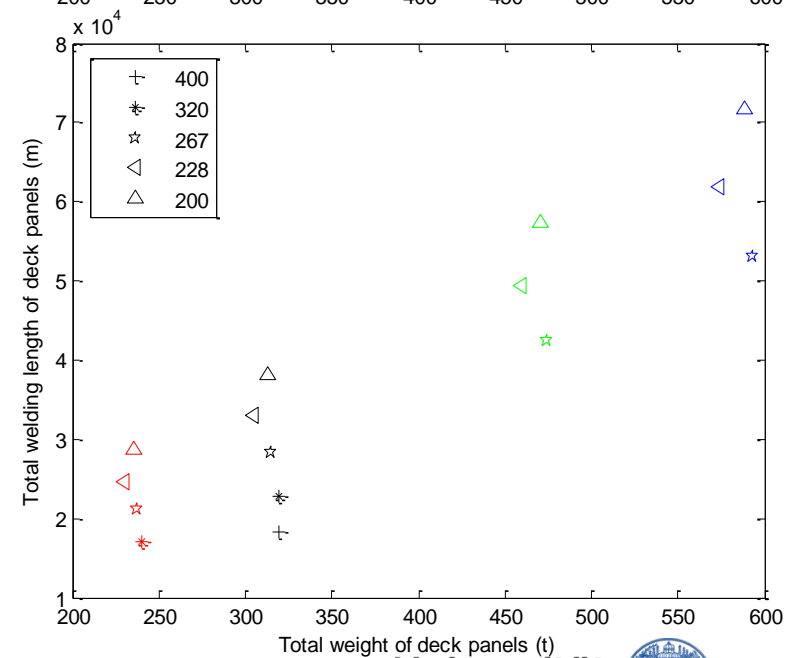
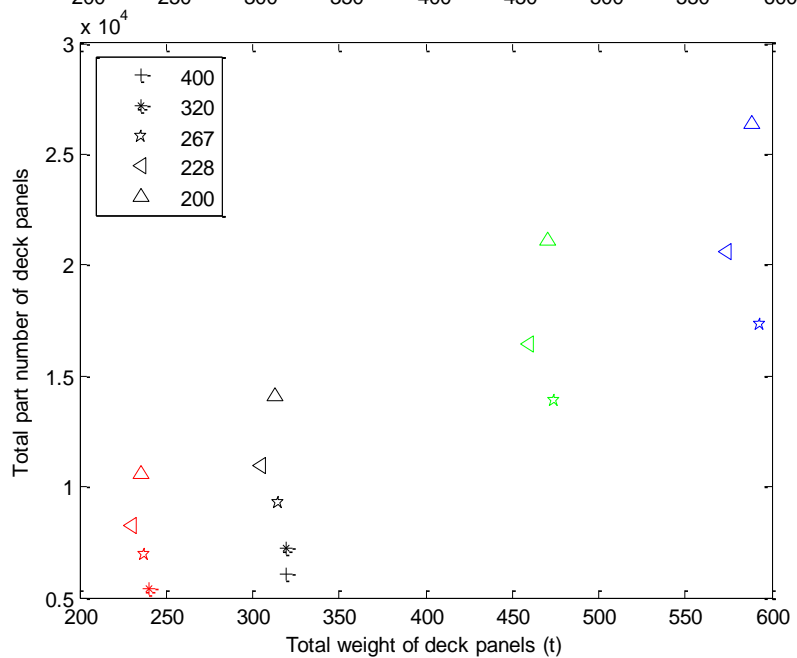


Cost optimization – Intermediate

Shell

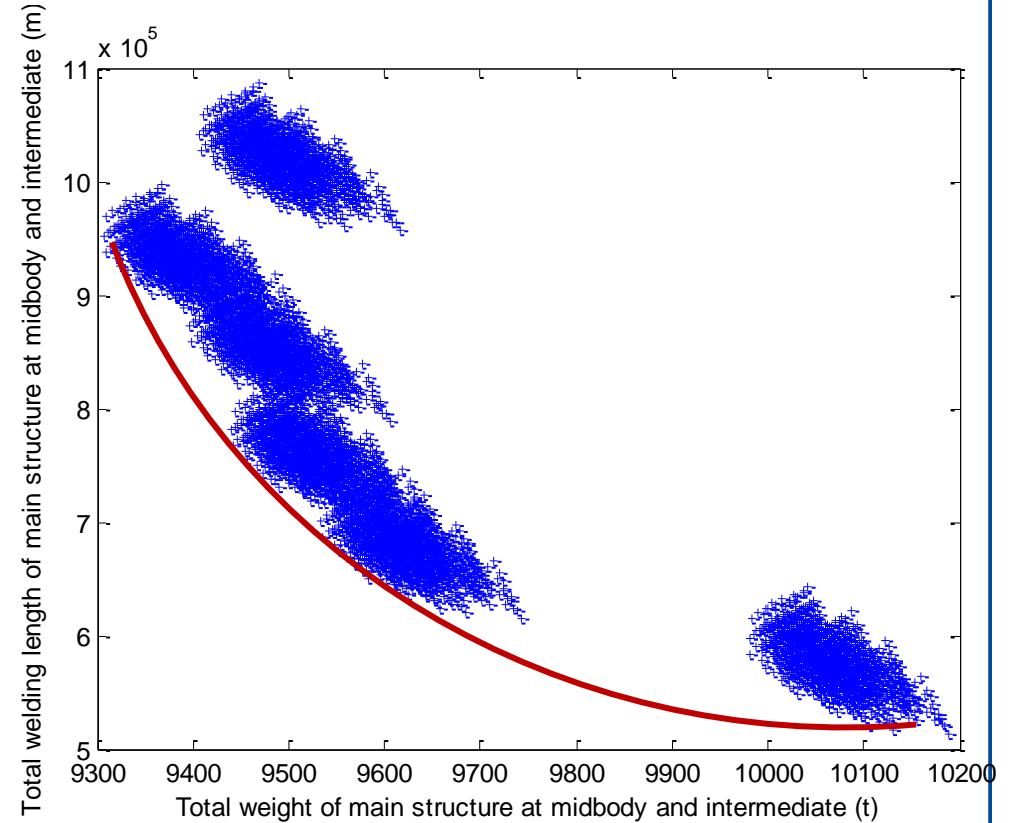
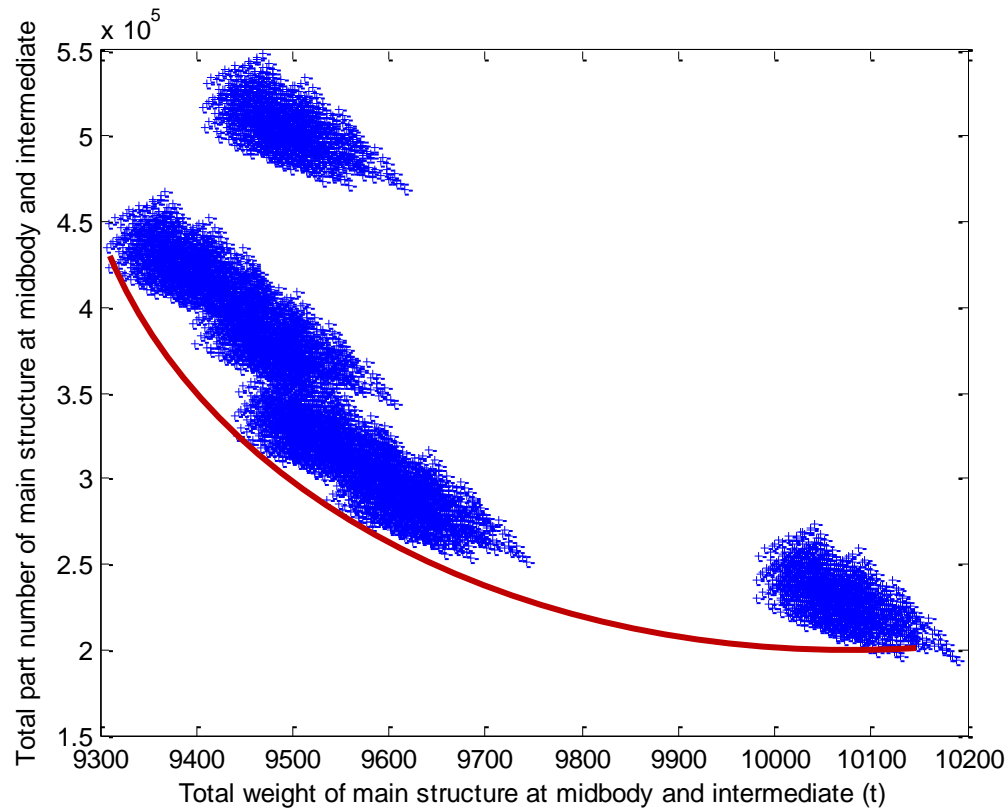


Deck

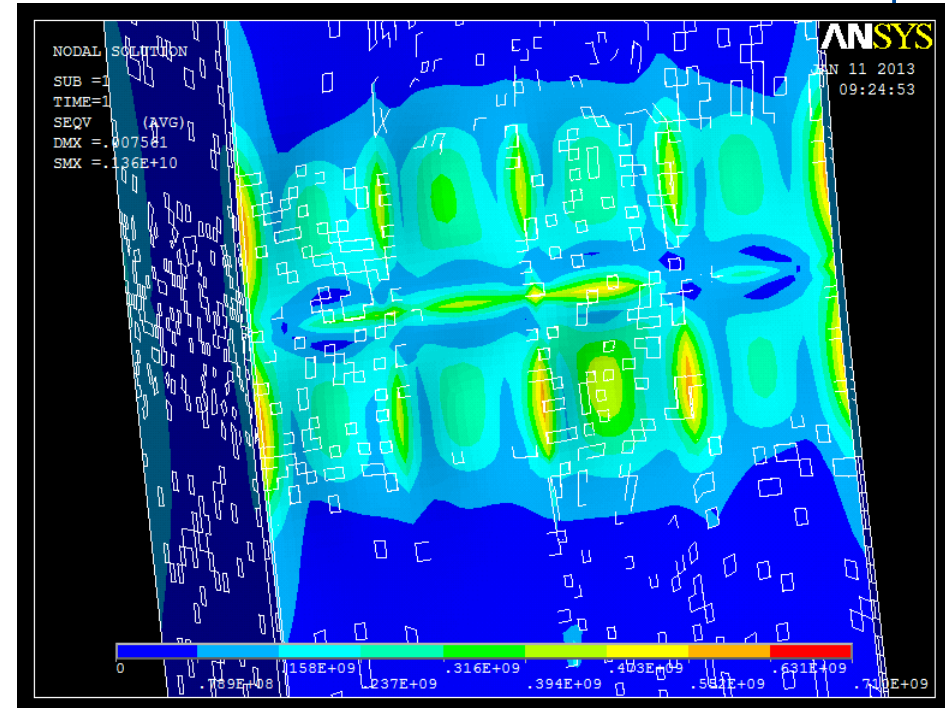
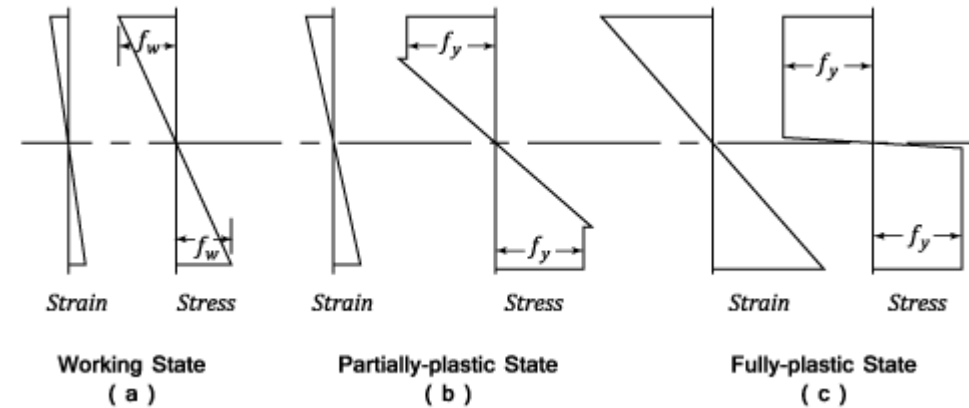







Cost optimization – Midbody+Intermediate

- ▶ Overall optimization (>2,800)
 - Compressive load is critical
 - Best solution could be in the middle



- ▶ Rules Calc
 - Partially rules' check
- ▶ FEM
 - Plastic hinge theory
 - Elastic FEM
 - Result transfer



- ▶ Transversal structure 
- ▶ Less stringer 
- ▶ Bigger web frame spacing 
- ▶ Global strength is not a problem 
- ▶ Reduce stiffener spacing 
- ▶ Cost optimization can be improved