Yun-Tzu Huang

6th EMship cycle: October 2015 – February 2017

Master Thesis

Hull Structural Safety Assessment of Aged Non-ice Class Container Vessels in an Arctic Operation

Supervisor: Professor Zbigniew Sekulski, West Pomeranian University of Technology, Szczecin, Poland
Internship tutor: Professor Jeom-Kee Paik , National Busan University, Busan, Korea
Reviewer: Professor Hervé Le Sourne, ICAM, Nantes, France

Szczecin, February 2017

Contents:

Internship in KOSORI
(The Korea Ship and Offshore Research Institute)


Vertical Type Fire Test


Horizontal Type Fire Test


Indoor Fire System Test


Fire Bucking Collapse Test


Large Scale Structural Failure Test


Dropped Object Test


Blast Wall / Door / Window Test

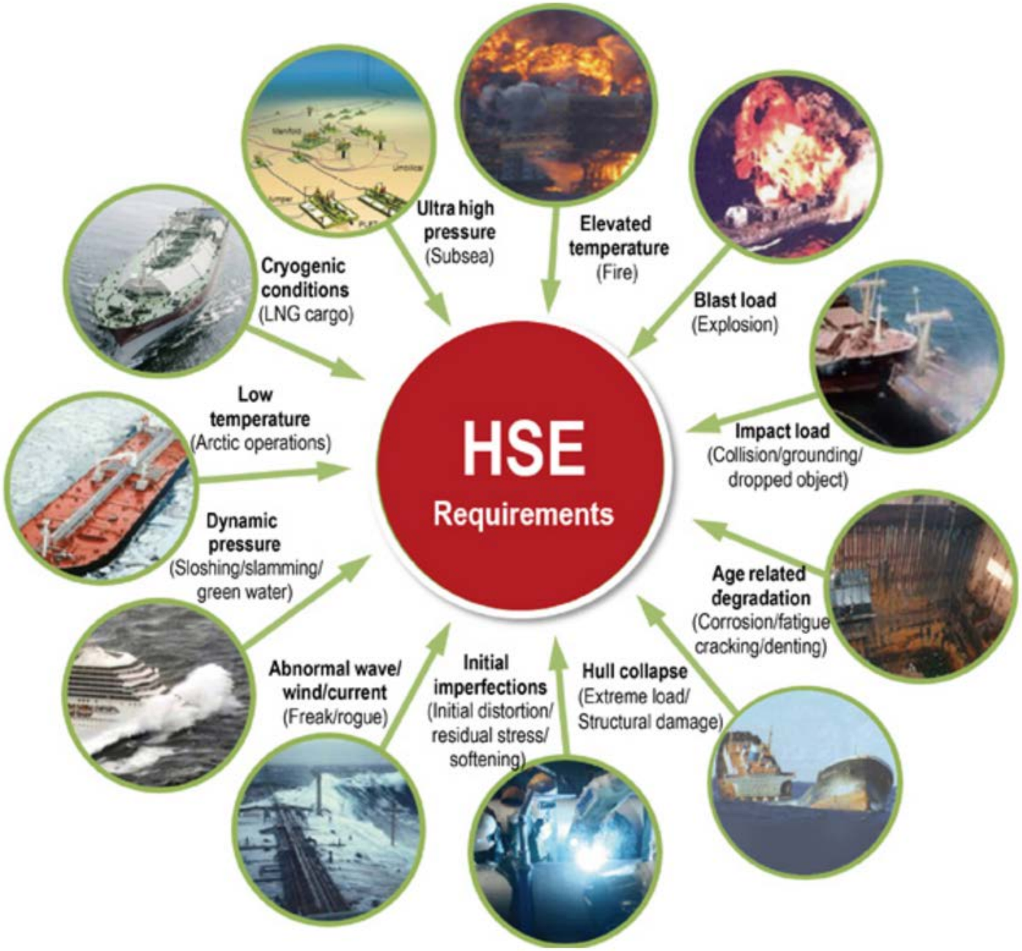

Outdoor Fire / Explosion Test


High Speed Impact Test


Pulse Pressure Loading Rig


Subsea Hyperbaric Pressure Test

Internship in KOSORI
(The Korea Ship and Offshore Research Institute)

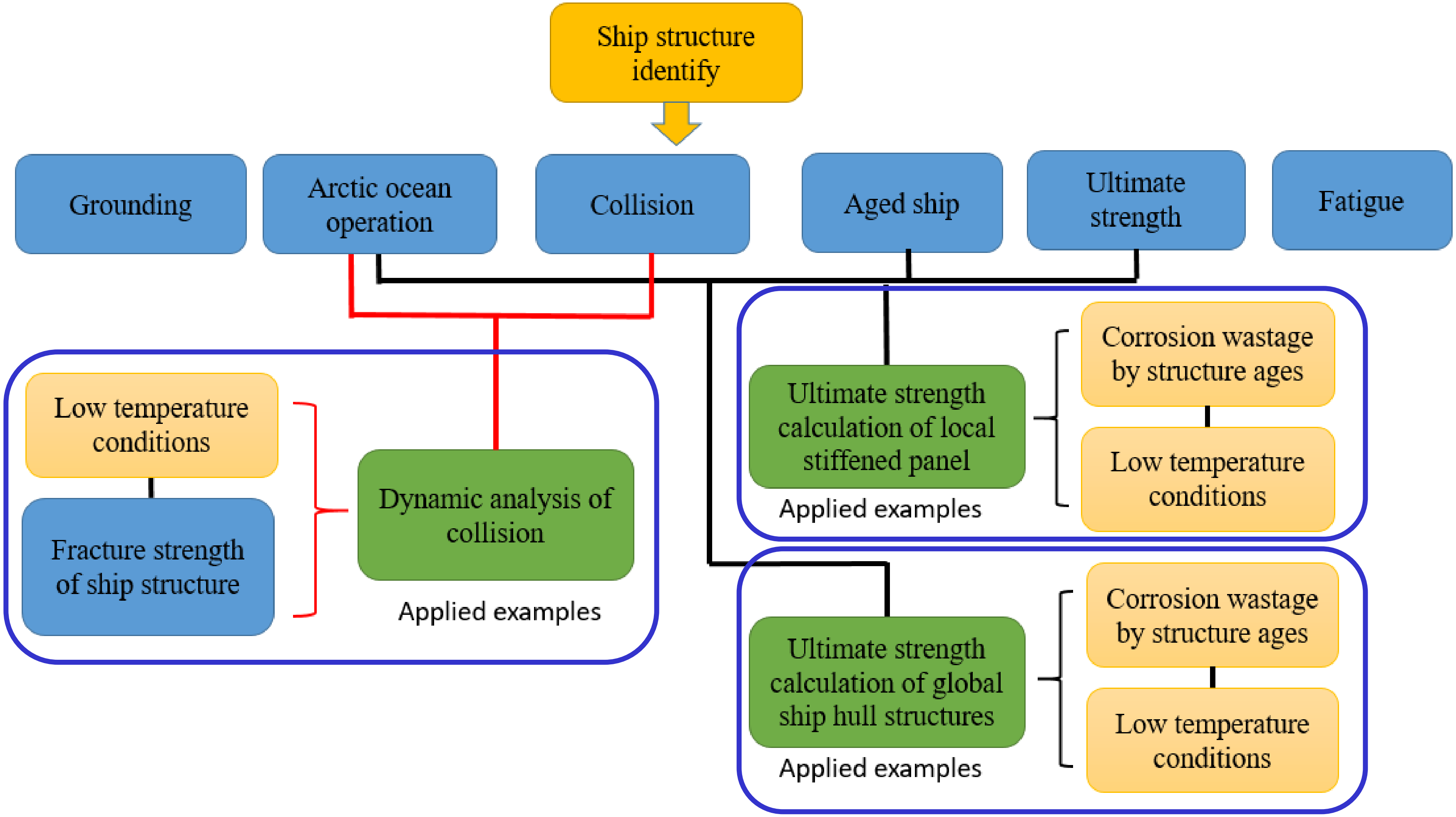


- ✓ Extreme and accidental conditions
- ✓ Welding induced high temperature causing initial
- ✓ Imperfections (e.g., initial distortions, residual stress or softening in the heat-affected zones of welded aluminum structures)
- ✓ Abnormal waves/winds/currents
- ✓ Dynamic pressure loads arising from sloshing,
- ✓ Slamming or green water; low temperature in Arctic operations
- ✓ Cryogenic conditions resulting from liquefied natural gas cargo; ultra-high pressure in ultra-deep waters; elevated temperature due to fire
- ✓ Blast loads due to explosion
- ✓ Impact loads associated with collision, grounding or dropped objects
- ✓ Age-related degradation such as corrosion, fatigue cracking and local denting damage
- ✓ Hull girder collapse or sinking

Introduction

- Global warming phenomenon affect
- Resources and operating in Northern Sea Routes (NSR)
- Safety of aged large container hull structures under low temperatures

Hull Structure Safety Assessment and Applied Analysis


Ship structure identify

Grounding

Arctic ocean operation

Collision

Aged ship

Ultimate strength

Fatigue

Low temperature conditions

Fracture strength of ship structure

Dynamic analysis of collision

Applied examples

Ultimate strength calculation of local stiffened panel

Corrosion wastage by structure ages

Low temperature conditions

Applied examples

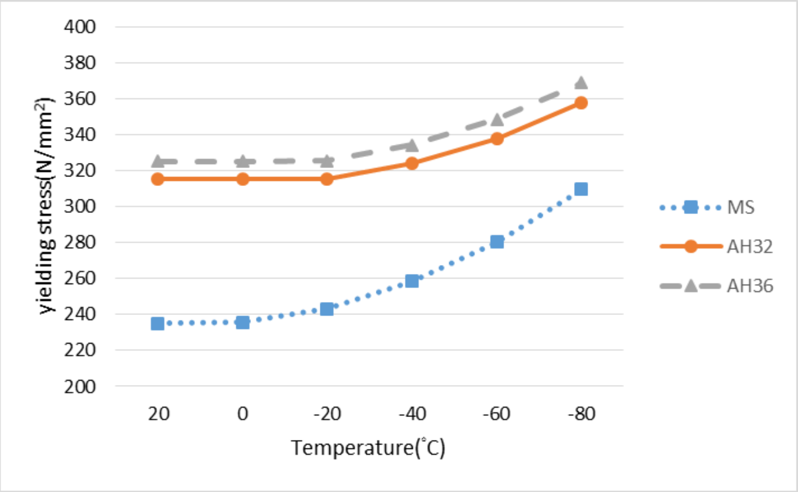
Ultimate strength calculation of global ship hull structures

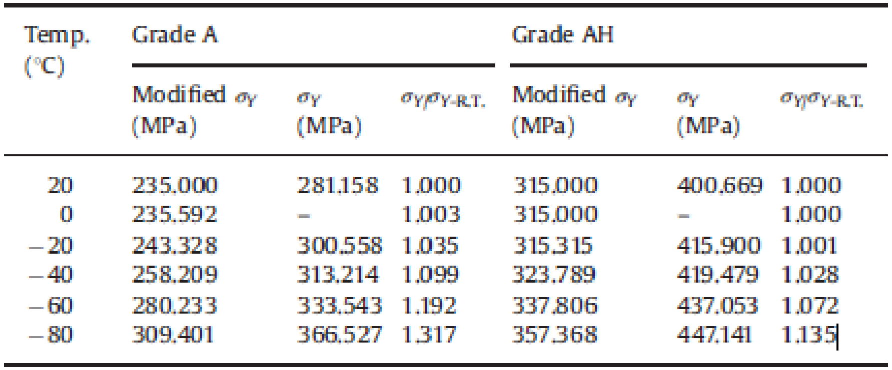
Corrosion wastage by structure ages

Low temperature conditions

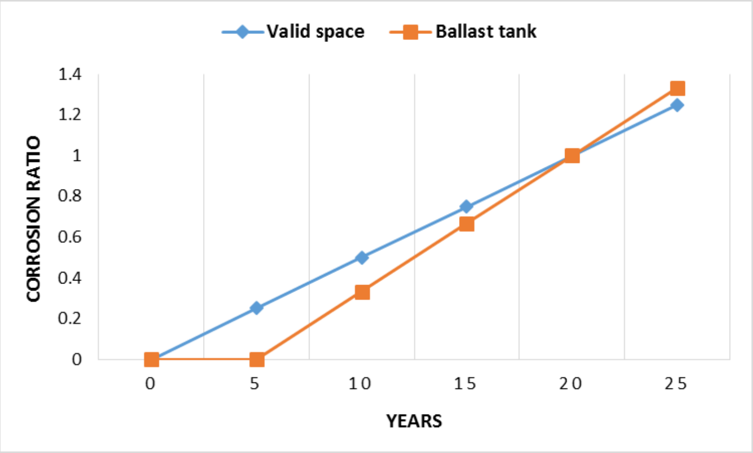
Applied examples

Considerations of Material and Corrosion Wastage





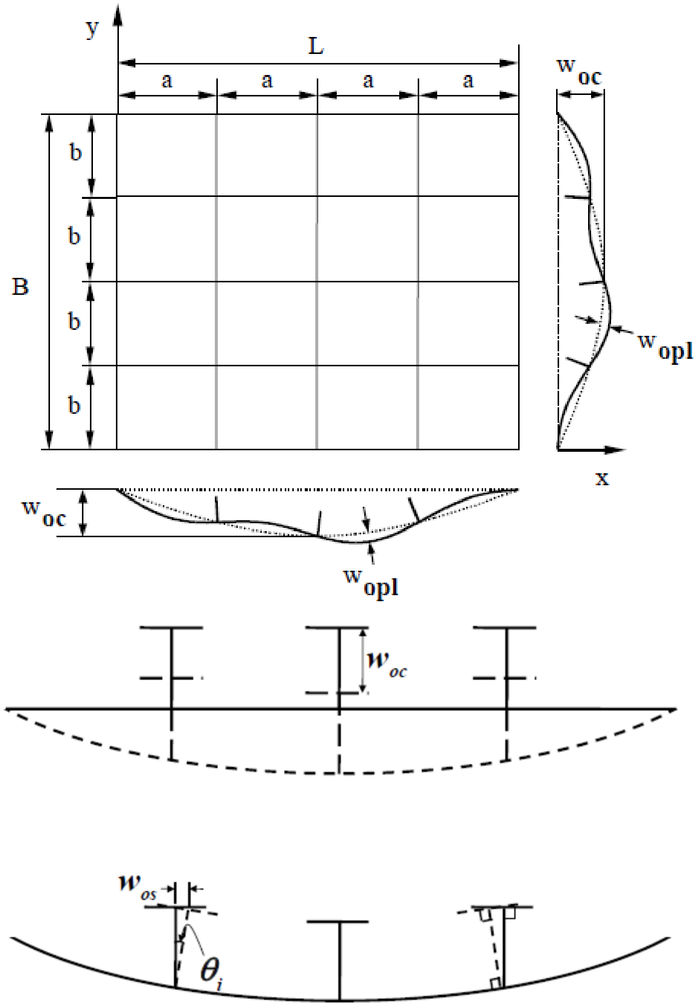
Temp. (°C)	Grade A			Grade AH		
	Modified σ_Y (MPa)	σ_Y (MPa)	$\sigma_Y/\sigma_{Y\text{-R.T.}}$	Modified σ_Y (MPa)	σ_Y (MPa)	$\sigma_Y/\sigma_{Y\text{-R.T.}}$
20	235.000	281.158	1.000	315.000	400.669	1.000
0	235.592	–	1.003	315.000	–	1.000
−20	243.328	300.558	1.035	315.315	415.900	1.001
−40	258.209	313.214	1.099	323.789	419.479	1.028
−60	280.233	333.543	1.192	337.806	437.053	1.072
−80	309.401	366.527	1.317	357.368	447.141	1.135



Ages of plates	5 years	10 years	15 years	20 years	25 years
Ratio of corrosion wastage (ballast tank area)	0.00	0.33	0.67	1.00	1.33
Ratio of corrosion wastage (pipe duct space/ void area)	0.25	0.50	0.75	1.00	1.25

From Park's research in"Nonlinear Structural Response Analysis of Ship and Offshore Structures in Low Temperature"

Initial Deflection



$$w_{opl} = A_0 \sin\frac{m\pi x}{a}\sin\frac{\pi y}{b}$$

$$w_{oc} = B_0 \sin\frac{\pi x}{a}\sin\frac{\pi y}{B}$$

- ➢ **Initial maximum deflection of plates w_{opl},**

where t_p is the plate thickness, and $\beta = \frac{b}{t_p}\sqrt{\frac{\sigma_{yp}}{E}})$

$$w_{opl} = 0.1\beta^2 t_p$$

$$w_{oc} = B_0 \sin\frac{\pi x}{a}\sin\frac{\pi y}{B}$$

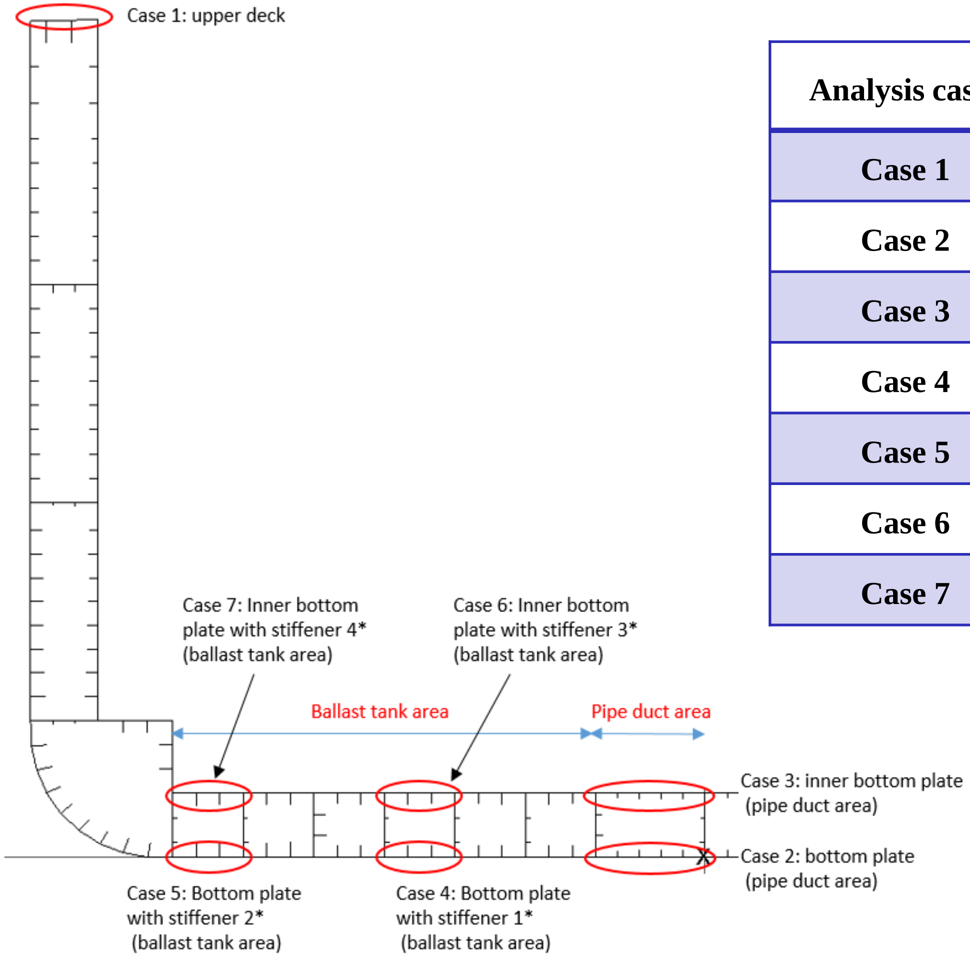
$$w_{os} = C_0 \sin\frac{z}{h_w}\sin\frac{\pi x}{a}$$

- ➢ **Initial maximum deflection of stiffeners w_{os},**

where a is the plate length.

$$w_{os} = 0.0015a$$

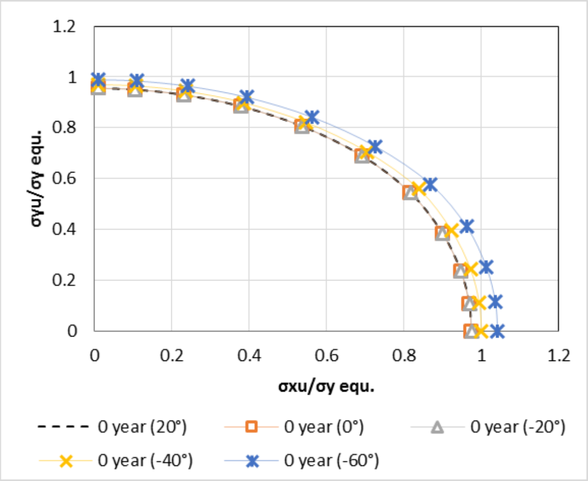
Analysis Model of Stiffened Plates

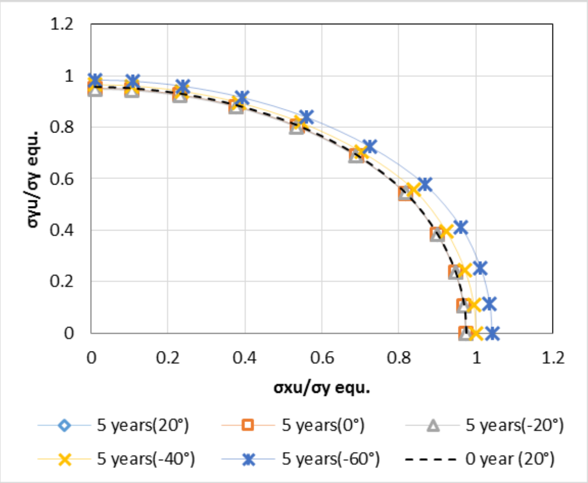


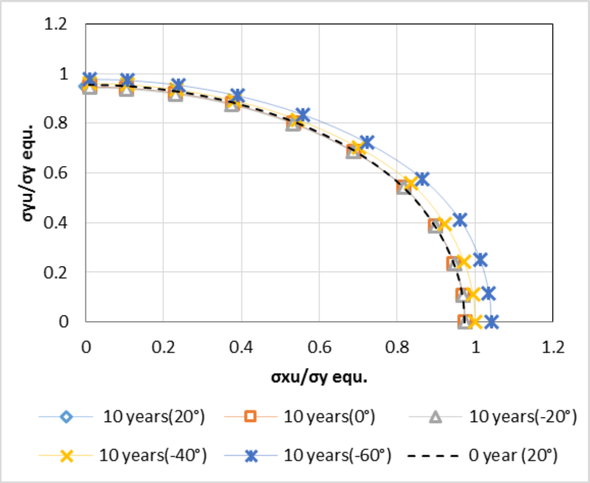
Analysis cases	Positions of stiffener panels
Case 1	Upper deck
Case 2	Bottom plate (pipe duct area)
Case 3	Inner bottom plate (pipe duct area)
Case 4	Bottom plate with stiffener 1* (ballast tank area)
Case 5	Bottom plate with stiffener 2* (ballast tank area)
Case 6	Inner bottom plate with stiffener 3* (ballast tank area)
Case 7	Inner bottom plate with stiffener 4* (ballast tank area)

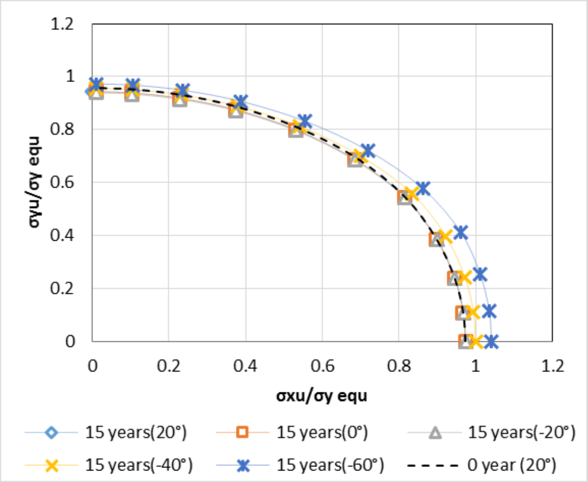
stiffener 1: 425x140x11/16 T-bar
stiffener 2: 550x150x12/18 T-bar
stiffener 3: 400x140x11/16 T-bar
stiffener 4: 450x150x11/18 T-bar

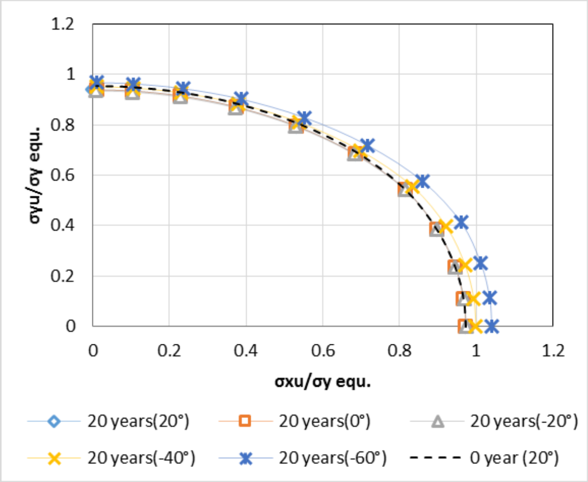
Ultimate Strength Analysis of Stiffened Plates

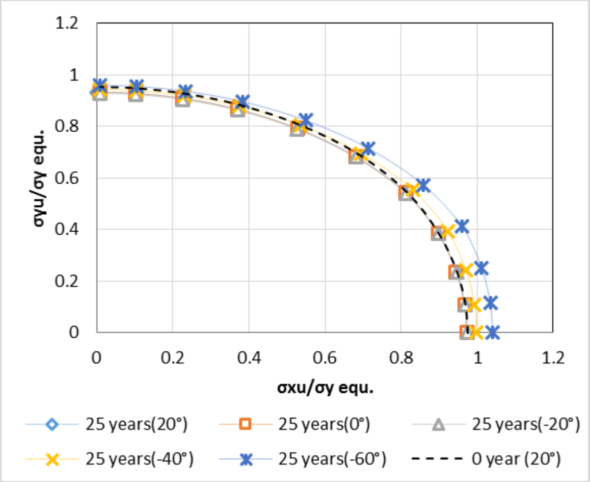




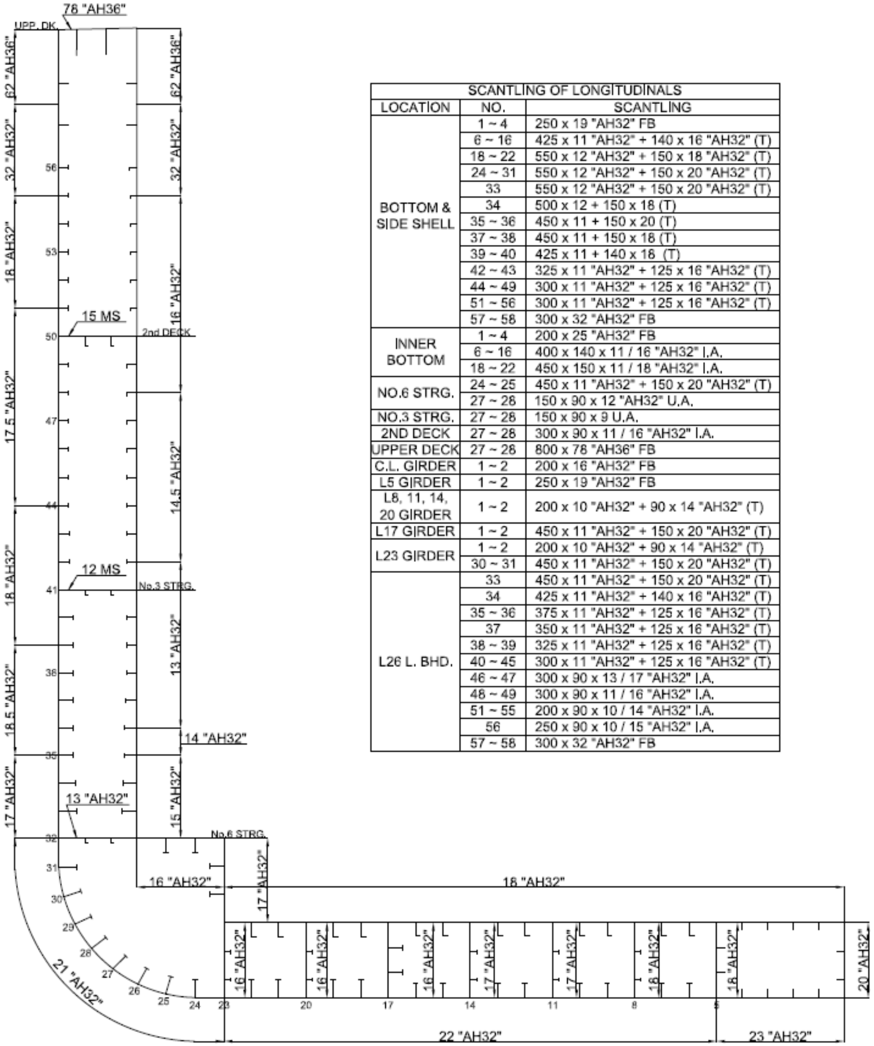




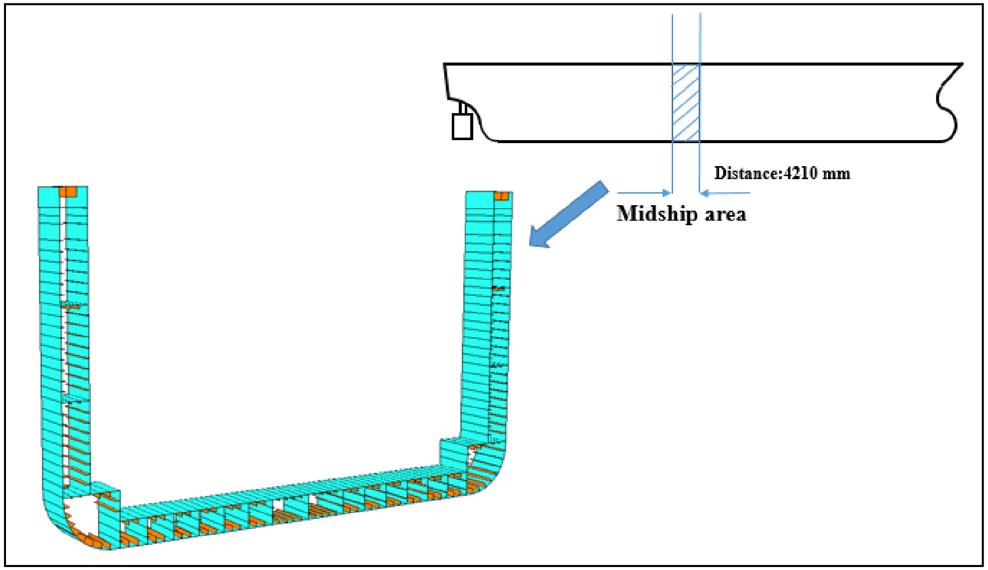




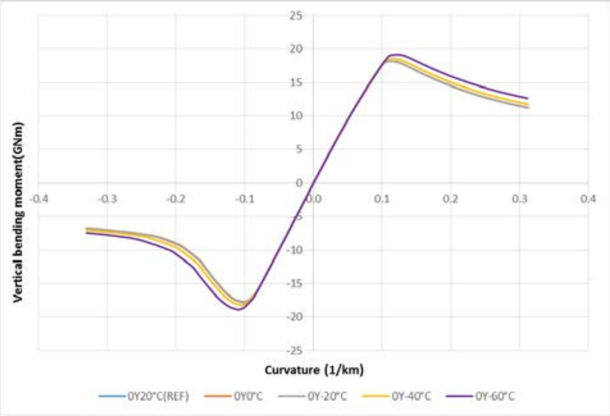
Analysis Model of Hull girder

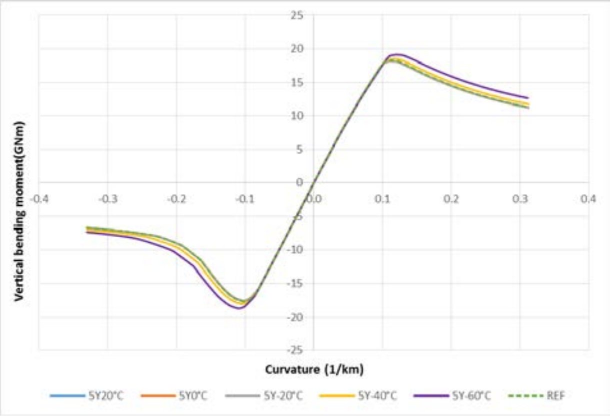


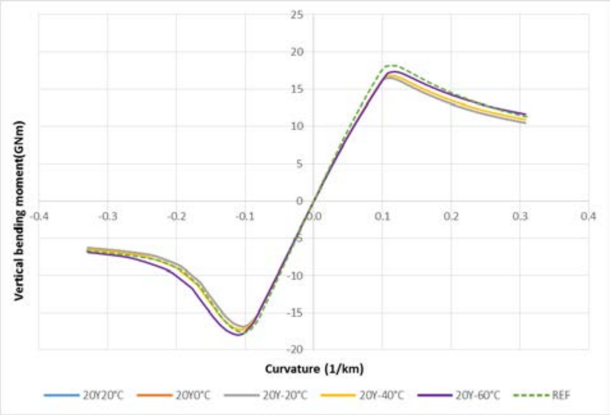
SCANTLING OF LONGITUDINALS		
LOCATION	NO.	SCANTLING
BOTTOM & SIDE SHELL	1 ~ 4	250 x 19 "AH32" FB
	6 ~ 16	425 x 11 "AH32" + 140 x 16 "AH32" (T)
	18 ~ 22	550 x 12 "AH32" + 150 x 18 "AH32" (T)
	24 ~ 31	550 x 12 "AH32" + 150 x 20 "AH32" (T)
	33	550 x 12 "AH32" + 150 x 20 "AH32" (T)
	34	500 x 12 + 150 x 18 (T)
	35 ~ 36	450 x 11 + 150 x 20 (T)
	37 ~ 38	450 x 11 + 150 x 18 (T)
	39 ~ 40	425 x 11 + 140 x 18 (T)
	42 ~ 43	325 x 11 "AH32" + 125 x 16 "AH32" (T)
	44 ~ 49	300 x 11 "AH32" + 125 x 16 "AH32" (T)
	51 ~ 56	300 x 11 "AH32" + 125 x 16 "AH32" (T)
	57 ~ 58	300 x 32 "AH32" FB
INNER BOTTOM	1 ~ 4	200 x 25 "AH32" FB
	6 ~ 16	400 x 140 x 11 / 16 "AH32" I.A.
	18 ~ 22	450 x 150 x 11 / 18 "AH32" I.A.
NO.6 STRG.	24 ~ 25	450 x 11 "AH32" + 150 x 20 "AH32" (T)
	27 ~ 28	150 x 90 x 12 "AH32" U.A.
NO.3 STRG.	27 ~ 28	150 x 90 x 9 U.A.
2ND DECK	27 ~ 28	300 x 90 x 11 / 16 "AH32" I.A.
UPPER DECK	27 ~ 28	800 x 78 "AH36" FB
C.L. GIRDER	1 ~ 2	200 x 16 "AH32" FB
L5 GIRDER	1 ~ 2	250 x 19 "AH32" FB
L8, 11, 14, 20 GIRDER	1 ~ 2	200 x 10 "AH32" + 90 x 14 "AH32" (T)
L17 GIRDER	1 ~ 2	450 x 11 "AH32" + 150 x 20 "AH32" (T)
L23 GIRDER	1 ~ 2	200 x 10 "AH32" + 90 x 14 "AH32" (T)
	30 ~ 31	450 x 11 "AH32" + 150 x 20 "AH32" (T)
L26 L. BHD.	33	450 x 11 "AH32" + 150 x 20 "AH32" (T)
	34	425 x 11 "AH32" + 140 x 16 "AH32" (T)
	35 ~ 36	375 x 11 "AH32" + 125 x 16 "AH32" (T)
	37	350 x 11 "AH32" + 125 x 16 "AH32" (T)
	38 ~ 39	325 x 11 "AH32" + 125 x 16 "AH32" (T)
	40 ~ 45	300 x 11 "AH32" + 125 x 16 "AH32" (T)
	46 ~ 47	300 x 90 x 13 / 17 "AH32" I.A.
	48 ~ 49	300 x 90 x 11 / 16 "AH32" I.A.
	51 ~ 55	200 x 90 x 10 / 14 "AH32" I.A.
	56	250 x 90 x 10 / 15 "AH32" I.A.
	57 ~ 58	300 x 32 "AH32" FB

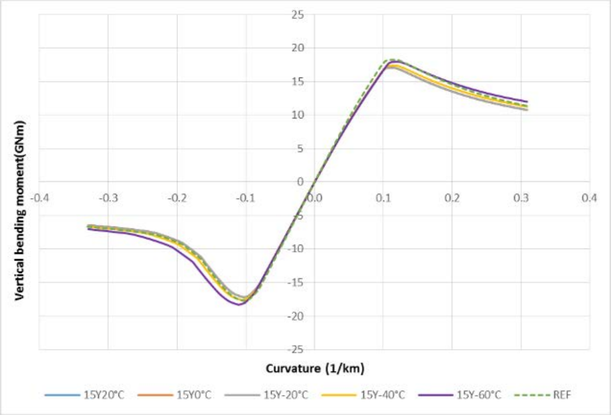


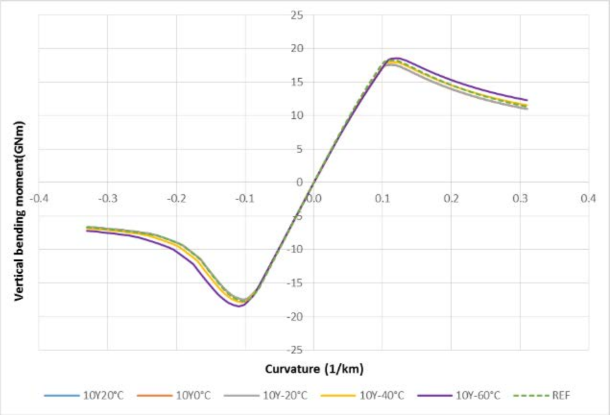
Vertical Hull Girder Bending Moment

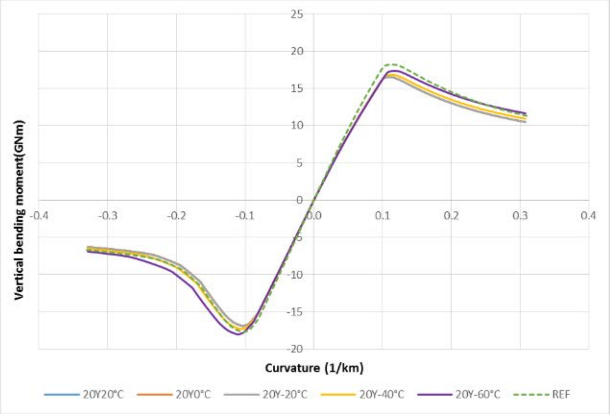




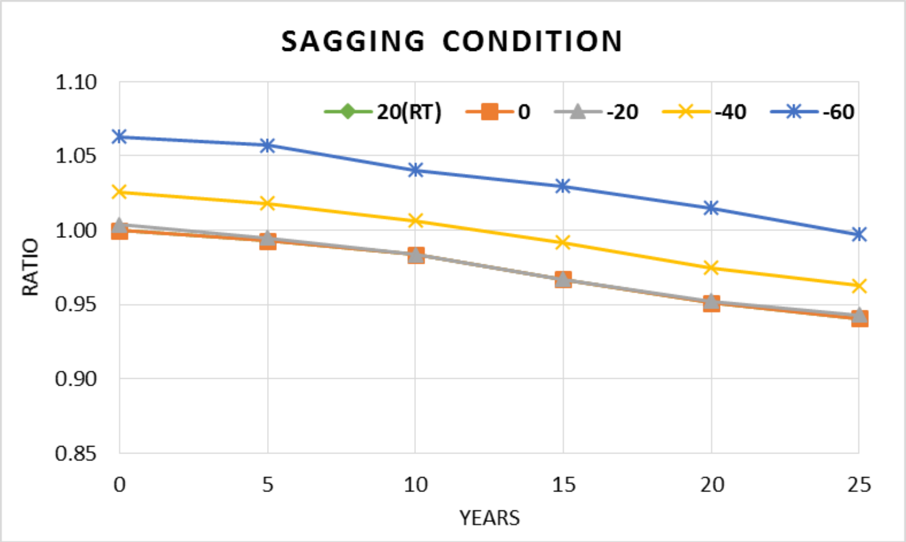


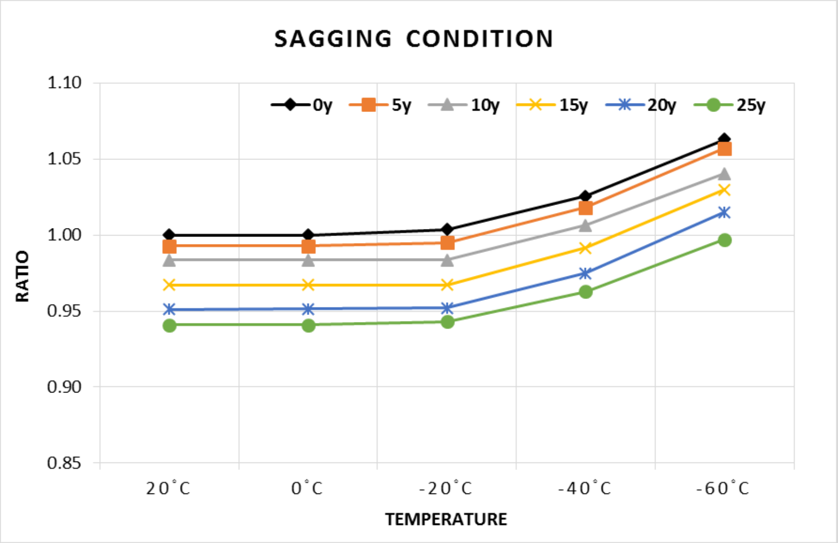


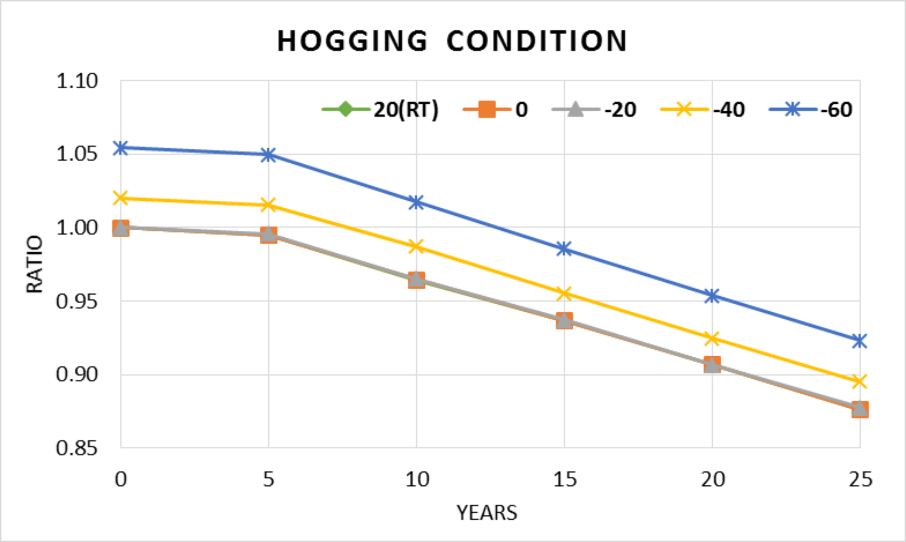


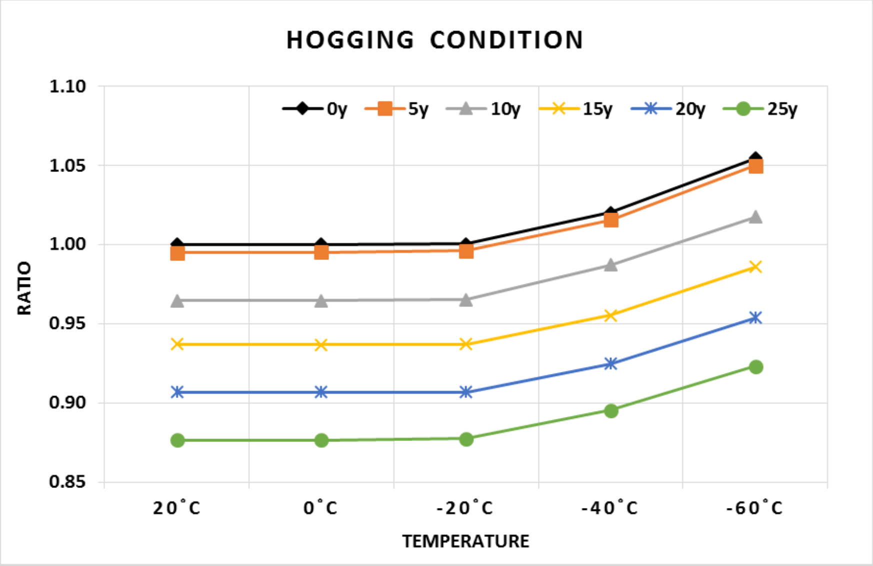


Ultimate Strength Analysis of Hull Girder Structures









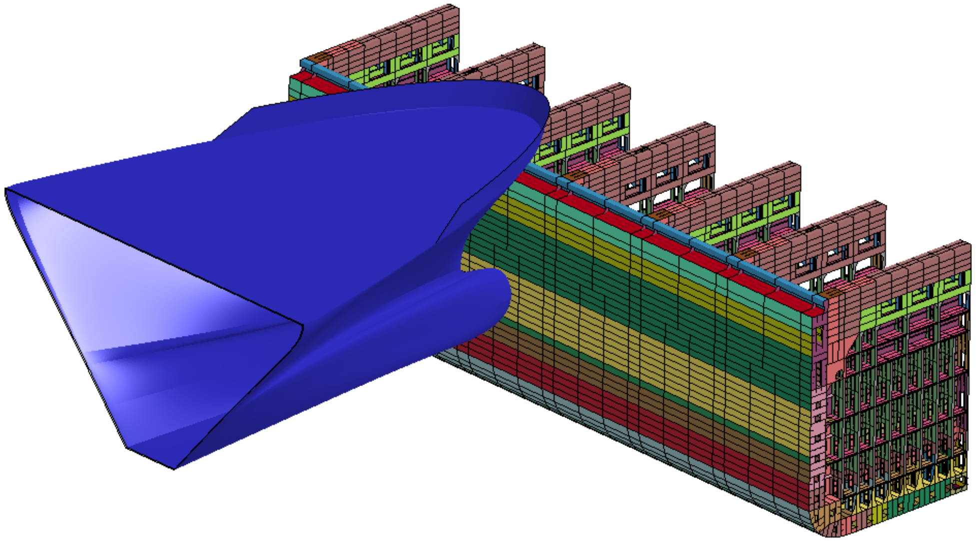
Results of Ultimate Strength of Hull Girder Structures

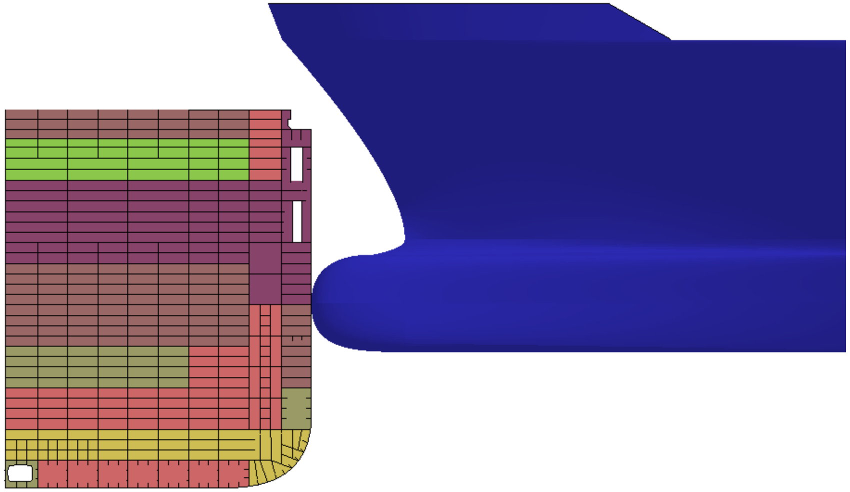
5%+

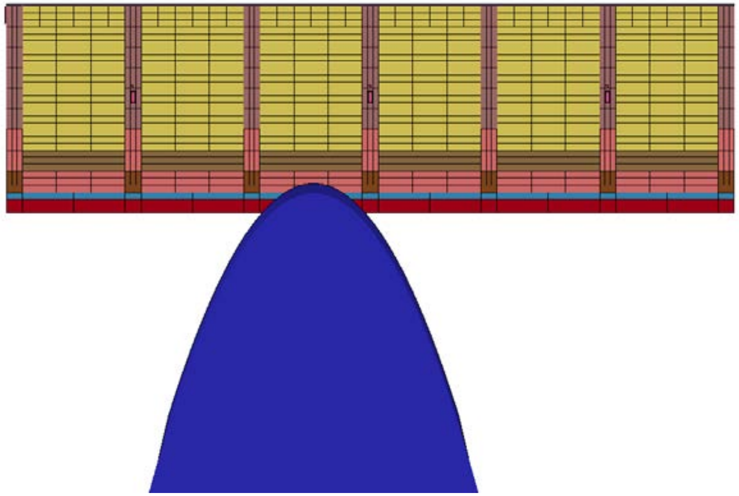
Temperature/ Years	**Hogging conditions**					**Sagging conditions**				
	20°C (RT)	0°C	-20°C	-40°C	-60°C	20°C (RT)	0°C	-20°C	-40°C	-60°C
0y	1.000	1.000	1.000	1.020	**1.054**	1.000	1.000	1.004	1.026	1.063
5y	0.995	0.995	0.996	1.016	1.050	0.993	0.993	0.995	1.018	1.057
10y	0.964	0.965	0.965	0.987	1.017	0.984	0.984	0.984	1.006	1.040
15y	0.937	0.937	0.937	0.955	0.986	0.967	0.967	0.967	0.992	1.030
20y	0.907	0.907	0.907	0.925	0.954	0.951	0.951	0.952	0.975	1.015
25y	**0.876**	0.877	0.878	0.895	0.923	0.941	0.941	0.943	0.963	0.997

12% -

Collision Analysis







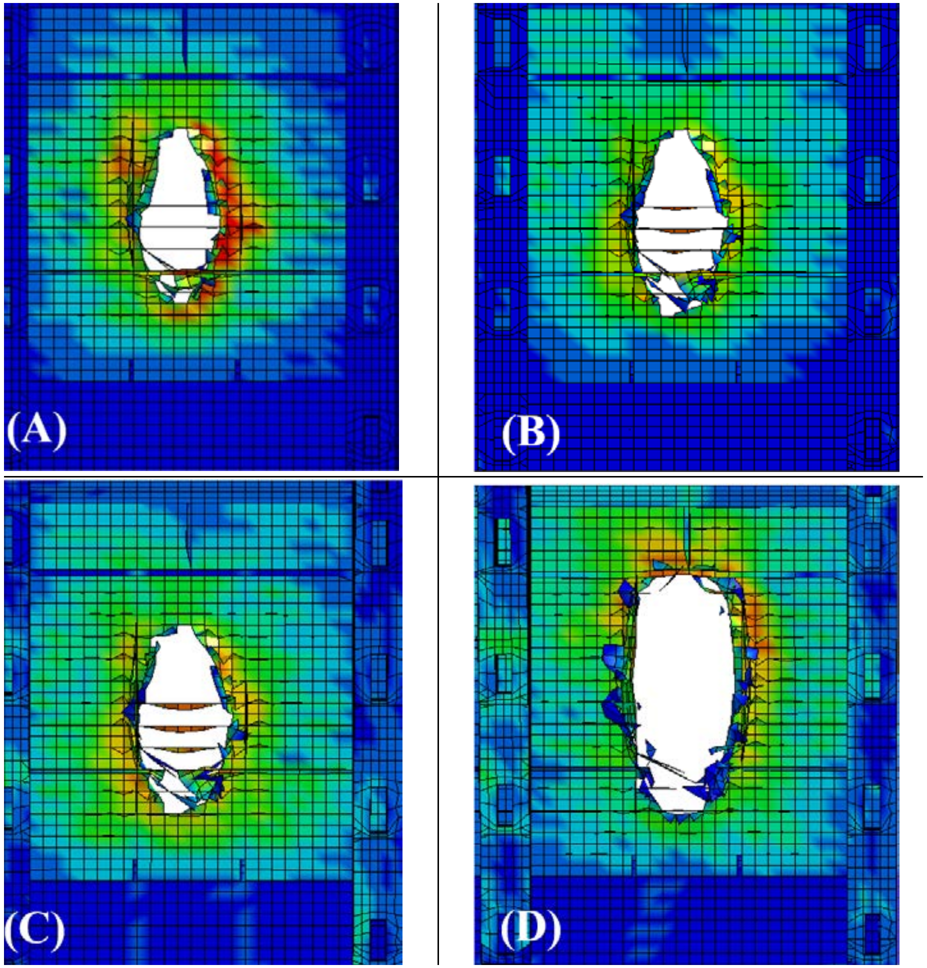
- Striking ship: smaller size container bow structures
- Struck ship: 13,000 TEU ship side
- Velocity: 2 knots
- Consider dynamic fracture strain and yielding stress

Collision Analysis Results

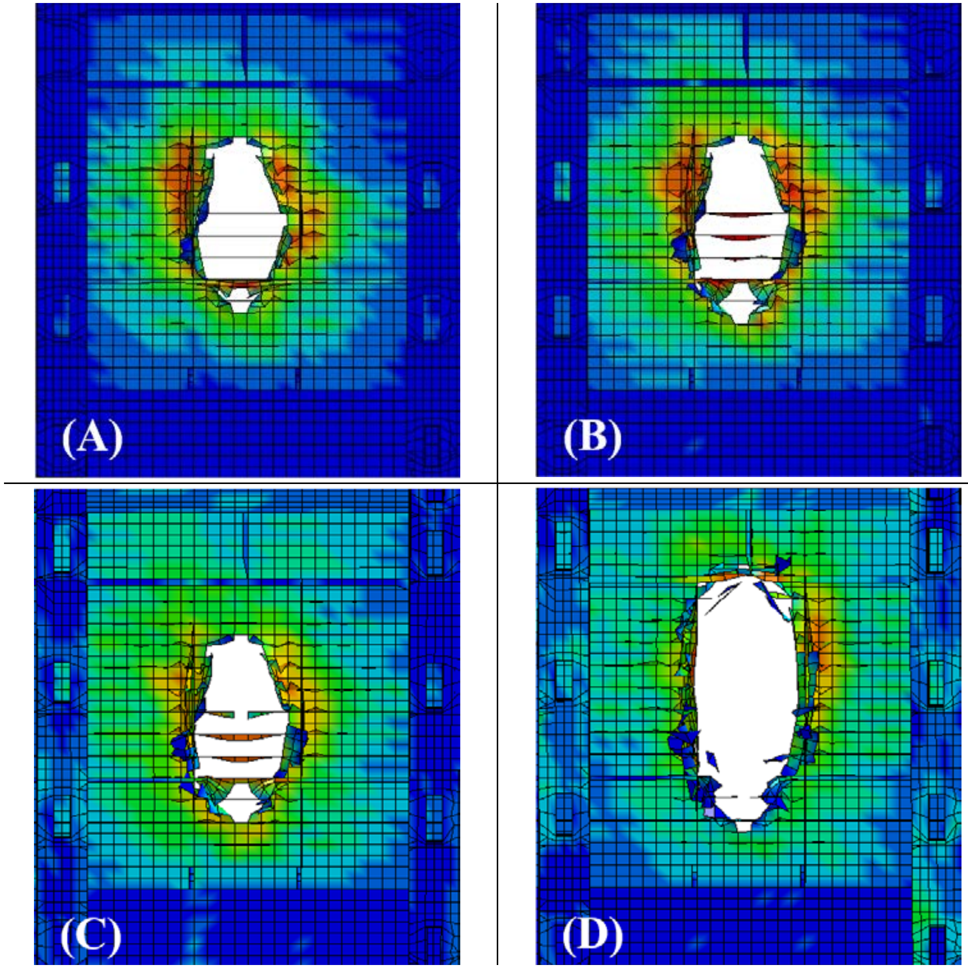
(20°C)

(-60°C)

Struck ship on inner shell with temperatures

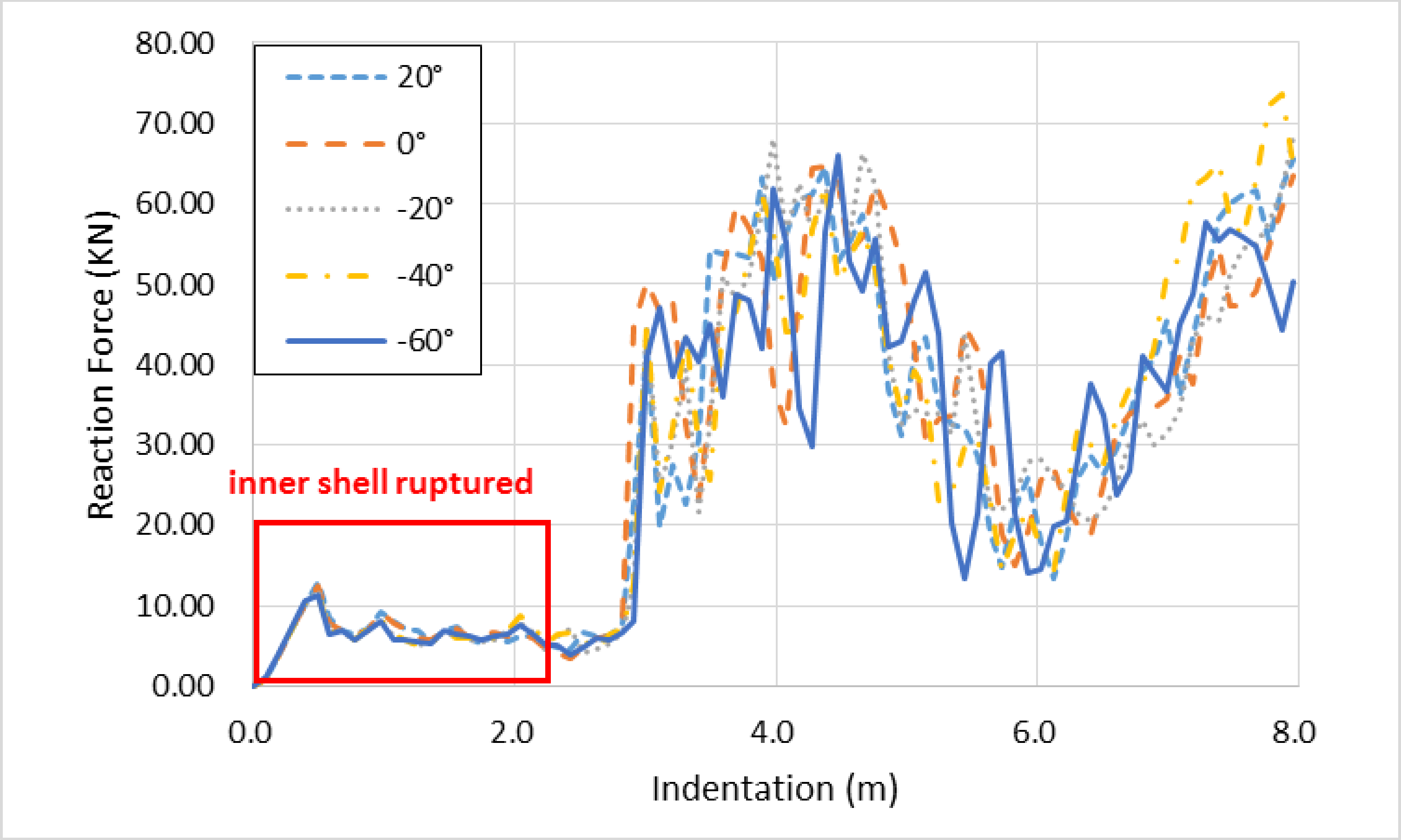


(20°C)

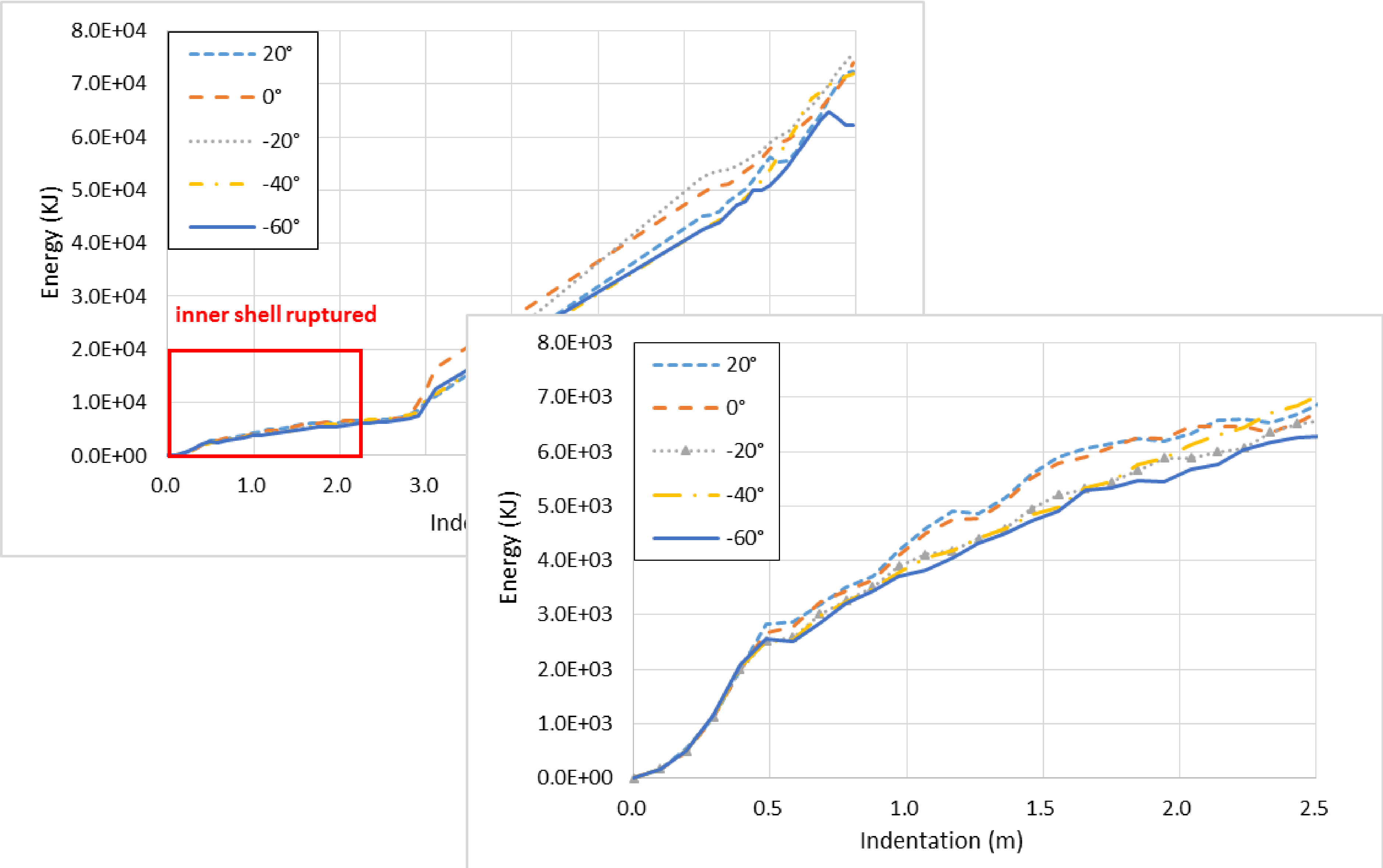


(-60°C)

Analysis results - Total reaction force



Analysis results – Total absorbed energy



inner shell ruptured

Conclusion

- **Steel plate or structures in the low temperature environment the material property of yielding stress will be higher.**
- **From stiffened panels results, before 15 years that the majority effect is yielding stress, but after 15 years it became to the corrosion wastage.**
- **For the effect of ultimate strength of hull girder structures between corrosion wastage and increasing yielding stress with low temperatures, we could summarized the majority effect is corrosion wastage.**
- **To conclude the safety assessment of non-iced aged structures that the low temperature provide the higher ultimate according to higher yielding stress which is benefit for structures. However the low temperature will cause material from ductile to brittle which related to fracture strain. It is the disadvantage for non-iced aged structures.**

- **Future work**

1. **Nonlinear consideration of corrosion wastage/ real corrosion wastage**
2. **Material property of yielding stress and fracture strain by experimental test for different plate thickness**
3. **More collision analysis with aged structures consideration**

Thank you for your listening