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Master Thesis

Structural and Fatigue Analysis of a Type C tank Vessel at Class Renewal No IV

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La Spezia, February 2018

INTERNSHIP AT BUREAU VERITAS

Classification Society Formed in Antwerp in 1828. Headquarters in Paris, France.

Services includes Testing, Inspection and Certification.

DNI; Inland Navigation Management is a is the Head Office for inland navigation activities worldwide, covering classification and statutory services for vessels operated on waterways, lakes and estuaries, as well as for vessels sailing at sea in restricted area for domestic trade when agreed by the relevant flag Authorities.

Internship guided by the department of Research and Development, DNI.

INTRODUCTION

Ship structural defects in the form of material wastage (corrosion).

Critical in the viewpoints of Safety and Economics.

Surveys has to be carried out at every stages to ensure structural integrity.

Visual Examination, Thickness Measurements can be implemented.

Corrosion Affected Areas

Thickness Measurements

To determine the extent of repairs and renewals of vessel's structural components.

Ultrasonic thickness (UT) gauging techniques, other NDT techniques (DP, X-ray etc).

The thickness is measured using the velocity of the sound through the material (standard frequency used is 5Hz).

UT Gauging

Objectives Of The Study

Carry out Structural and Fatigue analysis of an in-service vessel (Age > 15 years) taking into account the corrosion wastage.

Both Classification society rules and Direct engineering calculations (FEM) have been implemented.

Comparison of Results.

Propose Recommendations.

VESSEL UNDER INVESTIGATION

Type-C Inland Vessel ; Tanker

According to ADN,

Type C tank vessel applies to a tanker built and equipped for the carriage of dangerous liquids in bulk.

Flush deck (continuous from stem to stern)/double hull type with double bottom.

Main Particulars of Vessel

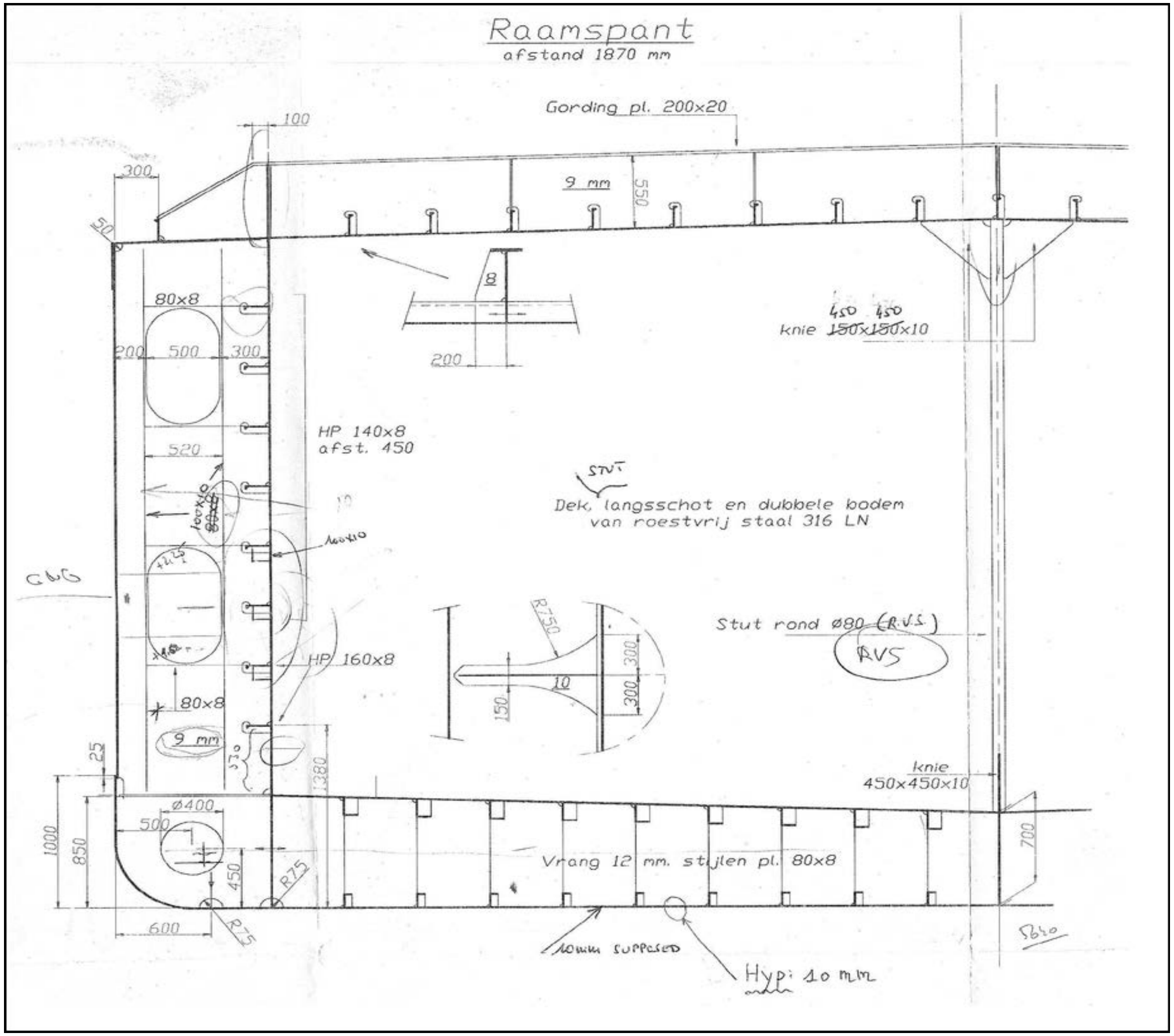
TYPE C - INLAND TANKER	
LOA(m)	109.23
LPP(m)	106.5
B(m)	11.4
T(m)	3.22
D(m)	5.03
Mass disp(t)	3370.54
Cb	0.862

Date of Build : 01 Oct 1984

Class renewal number IV (>15 years old)


RelationShip

Midship Section



UTM Report

The UT measurement report of the vessel has been provided for this study.

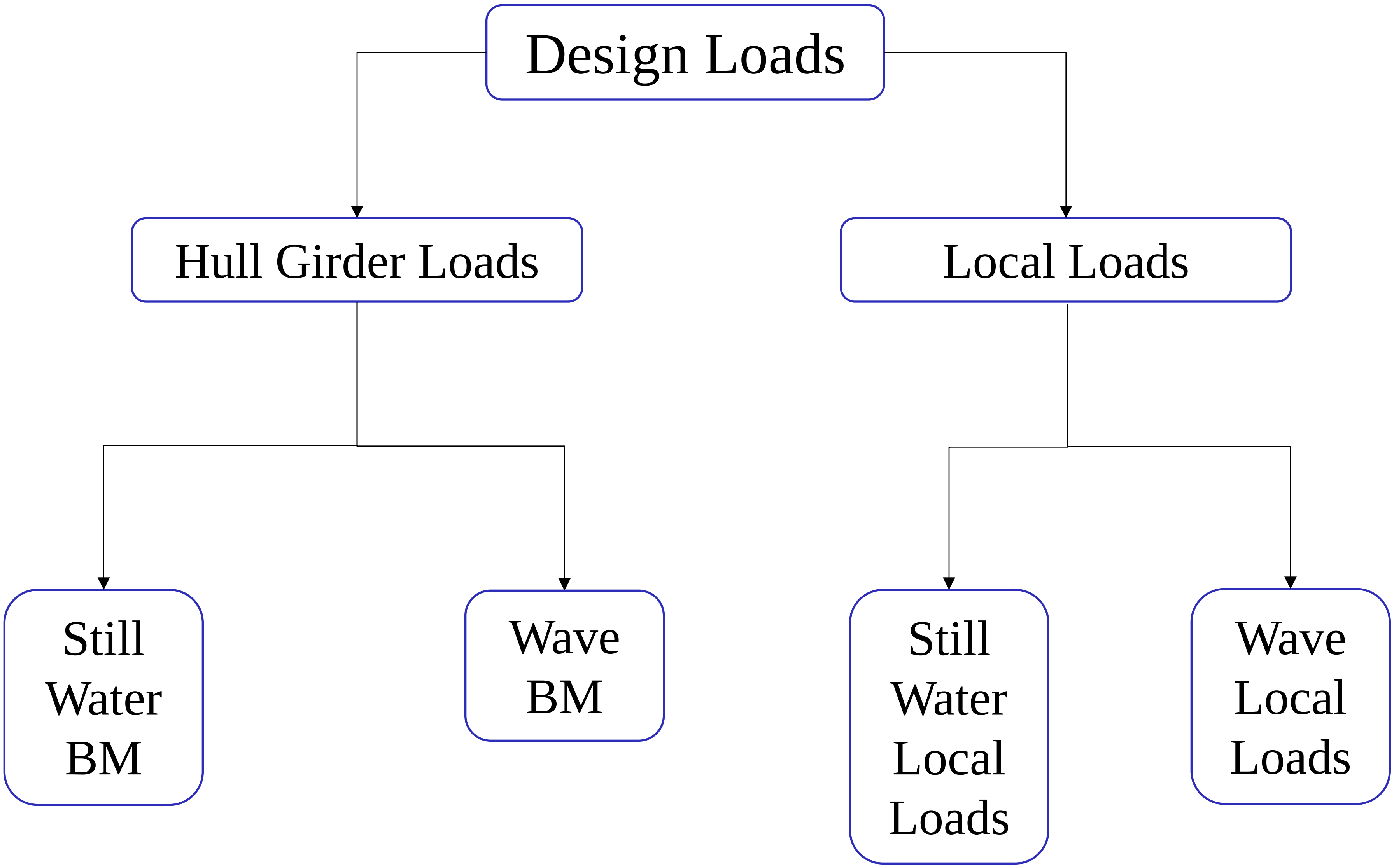
Minimum values of measured thickness have been taken into account – **Conservative Approach.**

STRENGTH CHECK; BV Rules

Strength Analysis Using Following Rules,

-NR 217.B1 DNI R04 E, PART B - Hull Design and Construction,
-NR 217.D1 DNI R04 E,PART D - Additional Requirements for Notations.

Software Tool; MarsInland (BV Inhouse Tool For Scantling Check).


Design Loads
Hull Girder Loads
Local Loads
Still Water BM
Wave BM
Still Water Local Loads
Wave Local Loads

Net Scantling Approach

Excluding the Margin For Corrosion.

Net scantlings were evaluated from the measured scantlings by deducting the corrosion margin (defined in rules; BV NR 597).

Conservative Approach (Gross = Measured).

Hull Girder Stresses

Hull Girder Bending Moments using Rule Formulations,

Hull Girder Bending Moments (BV Rules)	Hogging	Sagging
Design S.W.B.M -Navigation Condition (kNm)	43 172	52 947
Design S.W.B.M -Harbour Condition (kNm)	45 976	58 163
Design Vertical Wave BM - Rule (kNm)	34 862	34 862

Hull Girder Stresses,

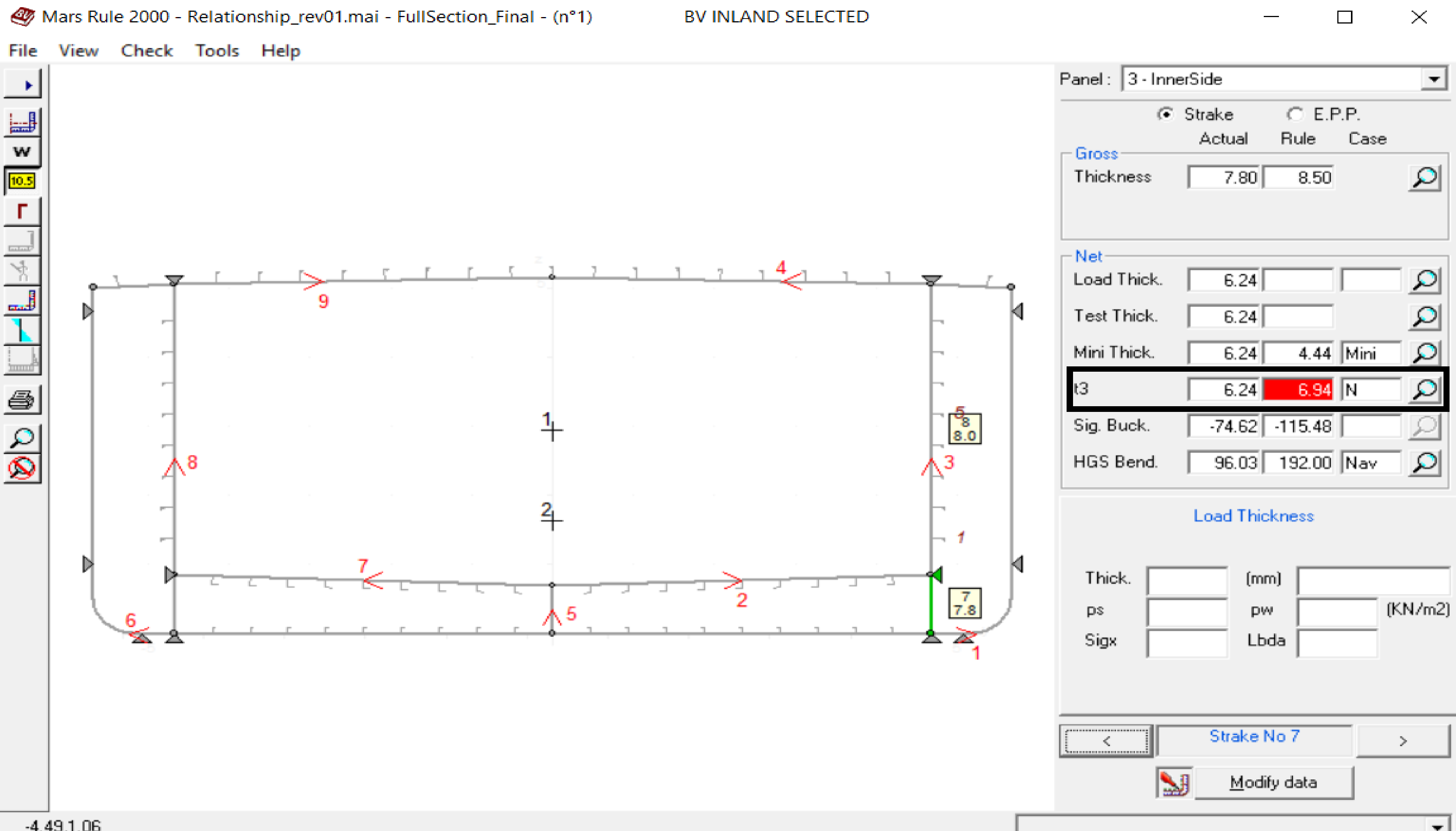
	Distance From Baseline (m)	Hogging, σ_H (N/mm^2)	Sagging, σ_H (N/mm^2)
Bottom	0	85.34	96.03
Deck	5.03	106.55	113.77

Scantling Check of Platings

To ensure that the net thickness values comply with the rule requirements.

Plating	Net Thickness		Definition
	Actual Thickness (mm)	Maximum Rule Thickness (mm)	
Bottom	6.5	6	1
Inner Bottom	8	5.5	2
Side Shell	6.9	**7.5**	3
Inner Side Shell	8	5	2
Deck Plate	8	6.5	3
Stringer Plate	13.4	8.5	3
CL Girder/Side Girders	6.2	**6.9**	3
Bilge	9.1	4.5	1
(1) Minimum rule thickness t1.			
Maximum of the values calculated on each E.P.P.			
(2)Thickness t2 based on external or internal design pressure			
and on a stress factor λT or λL coming from the overall bending stress			
The output value of Load Thick t2 is the maximum one.			
(3)Buckling thickness t3.			
value calculated on critical E.P.P.			

Side Girder; Buckling Failure



Scantling Check of Secondary Stiffeners

The actual section modulus and shear area based on the net scantling approach has been compared with the required rule values

Longitudinals	Shear Area(cm2)		Definition	Section Modulus(cm3)		Definition
	Actual	Rule	from rules	Actual	Rule	from rules
Bottom	5.85	2.03	2	**45.81**	58.17	3
Inner Bottom	8.59	3.67	2	108.38	79.85	3
Inner Side Shell(Lower)	9.55	3.2	2	92.59	32.15	3
Inner Side Shell(Upper)	8.36	3.05	2	70.01	62.88	3
Deck	11.17	2.43	2	105.92	72.29	3

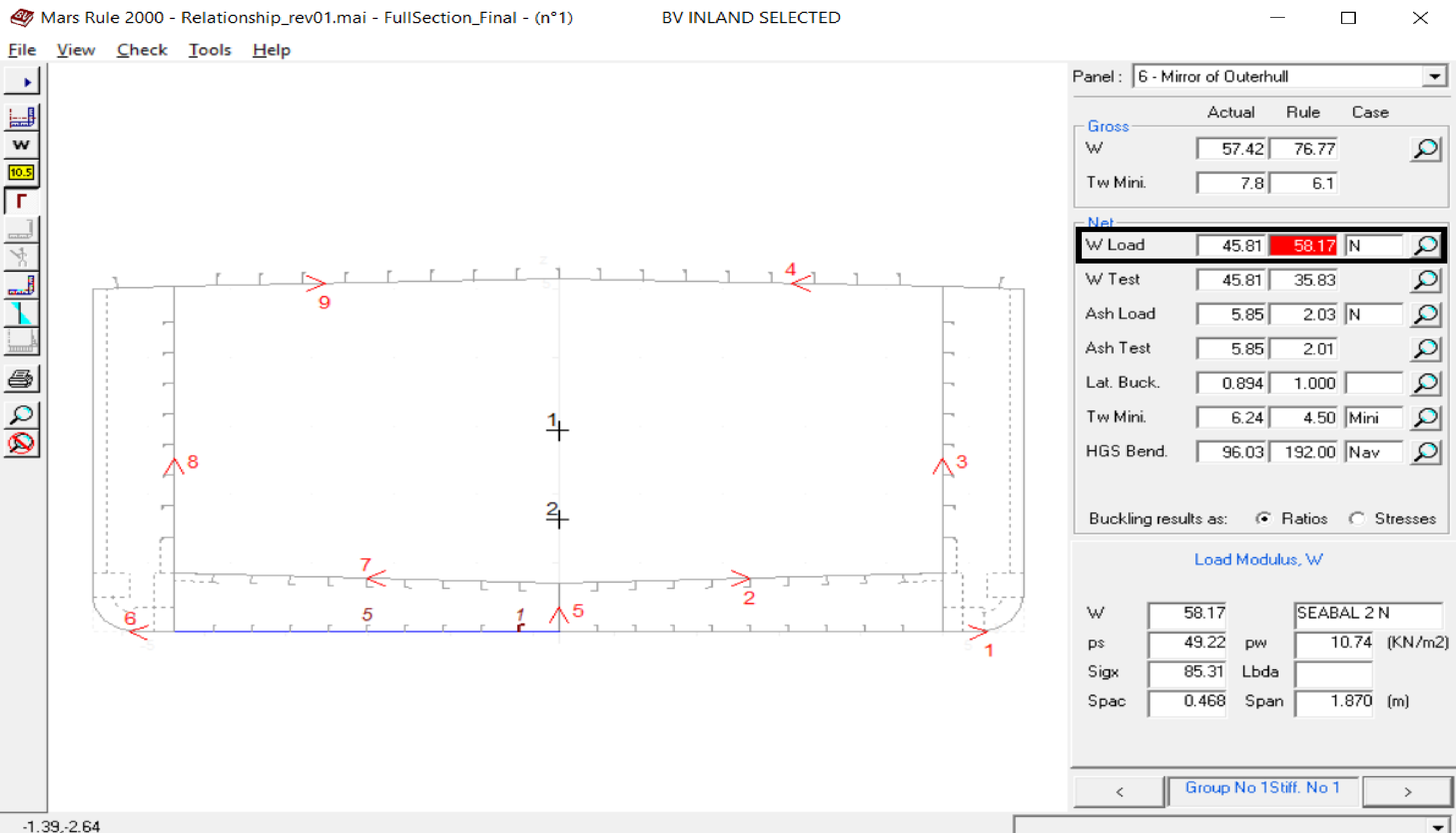
(1) Shear area based on external or internal design pressure(Ash Load)

(2) Shear area based on test pressure(Ash Test)

(3) Modulus based on external or internal design pressure and on a stress factor depending on the overall bending stress (W Load)

(4) Modulus based on test pressure(W Test)

Bottom Longitudinal; Non Compliance



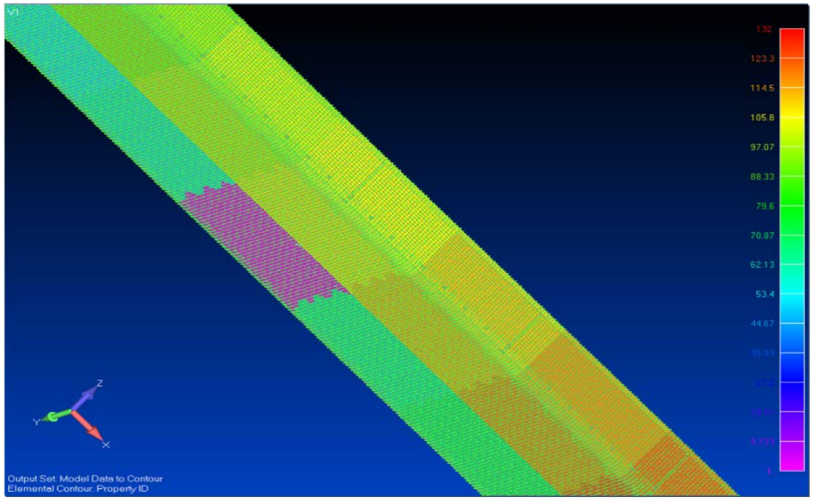
Strength Check of Primary Supporting Members

Carried out using FEMAP integrated with NX-NASTRAN.

Modelling carried out based on the net scantlings,

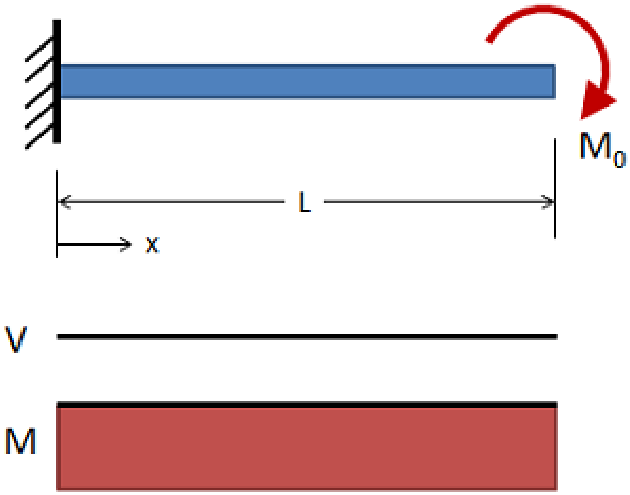
Net* = Measured Thickness – Corrosion Allowance

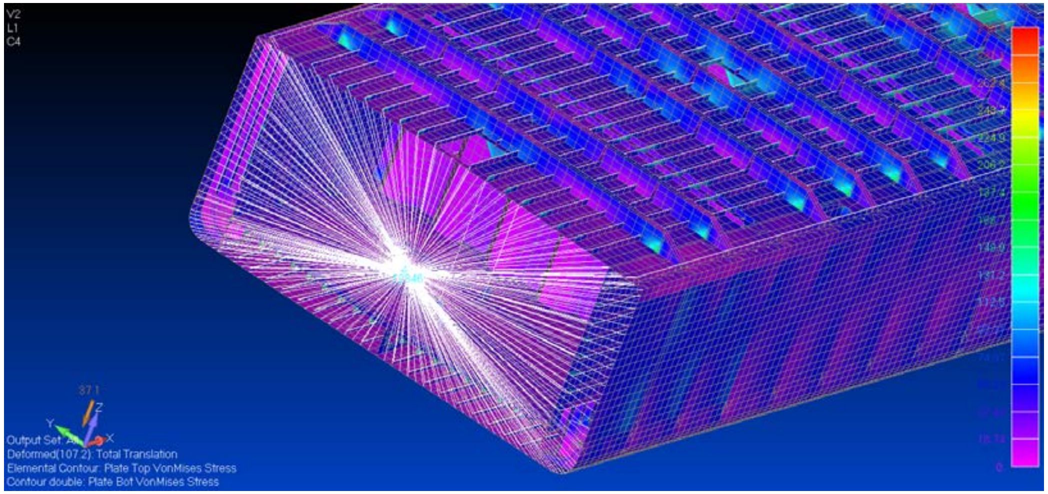
Different thickness in different locations.



Boundary Conditions; Case 1

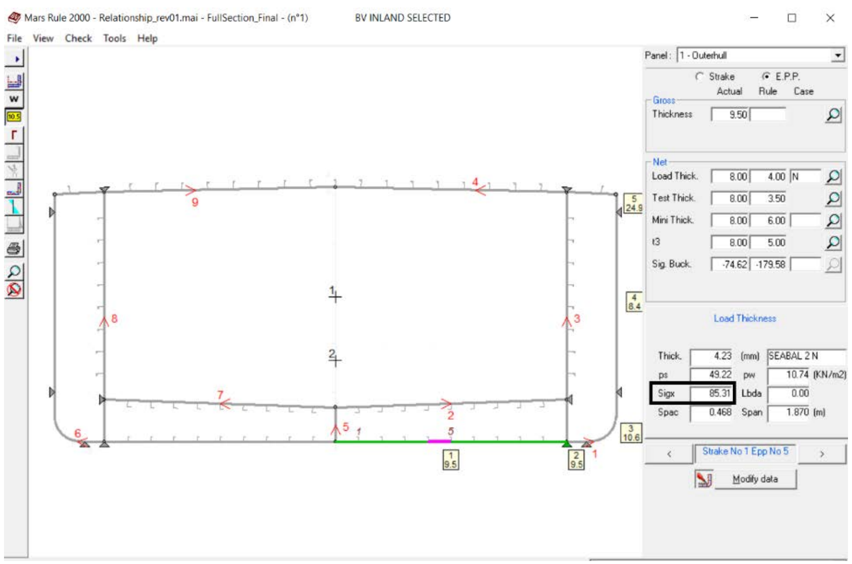
Cantilever Beam applied with Design Bending Moment.

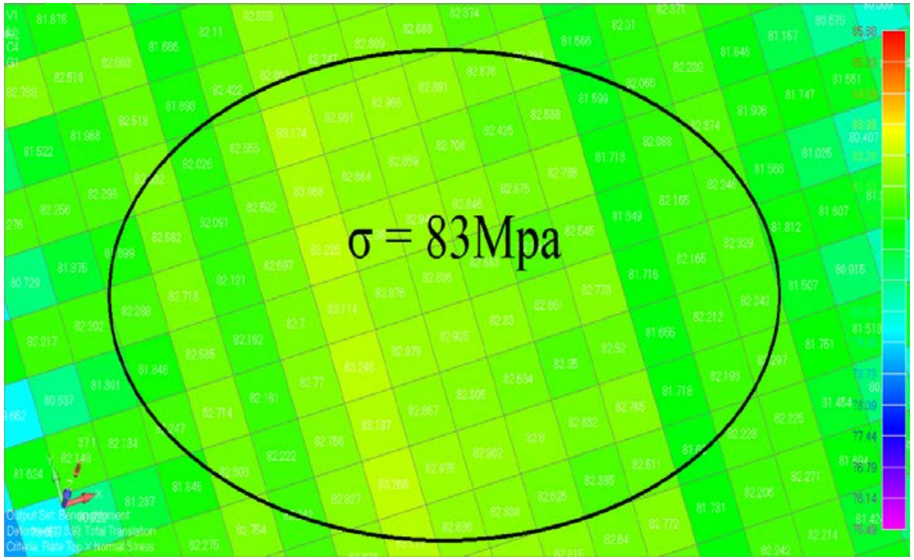




Hull Girder Stresses; Bottom Plating (Sagging Case)

Compared between the Mars Model and the FE Model (Midship),

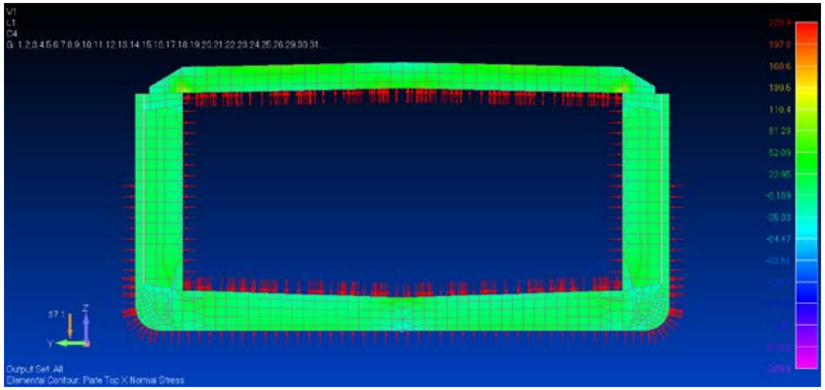
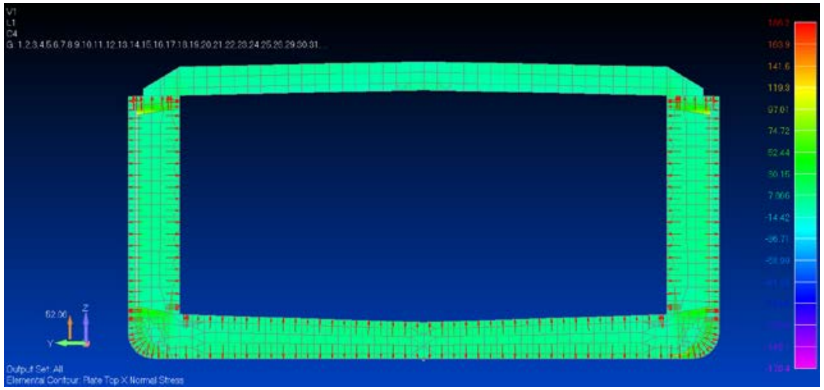
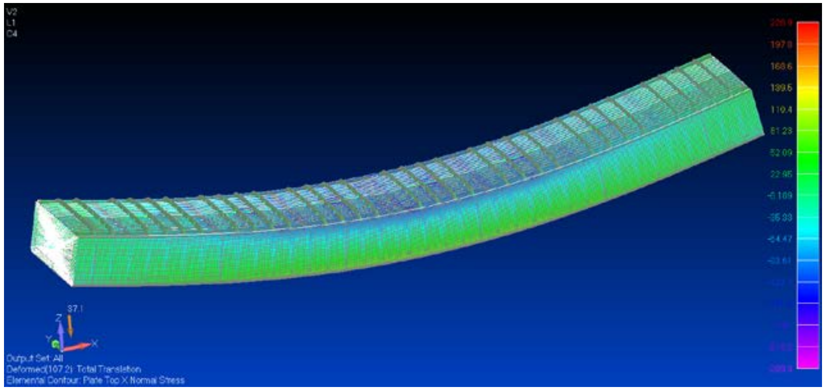
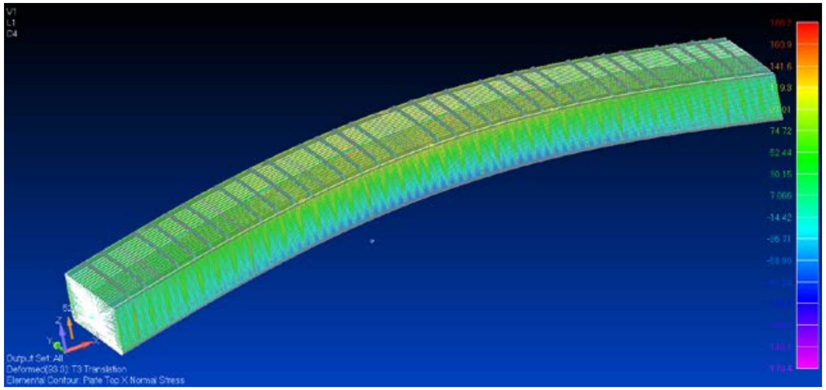




MarsInland (Mpa)	FEM (Mpa)	% Difference
85.31	83	2.7

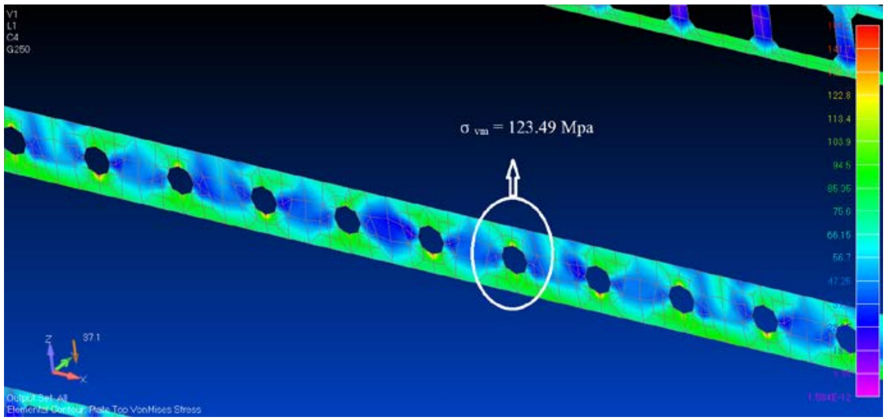
Boundary Conditions; Case 2

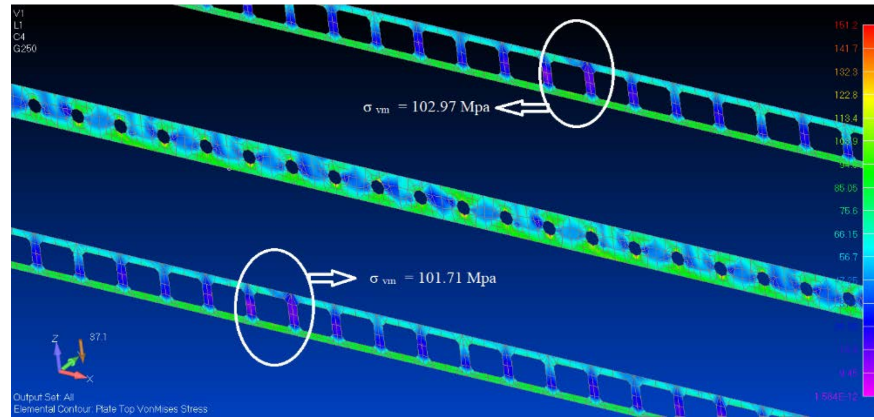
Simply Supported Beam Applied with Local Loads

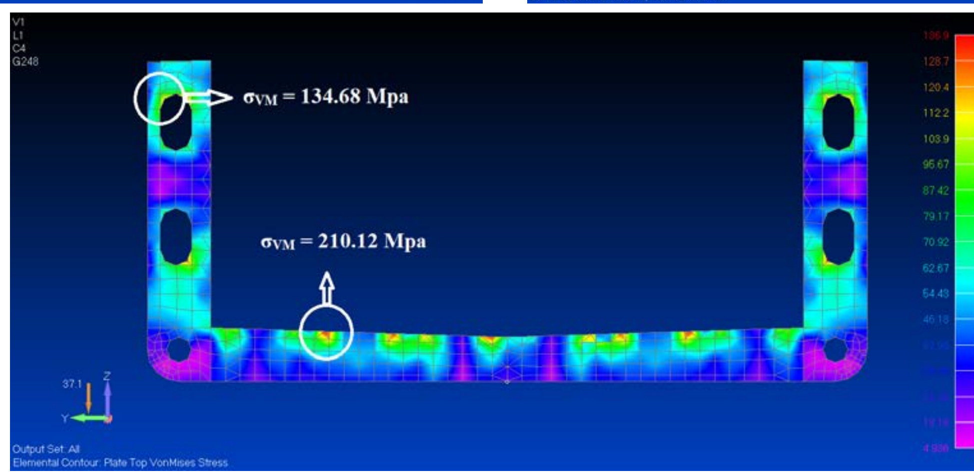





Results; Von-Mises Stress

Severe in Fully-Loaded Case (Test Pressure applied = 65kpa).

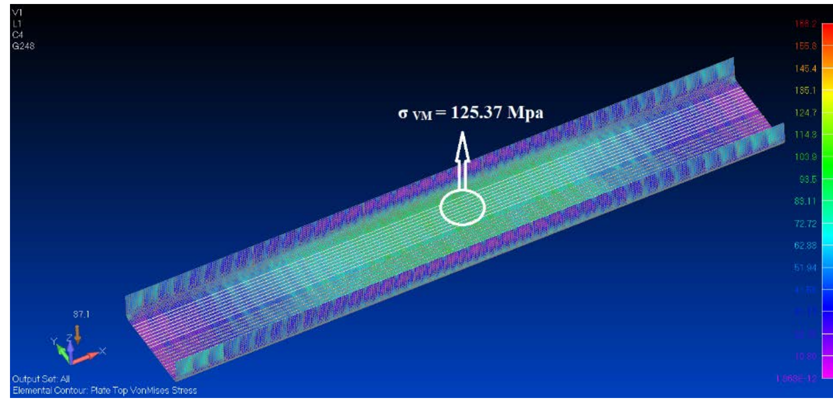






Von-mises Stresses are within the Limits; $\sigma_{VM} \leq \sigma_{MASTER}$ (219.42 Mpa)

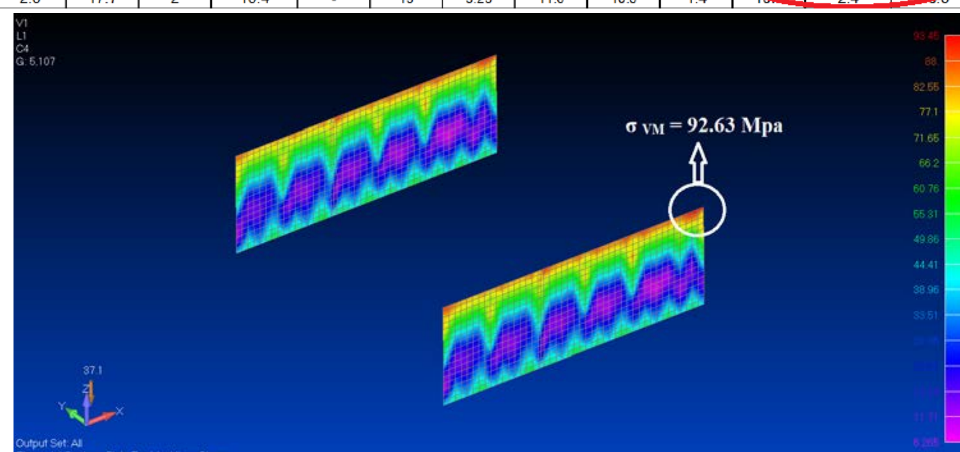
Critical Analysis



Report analysis : zone assessment

	Diminution	Permissible wastage
	[%]	[%]
Deck	0.21	10.00
Neutral axis	11.52	15.00
Bottom	15.42	10.00

STRAKE POSITION	No or Letter	Orig. Thk	Max Alwd Dim.	Gauged		Diminution P		Diminution S		No or Letter	Orig. Thk	Max Alwd Dim.	Gauged		Diminution P		Diminution S	
		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%
1st below sheer strake	-	10	1.50	9.4	9.2	0.6	6.0	0.8	8.0	-	10	1.50	8.4	8.4	1.6	16.0	1.6	16.0
2nd below sheer strake	-	13	3.25	10.7	11	2.3	17.7	2	15.4	-	13	3.25	11.6	10.6	1.4	10.8	2.4	[illegible]



FATIGUE ANALYSIS

Does not result in catastrophic failures,but high cost of maintenance.

Deterministic method

Maximum and minimum hull girder loads and local pressures has been calculated for each load case; Fully-loaded (60%) and Ballast case (40%)

For secondary supporting members; Stress from rules.

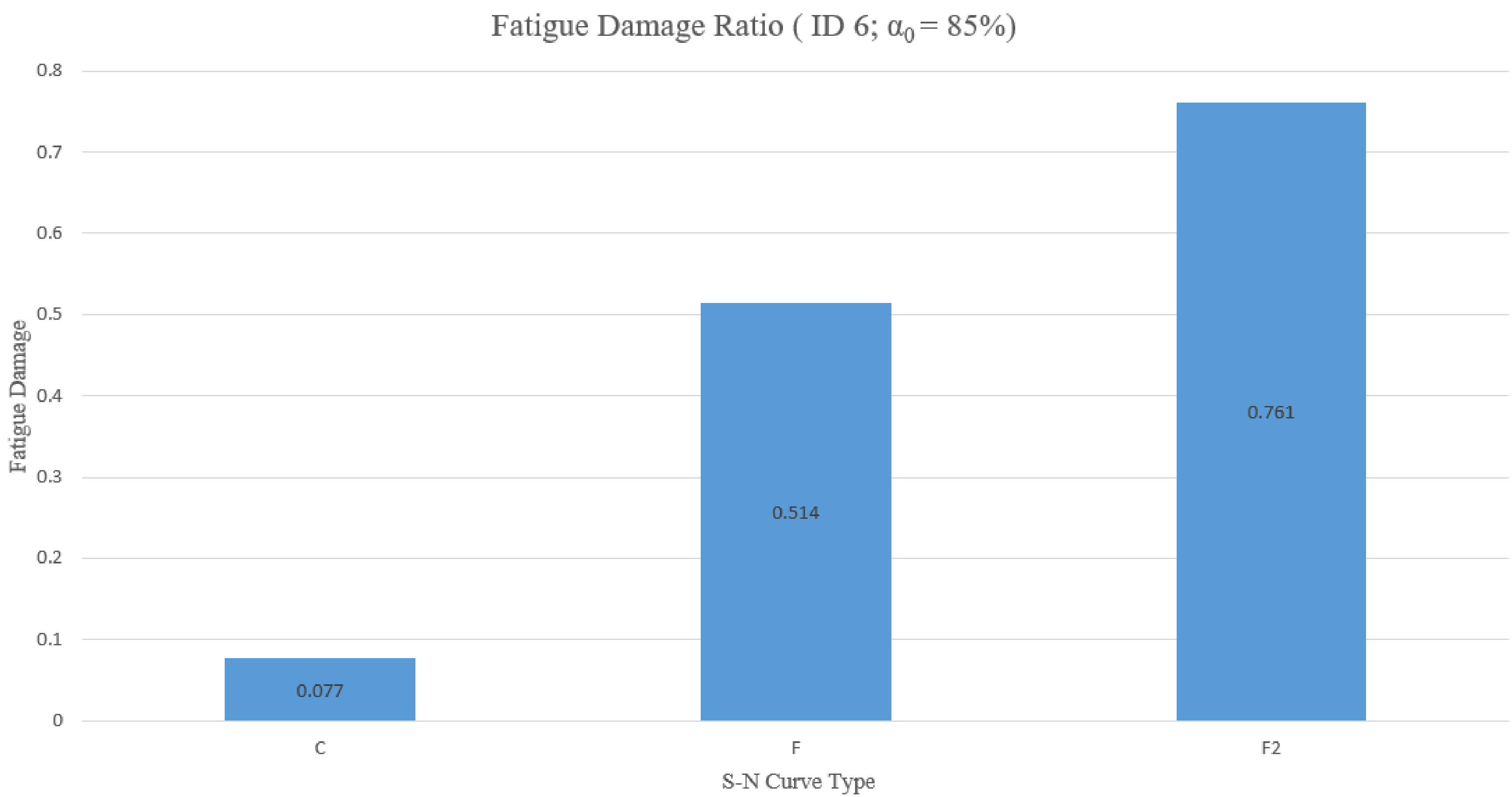
For primary structural members; Stress range from FE model.

Fatigue Damage Ratio

ID	Structural Details	Sailing Factors (α_0)			
		10%	**40%**	**60%**	**85%**
A	Detail 1 : End connection of bottom longitudinal secondary stiffeners with transversal bulkhead frame	0.033	0.133	0.200	0.283
B	Detail 2 : End connection of inner bottom longitudinal secondary stiffeners with transversal bulkhead frame	0.024	0.094	0.141	0.200
C	Detail 3 : End connection of inner side longitudinal stiffeners with side web frames	0.027	0.108	0.162	0.230
D	Detail 4 : Connection of bottom longitudinal secondary stiffeners welded with web frame and collar plate	0.031	0.123	0.184	0.260
E	Detail 5 : Connection of inner bottom longitudinal secondary stiffeners welded with web frame and collar plate	0.020	0.080	0.120	0.170
F	Detail 6 : Connection of inner side longitudinal stiffeners welded with web frame(Scallop)	0.014	0.055	0.082	0.116
G	Detail 7 : Connection of deck longitudinal stiffeners welded with transverse vertical plates(Scallop)	0.020	0.079	0.118	0.168
H	Deck Hatch Corners (Tank No 5)	0.055	0.218	0.327	0.463
I	Wing Tank Manhole Corners(Tank No 5)	0.059	0.237	0.356	0.505
J	Openings on CL Girder (Tank No 5)	0.033	0.132	0.197	0.280
K	Openings on Side Girder (Tank no 5)	0.008	0.030	0.045	0.064

⇨ **Critical!**

Fatigue Damage Ratio of Critical Detail For Various S-N Curve



Critical Analysis

Fatigue damage directly related to the wave height. The Inland vessel encounters max. wave height of 1.2m does not induce Fatigue damage.

Stresses evaluated using the rule formulations are more conservative.

Comparison study of fatigue damage ratio (Stresses evaluated using Rules and FEM).

ID	Structural Detail	Stresses evaluated using Rules	Stresses extracted from FE model	% Difference
6	Detail 6:Connection of deck longitudinal stiffeners welded with transverse vertical plates(Scallop)	**1.096**	0.761	30.57

Conclusions

The impact of thickness reduction due to corrosion has not considerably affected the strength of most of the structural items except the bottom longitudinals and CL/Side girder strakes.

Actual Section modulus (45.81 cm^3) < Required (58.17 cm^3)

For primary supporting members and transverse frames, the strength analysis using FEA gives a maximum von-mises stress of 210.12 N/mm2, which can be considered as acceptable. (Permissible von-mises stress is 219.42 N/mm2),

The highest value of fatigue damage ratio (D=0.505) is observed on the wing-tank manhole radius in the deck area for a sailing factor of 85% due to higher normal stresses.

The most conservative results are obtained with type F2 curves (with lower Sq values).

Corrosion and resulting deterioration of welds and scantlings have a considerable impact on the fatigue life of structural details. However, the damages are within the acceptable limits.

The scantlings of the vessel have been designed in the a safe and conservative manner.

Recommendations

Partial safety factors proposed by the classification society should be reconsidered and modified by proper validation techniques like similar investigations.

Stress concentrations can be avoided by proper construction techniques recommended in the class rules, also strength issues can be resolved by adequate reinforcements.

The results can be optimized by the implementation of probabilistic approaches.


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