Structural Assessment of Crane on Heavy Lift Ship with Load Check and Fatigue Life Calculation

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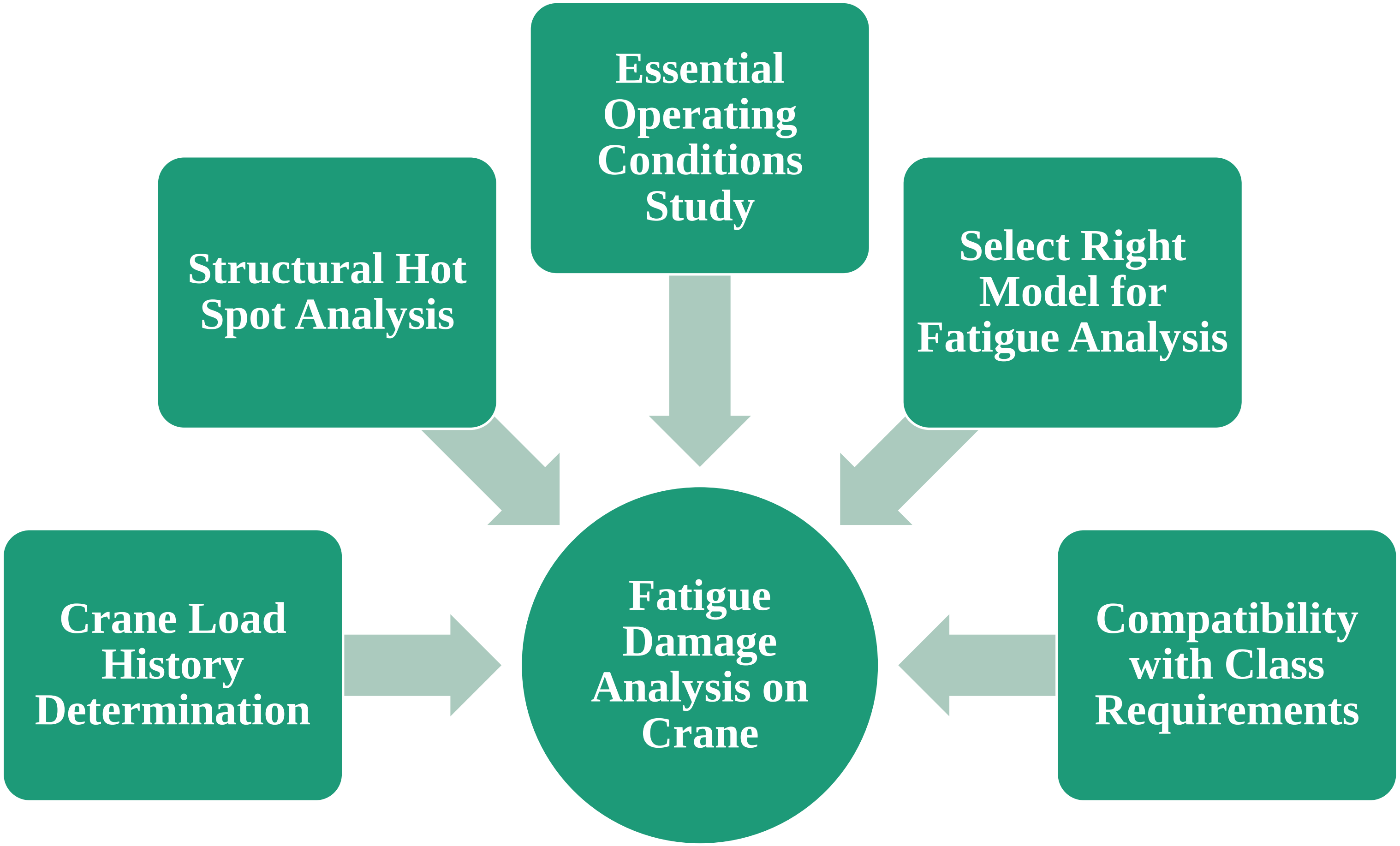
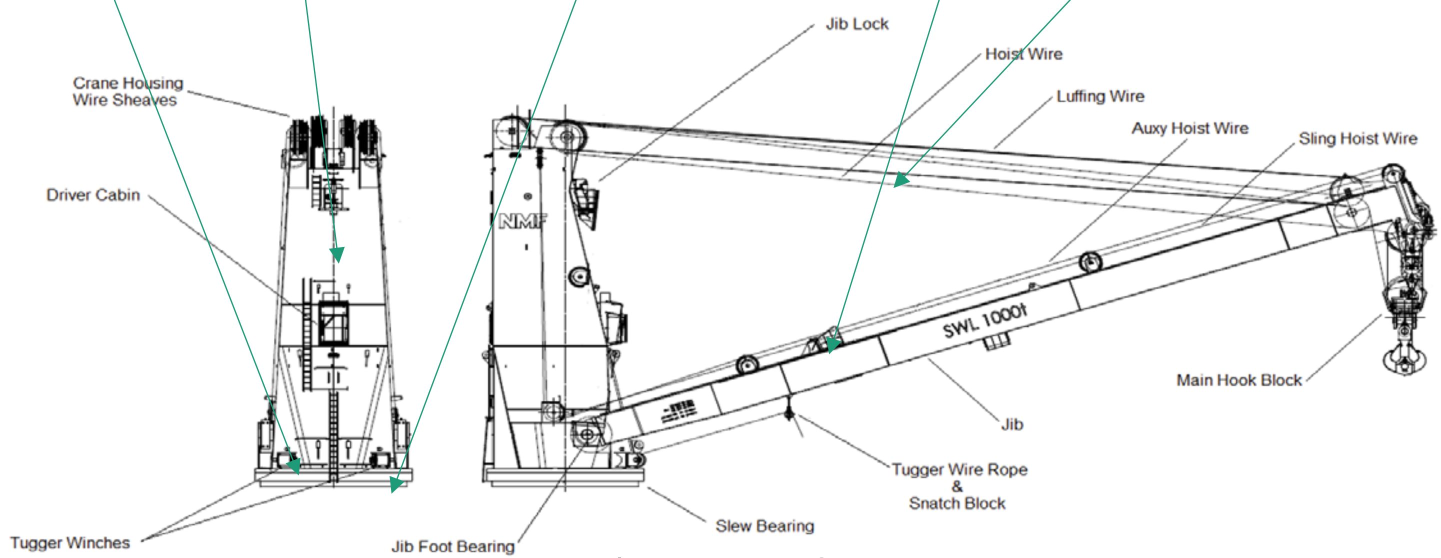
Major Goals Achieved



Crane Structure

- Pedestal
- Crane housing
  - Wire connection
  - Openings
- Slewing Bearing
  - Slew ring bolts
- Crane Boom
  - Pin Bearing
- Crane wires
  - Material & stiffness
  - Wire connections



183 Ship Cranes

Cranes:	**2 x 1,000 mtons SWL, combinable up to 2,000 mtons.**
Capaicity:	1,000 MT @ 16m outreach 800 MT @ 25m outreach 500 MT @ 38m outreach
Slewing:	360 degree with hydraulic motor drive
Luffing :	18.17 degree to 84.35 degree
Hoisting:	Maximum boom tip height of 37.3 meters
Operating: **Conditions**	5.4 degree inclination (5 degree Heel and 2 degree trim.)
Wind Speed:	20m/sec

Lloyds Register Rules and Guidelines

Load case Type 1

$$Crane\ Loads = F_d\left(L_g + F_h(L_1 + L_{h1}) + L_{h2} + L_{h3}\right)$$

- F_d=Duty factor
- L_g=dead load
- F_h=Live load
- L_l=Hoisting factor
- L_{h1}=Horizontal component due to the heel and trim.
- L_{h2}=The next most unfavourable horizontal load.
- L_{h3}= The horizontal component due to the heel and trim.

Load case Type 2

$$Crane\ Loads = F_d\left(L_g + F_h(L_1 + L_{h1}) + L_{h2} + L_{h3}\right) + L_w$$

- L_w=The most unfavourable wind load

Load case Type 3

the crane is considered in the stowed position

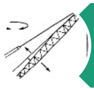
DNV-GL rules and guidelines for lifting appliances

Crane Loads

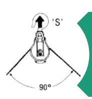
Regular Loads


- Dead Loads


- Hoist Loads

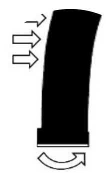

- Dynamic Forces of cargo


- Dynamic Forces of ship


- Diagonals Pull loads due to cargo.


- Partial Drop off forces

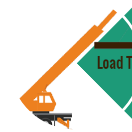
Irregular Loads


- Wind Loads


- Snow and Ice


- Temperature

Special Loads

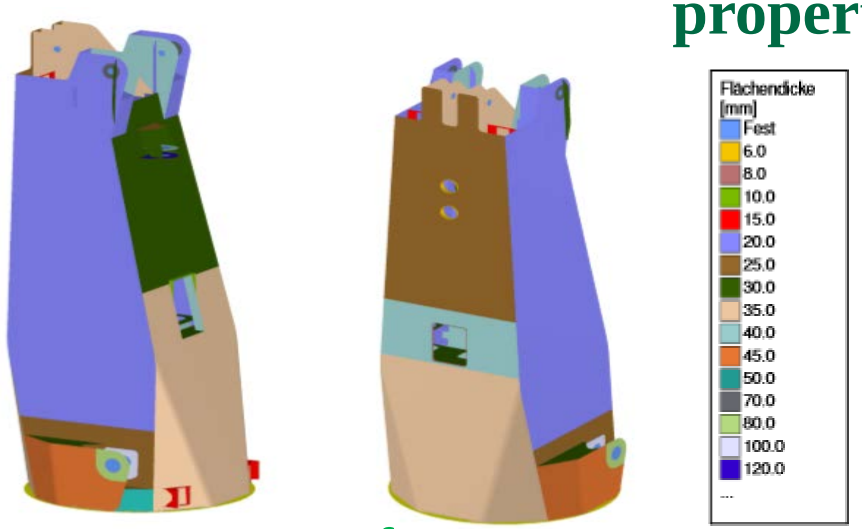

- Dynamic load testing

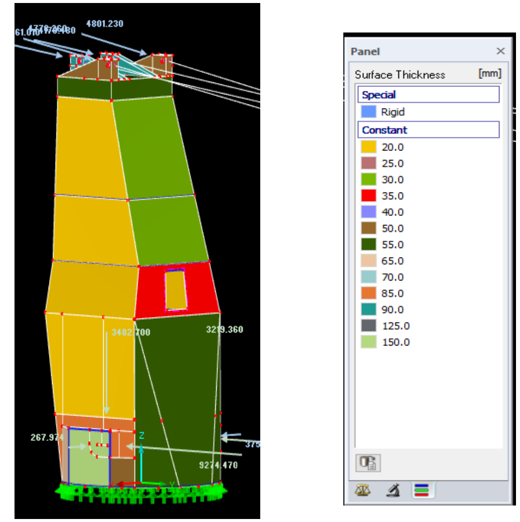

- Buffering Forces


- Loads due to the safety system.


- Tear off of hoist loads

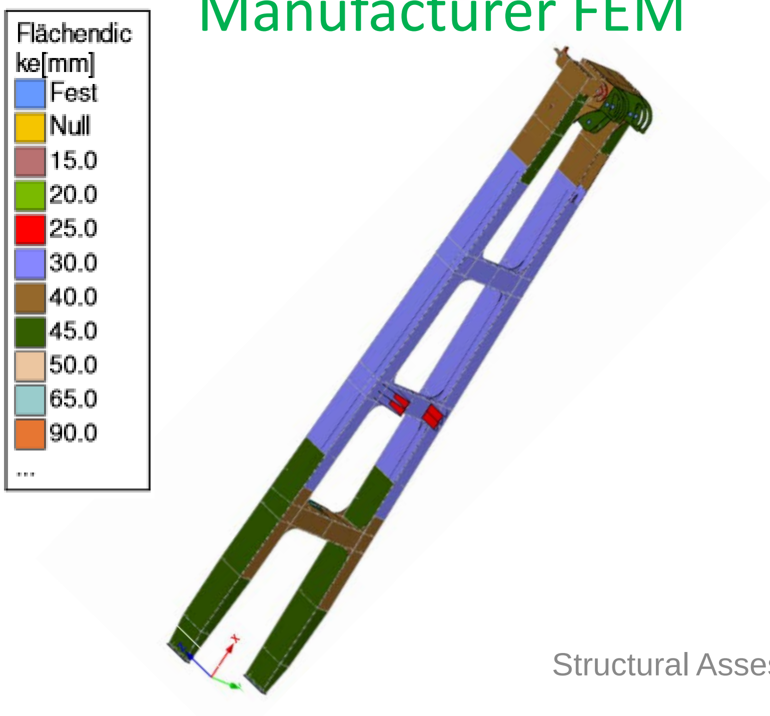
Matching the model with the actual crane material properties

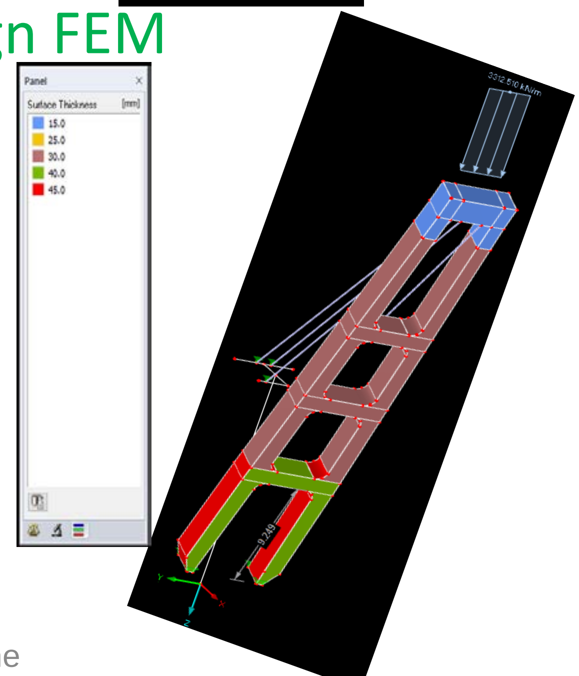




Manufacturer FEM

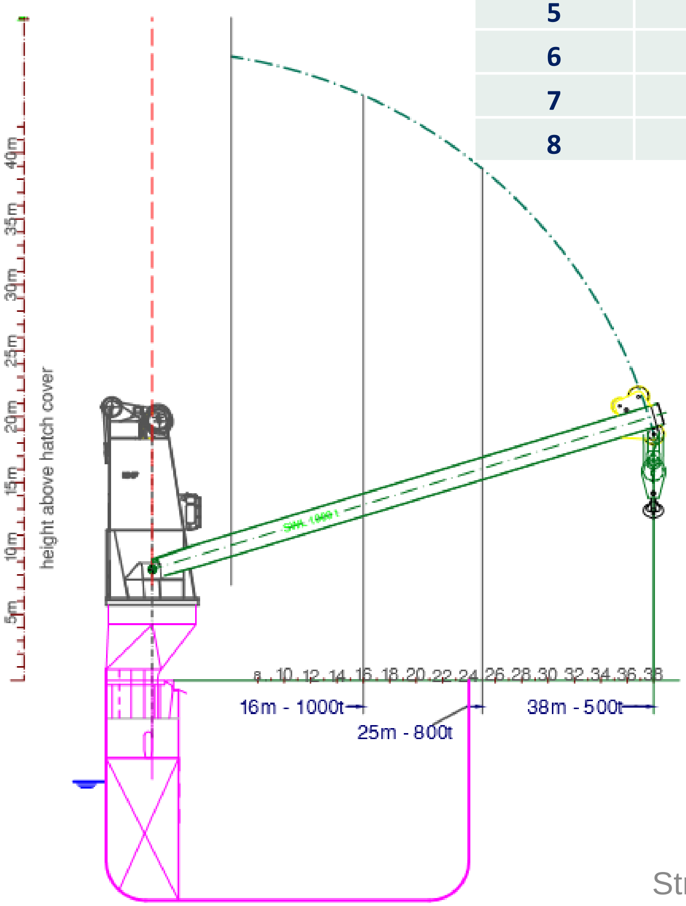
Design FEM





Analysing the Load Cases

Load Case S.No.	Boom angle. (degrees)	load SWL (tons)	Outreach	Weight of Boom(t)	Total Weight	Force P(KN)
1	69.74	1000	16	152	1152	11301.12
2	54.04	800	25	152	952	9339.12
3	18.17	500	38	152	652	6396.12
4	54.04	500	25	152	652	6396.12
5	69.74	500	16	152	652	6396.12
6	18.17	350	38	152	502	4924.62
7	54.04	350	25	152	502	4924.62
8	18.17	250	38	152	402	3943.62



Physical conditions considered:

- Wind conditions at 20m/sec
- List of ship 2 degree
- Trim of ship 5 degree
- Ship speed zero during cargo operation
- Temperature less than 150 degree
- Material of structure steel S355
- Wire stiffness and material properties matched with real crane
- No influence of waves

Validation of result with manufacturer Data

3.2 SWL 1000t 16m

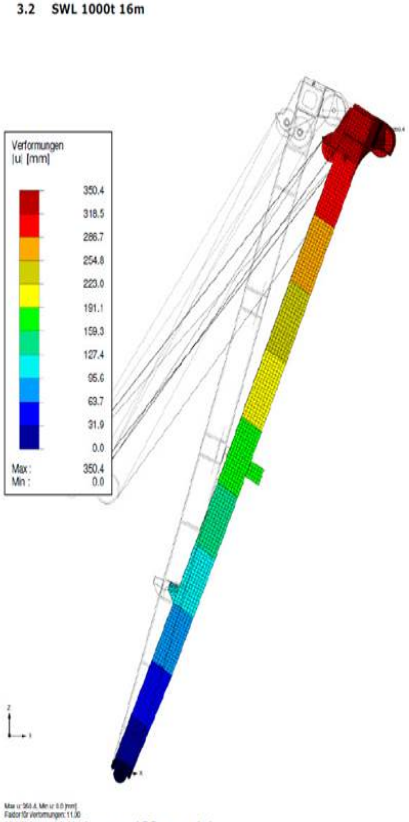
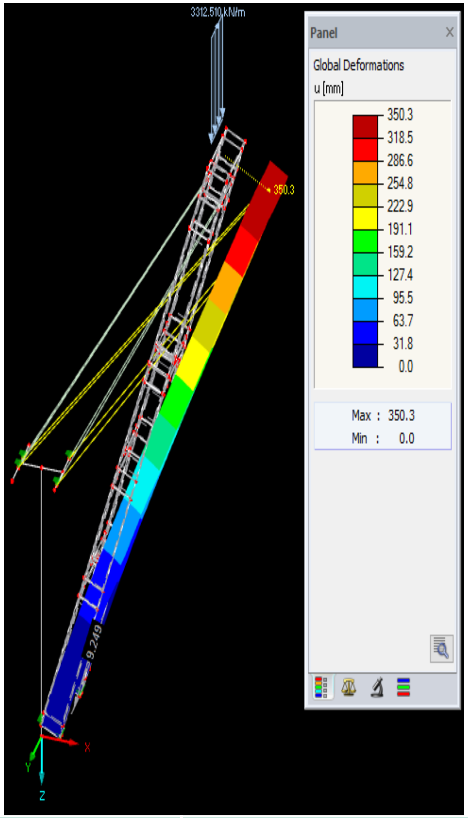


Abbildung 14: Verformungen LF B, g=+x, wind=+x



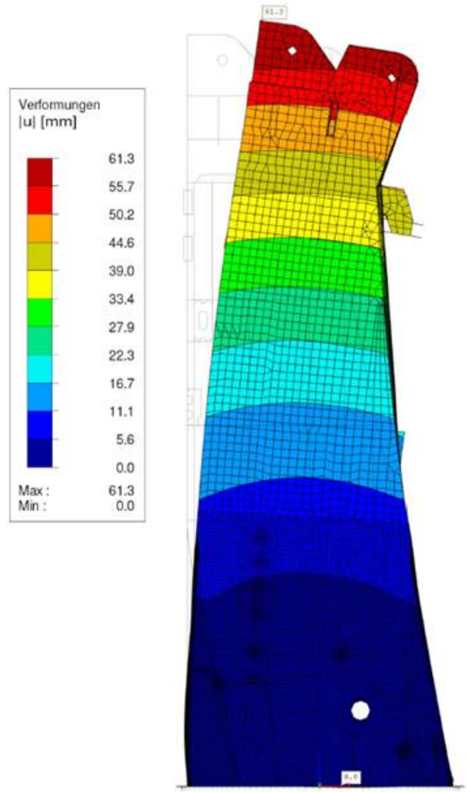
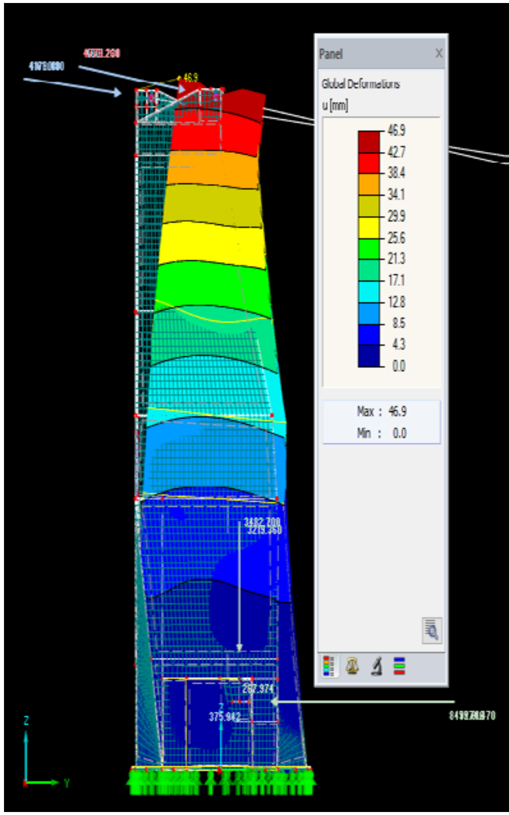
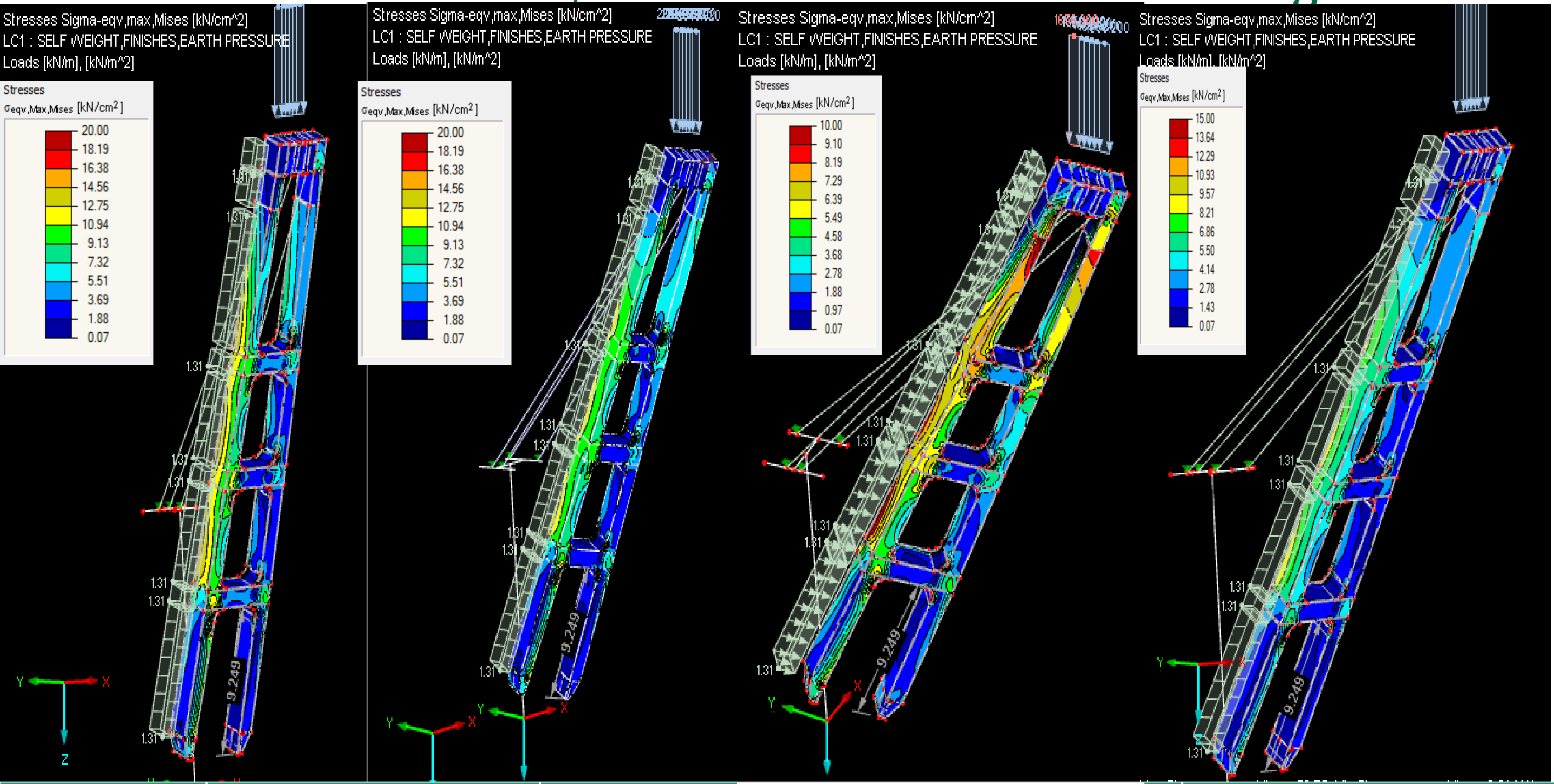


Abbildung 13: Verformung LF 3 500t 38m



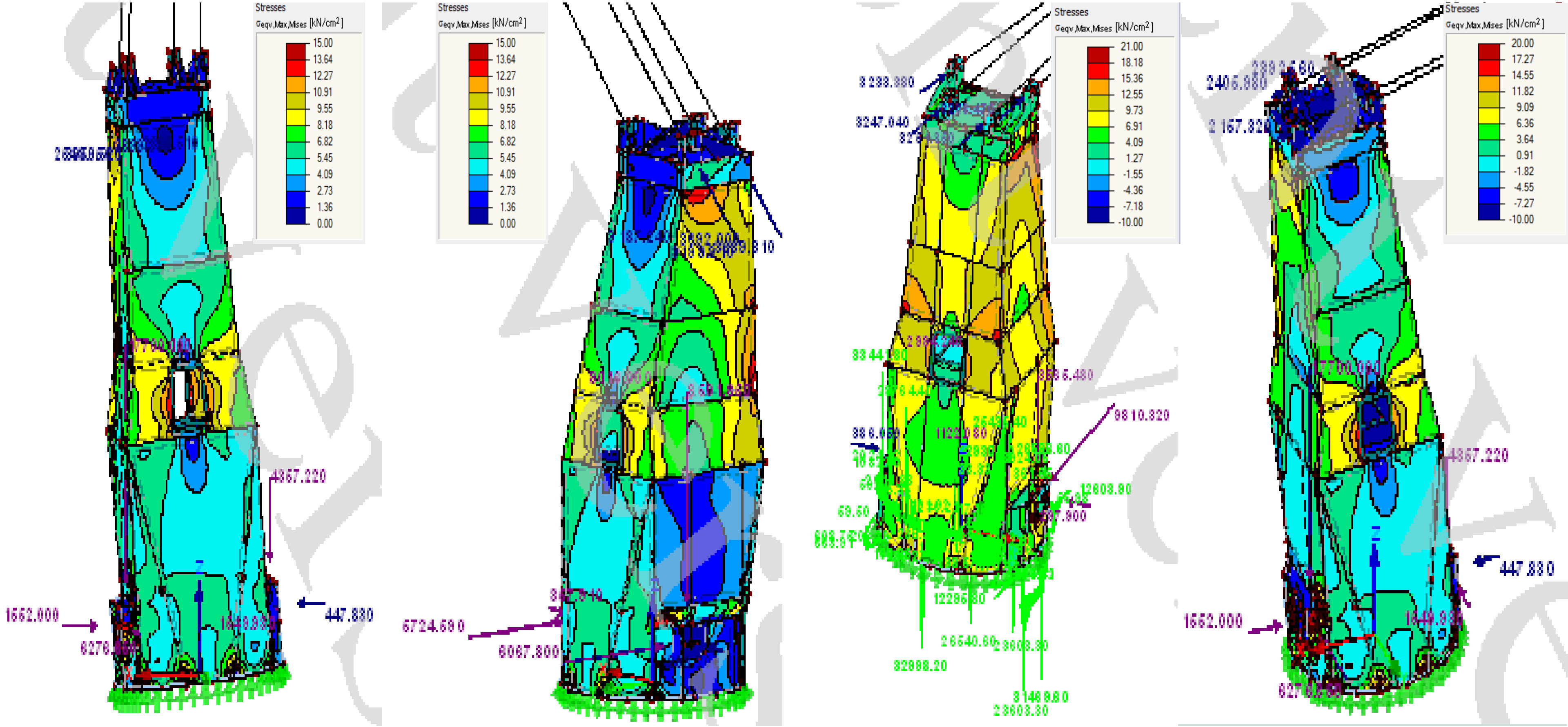
Study	MFG FEM	Design FEM	MFG FEM	Design FEM
Deflection:	350.4mm	350.3mm	61.3mm	46.9mm
Model Wt:	152 tons	151.7 tons	157 tons	156.7 tons
Material	940KN/mm^2, 102KN/mm^2	940KN/mm2, 102KN/mm2	Steel S-355	Steel S-355

Stress History of Boom with inclination 5.4 deg



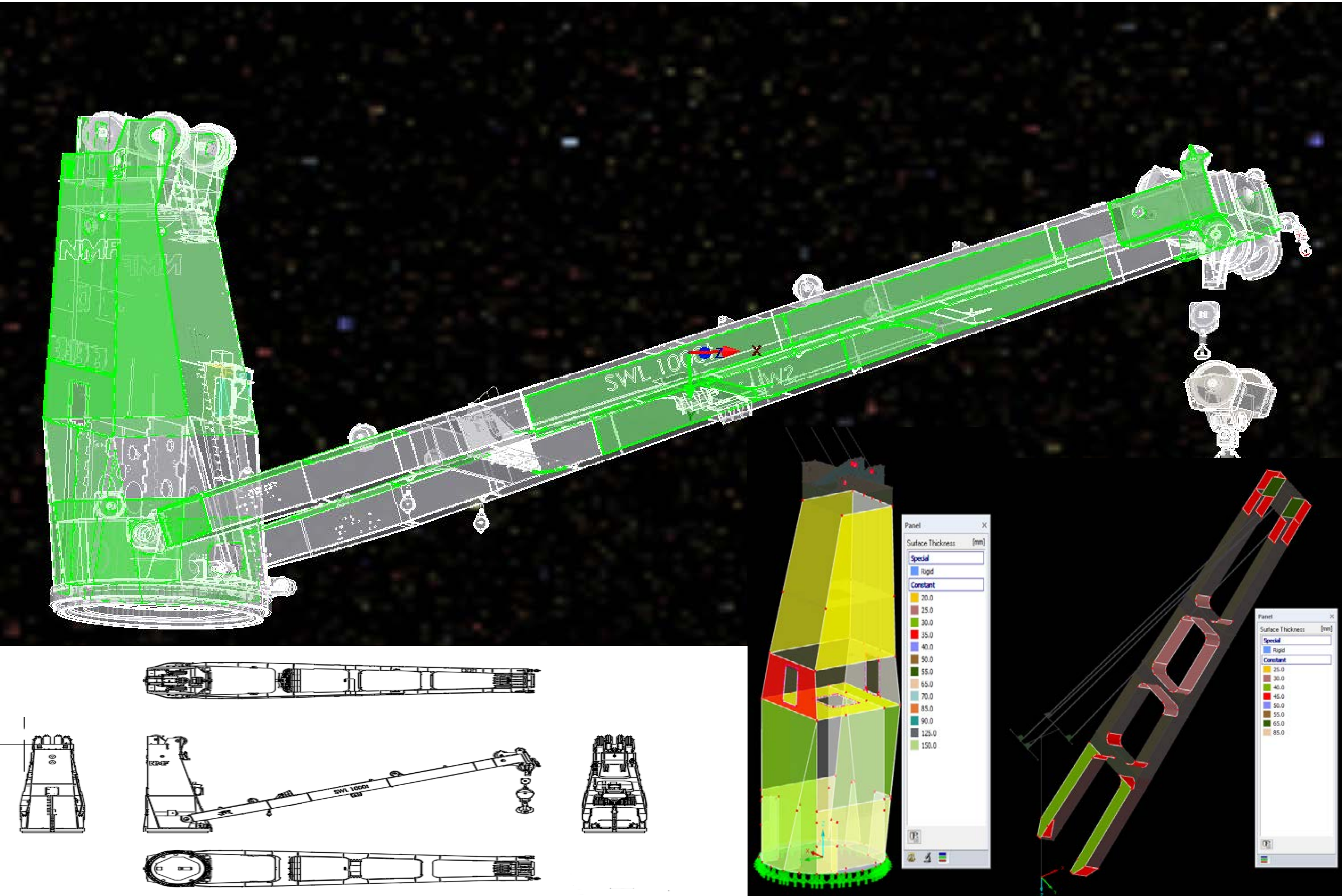
Study	Load Case 1	Load Case 2	Load Case 3	Load Case 4
Max Stress	20KN/cm2	20KN/cm2	10KN/cm2	11KN/cm2
Load	1000 tons	800 tons	500 tons	500 tons
Boom Ang	69.74 degree	54.04 degree	18.17 degree	54.04 degree

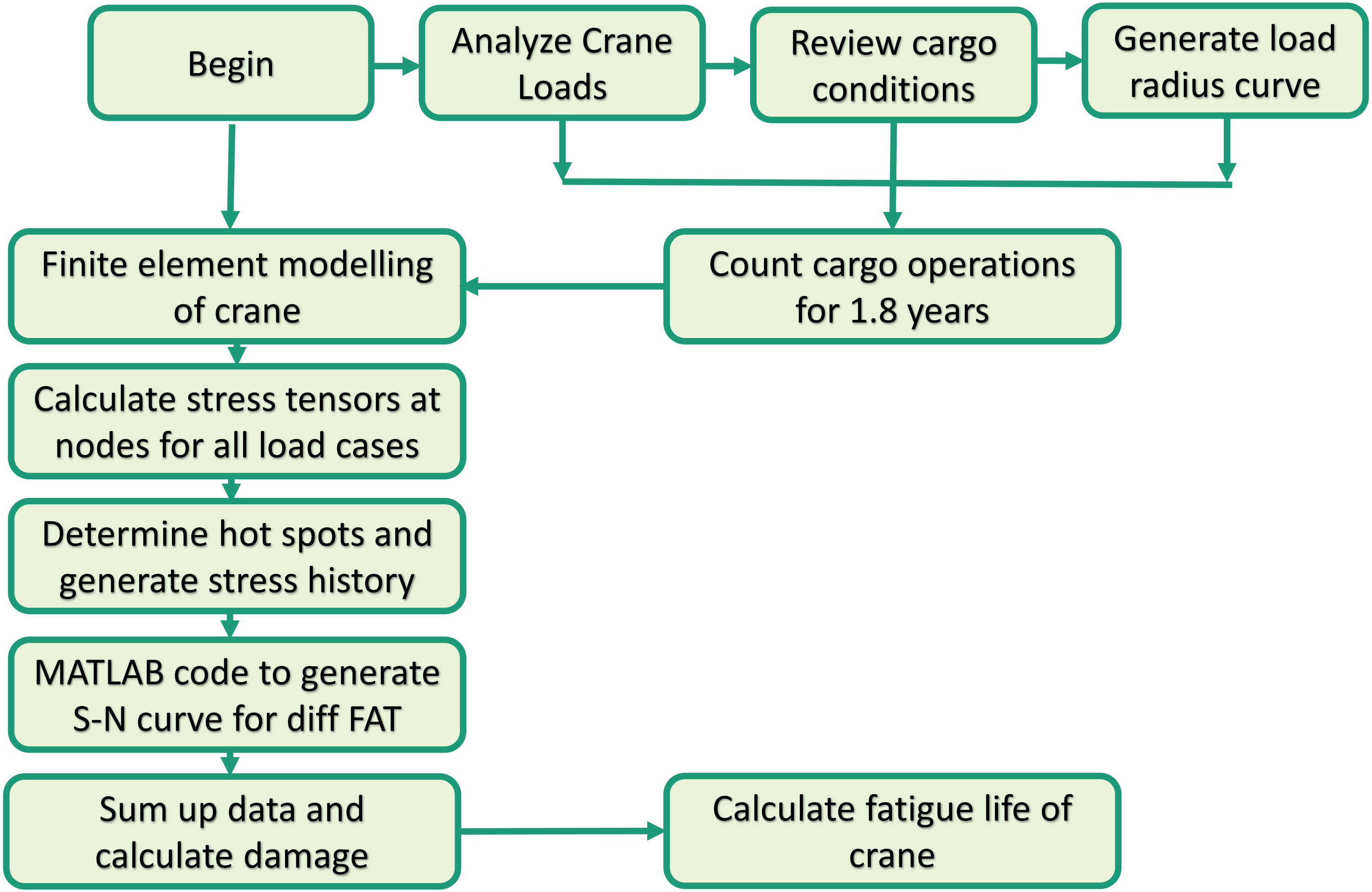
Stress History of Housing with Inclination 5.4 degree

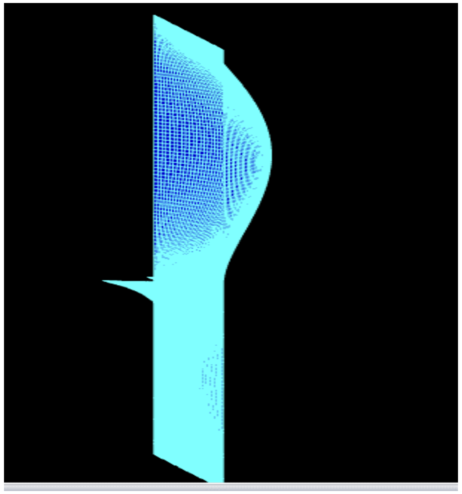


Study	Load Case 1	Load Case 2	Load Case 3	Load Case 4
Max Stress	13.30KN/cm2	12.2KN/cm2	21.0KN/cm2	11.7KN/cm2
Load	1000 tons	800 tons	500 tons	500 tons
Boom Ang	69.74 degree	54.04 degree	18.17 degree	54.04 degree

Hot Spot Locations all Load Cases




Begin
Analyze Crane Loads
Review cargo conditions
Generate load radius curve
Finite element modelling of crane
Count cargo operations for 1.8 years
Calculate stress tensors at nodes for all load cases
Determine hot spots and generate stress history
MATLAB code to generate S-N curve for diff FAT
Sum up data and calculate damage
Calculate fatigue life of crane



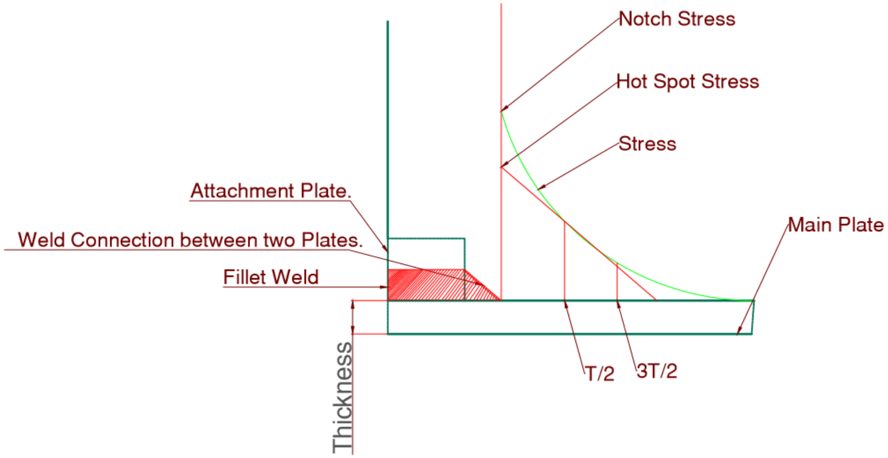


Plate Analysis

- Carried out to check failure of plate
- Notch case of 120 to 160 used
- Analysed by coarse grid stresses
- MATLAB program used for analysis

Weld Analysis

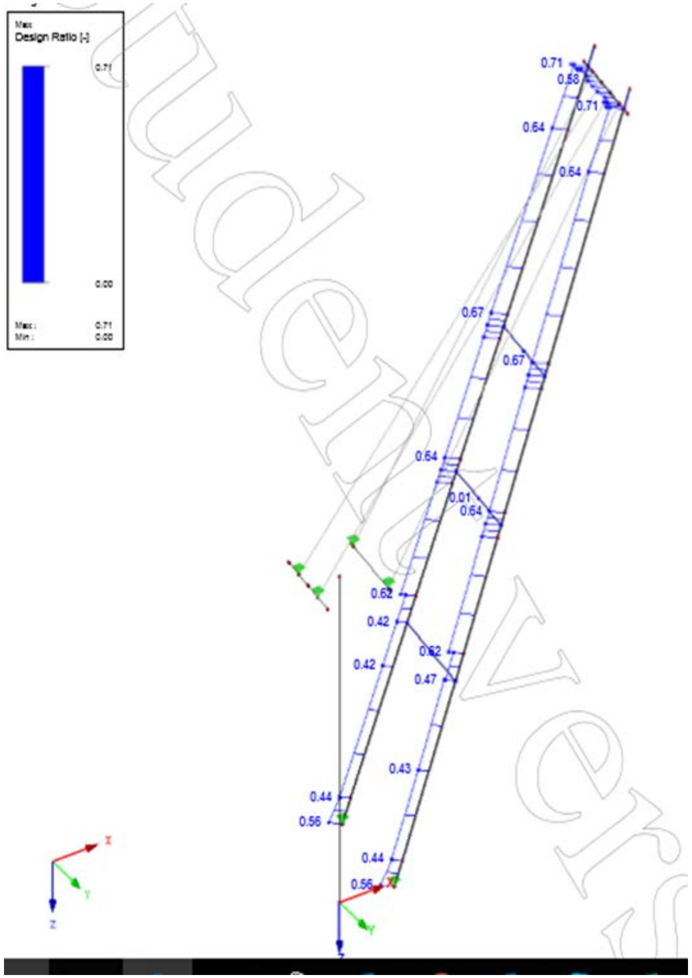
- Carried out to check failure of welds
- Notch case of 80 to 120 used
- Analysed by special fatigue finite element module
- More elaborate approach used for analysis

Locating Maximum Fatigue Damage

Maximum damage given by manufacturer

Outreach [m]	SWL [t]	Damage ratio for 1 load cycle D_1	Load cycles n	Damage ratio D
≤ 16	≤ 500	0,000005968	1040	0,006206235
	≤ 1000	0,000031545	2080	0,065612683
≤ 25	≤ 350	0,000009908	3120	0,030913944
	≤ 500	0,000020310	3120	0,063366019
	≤ 800	0,000061810	3120	0,192845744
≤ 38	≤ 250	0,000020435	3120	0,063757248
	≤ 350	0,000031758	3120	0,099084534
	≤ 500	0,000067995	2080	0,141428567
		Total	20800	0,663214975

Maximum damage calculated on welds :



=~ 0.71

1.00

Damage difference=0.71-0.663=0.047

Plate fatigue determination

- Grid stresses obtained
- Plate joining located
- Notch case of 120 to 160
- Damage found at each grid point
- Cumulative damage found by summing the results of 8 load cases

Grid Number	X cordinate	Y Cordinate	Z Cordinate	Damage at each Grid
Column1	Column2	Column3	Column4	Column5
1	10.4611	-0.9153	24.0095	0.1572
2	10.4612	0.4153	-24.0095	0.1511
3	10.4612	-0.0847	-24.0095	0.1508
4	10.4612	-0.5847	-24.0095	0.1515
5	10.4613	-1.0847	-24.0095	0.1686
6	9.9921	0.9153	-24.1827	0.16
7	9.9921	0.4153	-24.1827	0.187
8	9.9921	-0.0847	-24.1827	0.1874
9	9.9922	-0.5847	-24.1827	0.1741
10	9.9922	-1.0847	-24.1827	0.154
11	9.523	0.9152	-24.3558	0.1492
12	9.523	0.4152	-24.3558	0.1548
13	9.5231	-0.0848	-24.3558	0.1788
14	9.5231	-0.5848	-24.3558	0.1495
15	9.5231	-1.0848	-24.3558	0.1536
16	9.0539	0.9152	-24.529	0.1699
17	9.054	0.4152	-24.529	0.1633
18	9.054	-0.0848	-24.529	0.1617
19	9.054	-0.5848	-24.529	0.1621
20	9.0541	-1.0848	-24.529	0.1641
1	4.0707	2.0747	-10.1546	0.1551
2	4.5398	2.0747	-9.9815	0.1561
3	5.0088	2.0747	-9.8083	0.1534
4	4.2234	1.8605	-10.5682	0.1634
5	4.6924	1.8605	-10.3951	0.1525
6	5.1615	1.8605	-10.2219	0.1659
7	4.2942	1.415	-10.7601	0.1547

Design equations and the calculation of the parameters:

- $\Delta\sigma \leq 1.5x f_y$
- $\Delta\tau \leq \frac{1.5\, f_y}{\sqrt{3}}$
- $\left(\frac{\gamma_{Ff}.\Delta\sigma_{E,2}}{\Delta\sigma_C/\gamma_{Mf}}\right)^3 + \left(\frac{\gamma_{Ff}.\Delta\tau_{E,2}}{\Delta\tau_C/\gamma_{Mf}}\right)^3 \leq 1.0$

Important Findings

- Maximum boom outreach (38mts) is the limiting load case
  - Housing deflections are maximum (46.9mm)
  - Horizontal bearing forces are maximum

- Maximum fatigue damage is found to occur on the boom tip after 25 years of lifetime

- Structure welds are more prone to fatigue failure compared to the plating

- The housing bottom plating and the foundation shape is critical for analysis and hot spot point of view

- The window areas on housing need to be minimized to give more structural strength

Structural Assessment and Fatigue Life Determination Tool in Order to Simplify the Inspection Task Onboard