Fatigue Assessment for Bulk Carrier According to the CSR

Student: Akram Madi

Supervisor: Dr. Maciej Taczala

OUTLINE

Objectives & Methodology

Fatigue Assessment Hypothesis

Bulk Carrier Descriptions

Poseidon Global FEM-Model

ANSYS Global FEM-Model

Submodelling

Hot spot Extrapolation & SCF

Cumulative Fatigue Damage

Conclusion and Recommendation

Objectives

Develop Global FEM under CSR

Develop submodels for evaluating the stress concentration factor (SCF)

Assess the fatigue strength according to CSR

METHODOLOGY

Literature Review

Rules of Classification Societies (CSR)

FEM Software (Ansys – Poseidon)

Fatigue Assessment Hypothesis

- **Design S-N curves**

- **Representation of long term distribution of stress ranges by two-parameters of Weibull probability distribution**

- **Minimum design life 25 years in North Atlantic**

- **Palmgren-Miner cumulative fatigue damage**

# FE Analysis -Fatigue Assessment

- **Dynamic fatigue loads**

    Tuned on 10^{-4} probability level, North Atlantic

    Load combination factors

- **Fatigue loads conditions**

- **Model based on average (over life) corroded thickness, $t_{gross} - 0.5\ t_{corr}$**

- **Hot spot stress calculated using very fine mesh (mesh size $t \times t$)**

Bulk Carrier

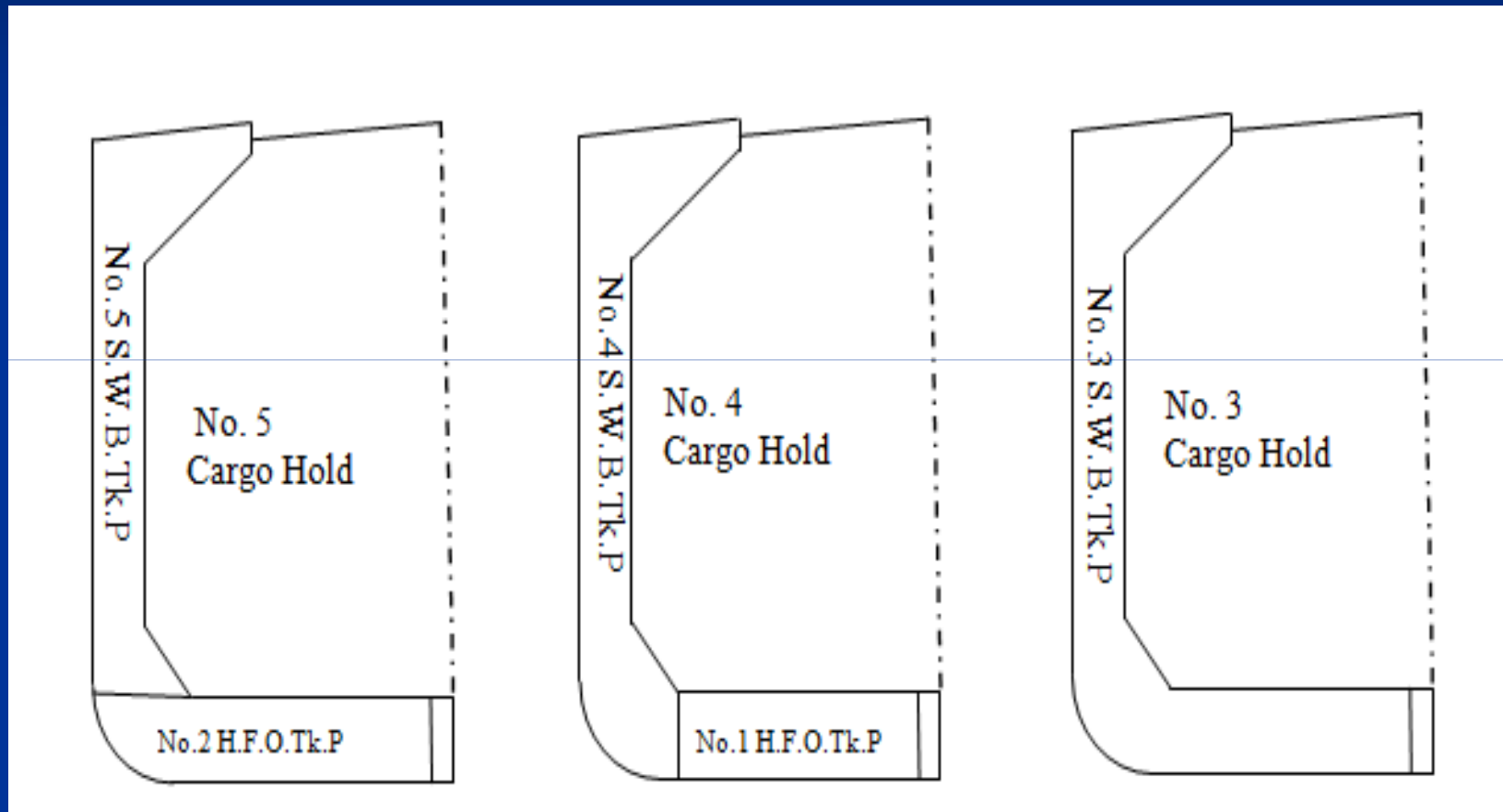## Specification Characteristics

Length (o.a)　　L_{oa}	190	m
Length (p.p)　　L_{pp}	182.6	m
Length scantling	180.72	m
Breadth (mld)	23.6	m
Depth (mld)	14.6	m
Draft (scantling) T_{scan}	10.1	m
Dead Weight	30000	t
Service Speed	14	kn

Bulk Carrier

Web frame spacing: 2400
Frame spacing : 800
Stiffener spacing: 740
Hatch : 19200 x 17800
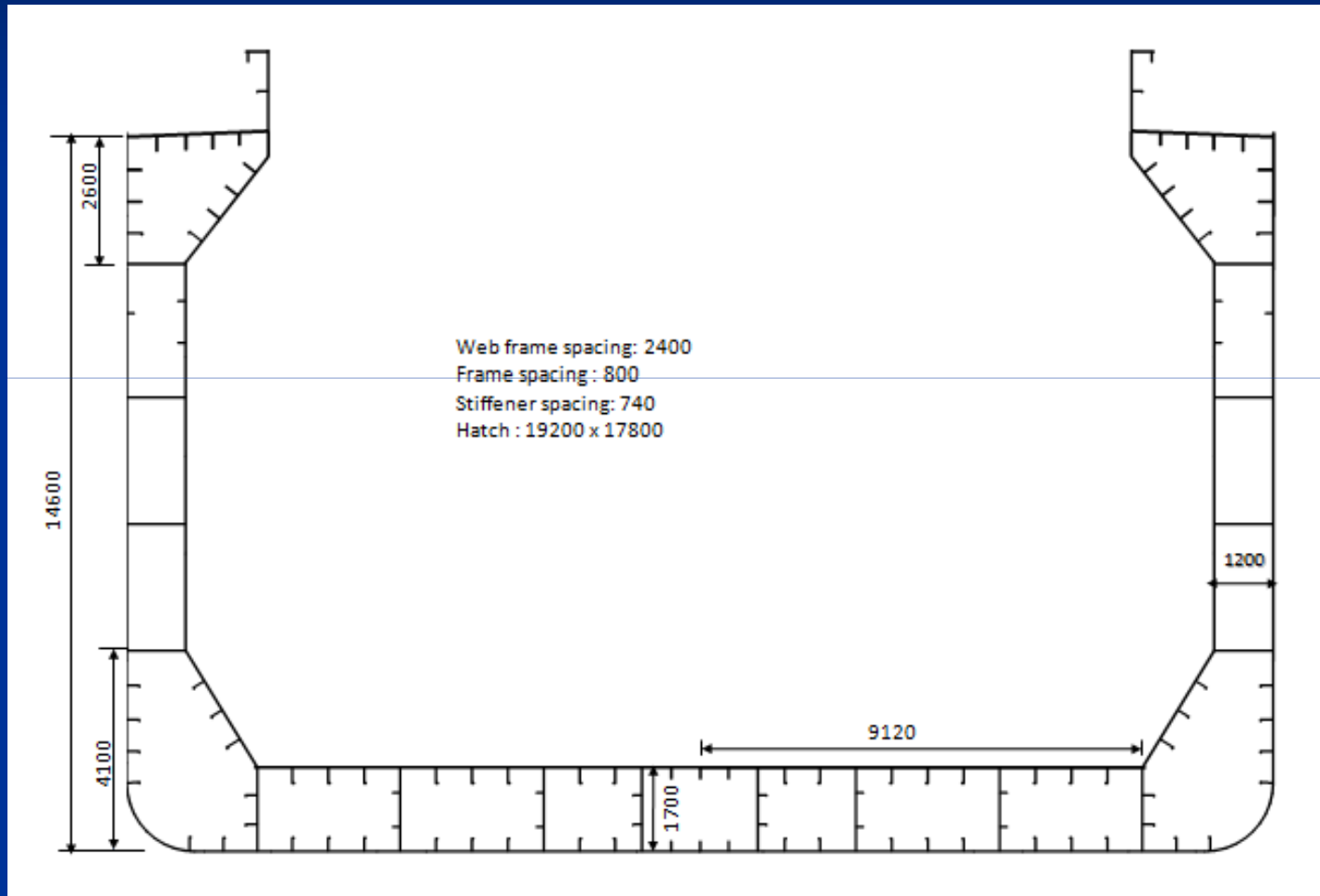
Bulk Carrier

Poseidon Global FEM

Type of element: Shell element for plate and stiffeners
Extend of the model: 3 holds
Boundary Condition: simply supported

Nodes on longitudinal members at both ends of the model	Translational			Rotational		
	Dx	Dy	Dz	Rx	Ry	Rz
All longitudinal members	RL	RL	RL	-	-	-
RL means rigidly linked to the relevant degrees of freedom of the independent point						

Location of the independent point	Translational			Rotational		
	Dx	Dy	Dz	Rx	Ry	Rz
Independent point on aft end of model	-	Fix	Fix	Fix	-	-
Independent point on fore end of model	Fix	Fix	Fix	Fix	-	-

Poseidon Global FEM

| Ship type	Loading conditions			
	Full load condition		Ballast condition	
	Homogeneous	Alternate	Normal ballast	Heavy ballast
BC-A	✓	✓	✓	✓
BC-B	✓	---	✓	✓
BC-C	✓	---	✓	✓

Poseidon Global FEM

Appendix 3 - STANDARD LOADING CONDITION FOR FATIGUE ASSESSMENT

Table 1:   Fatigue Assessment applicable to empty hold in alternate condition of BC-A (mid-hold is empty hold)

| No.	Description	Draught [a)]	Loading pattern	Aft	Mid	Fore	Load case (Design wave)				Still water vertical bending moment [b)]	Remarks (see below)
1	Full Load	T	M_H M_H M_H				H1	F1	R1	P1	$M_{S,(1)}$	1)
							H2	F2	R2	P2		
2	Alternate Load	T	M_{HD} M_{HD}				H1	F1	R1	P1	$M_{S,(2)}$	2)
							H2	F2	R2	P2		
3	Normal Ballast	T_{NB}					H1	F1	R1	P1	$M_{S,(3)}$	
							H2	F2	R2	P2		
4	Heavy Ballast	T_{HB}					H1	F1	R1	P1	$M_{S,(4)}$	3)
							H2	F2	R2	P2		
							H1	F1	R1	P1	$M_{S,(4)}$	4)
							H2	F2	R2	P2		

Poseidon Global Mesh
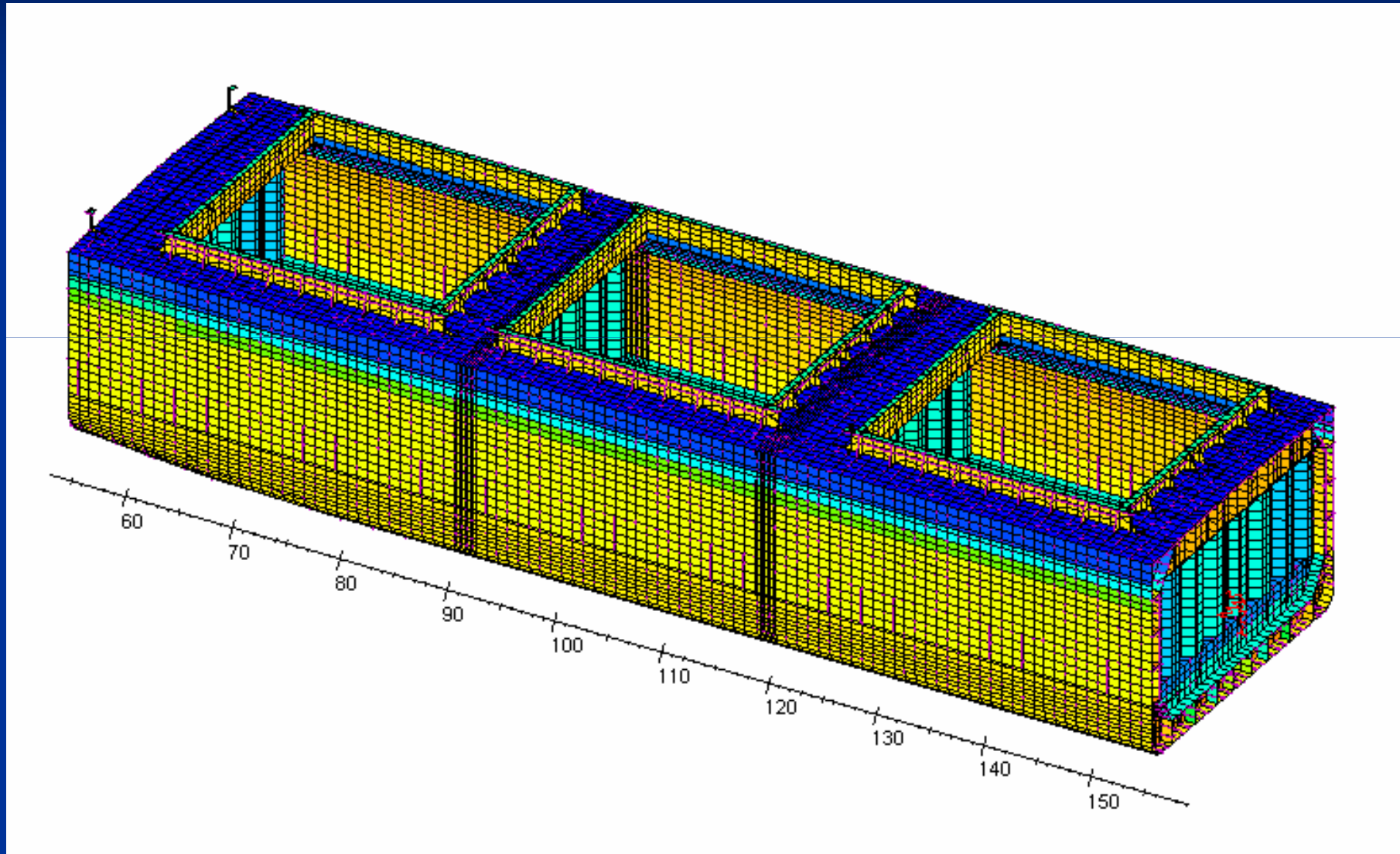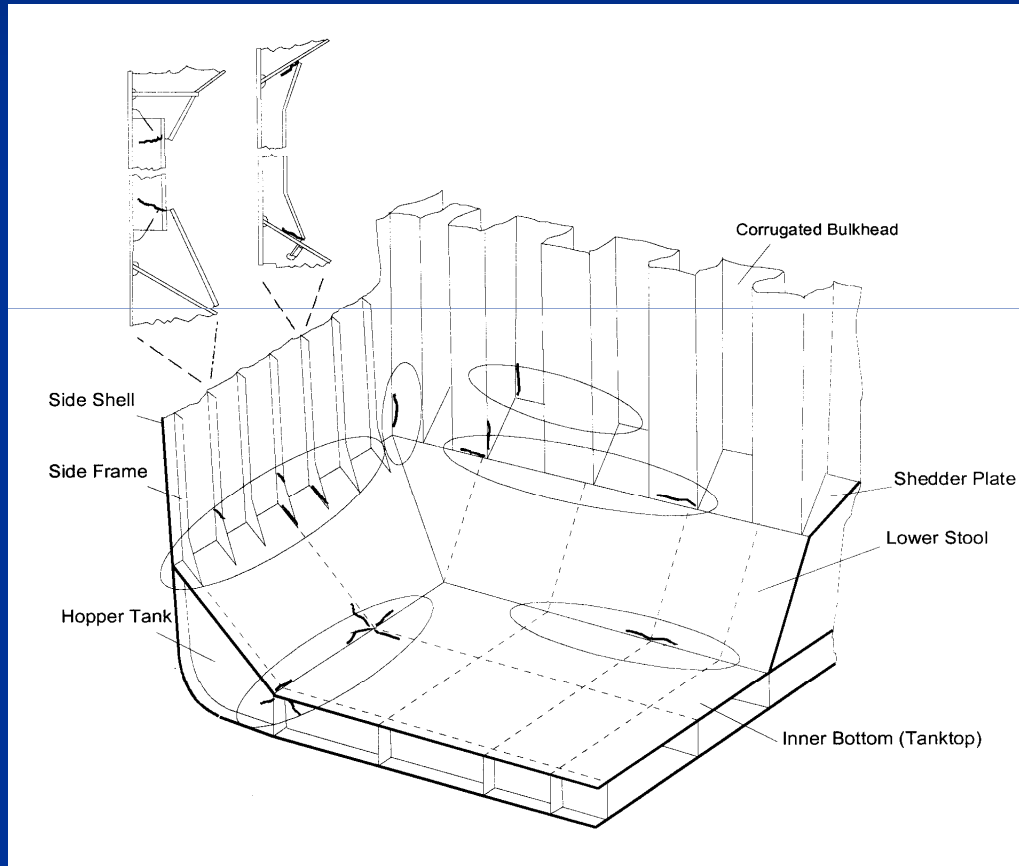
Homogenous Loading– H1
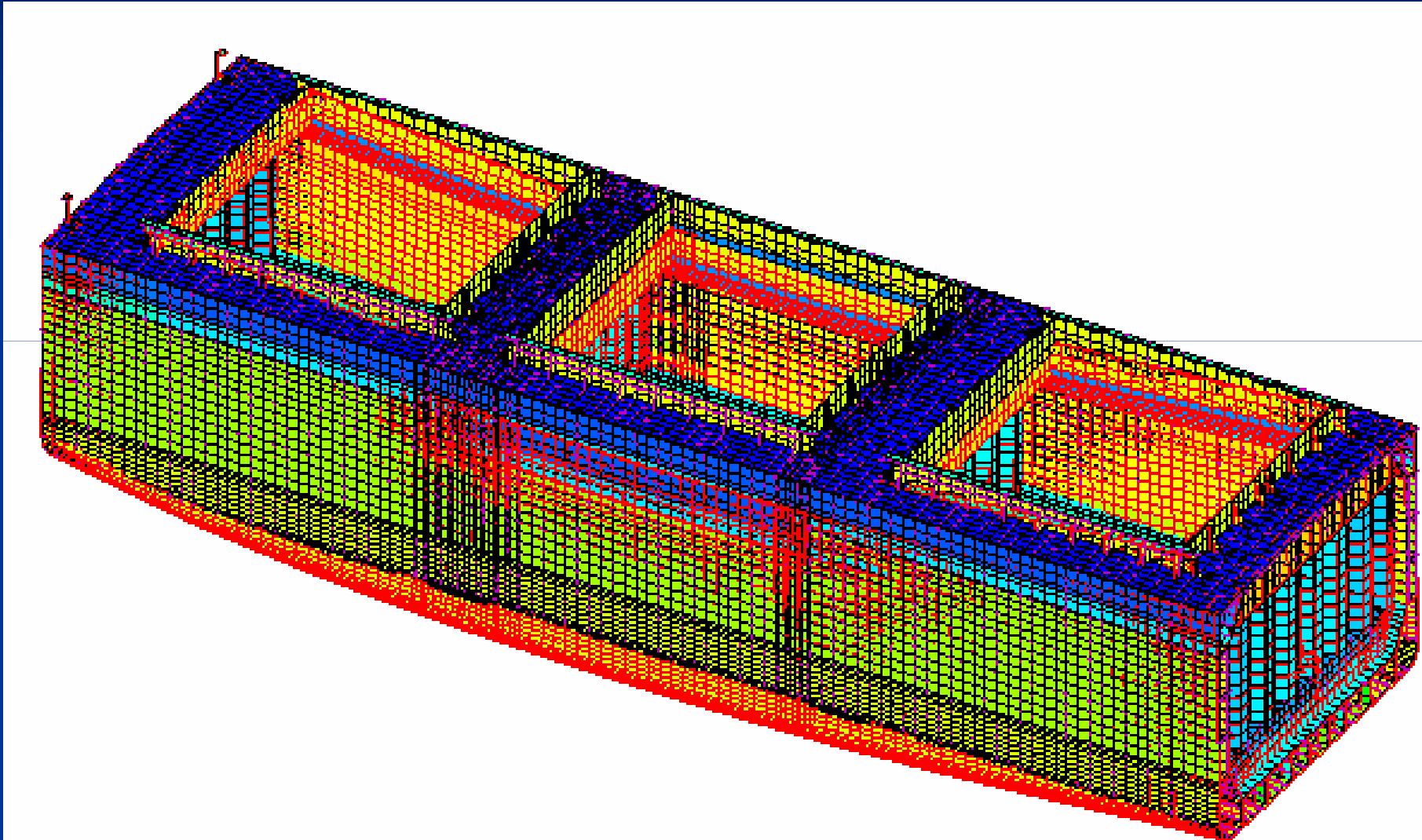
ANSYS Global FEM
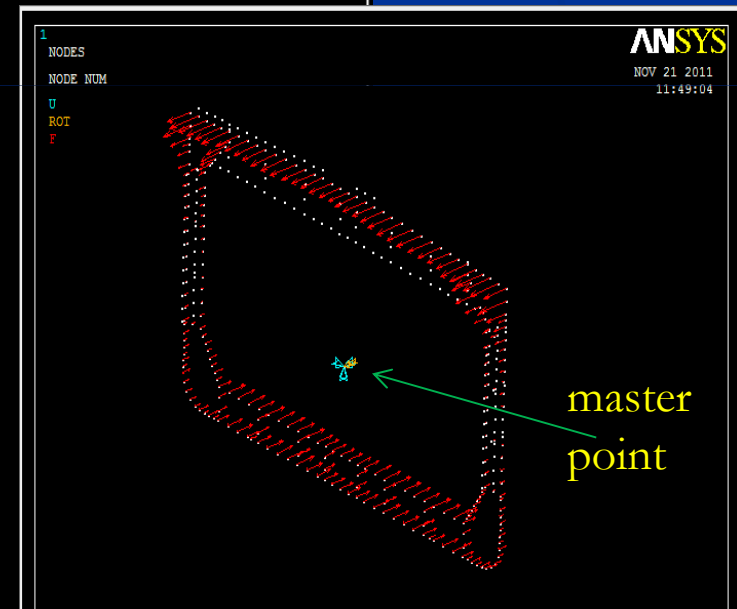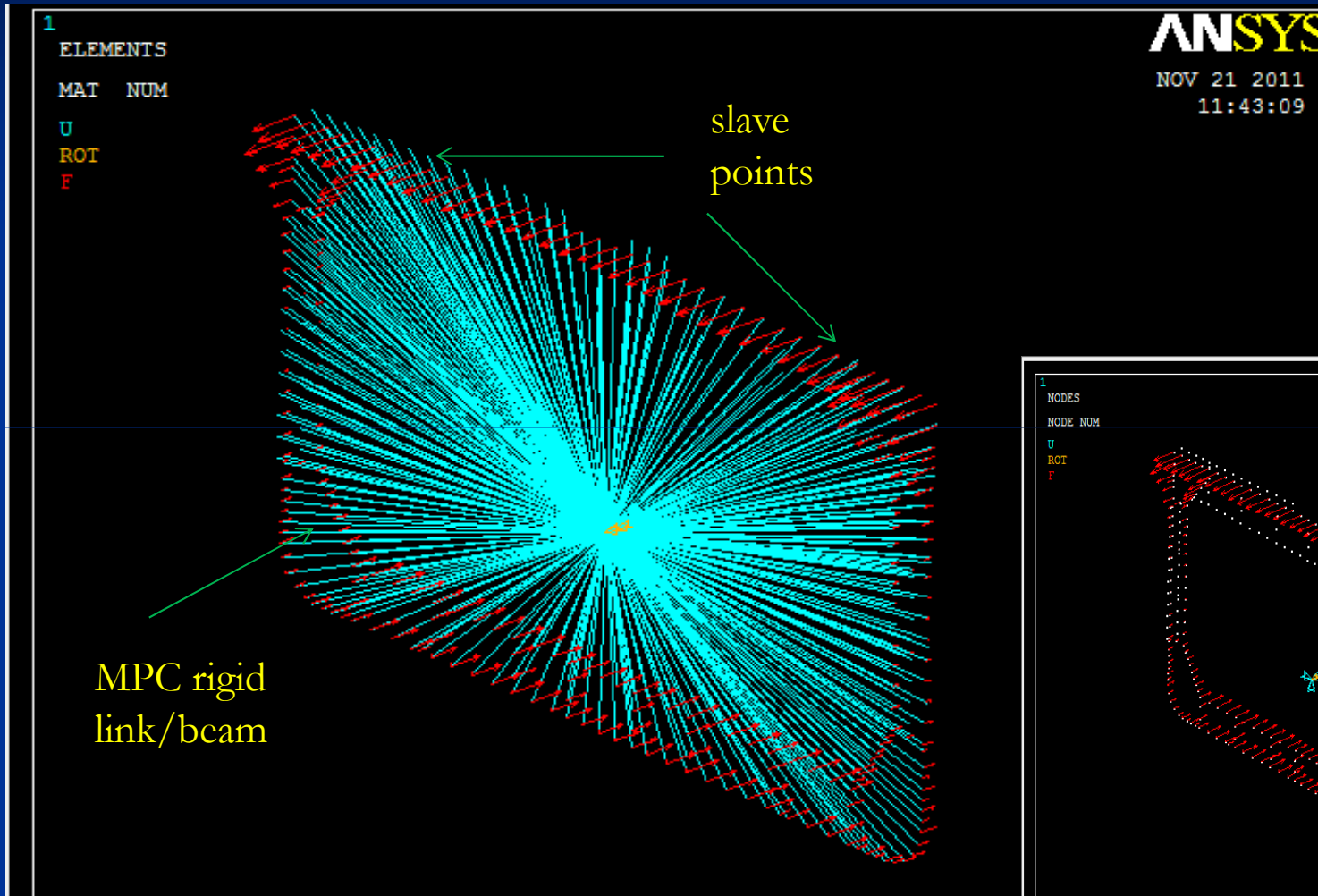
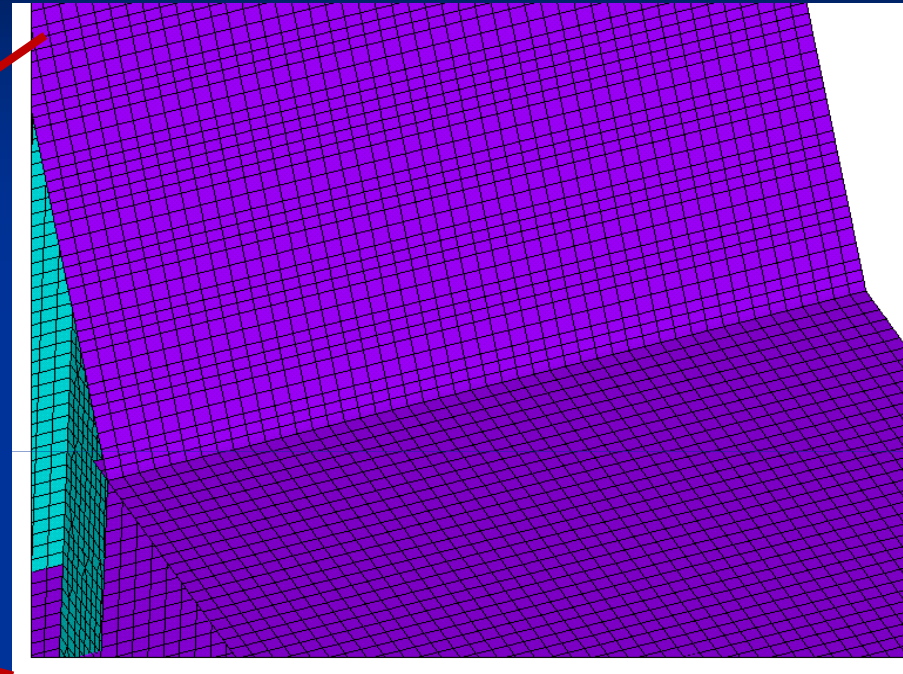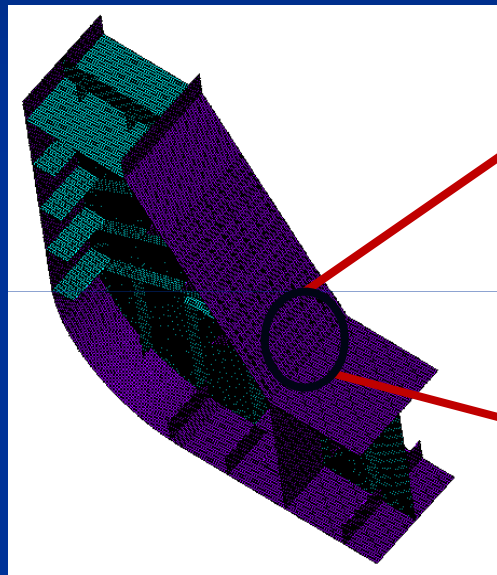# ANSYS Global FEM
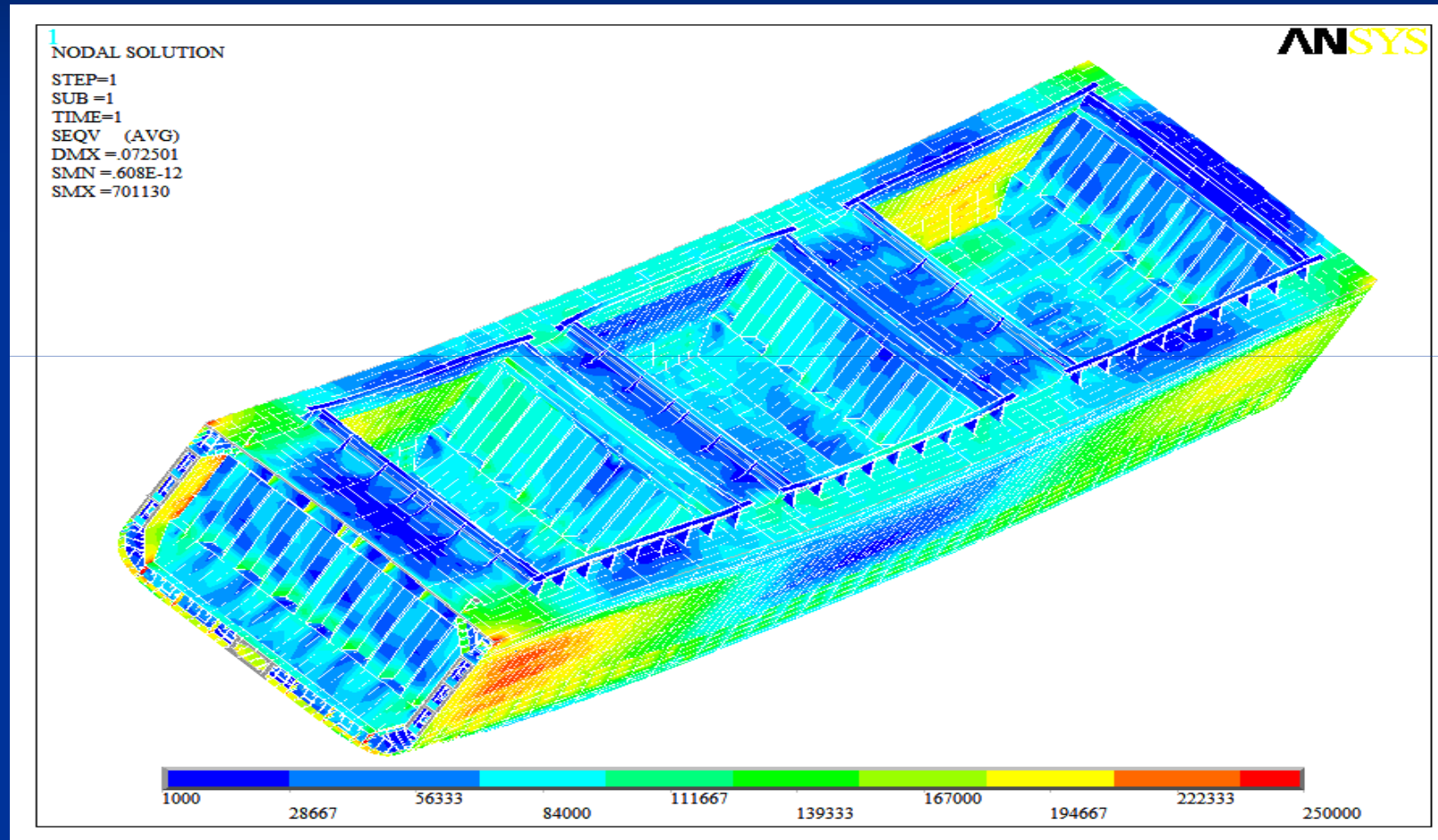
Structural Critical Detail
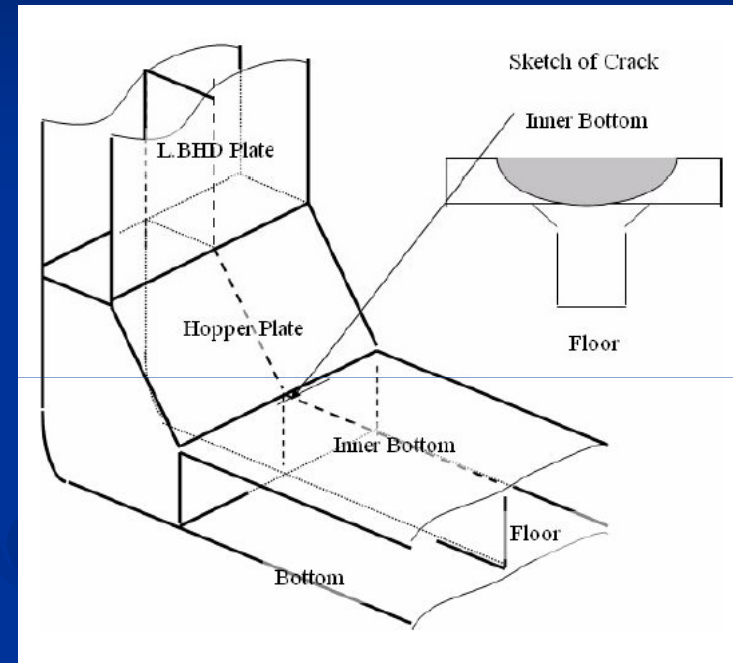
Submodel

Procedures:

➢ **Create and analyze the coarse model.**

➢ **Create the submodel.**

➢ **Perform the cut boundary interpolation**

➢ **Analyze the subomdel.**

➢ **Verify the Distance Between the CB and area of Stress Concentration is Adequate**

Hopper-IB Knuckle Submodel
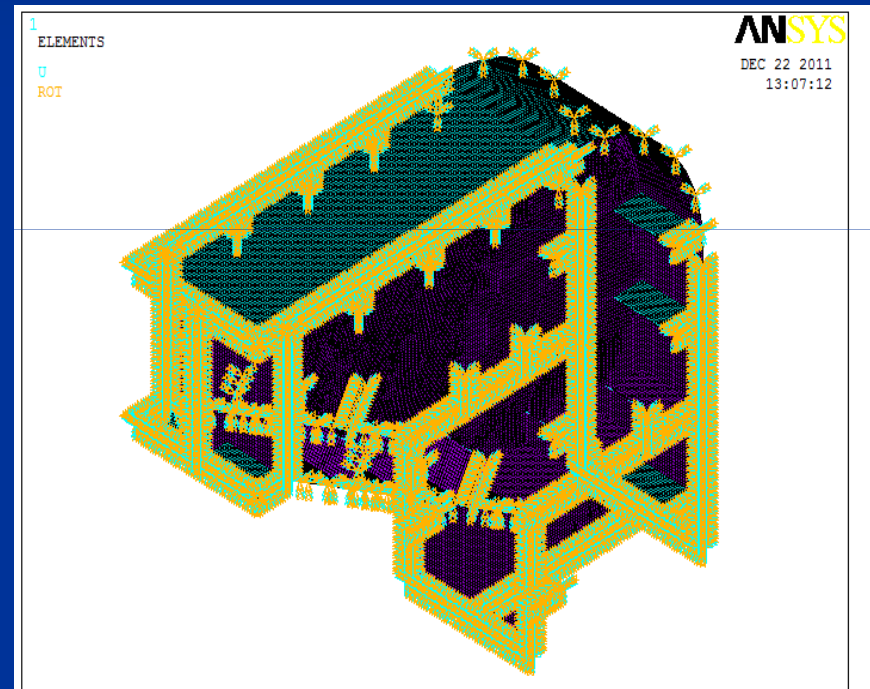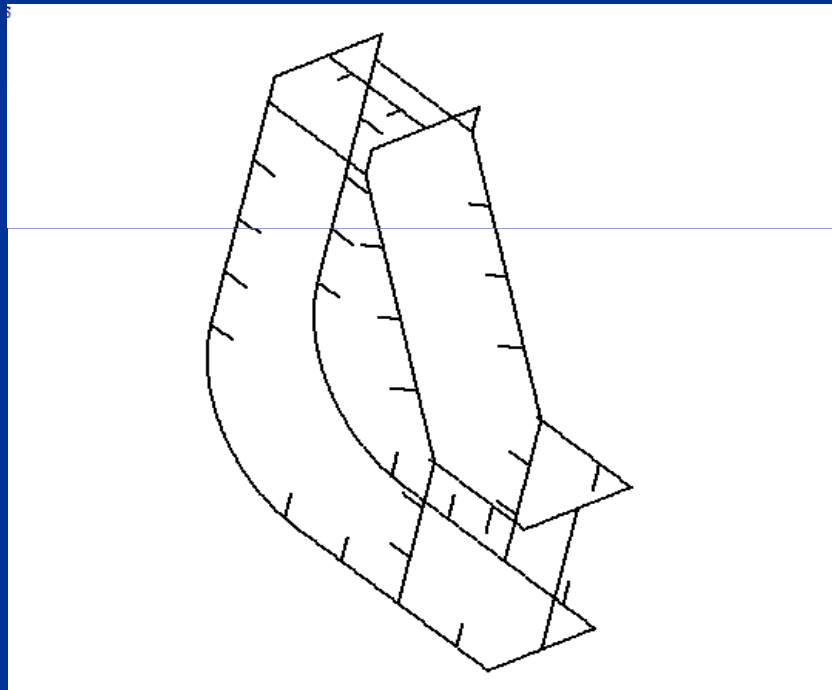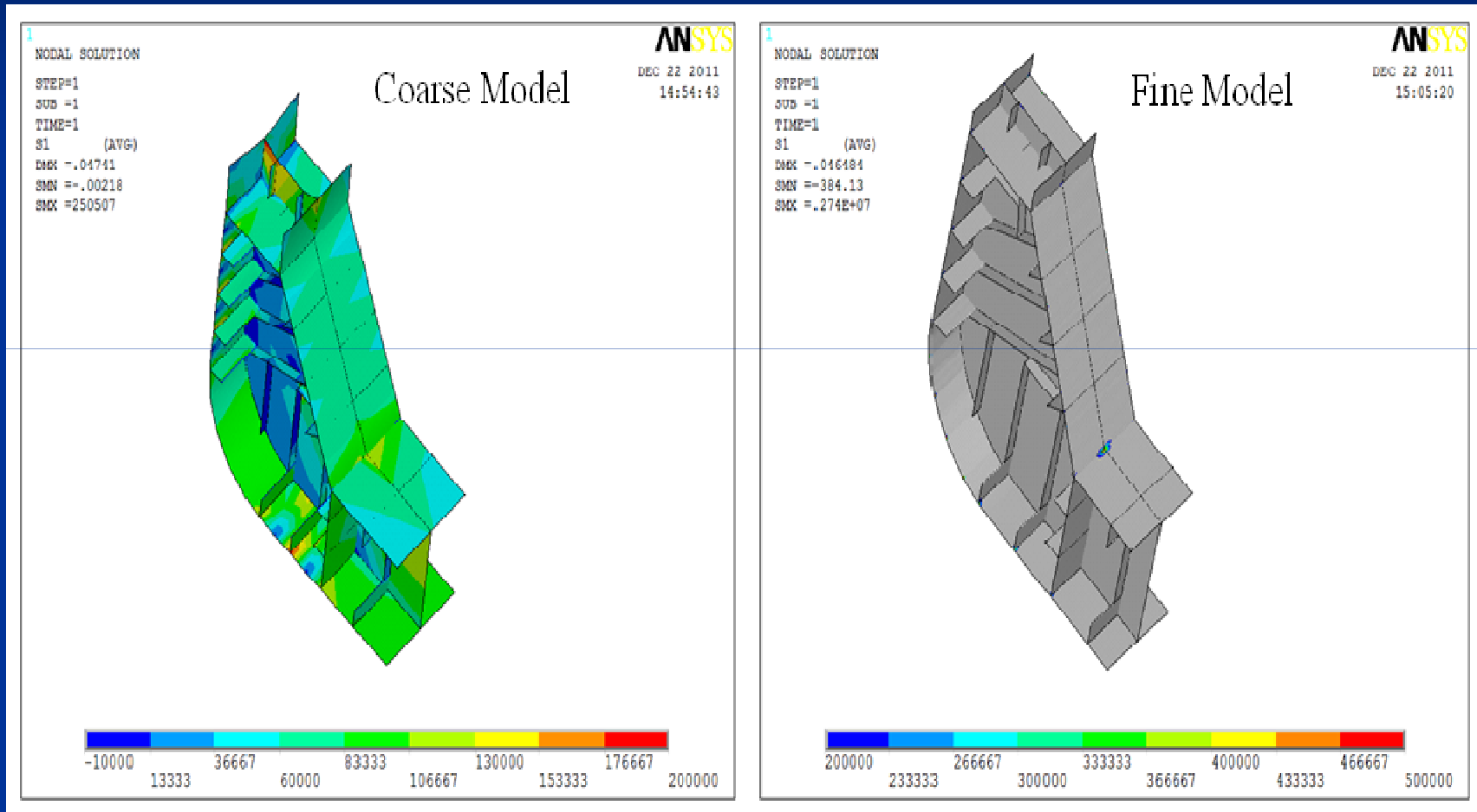

Mesh Size:
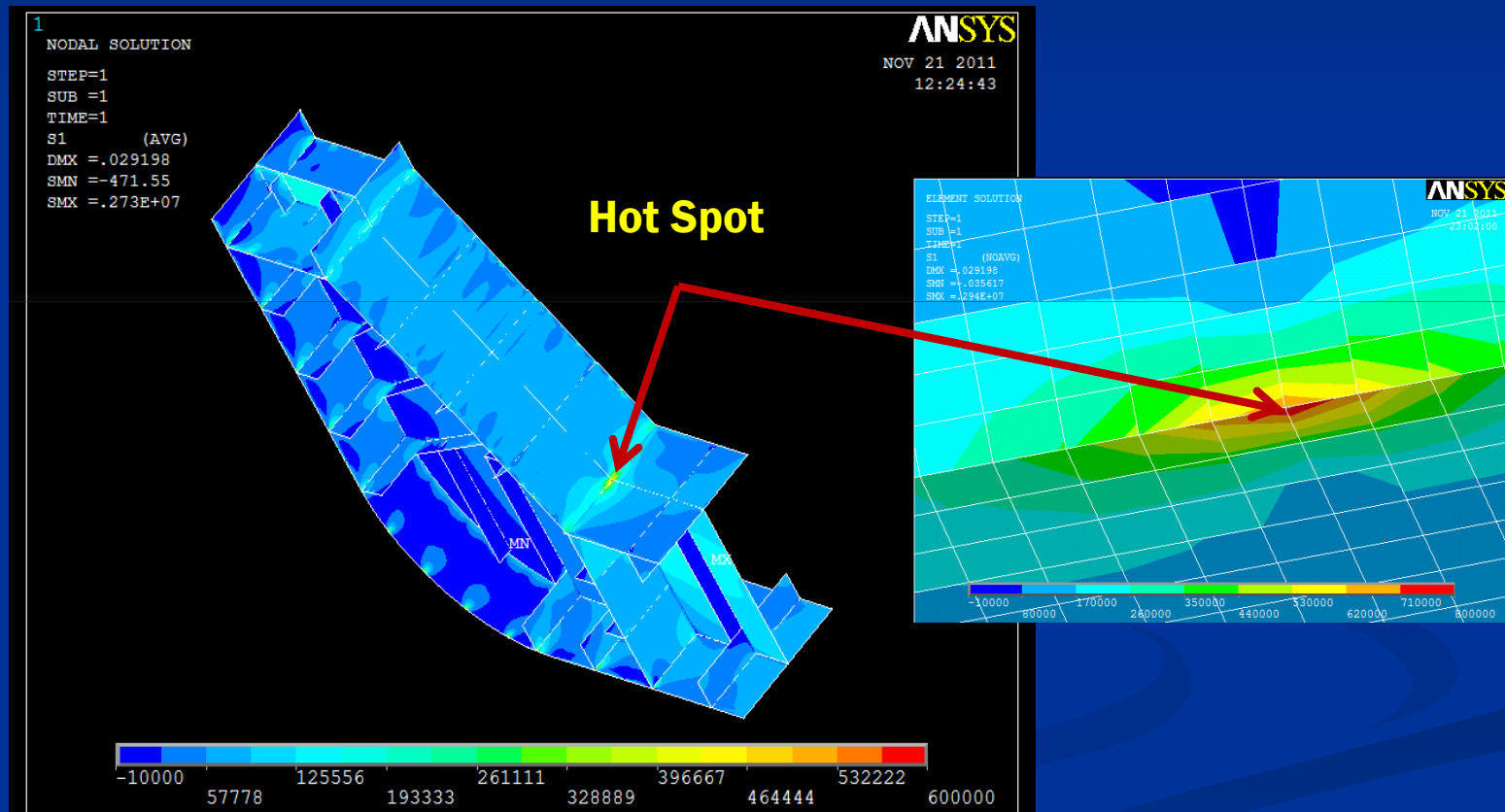txt (24x24 mm)
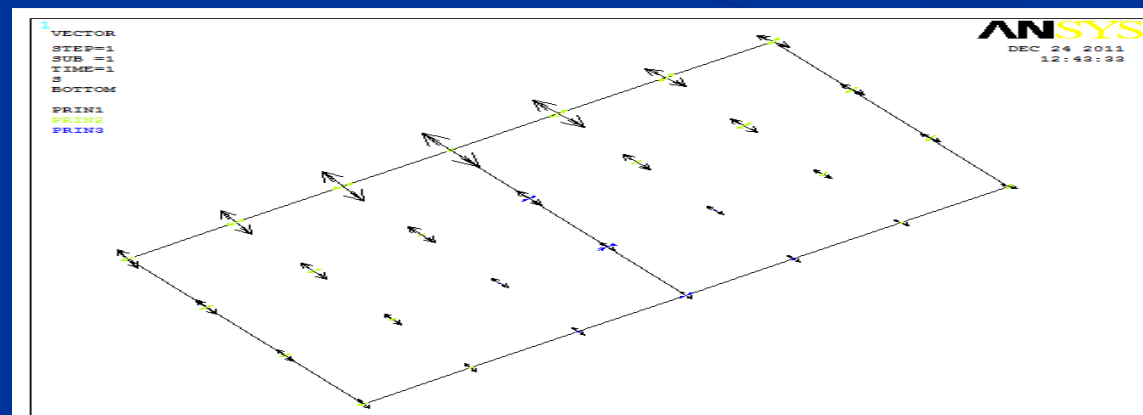**Mesh Type:**
4 node shell Element
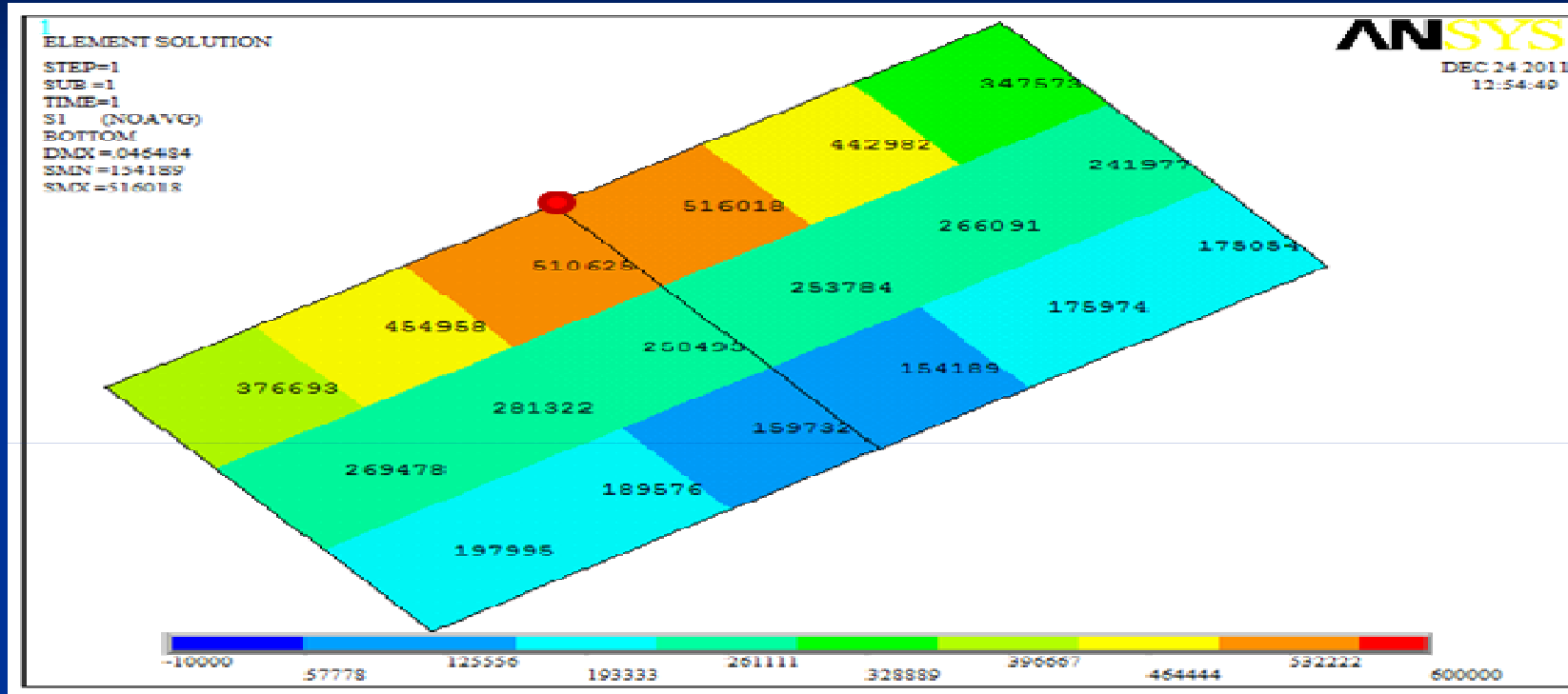**Load to GM:**
Heavy Ballast
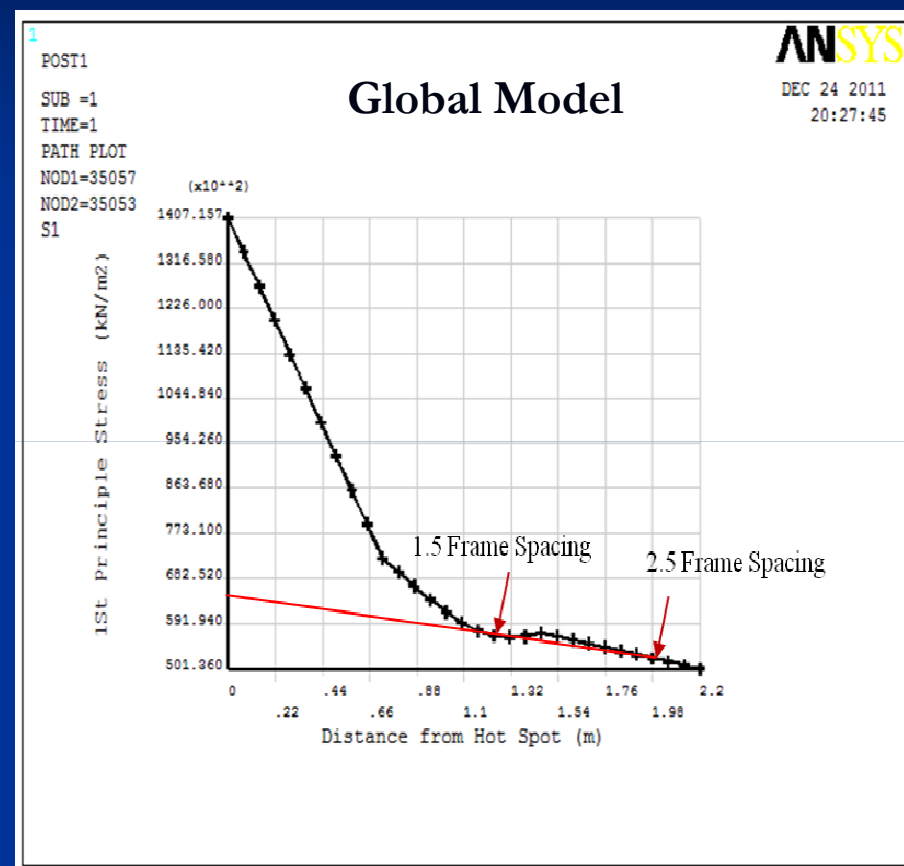
Hopper-IB Knuckle Submodel
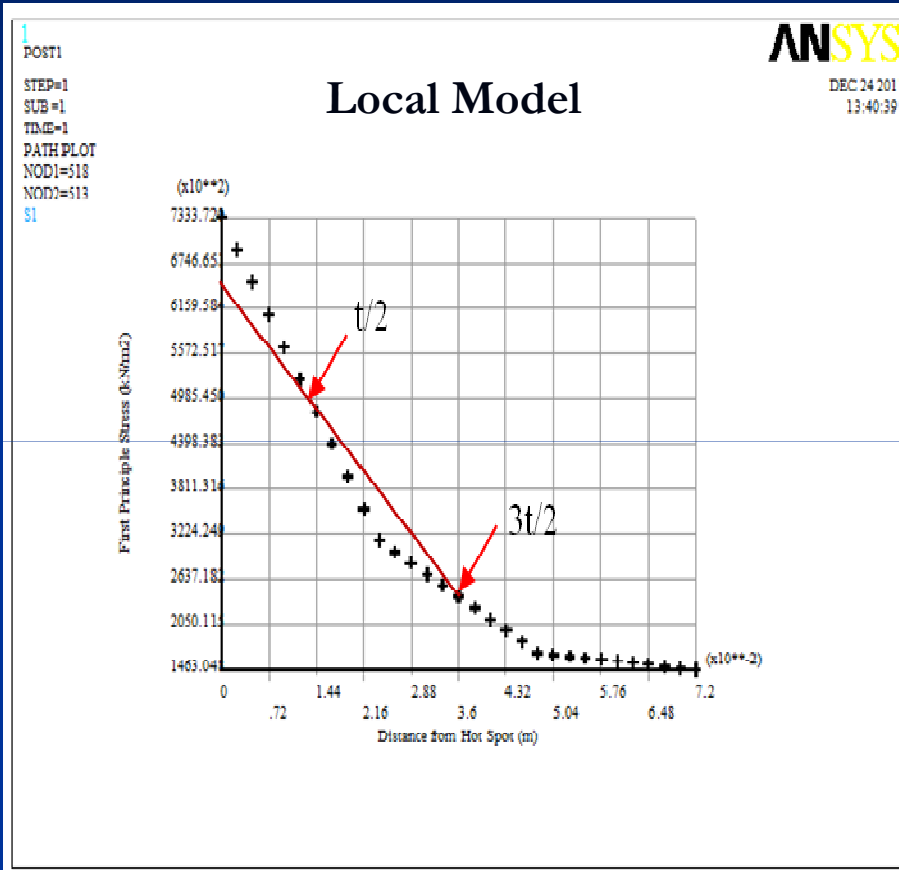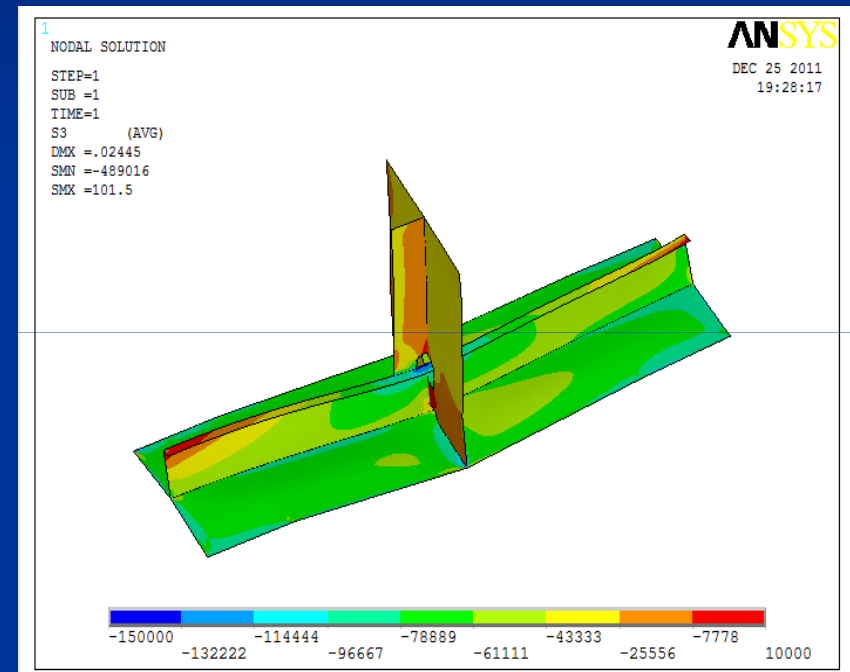
Hopper-IB Knuckle Submodel

Hopper-IB Knuckle Submodel
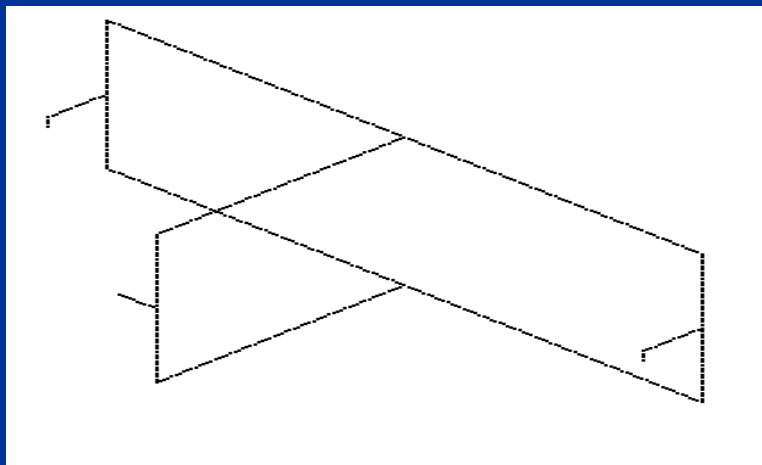
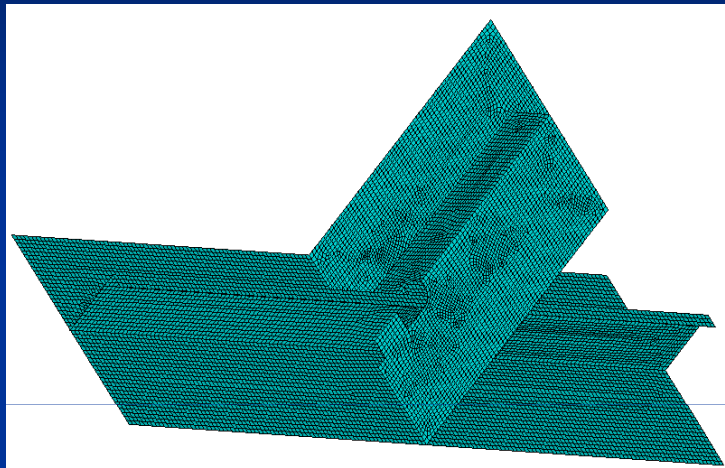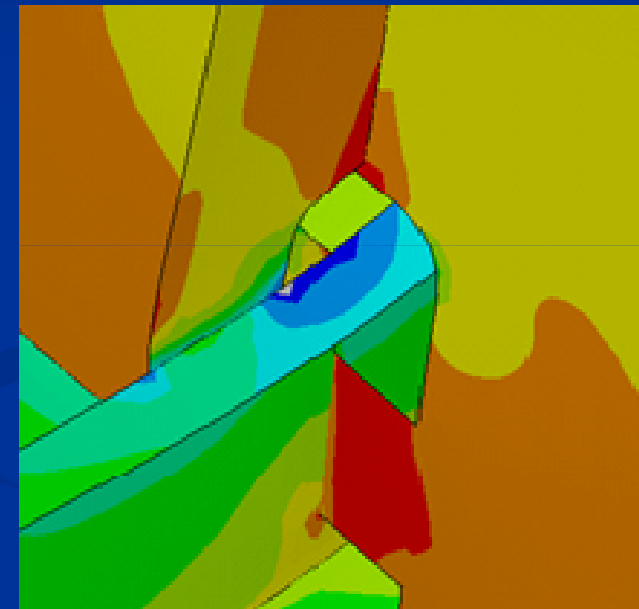# Hopper-IB Knuckle Sub model

Hopper-IB Knuckle Sub model

SCF from Simplified Procedure by CSR	SCR from FEM
5.27	10

Longitudinal-Web Frame Submodel

Longitudinal-Web Frame Submodel
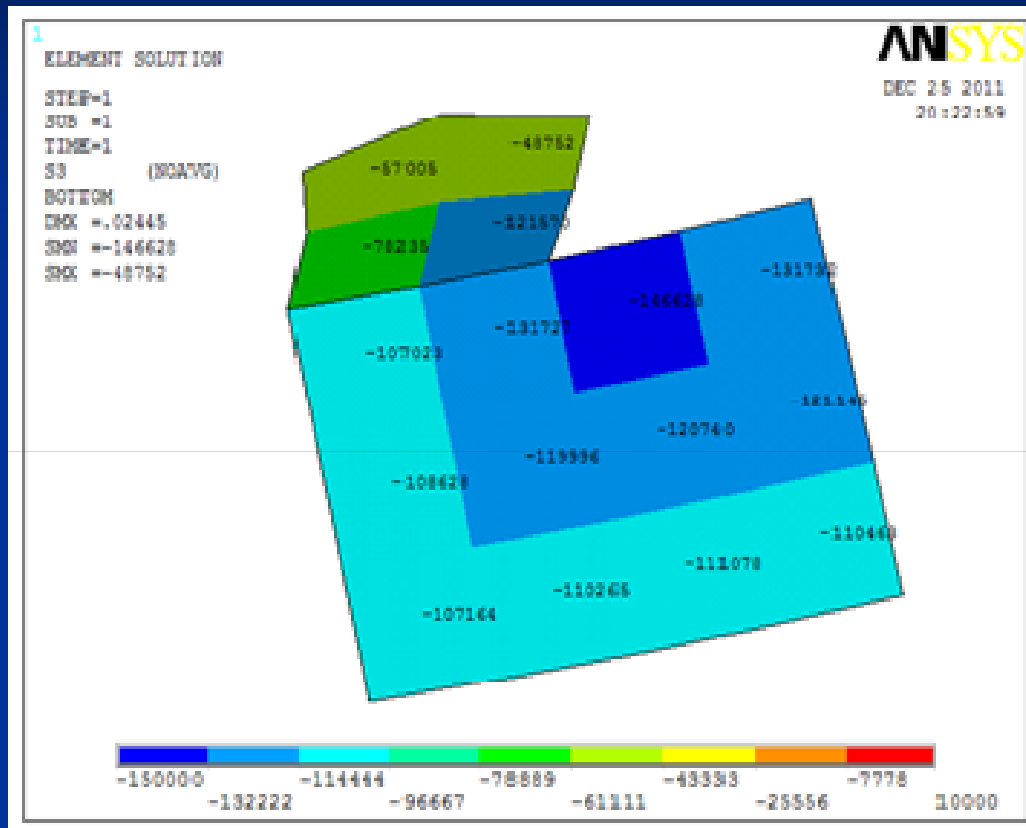
SCF from Tabulated CSR		SCF from FEM
Axial	Lateral Pressure	
1.1	1.65	1.58

Cumulative Fatigue Damage

Load condition	Load case	$\sigma_{W,i(k)}$	$\Delta\sigma_{W,i(k)}$	$\sigma_{mean,i(k)}$	$\Delta\sigma_{W,I(k)}$	$\sigma_{mean,I(k)}$	$\sigma_{mean,I(k)} + 0.5\Delta\sigma_{W,I(k)}$	LC #
Homogeneous	1H1	141.70	21.47	152.44	391.2	36.60	232.20	2
	1H2	163.17						
	1F1	292.75	343.19	121.16				
	1F2	-50.44						
	1R1	47.00	193.85	143.93				
	1R2	240.85						
	1P1	-159.00	391.20	36.60				
	1P2	232.20						
Alternate	2H1	-383.00	226.12	-269.94	559.3	-382.35	-102.70	4
	2H2	-156.88						
	2F1	-130.00	334.75	-297.38				
	2F2	-464.75						
	2R1	-426.40	269.00	-291.90				
	2R2	-157.40						
	2P1	-662.00	559.30	-382.35				
	2P2	-102.70						
Normal ballast	3H1	-35.00	54.00	-62.00	334	-193.00	-26.00	3
	3H2	-89.00						
	3F1	-11.00	185.20	-103.60				
	3F2	-196.20						
	3R1	-133.90	81.60	-93.10				
	3R2	-52.30						
	3P1	-360.00	334.00	-193.00				
	3P2	-26.00						
Heavy ballast	4H1	644.75	248.95	520.28	251.49	423.01	548.75	1
	4H2	395.80						
	4F1	548.75	251.49	423.01				
	4F2	297.26						
	4R1	653.11	170.31	567.96				
	4R2	482.80						
	4P1	380.30	32.50	396.55				
	4P2	412.80						

Cumulative Fatigue Damage

$$D_j = \frac{\alpha_j N_L \Delta\sigma_{E,j}{}^4}{K(\ln N_R)^{4/\xi}} \left[\Gamma\left(\frac{4}{\xi}+1, v\right) + v^{-3/\xi} \gamma\left(\frac{7}{\xi}+1, v\right) \right]$$
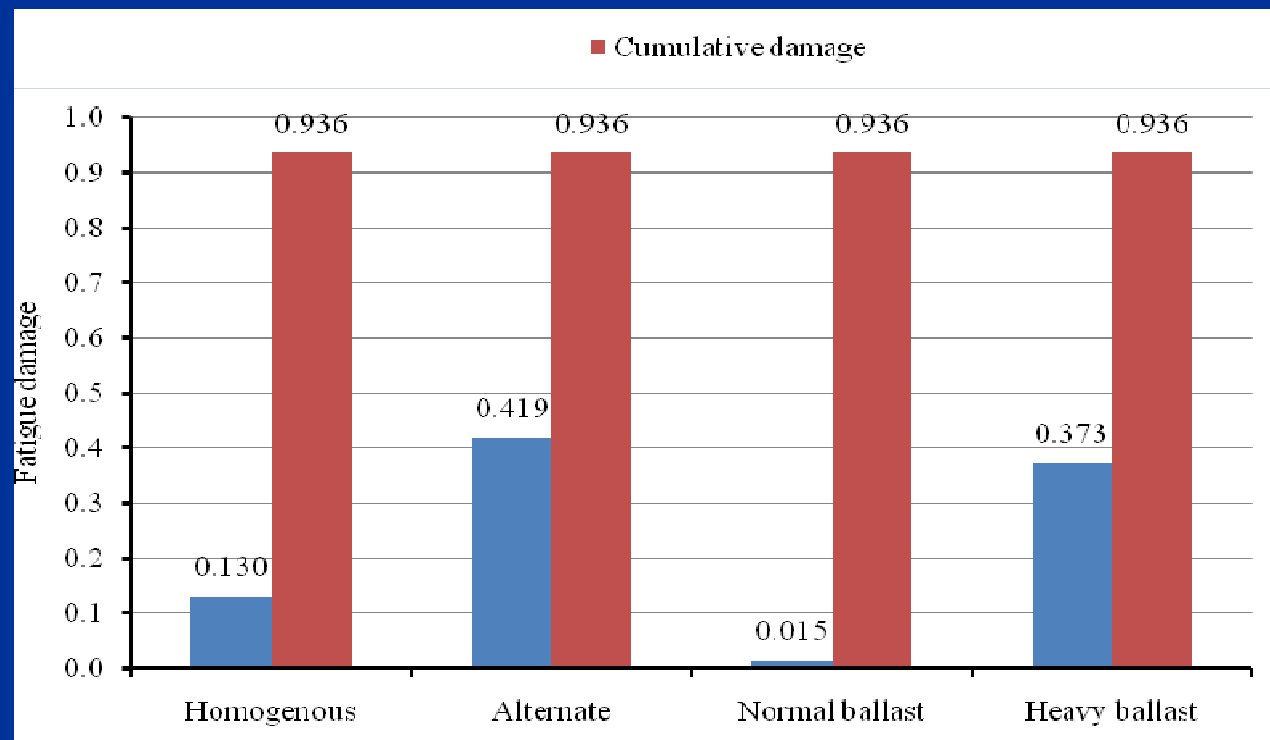
Conclusions

Geometry SCF from direct FEM for longitudinal stiffener web frame end connection depend on the geometry of structure and load combination

Cumulative fatigue damage for Hopper-IB knuckle is less than the limit criteria for fatigue damage and can survive up to 25 years in North Atlantic environment.

Submodelling is significantly less time consuming nevertheless efficient in getting reasonable result in the region of interest for fatigue analysis

GL Poseidon Software for BC used as pre-processor for modeling and ANSYS code as post-processor for fatigue analysis is a very efficient

Recommendations

Fatigue investigation to carry systematic identifications of error sources in applying design loads and structural modeling and its effect on the predicted fatigue damage

FE analysis using 8-node/or solid element for fatigue analysis for these particular details can be done to compare with result from the 4-node shell element

Different longitudinal stiffener web frame end connections geometries can be analyzed for all loading conditions to obtain the combined geometry stress concentration factors and presented as tabulated reference in the rules.