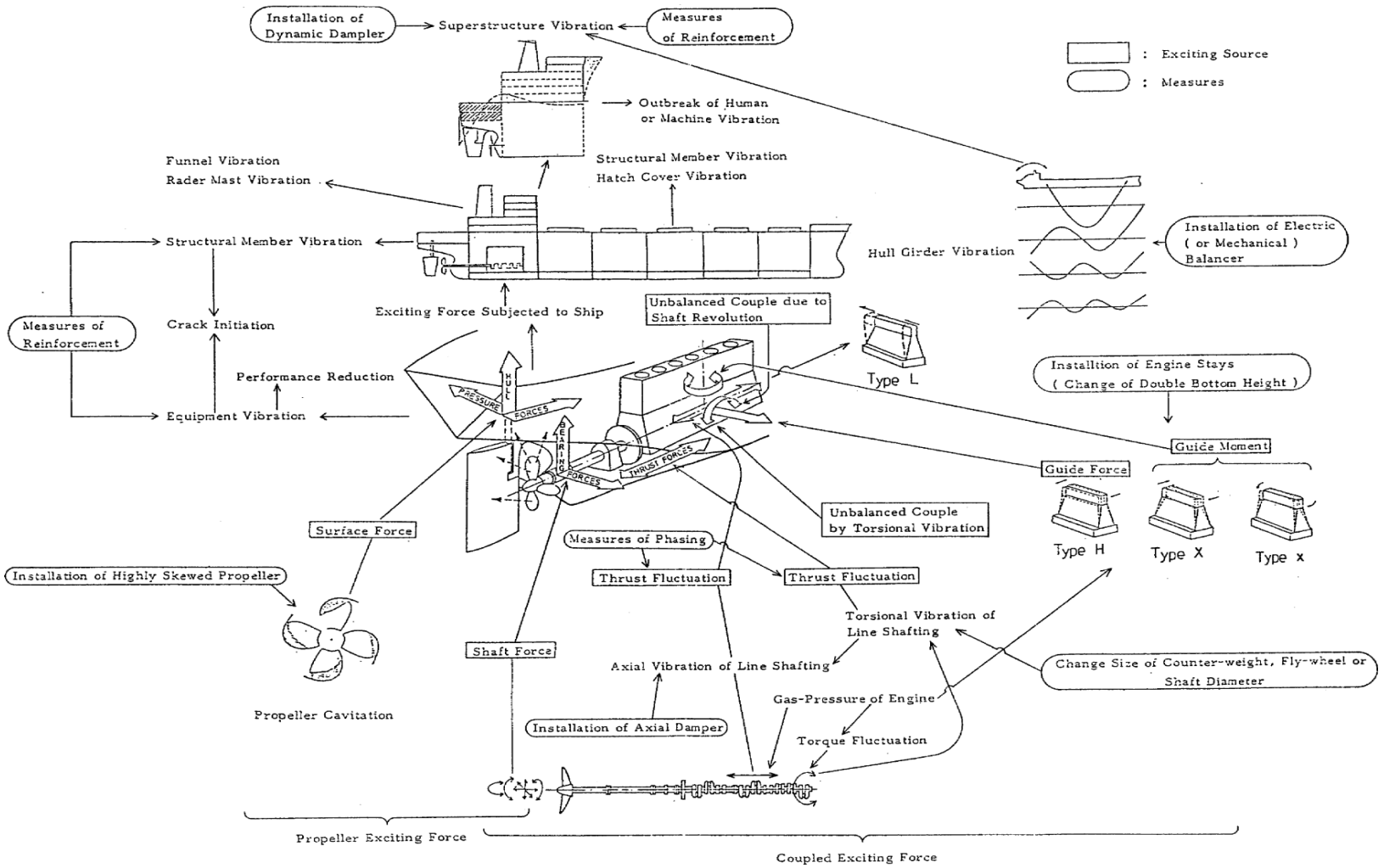
Structural response of the ship hull elements subject to excitation generated by the main engine

Master student: Andrey Smolko

Supervisor: Prof. Maciej Taczala

Szczecin, February 2013

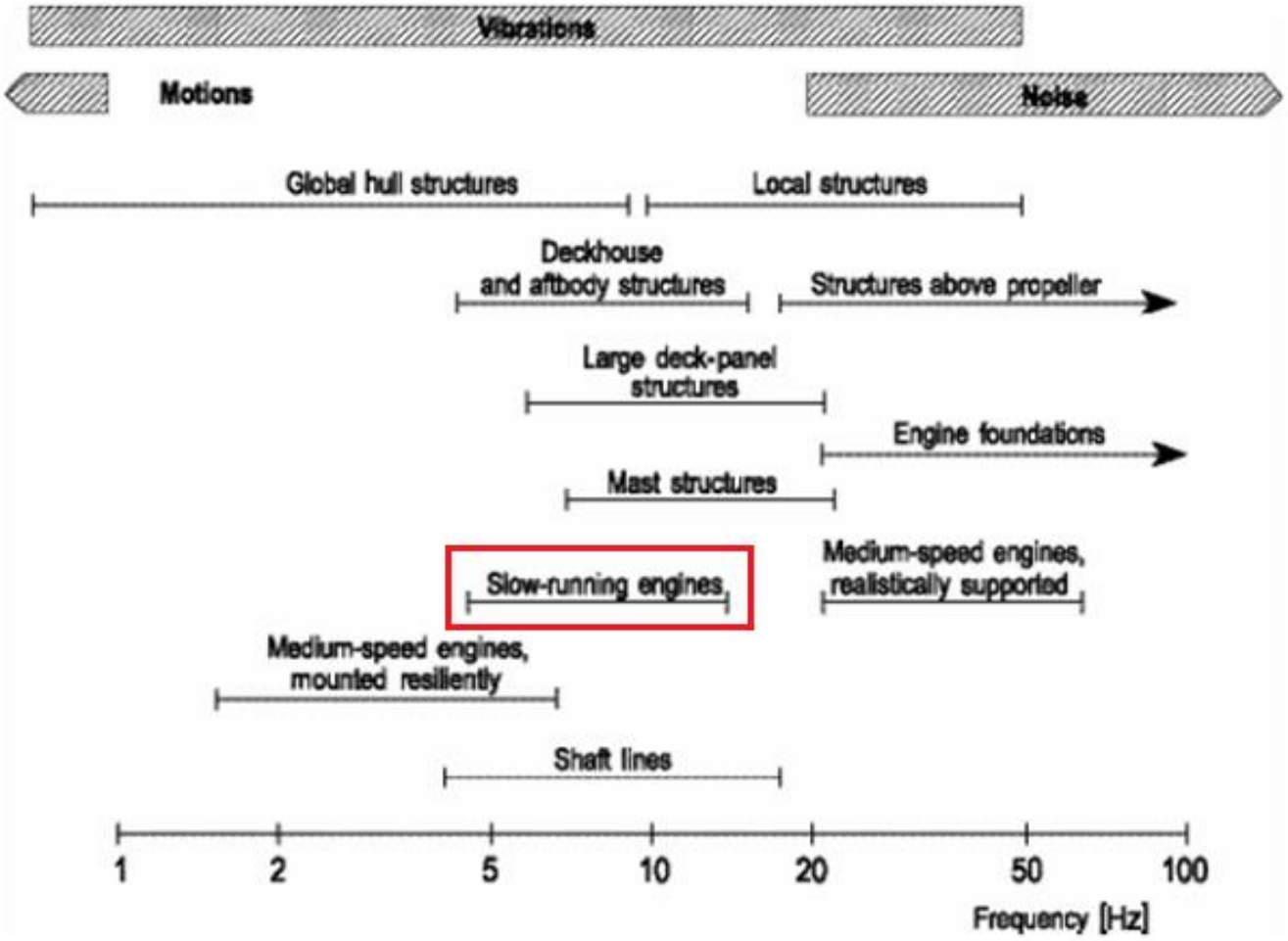
Ship excitation forces



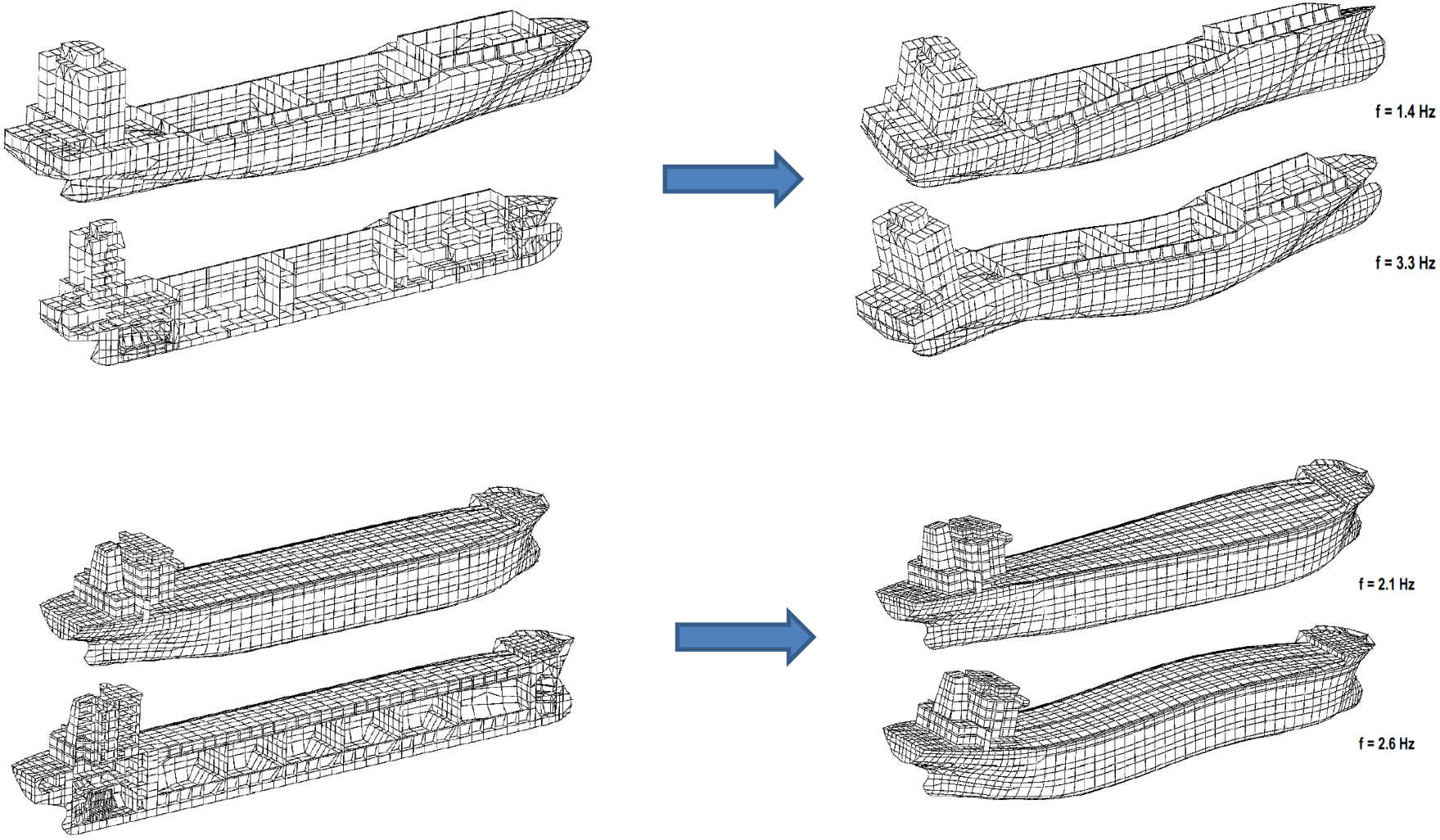
Classification of a diesel engine exciting forces

- Unbalanced forces or unbalanced moments induced by inertia forces due to the movement pistons, etc.
- Guide forces or guide moments which are generated by combustion pressure of gas
- Longitudinal exciting force which is induced by the inertia force of longitudinal deflection on the crankshaft due to gas pressure.
- Fluctuation in thrust force which comes from torque variation in line shaft

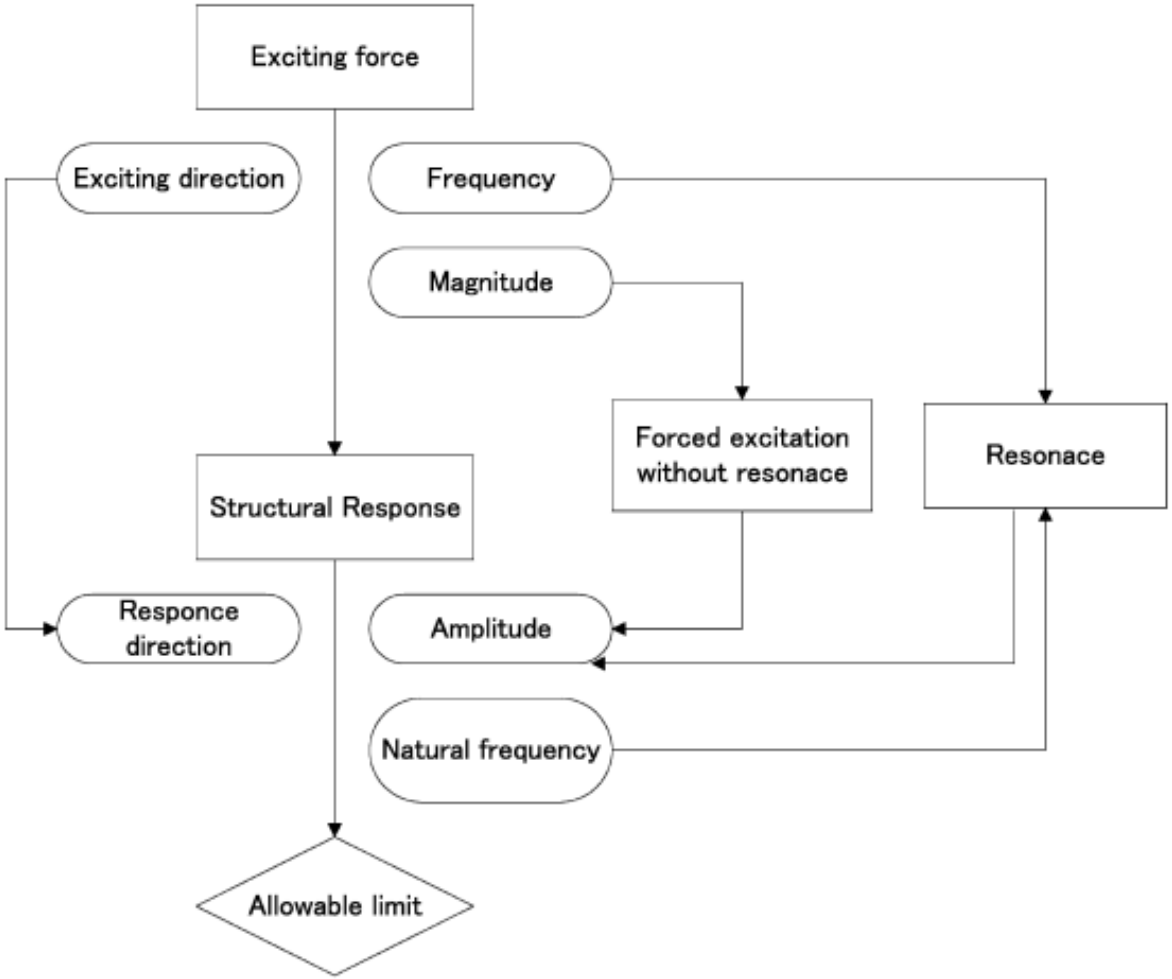
Natural frequency ranges in shipbuilding application



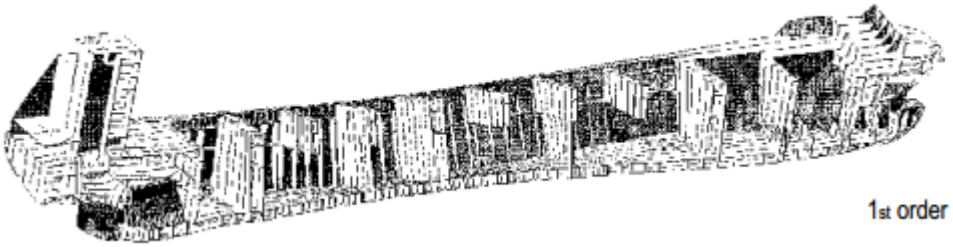
Global structures



Relation ship between the exciting forces and responses



Global vibration modes in the case of excitation by the main engine

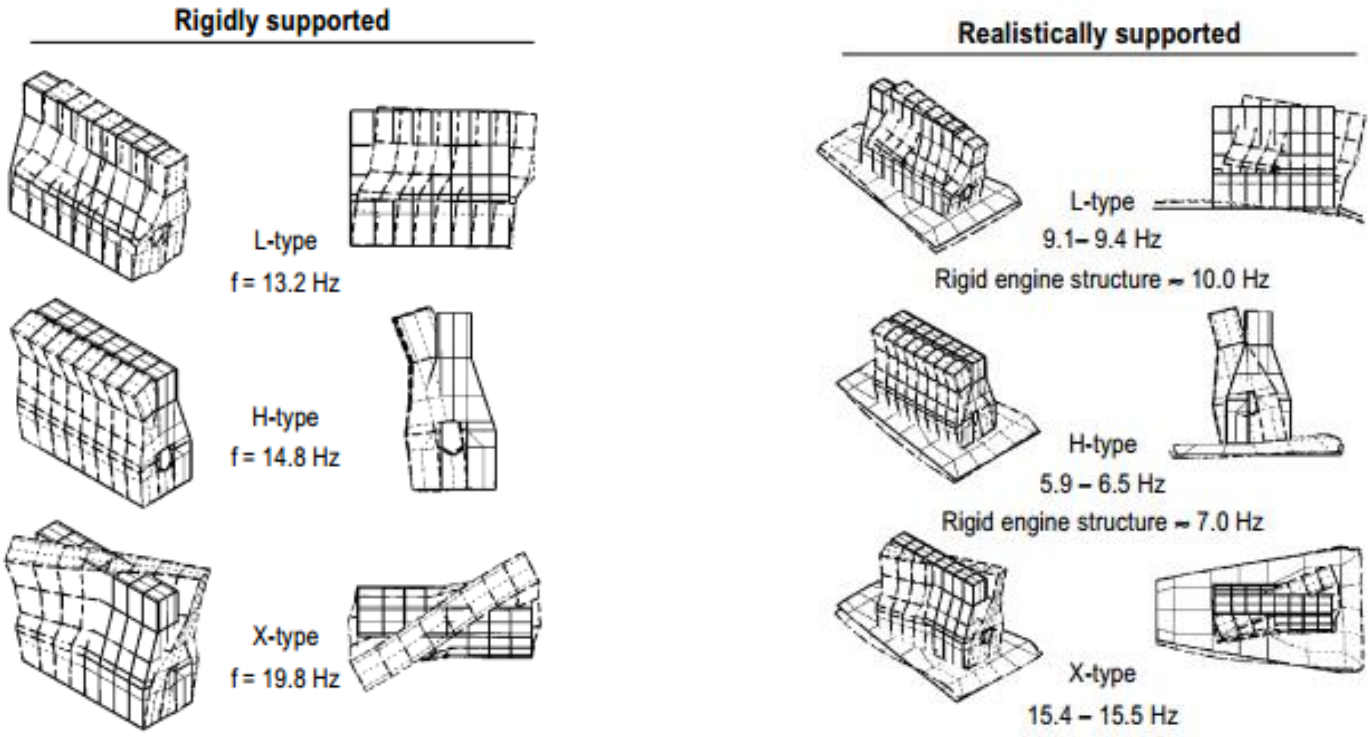


The first order (1.5 Hz) excites the fundamental torsion vibration mode of the ship hull

The vertical second order (3 Hz) mass moment
Causes four-node vertical bending vibrations
Of the ship hull

Engine/foundation substructures

Slow-running diesel engine – three fundamental modes



Bulk carrier “Miedwie” case study

Main engine
Wartsila/Sulzer RTA48T-B

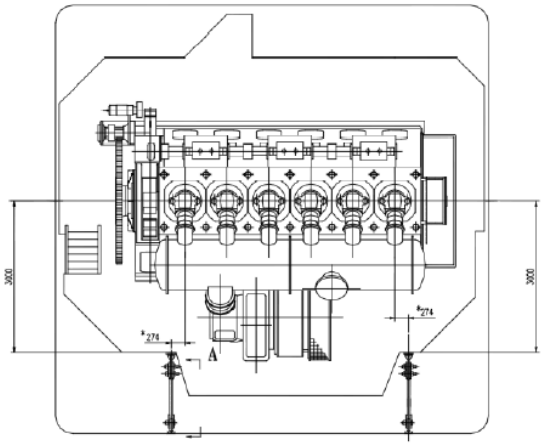
Number of cylinders:	6
Cylinder arrangement	In-line
Operation:	2-stroke
Cylinder bore:	480 mm
Piston stroke:	2000 mm
Load, nominal (at Rx):	7800 kW
Speed, nominal (at Rx):	118 rpm
Dry weight:	205000 kg
Wet weight:	225800 kg
Turbocharger (ABB type):	1 x TPL73B12
Scavenge air cooler:	1 x SAC43F

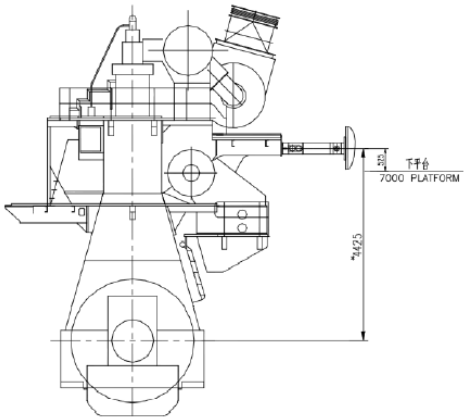
Ship Particulars

Length overall	190.00 m
Length between perpendiculars	182.60 m
Breadth moulded	23.60 m
Depth moulded	14.60 m
Freeboard draught	10.10 m

Class:
D.N.V. class: + 1A1 ICE-1C Bulk Carrier CSR ESP BC-A Holds 2,4&6 or 3, or 4 may be empty, GRAB(20) ES(D) EO NAUT-OC BWM-E(s,f) TMON BIS

Vibration problem on board





Problems:

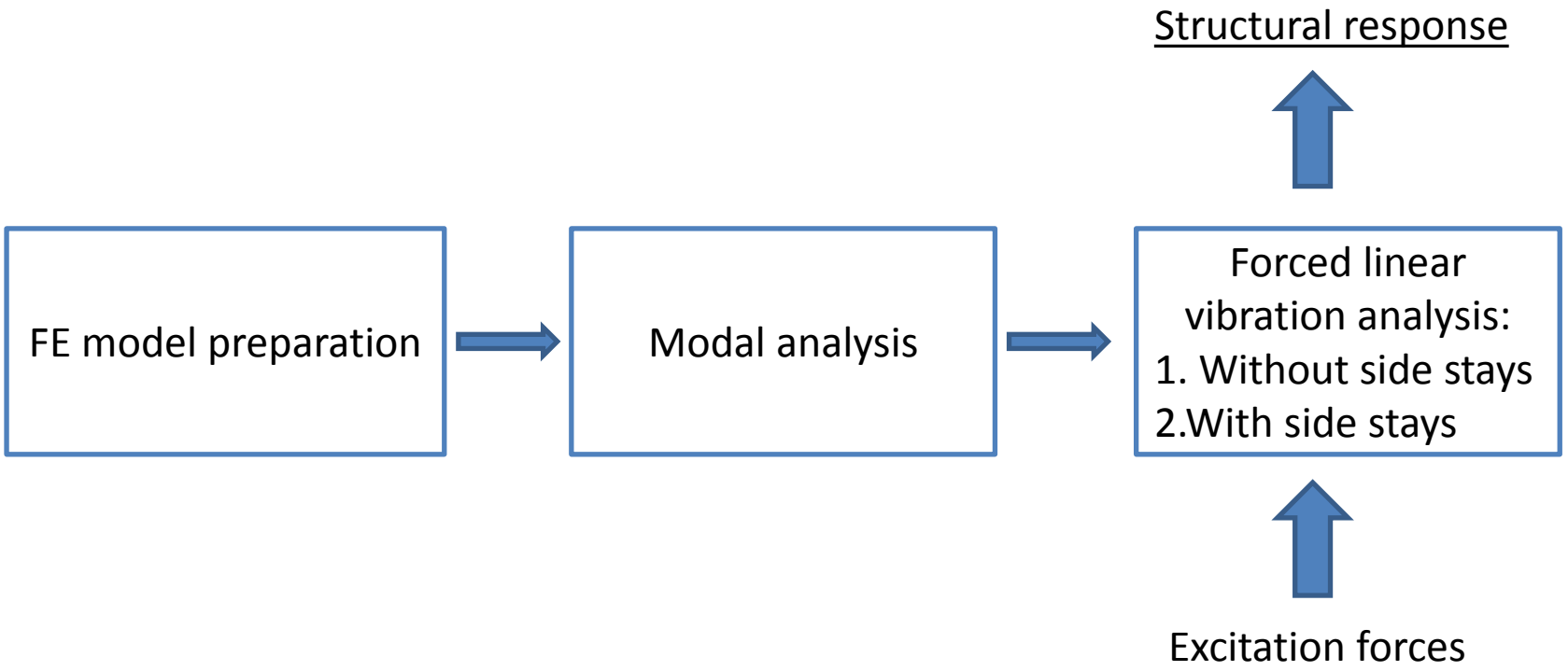
-High level vibration in the engine room when engine running with reduced speed (80-90 Hz)

-Fatigue crack along welded joint

-'Rocking' lateral vibration

Lateral side friction side stays

Analysis Scheme

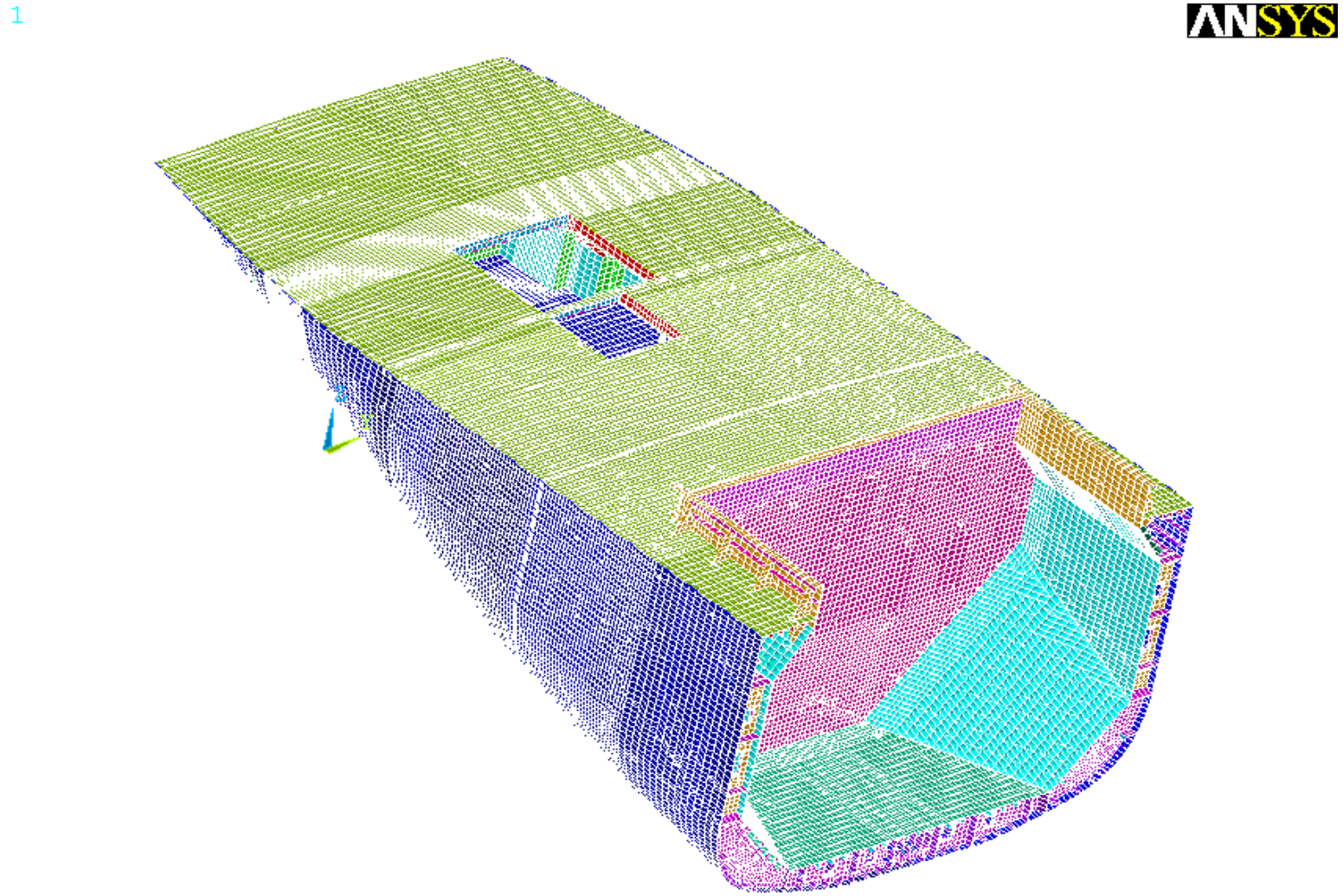


FE model preparation

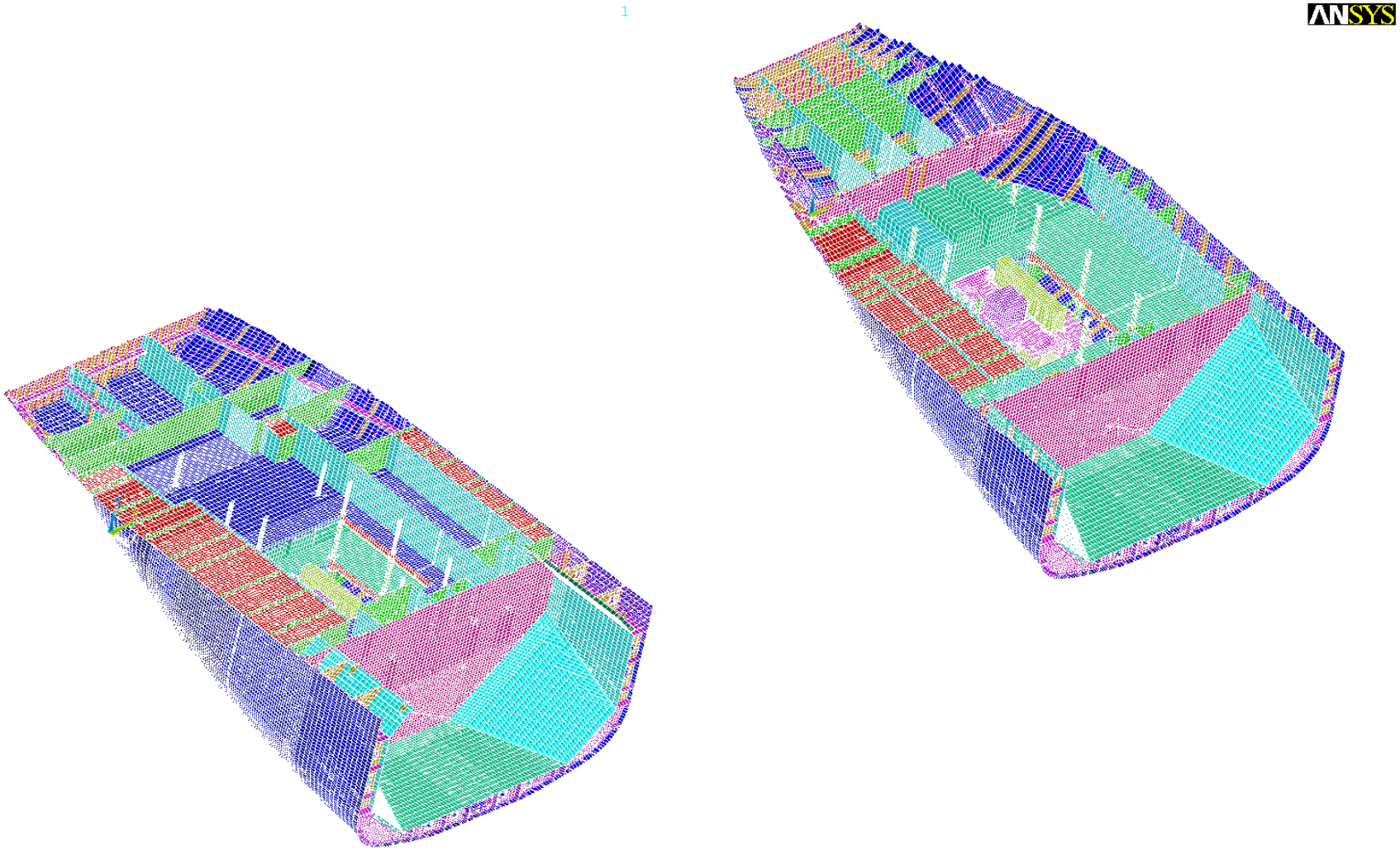
Submodels:

- Hull structure
- Electrical generators
- Main diesel engine
- Turbocharging system
- Shaft line
- Superstructure

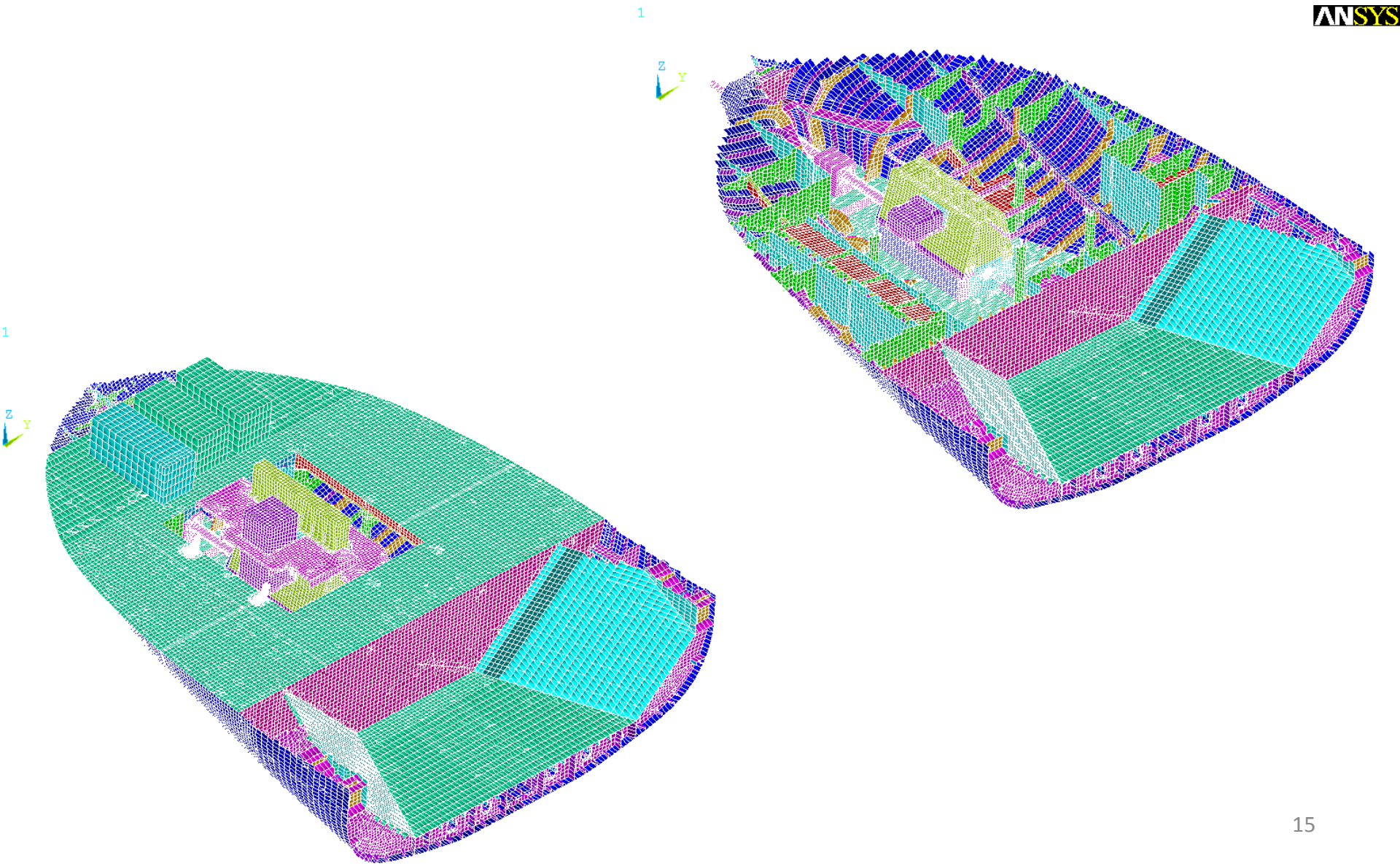
Hull structure (I)



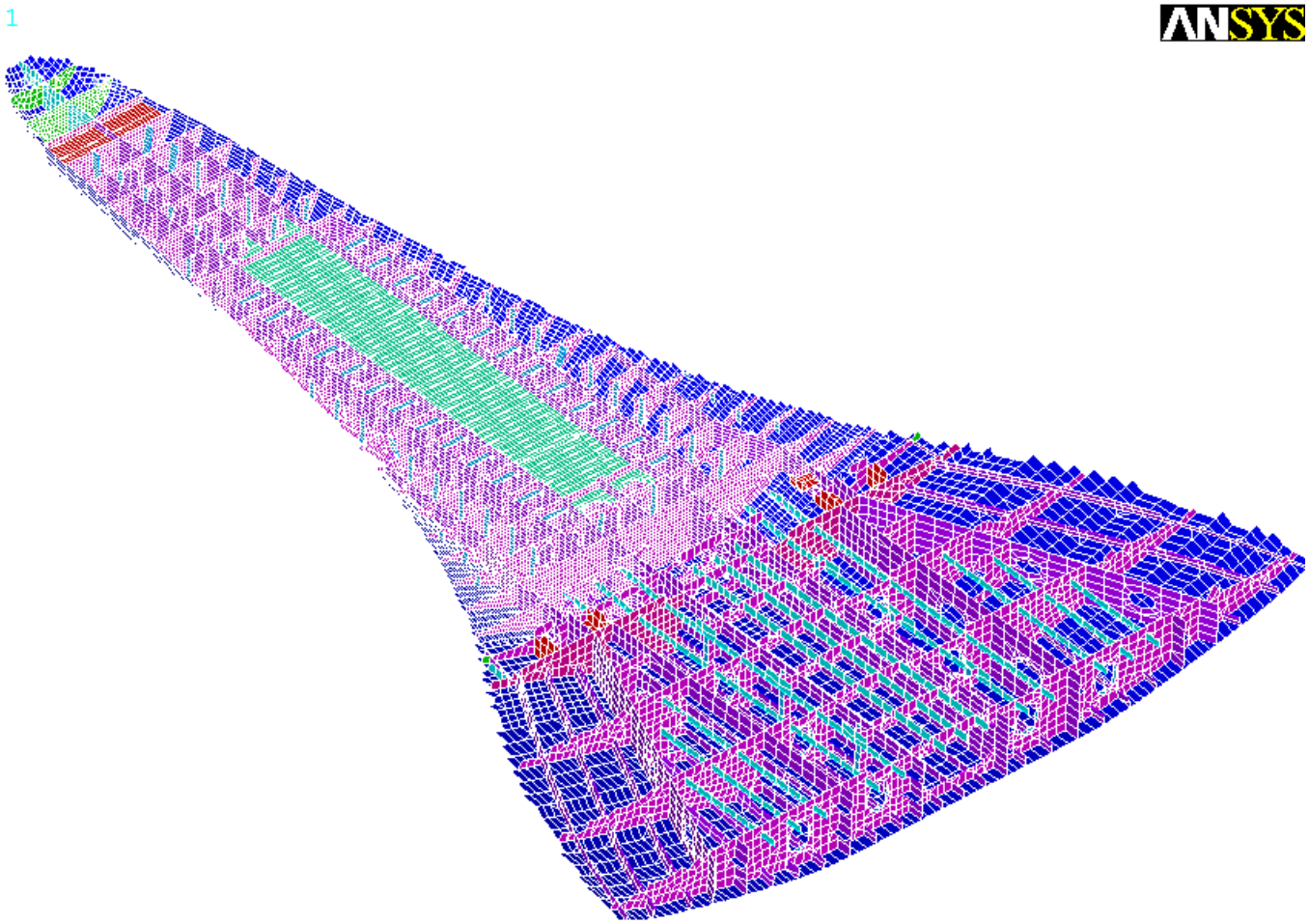
Hull structure (II) platform 11100



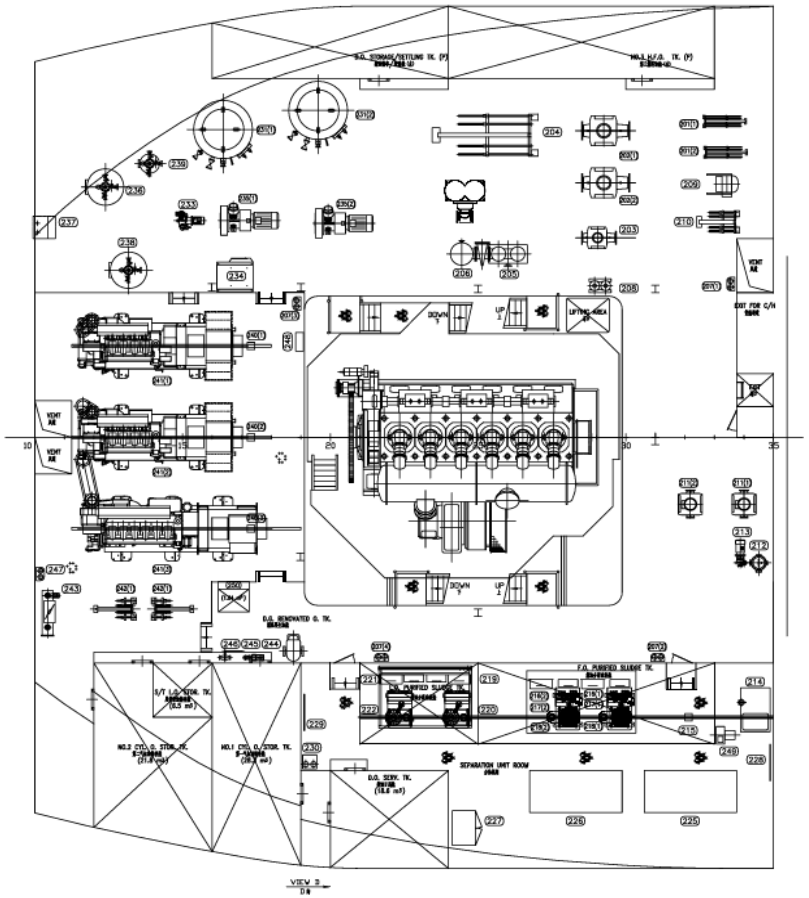
Hull structure (III) platform 7000

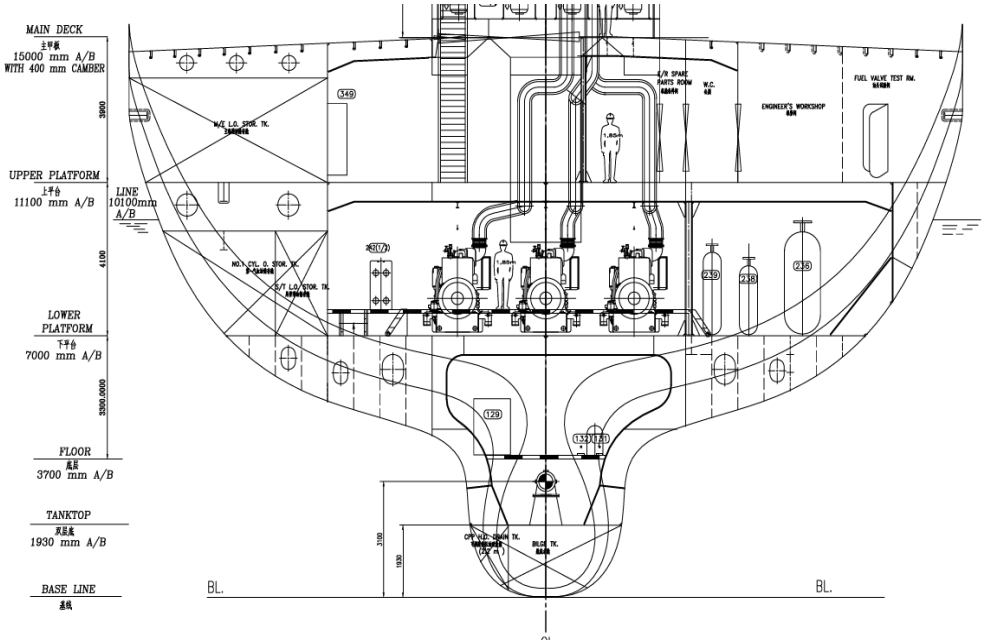


Hull structure (III) doublebottom structure



Electrical generator set positions

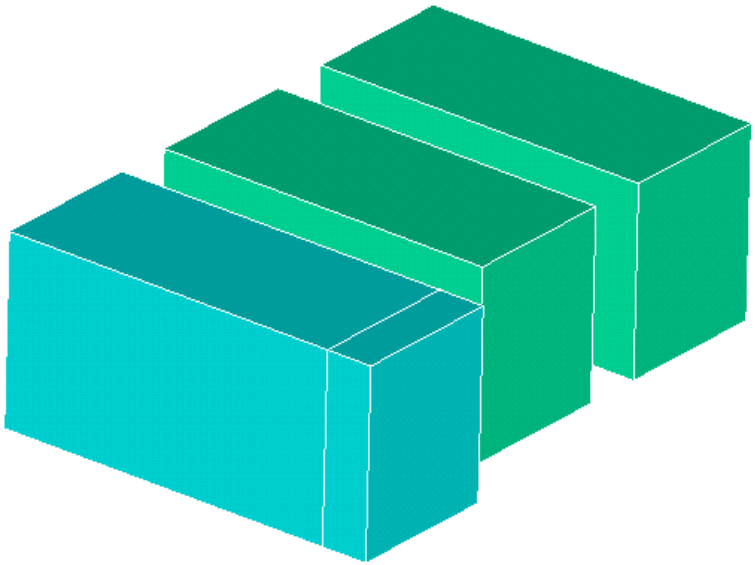




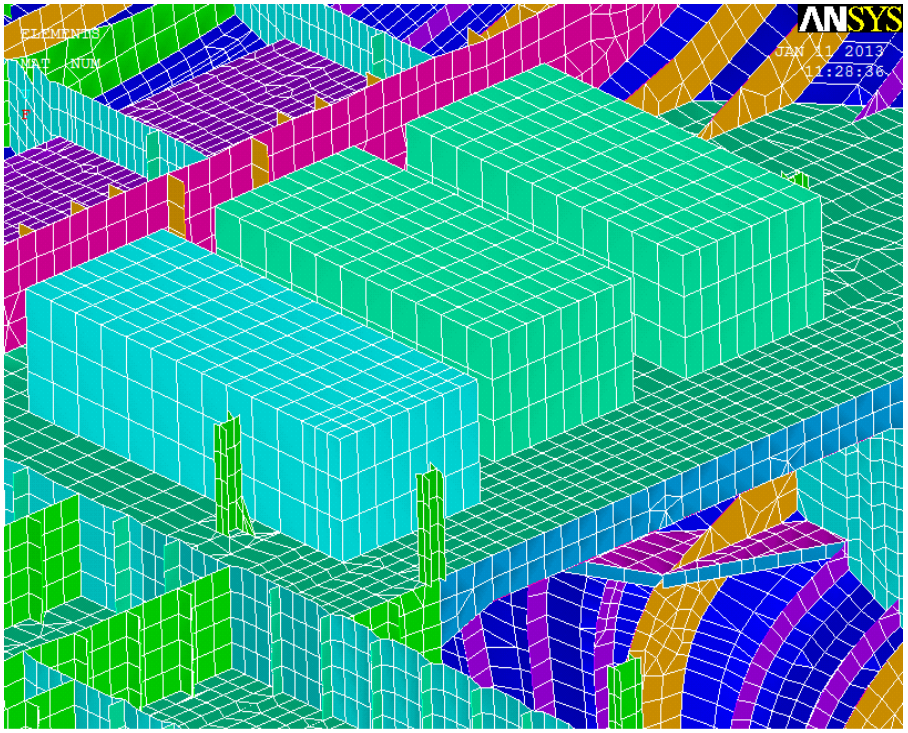
Type	Wet weight (t)	A (mm)	C (mm)	L(mm)
645W4L20	14.7	4537	1920	2248
875W6L20	17.9	5062	1920	2248

3 generators – total weight 50.5 tones

FE representation



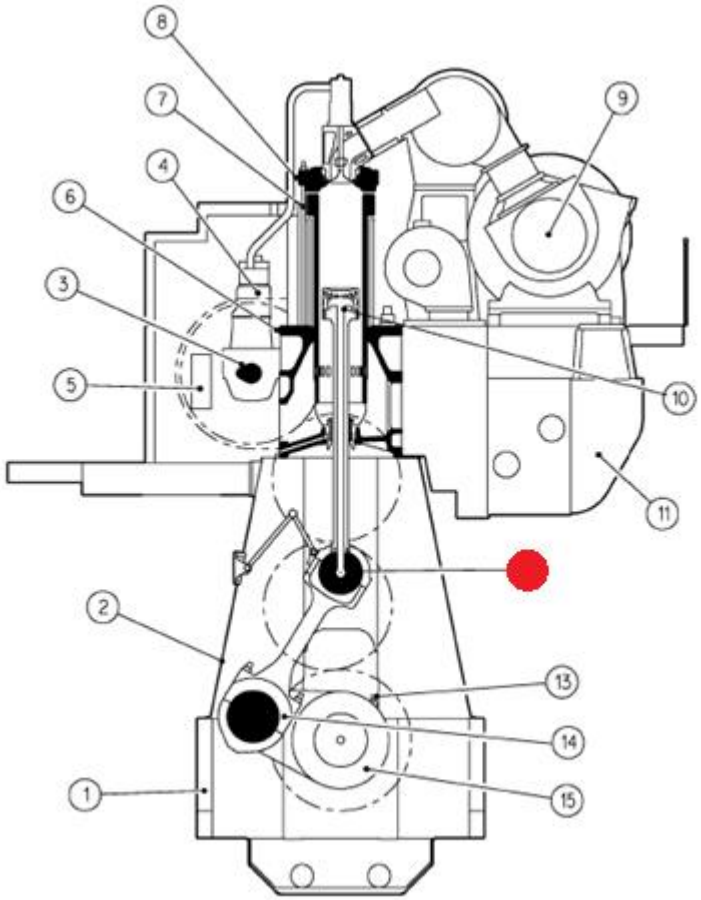
Geometrical models



FE models

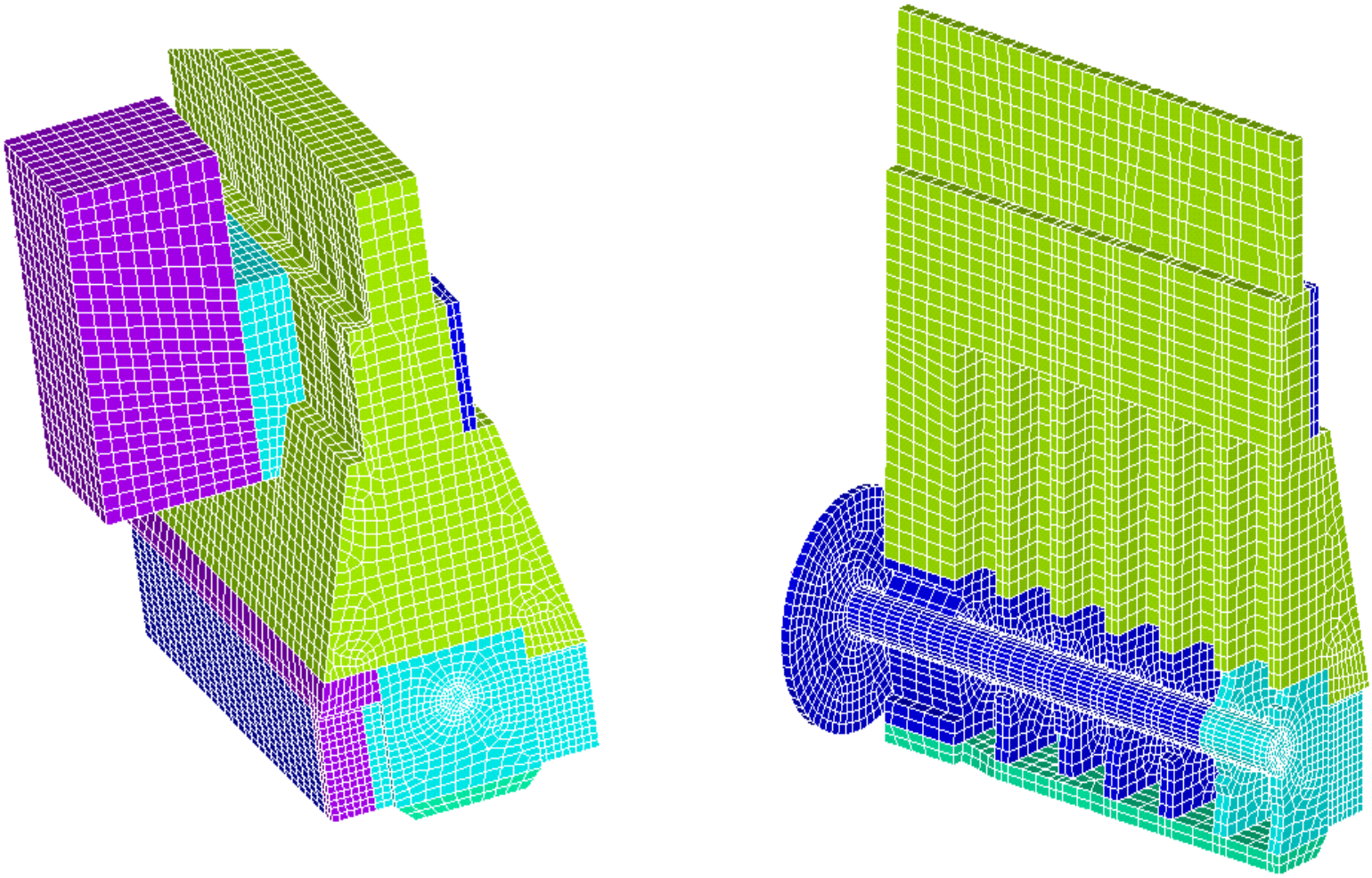
Main engine - 6RTA48T-B

Number of cylinders:	6
Cylinder arrangement	In-line
Operation:	2-stroke
Cylinder bore:	480 mm
Piston stroke:	2000 mm
Load, nominal (at Rx):	7800 kW
Speed, nominal (at Rx):	118 rpm
Dry weight:	205000 kg
Wet weight:	225800 kg
Turbocharger (ABB type):	1 x TPL73B12
Scavenge air cooler:	1 x SAC43F

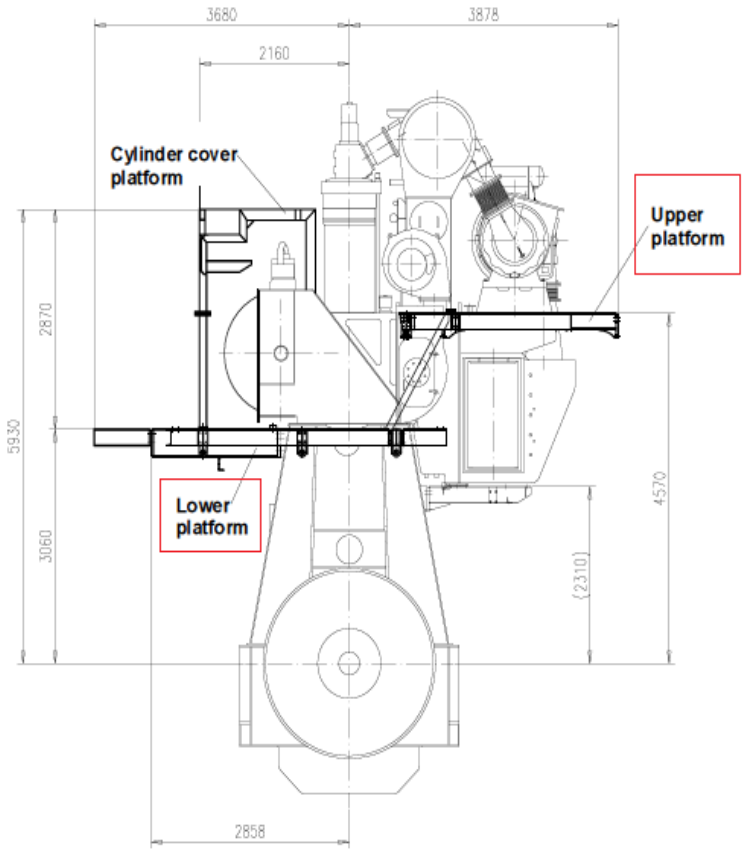


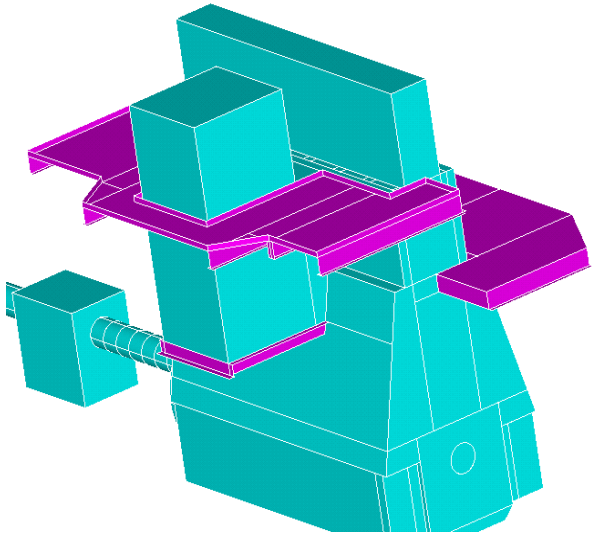
- *Crosshead*

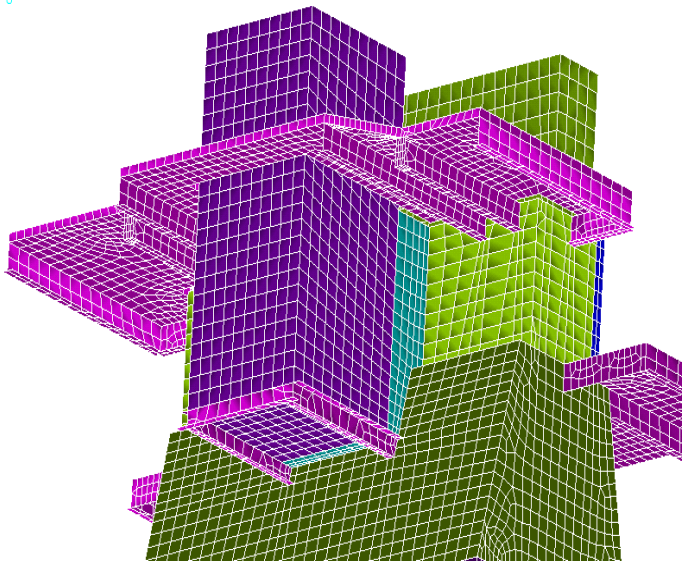
FE model of the main engine



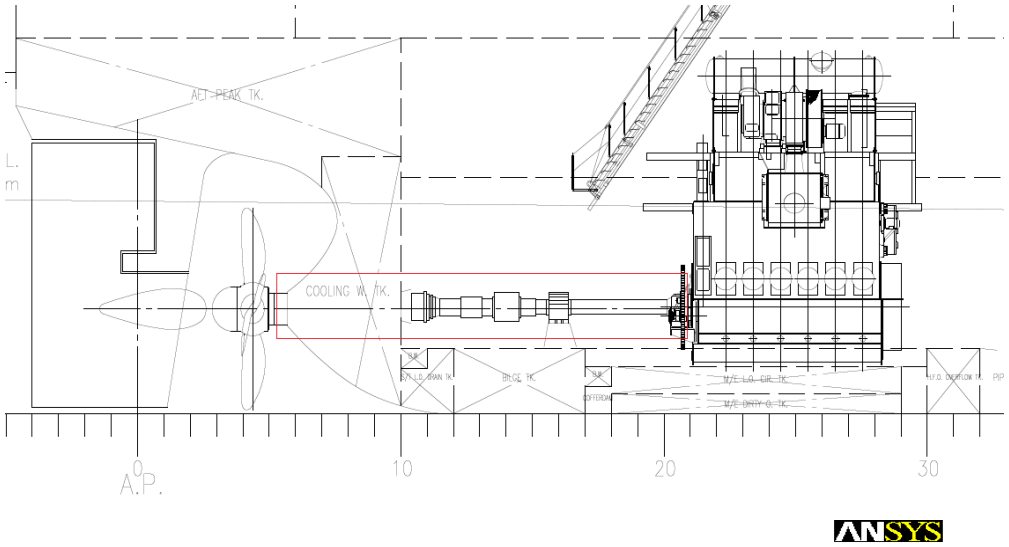
Engine platforms

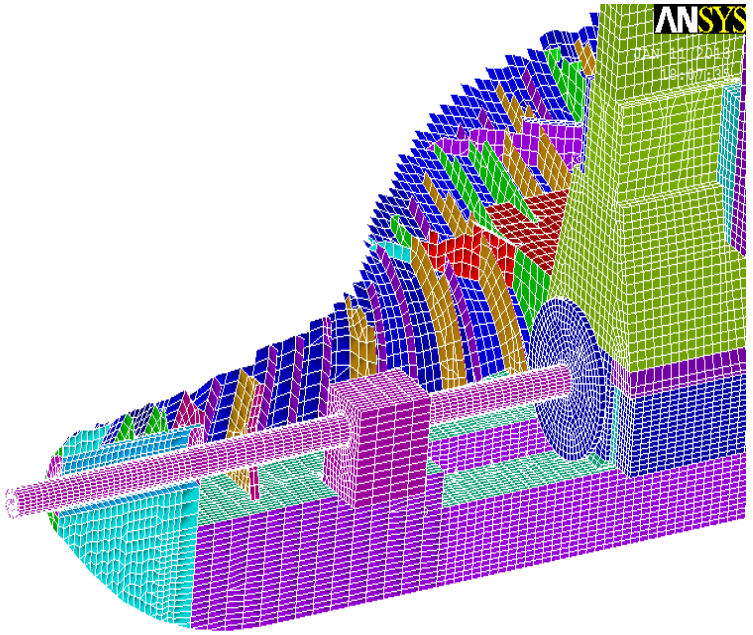


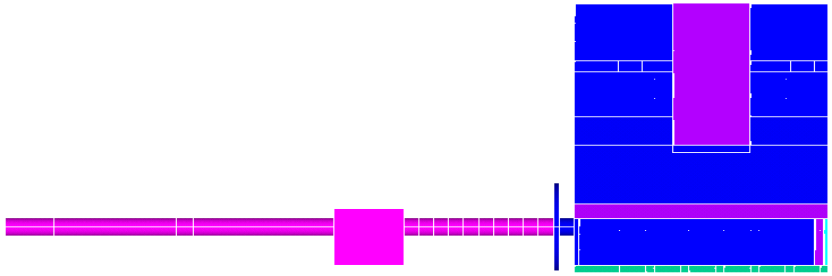




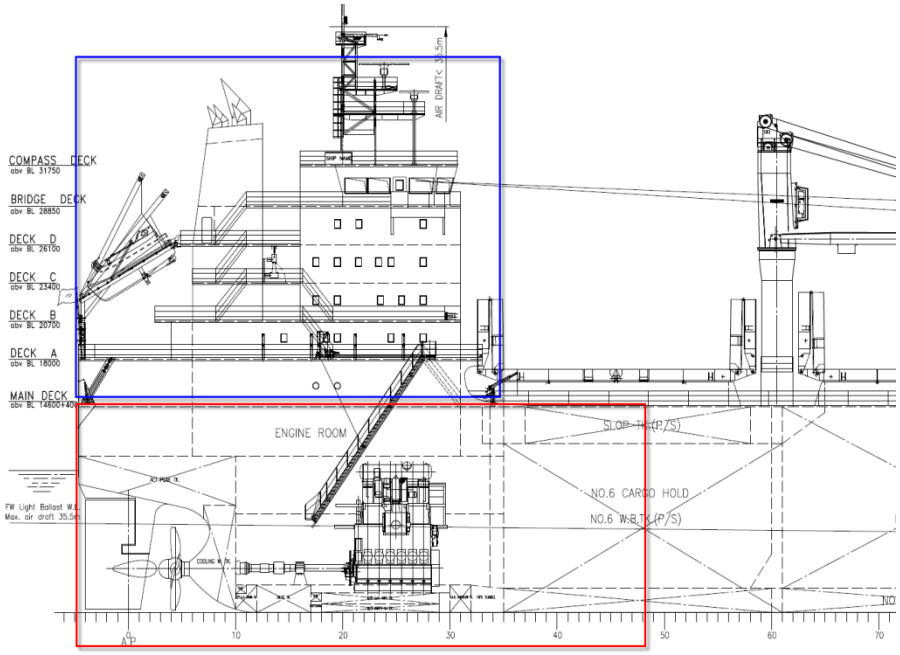
FE model of shaft line

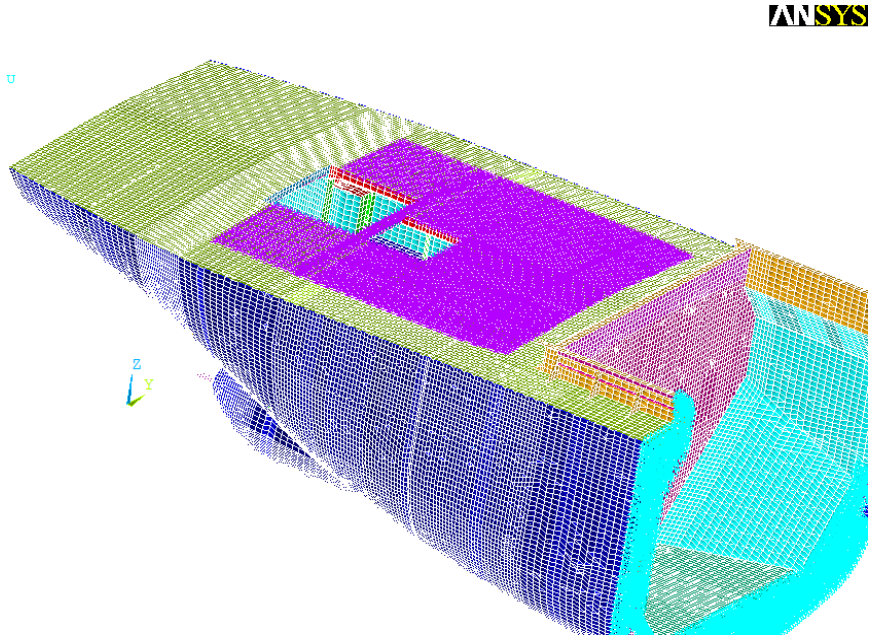




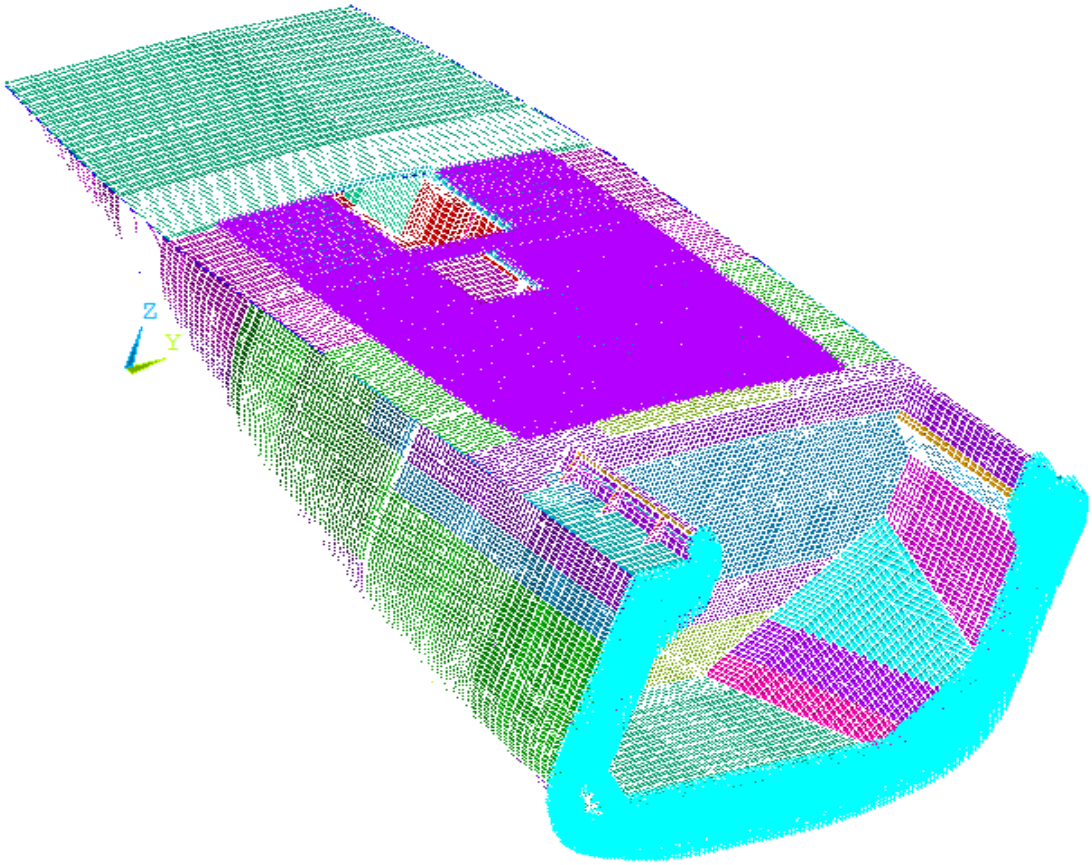


Superstructure representation



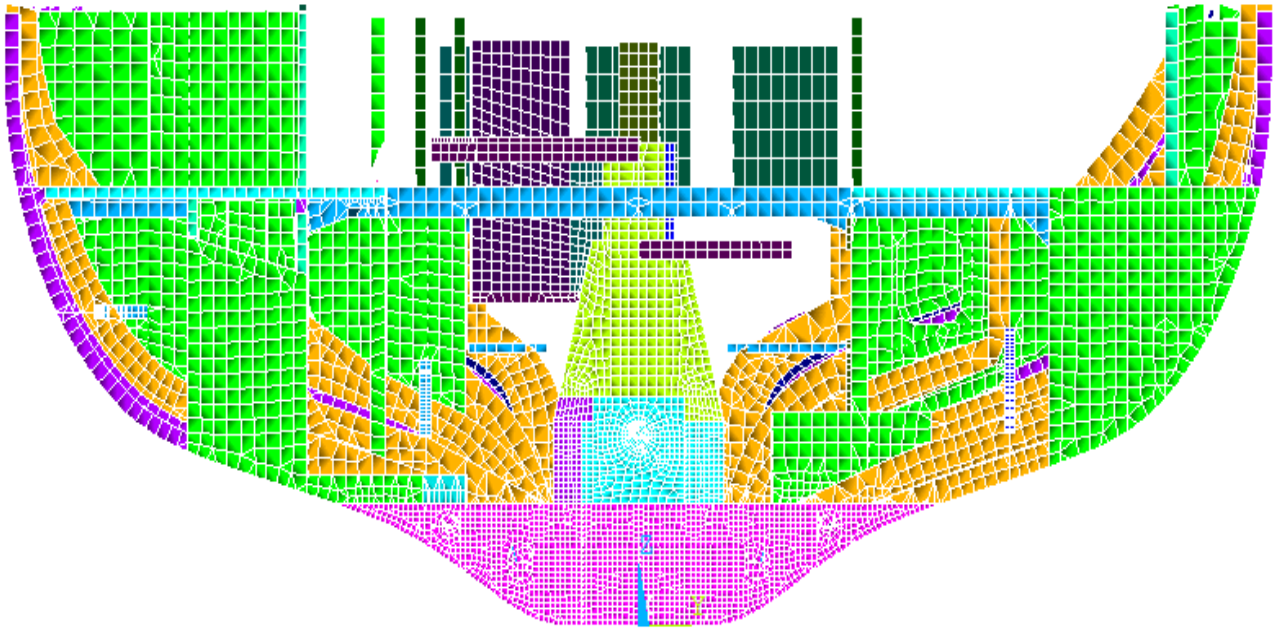


Modal analysis



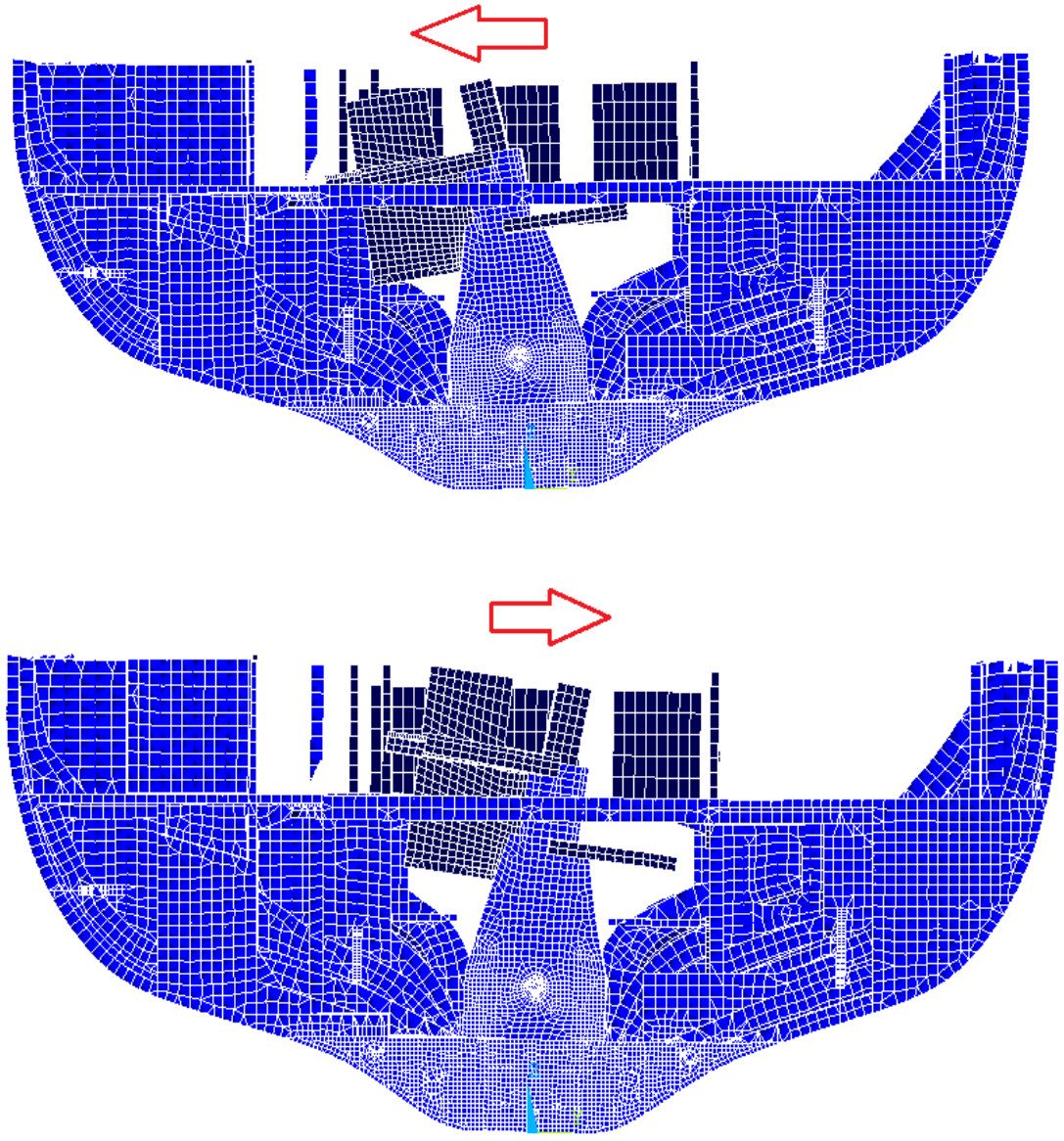
Boundary conditions – no translation degrees of freedom

Modal analysis without side stays

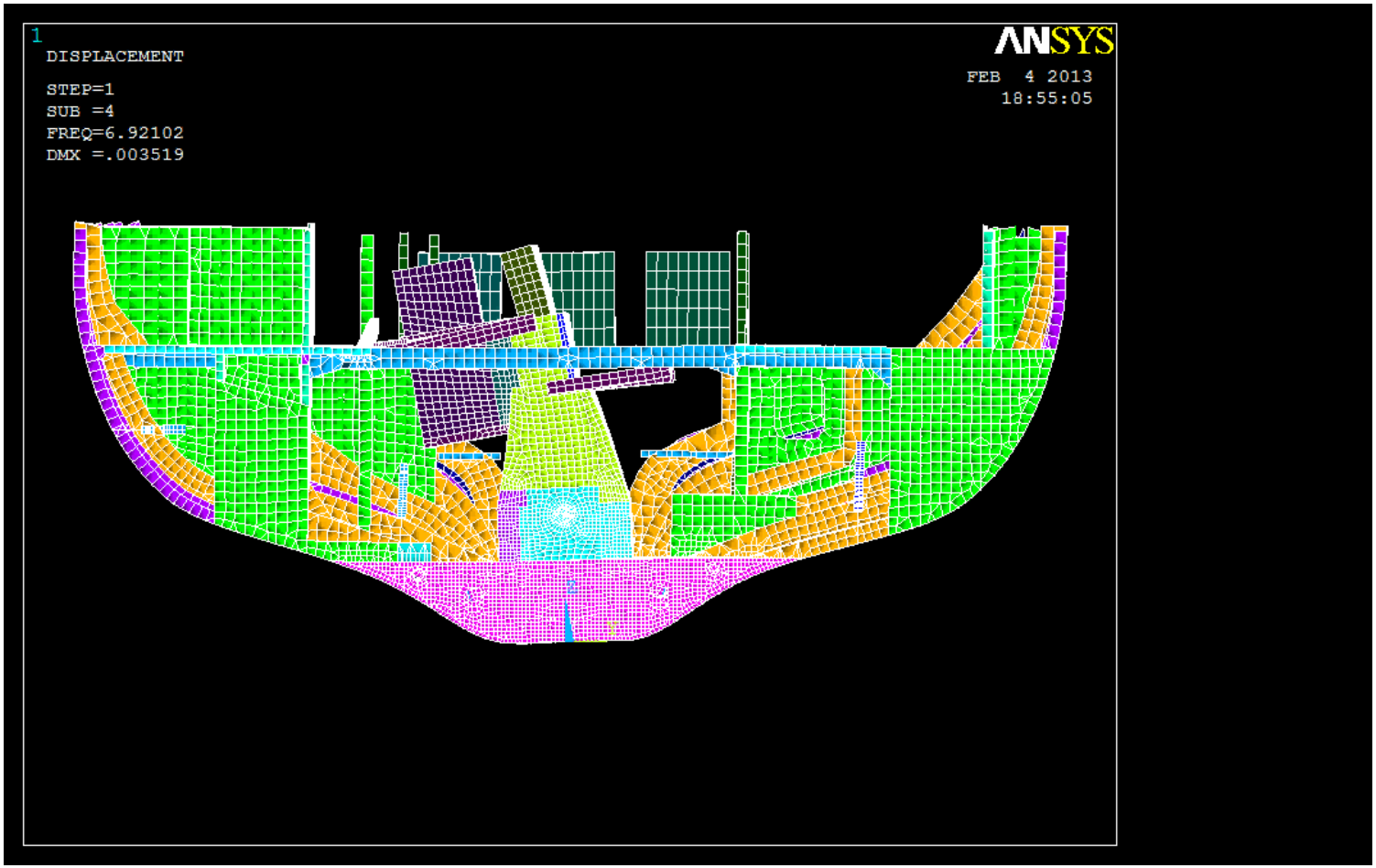


Calculated natural frequencies

- 4.97 Hz - vertical
- **5.89 Hz – H-type**
- 6.53 Hz - vertical
- **6.92 Hz – H-type**
- **7.15 Hz – H-type**
- 9.3 Hz – X-type
- 9.52 Hz – L-type
- 9.53 Hz – L-type



5.89 Hz – H-type



6.92 Hz – H-type

7.15 Hz – H-type

Modal analysis of the rigid engine on the elastic foundation

E=1e+013 Pa

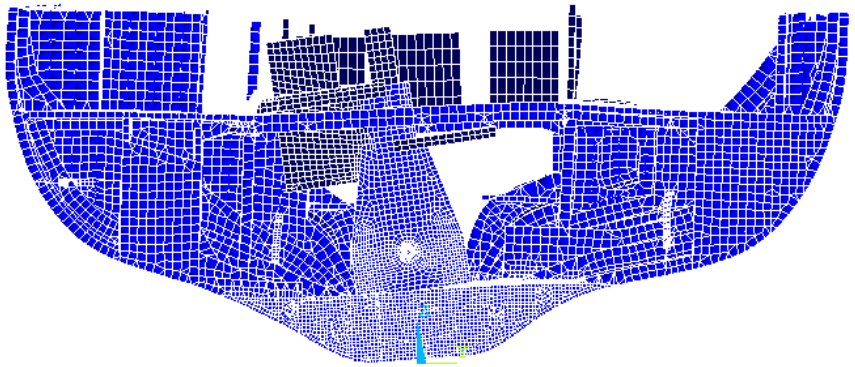
Four H-type modes:

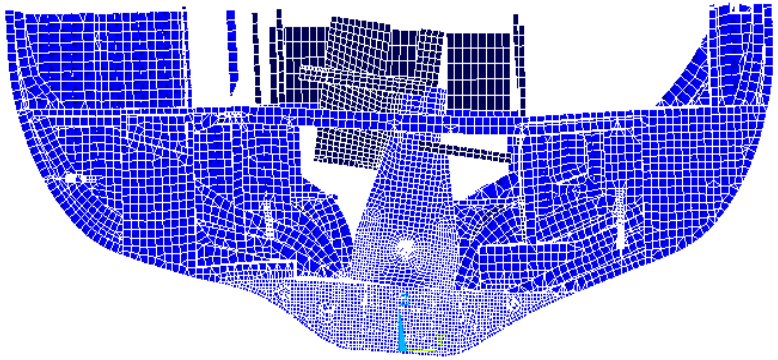
9.18 Hz

9.46 Hz

9.52 Hz

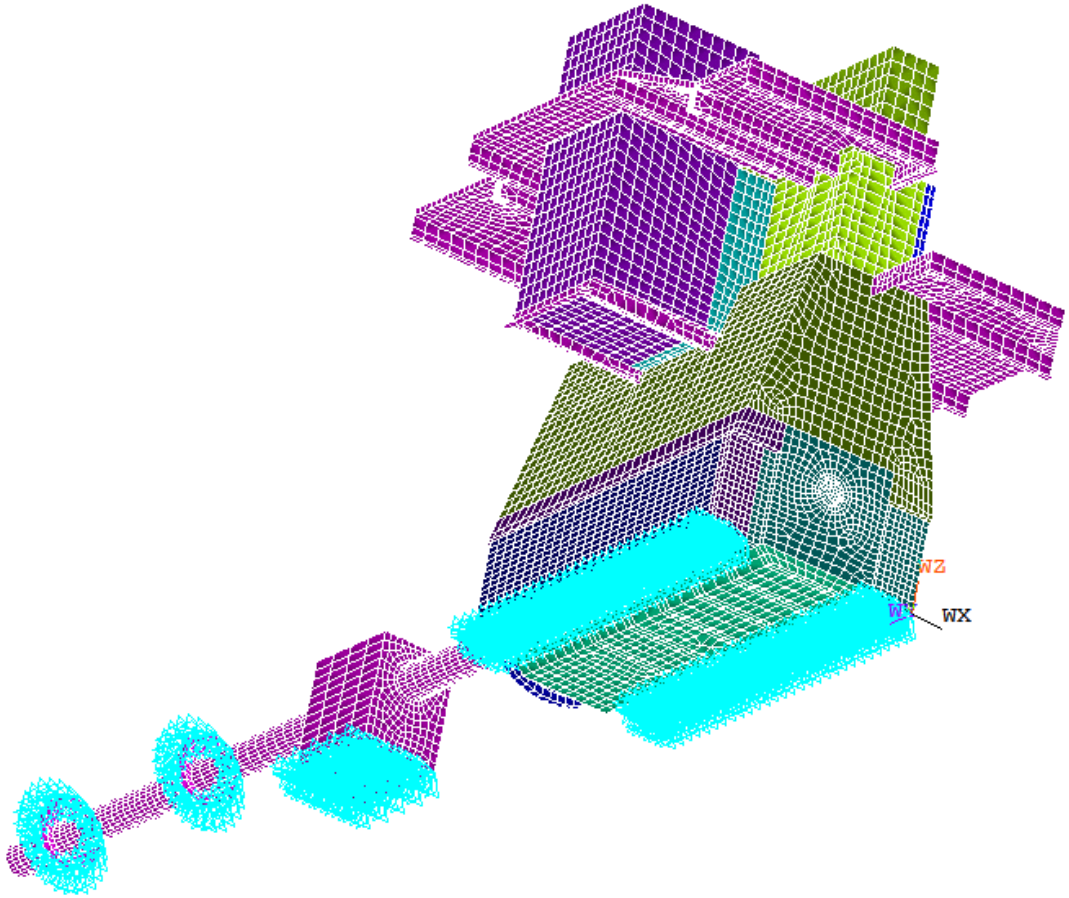
9.55 Hz

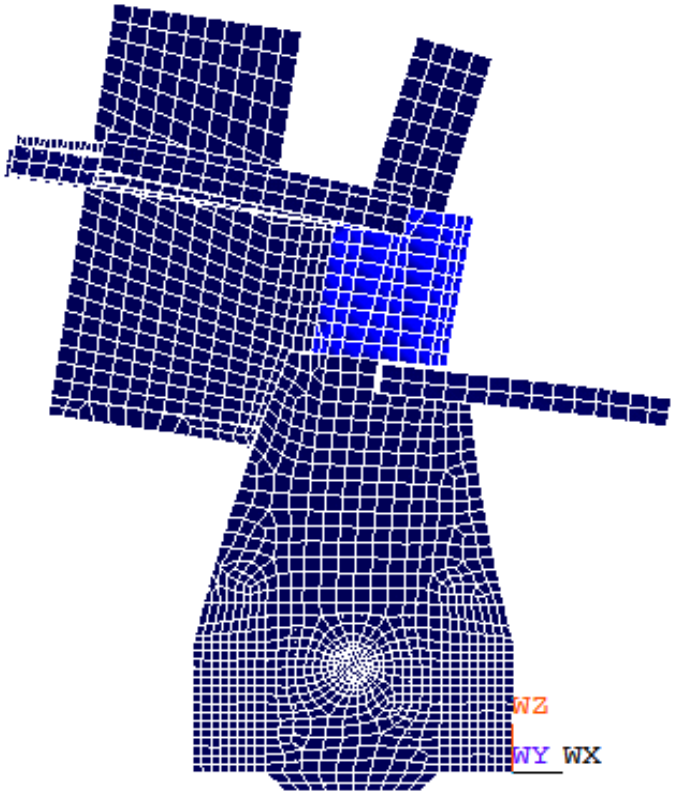




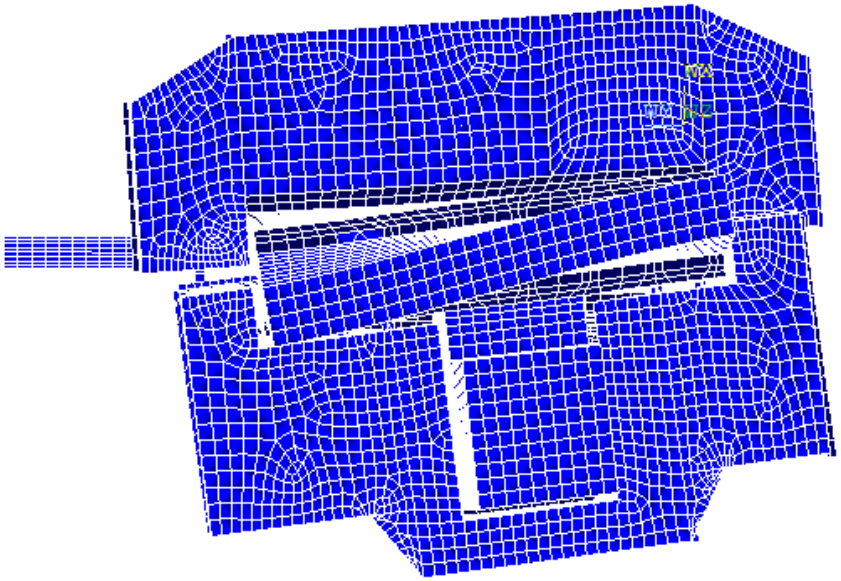
Shift is 2-2.5 Hz

Modal analysis of the engine structure on the rigid foundation



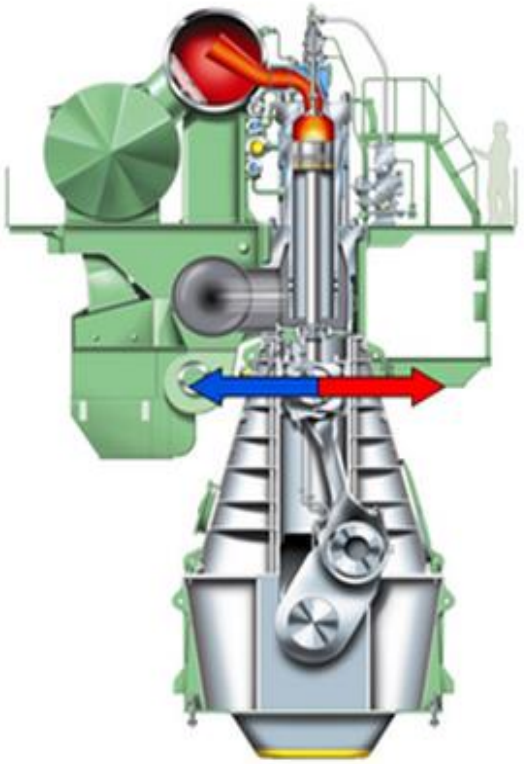


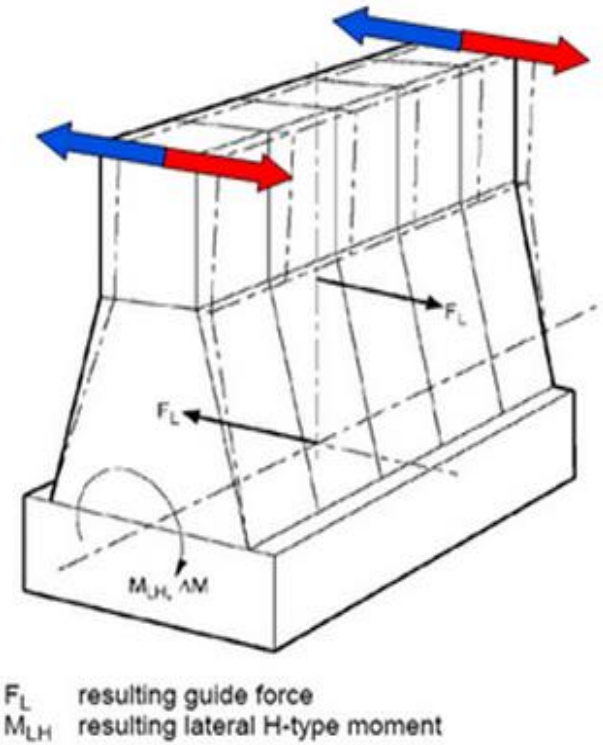
H-type 8.55 Hz



X-type 12.95 Hz

Forced vibration analysis

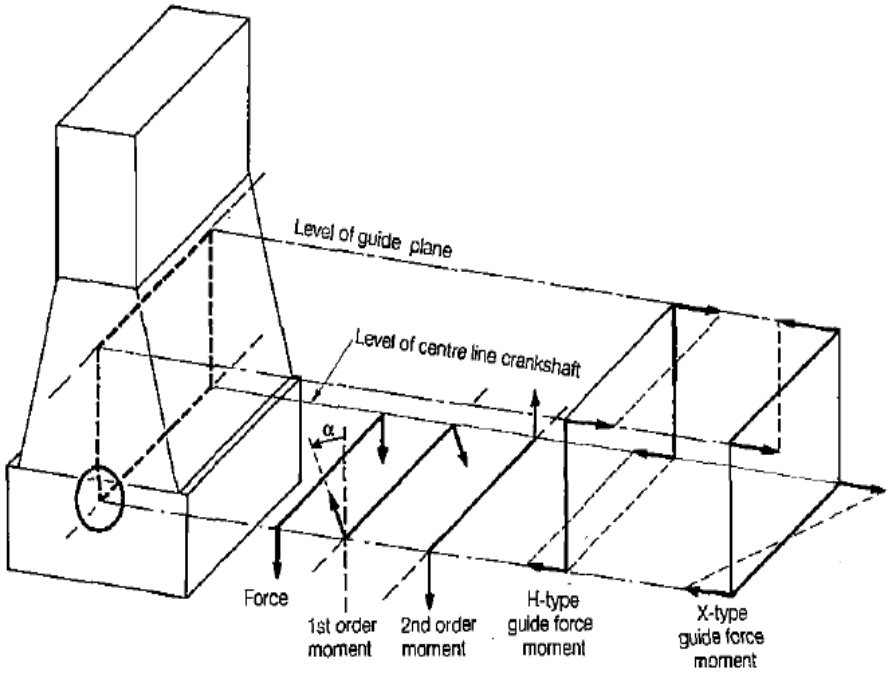


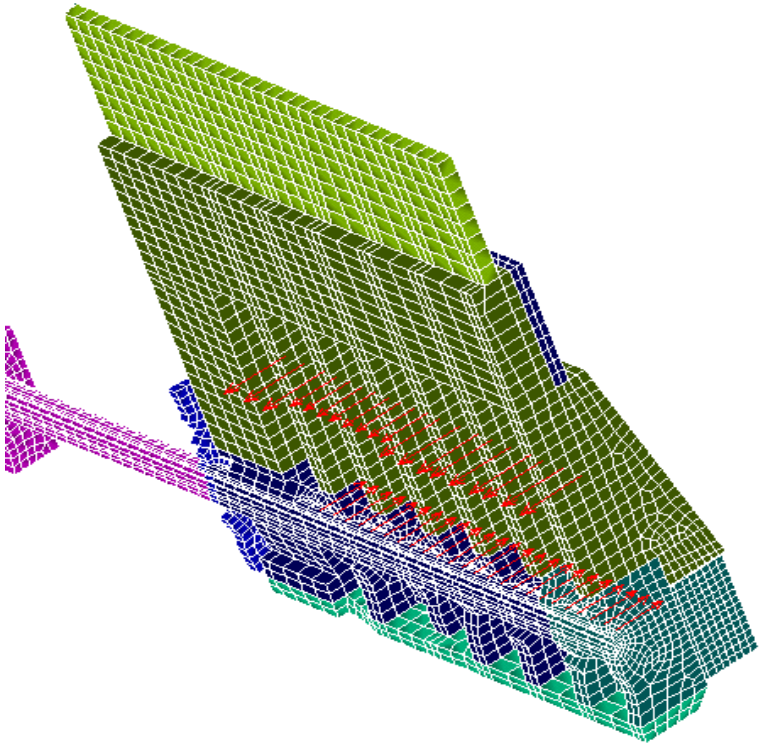


F_L resulting guide force
M_{LH} resulting lateral H-type moment

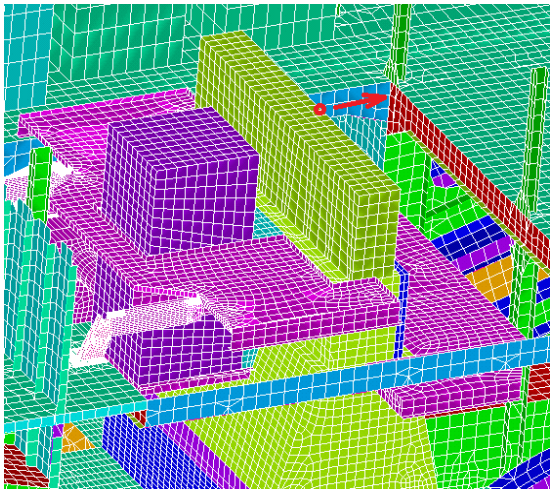
6th order frequency

Lateral guide forces

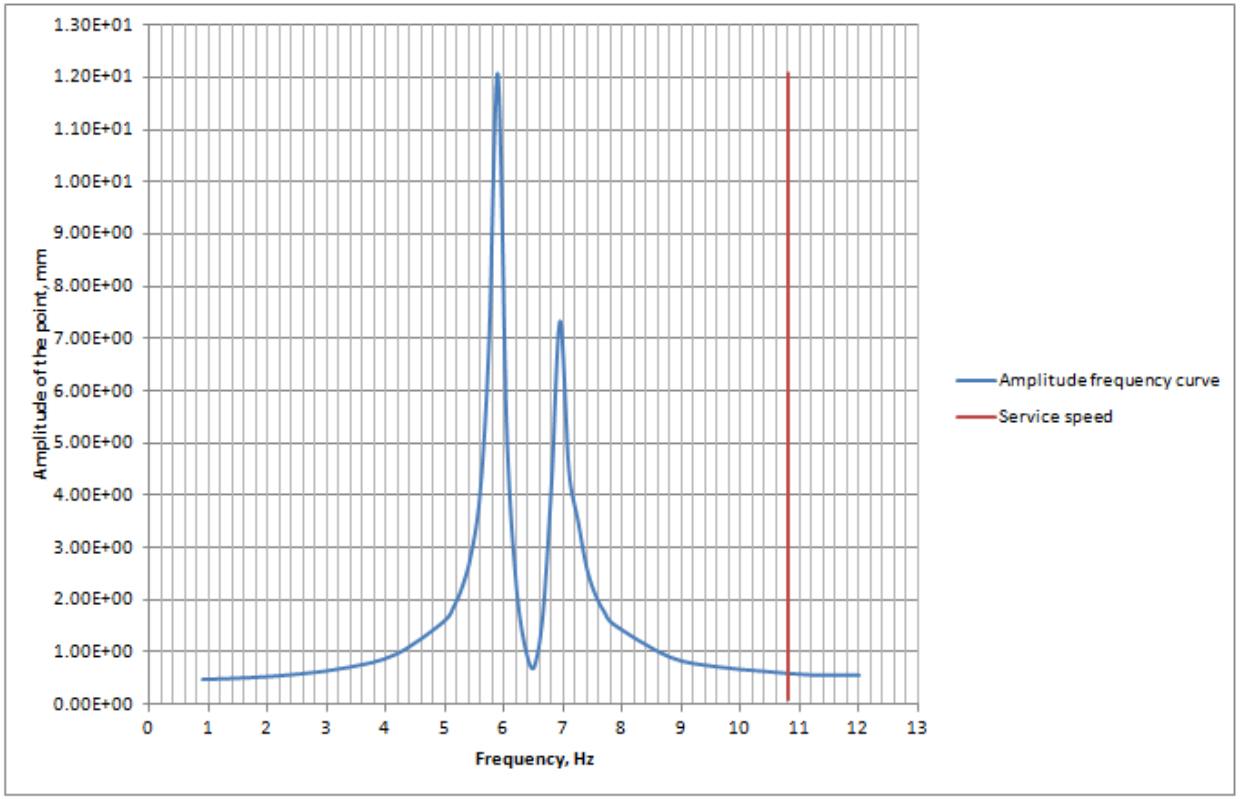




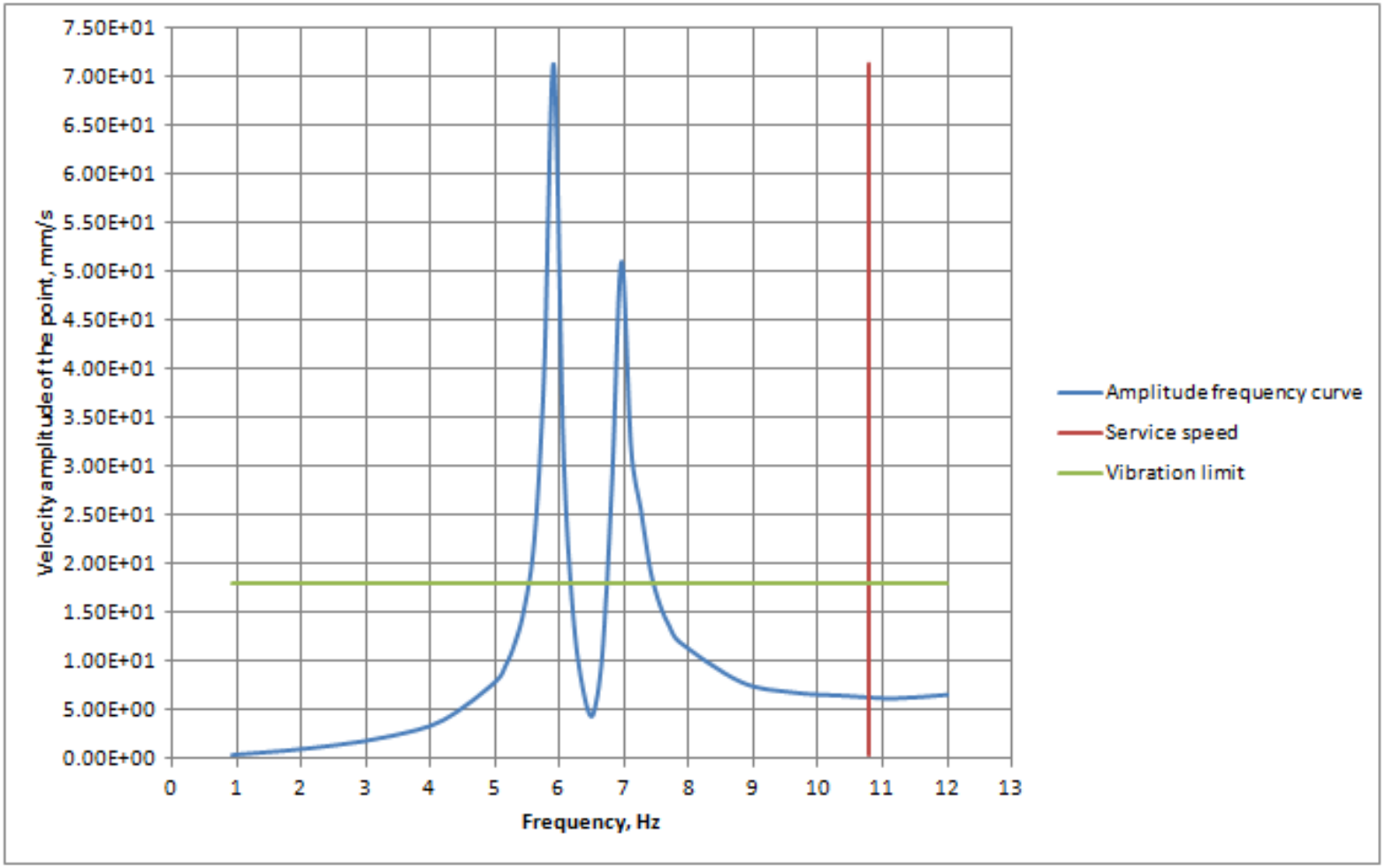
Results without side stays configuration



Position of a central node

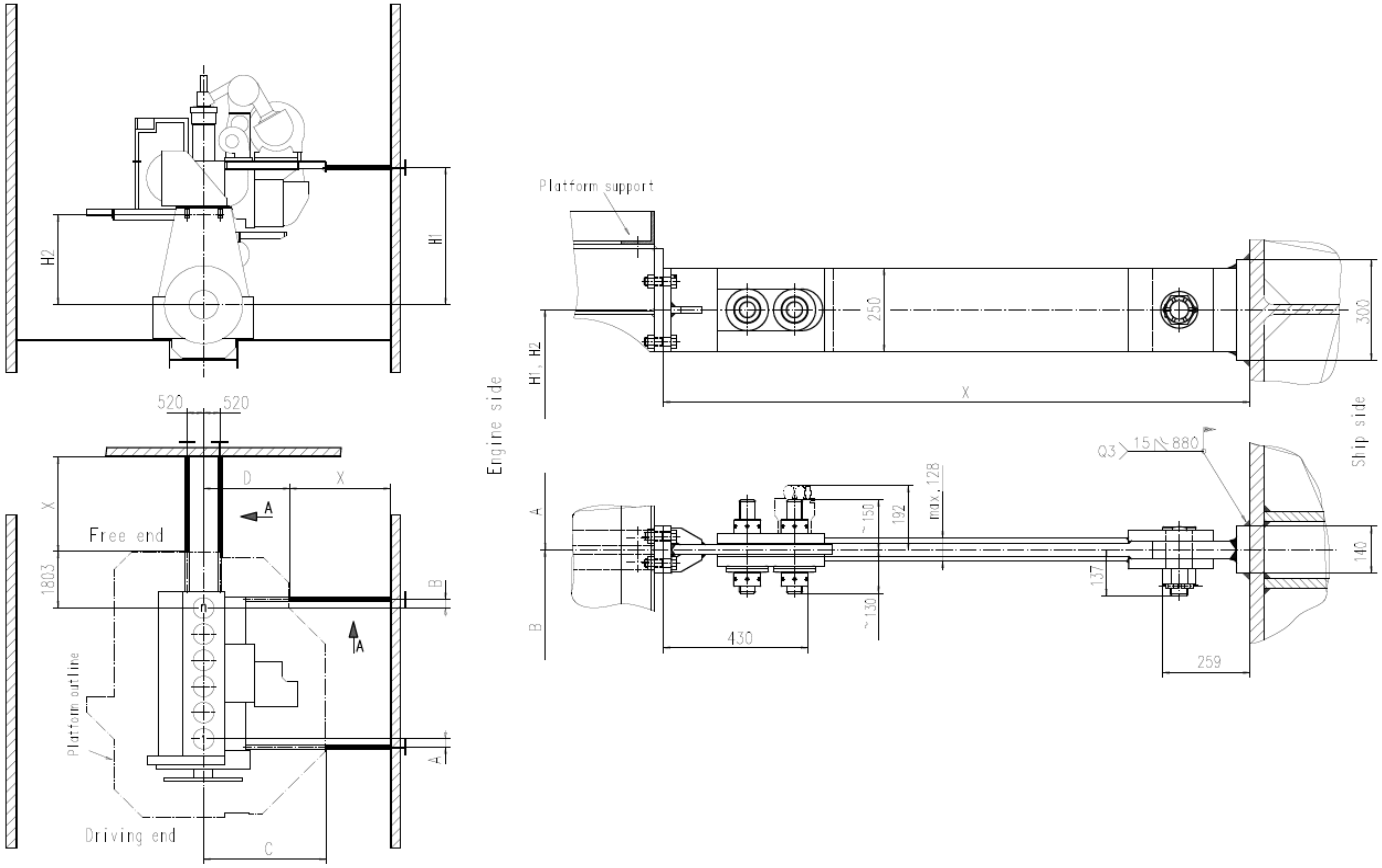


Amplitude frequency curve for the Y-displacement

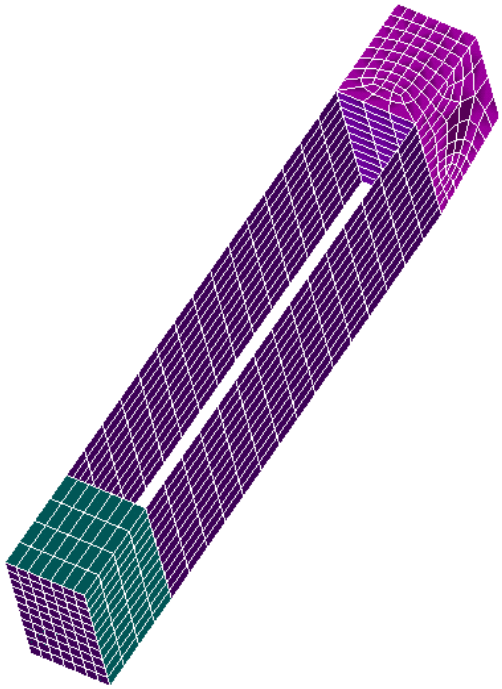


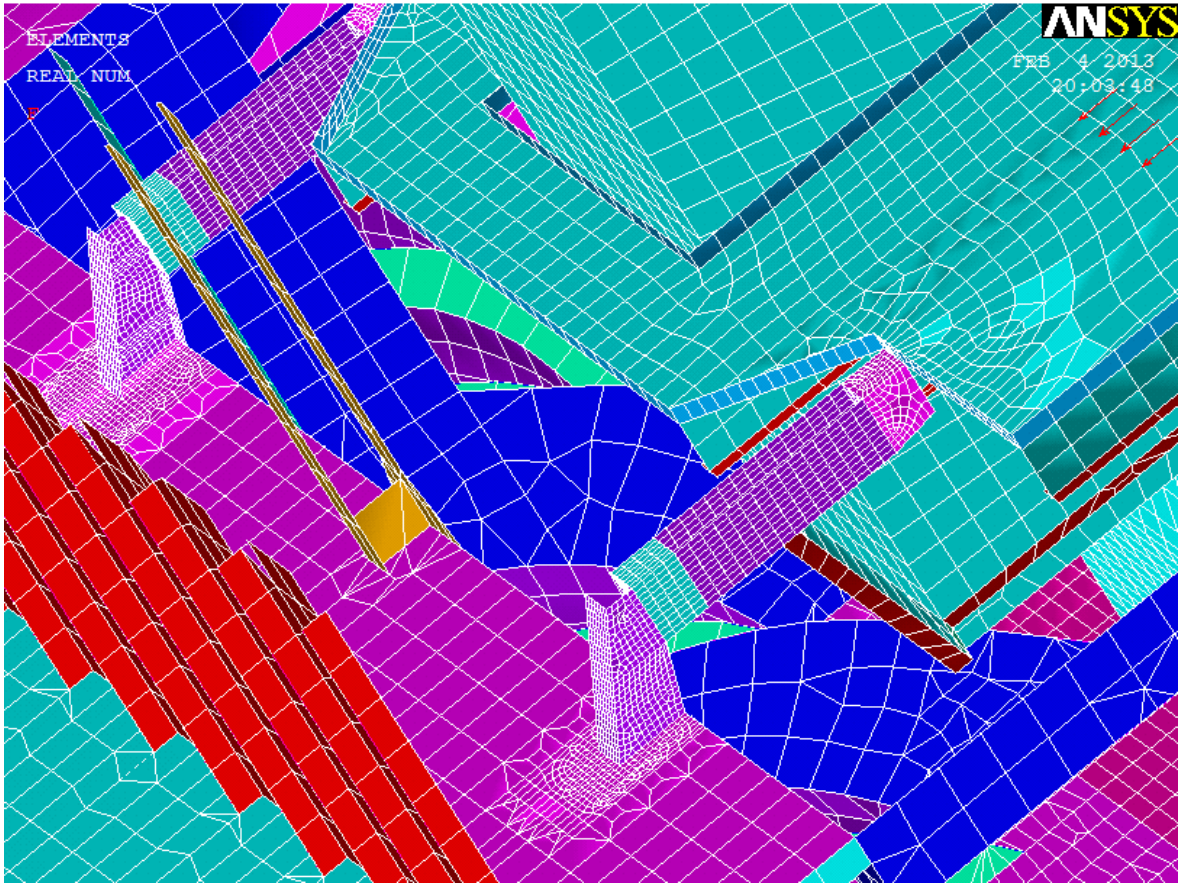
Amplitude frequency curve for the Y-velocity

Analysis of the forced engine vibration with installed side stay

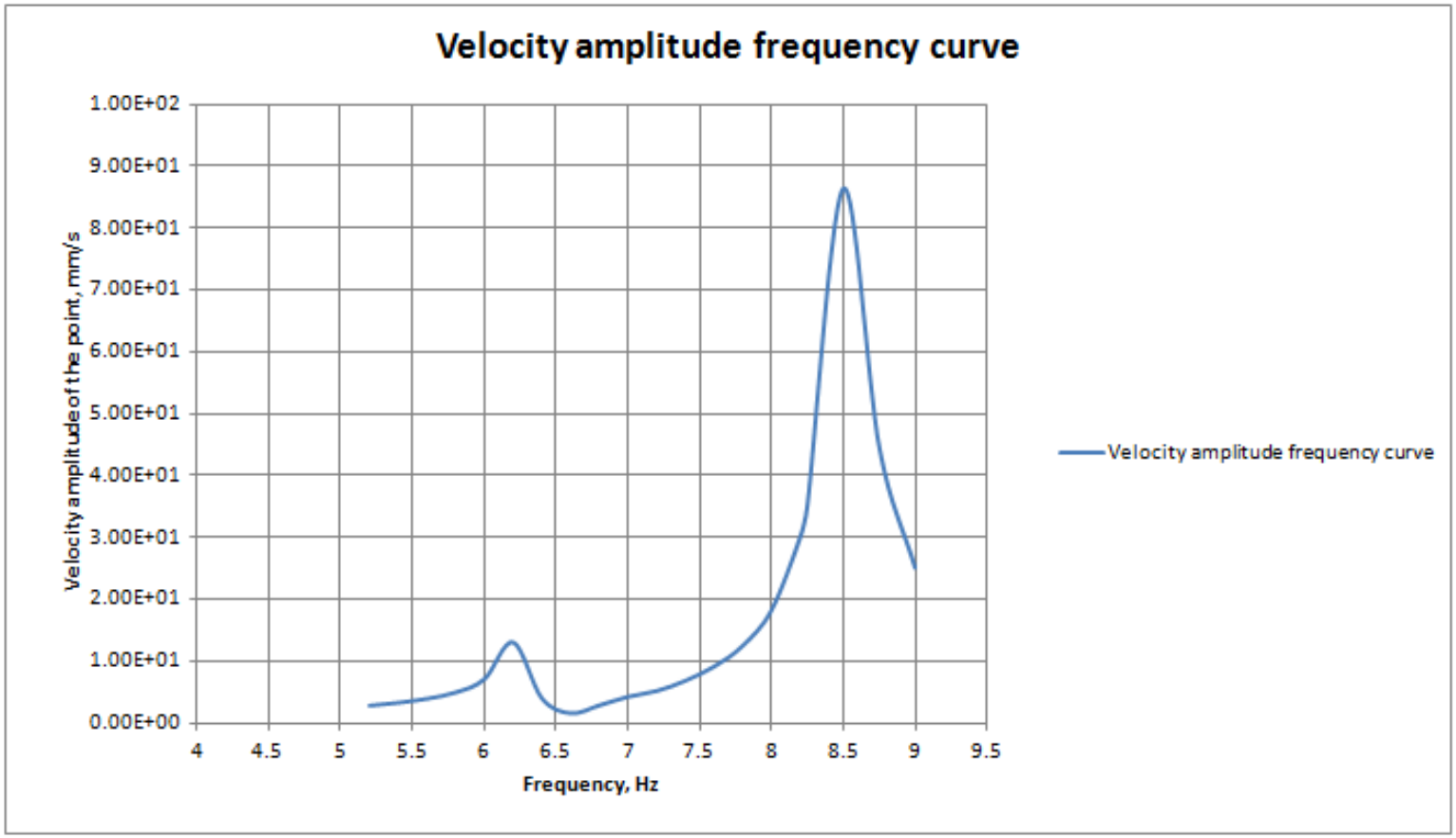


Modified FE model



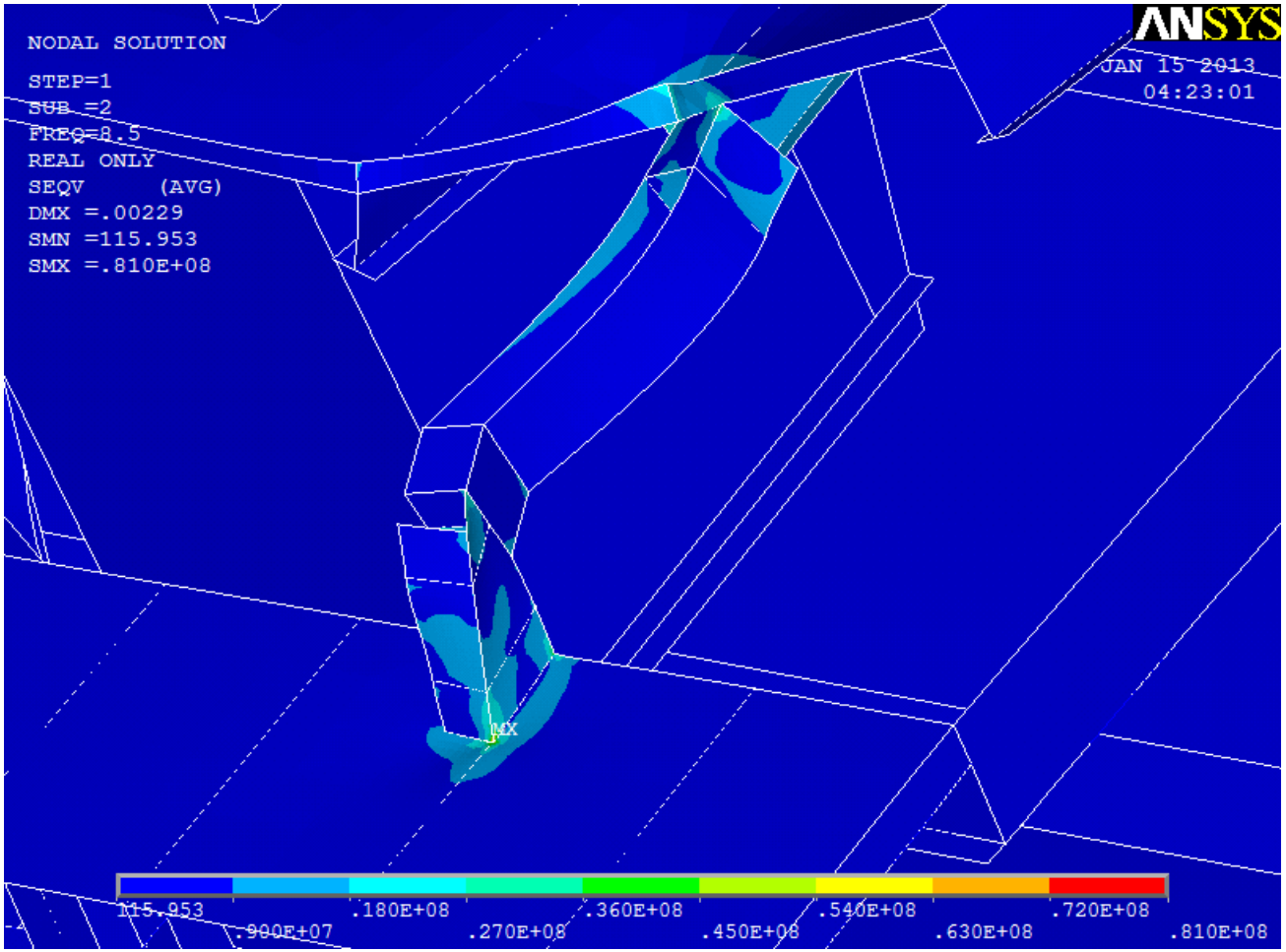


Results of the simulation

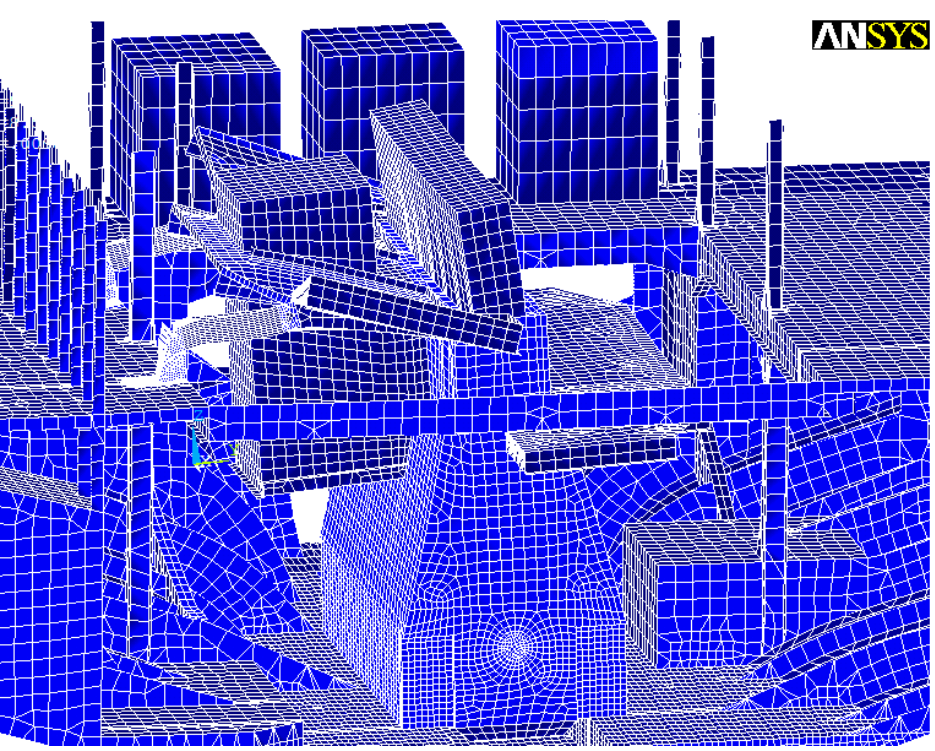


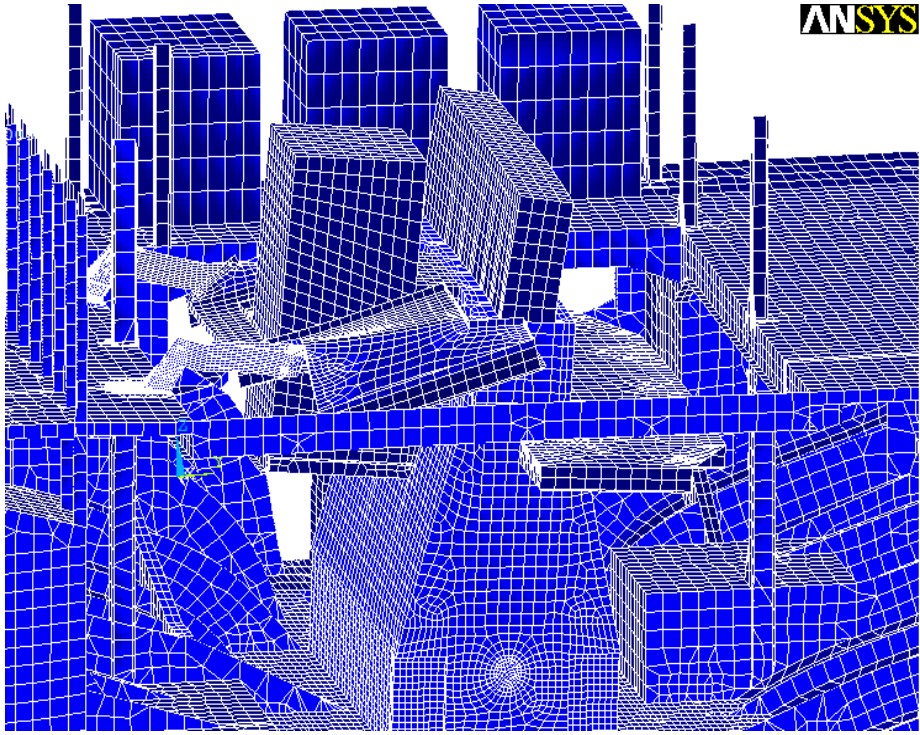
Amplitude frequency curve for the Y-velocity

Stress field



H-type mode





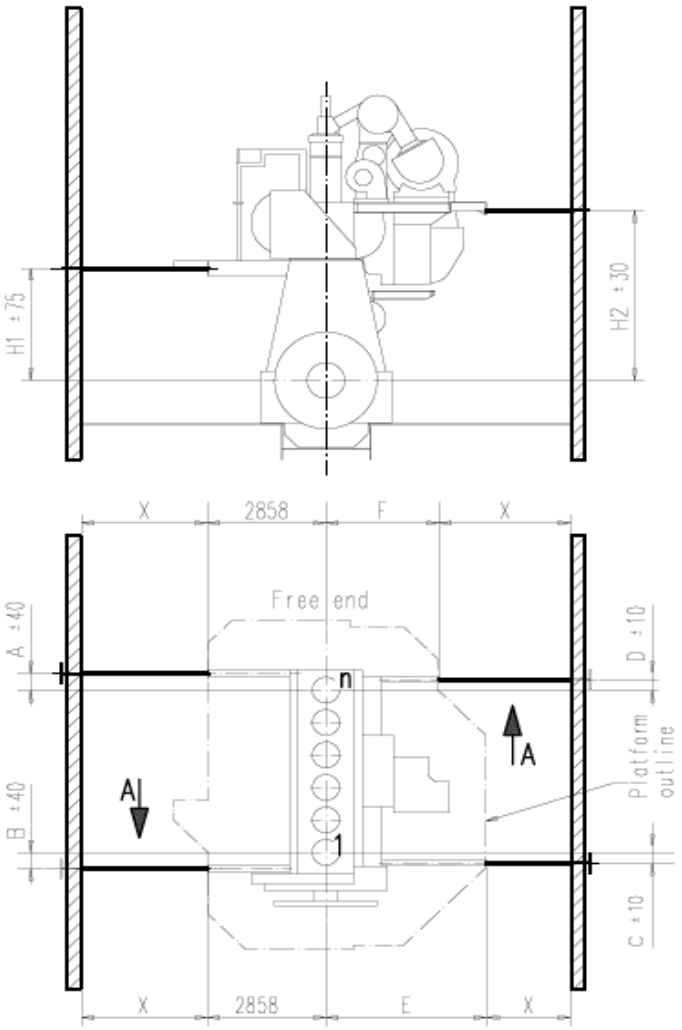
Conclusions

Solutions:

- Installation of the friction side stay was incorrect (too tight) and it caused resonance effect. Proper friction force adjustment may reduce high vibration level.
- Eliminate stress concentrators

Potential solutions:

- Hydraulic stays
- Modification of engine foundation


H1 ±75
H2 ±30
X
2858
F
X
Free end
A ±40
D ±10
n
A
A
1
Platform outline
B ±40
C ±10
X
2858
E
X