Shock Analysis of On-board Equipment Submitted to Underwater Explosion

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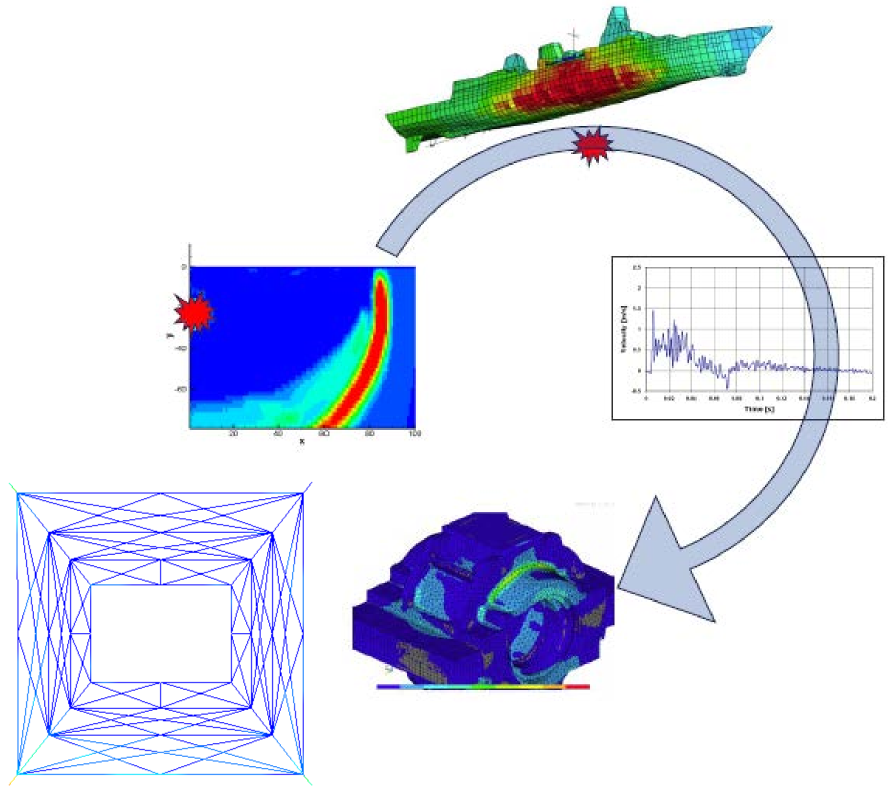
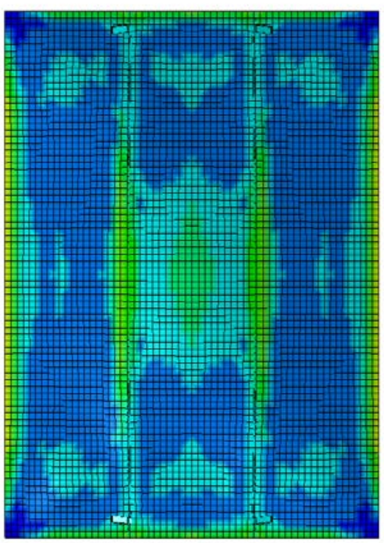


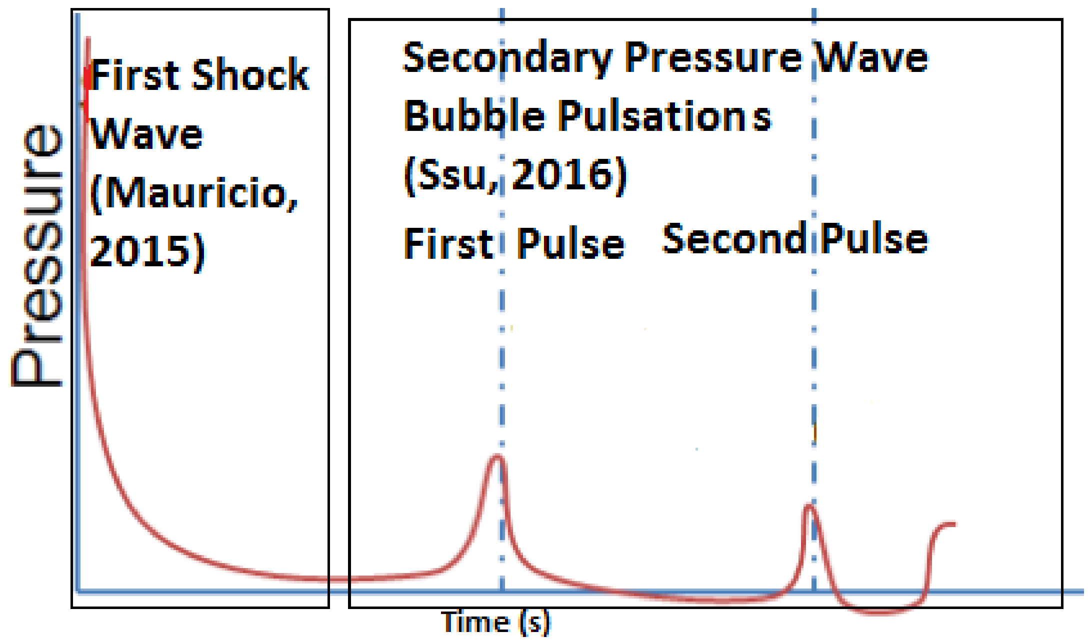
CONTENTS

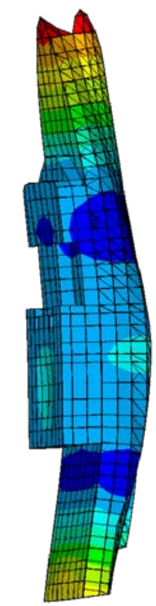
1. BACKGROUND

- **First shock wave (Mauricio,2015)**
  - Exponential decay
  - In a very short time
  - High energy and Pressure

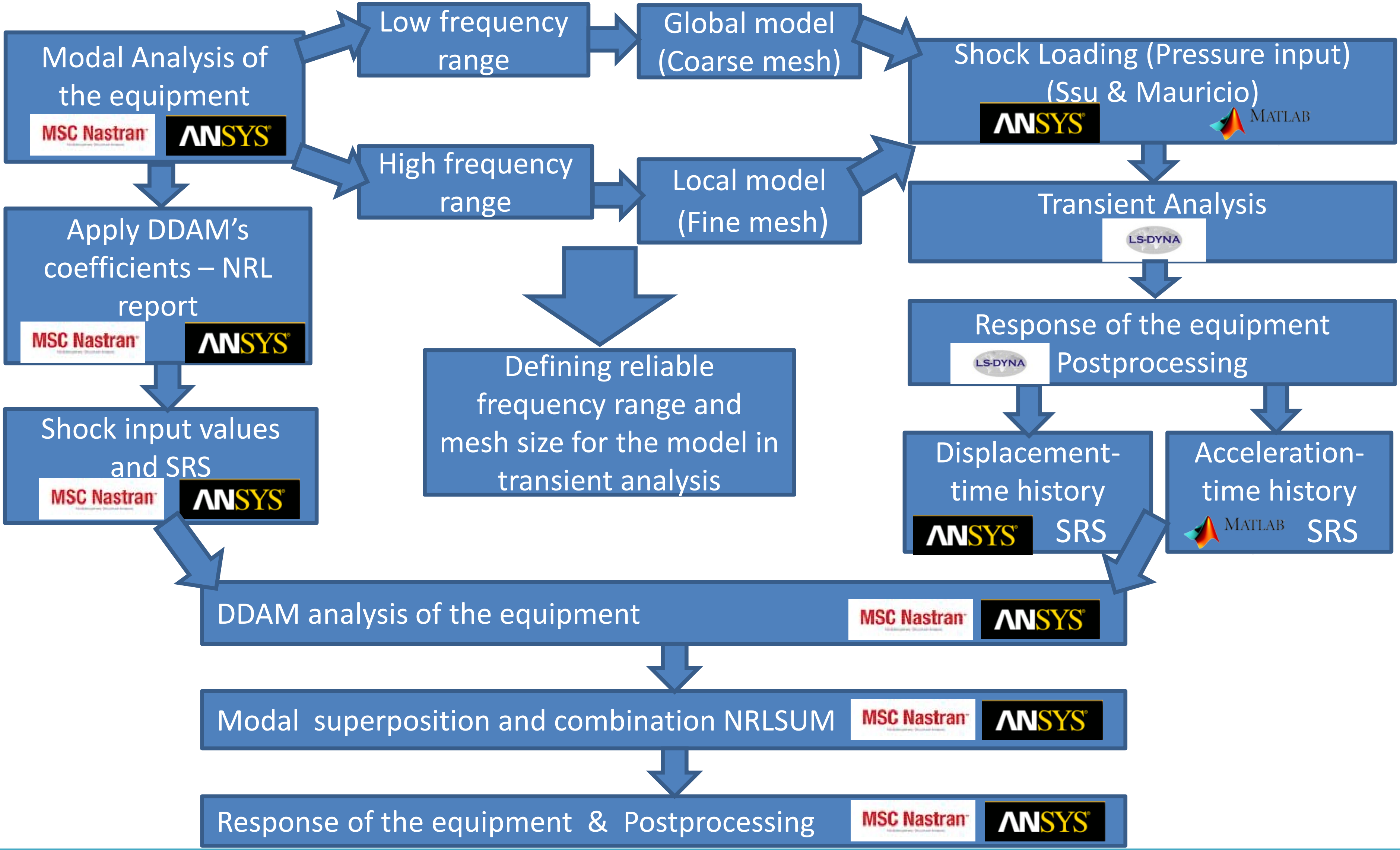
- **Bubble oscilations (Ssu,2016)**
  - Non-lineer
  - Longer time duration
  - Low frequency





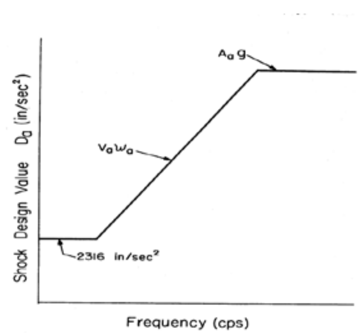


2. OBJECTIVES: Flow chart



3. DYNAMIC DESIGN ANALYSIS METHOD (DDAM)

- Based on Shock Response Spectrum (SRS) theory
- Uses the modal analysis informations
- Final response is obtained by modal summation methods



DDAM

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Modal Analysis

- Modal solution
- Natural frequencies
- Mode shapes
- Modal effective mass

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Shock Response Spectrum

- Shock response spectrum calculation
- From NRL coefficients or transient analysis
- Excitation directions

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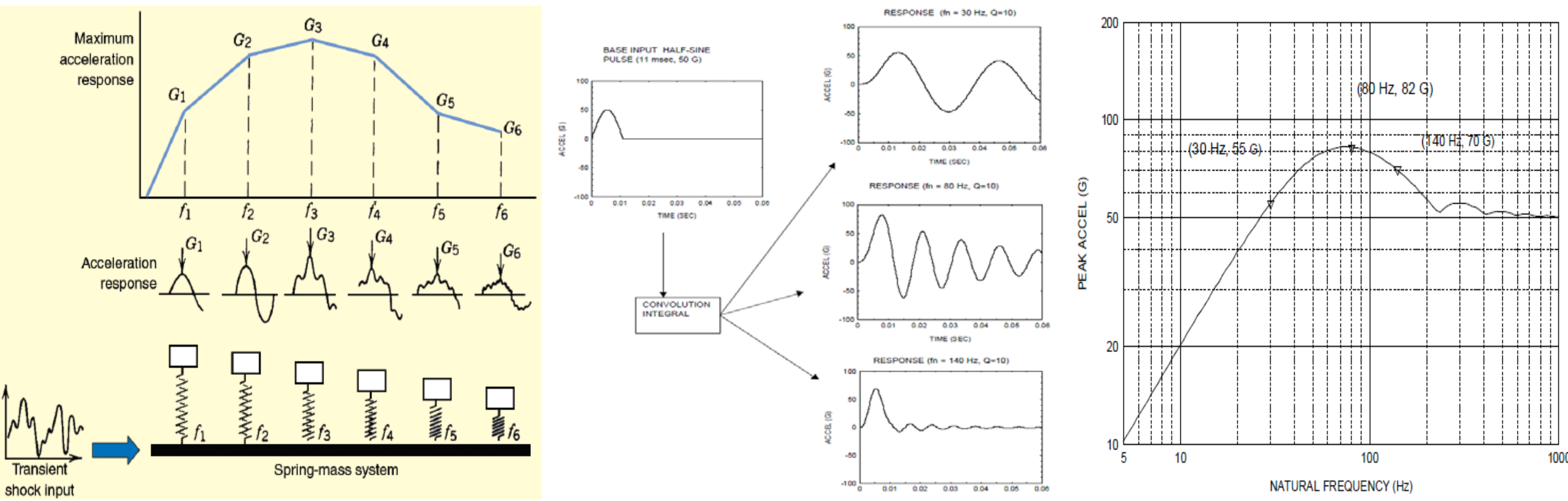
Response of the Structure

- Modal superposition
- NRL summation (80% of effective mass)
- Displacement, Stress, strain, forces, etc.

4. SHOCK RESPONSE SPECTRUM (SRS)

- SRS is used to evaluate the peak response of the structures and equipment.

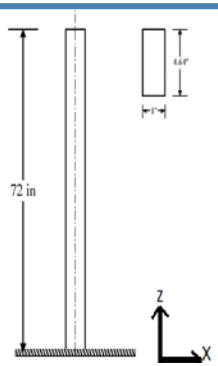


Building of shock response sprectrum

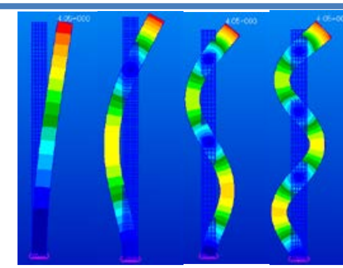
Shock Response Spectrum Generators

- MATLAB® (Acceleration time-history)
- ANSYS (Displacement time-history)

5. DDAM ANALYSIS OF A CANTILEVER BEAM



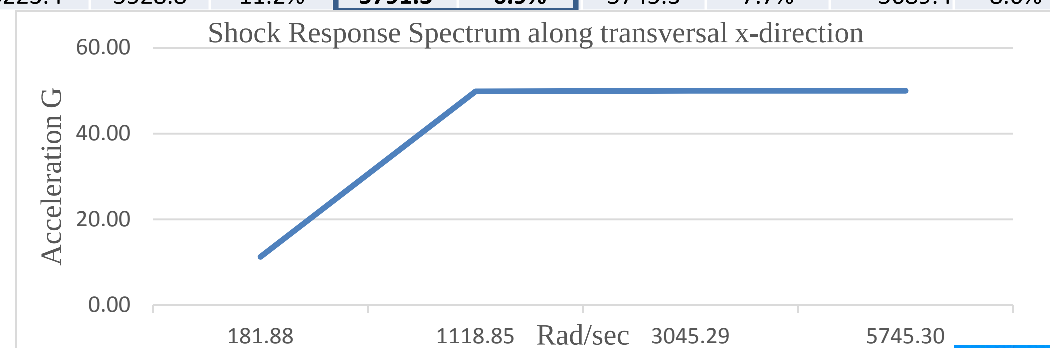
Main Properties of a Cantilever Beam		
L	72 (in)	1.8288 (m)
h	4.64 (in)	0.117856 (m)
b	1 (in)	0.0254 (m)
E	2,9e7 (psi)	2e11 (N/m²)
ρ	0.00073 (lbf·s2/in⁴)	7803.7 (kg/m³)



- Modal analysis
- Participation factor
- Modal effective mass
- Percentage of the modal effective mass

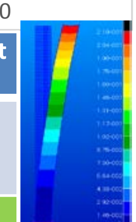
Mode No	Reference	Nastran - Element size - (0.2 m)		**Nastran - Element size - (25.4 mm)**		Nastran – SOLID-Element size – (12.7 mm)		ANSYS, SI unit, Element size- (25.4 mm)	
	Radians (rad/sec)	Radians (rad/sec)	Discr.	**Radians (rad/sec)**	**Discr.**	Radians (rad/sec)	Discr.	Radians (rad/sec)	Discr.
1	181.7	179.6	1.2%	**180.6**	**0.6%**	181.9	-0.1%	180.5	0.7%
2	1134	1094.3	3.5%	**1115.1**	**1.7%**	1118.9	1.3%	1109.6	2.2%
3	3176.1	2957.5	6.9%	**3051**	**3.9%**	3045.3	4.1%	3018.4	5.0%
4	6223.4	5528.8	11.2%	**5791.3**	**6.9%**	5745.3	7.7%	5689.4	8.6%

- SRS is obtained by NRL coefficients
- Shell mounted, Surface ship, Elastic



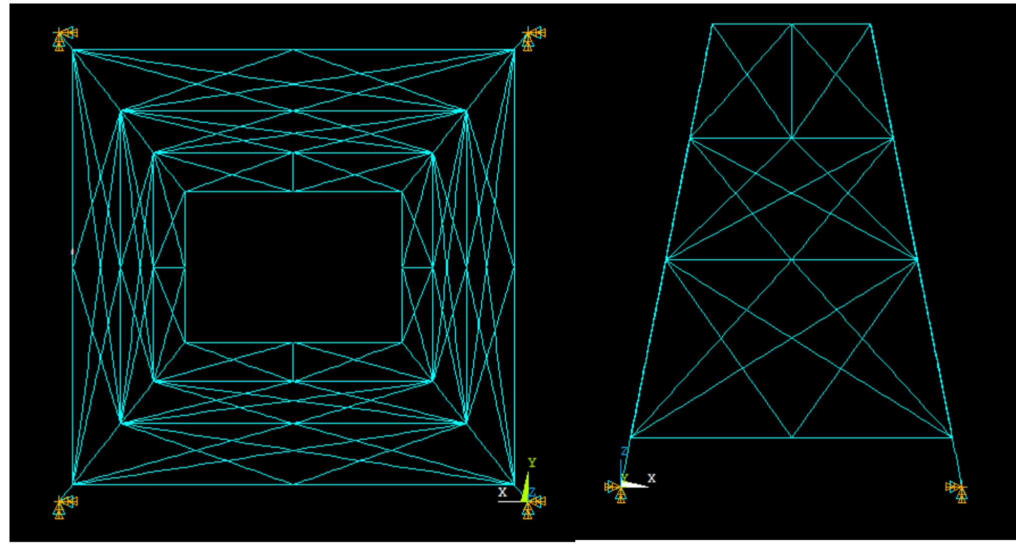
- Final displacement response

Reference		Nastran - Element size - (0.2 m)			**Nastran - Element size – (25.4 mm)**			Nastran – SOLID-Element size – (12.7 mm)			ANSYS, SI unit, Element size- (25.4 mm)	
Total displacement (in- m)		Total displacement (in- m)		Discr.	**Total displacement (in- m)**		**Discr.**	Total displacement (in- m)		Discr.	Total displacement (in/ m)	Discr.
0.22	0.0056	0.22	0.0056	-0.20%	**0.22**	**0.0056**	-0.30%	0.22	0.0055	0.60%	0.0056	-0.30%



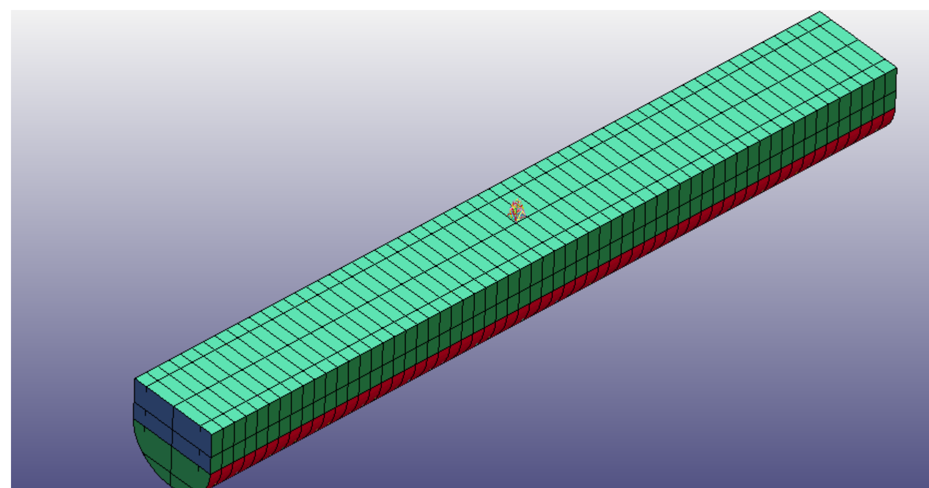
6. SHOCK ANALYSIS OF AN ANTENNA STRUCTURE

- NRL Coefficient DDAM analysis
- Transient analysis
  (Direct integration method)
- DDAM analysis from time history input



High tensile steel Properties	
E (MPa)	210000
ρ (kg/m³)	7810
ν	0.3
σ_y (MPa)	800

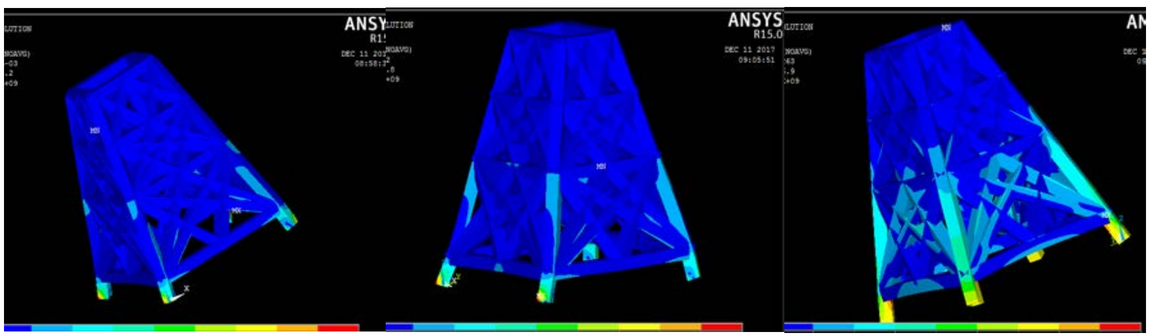
Cross section of the antenna is square beams assembly



6.1. NRL Coefficient DDAM Analysis of the Antenna

- Percentage of the modal effective mass passes % 80 at each direction
- 250 Hz as an upper level in DDAM
- NRL cofficients are taken into account for deck mounting system and hull mounting system in a surface ship

MODE No	ANSYS	X direction	Y direction	Z direction
	Frequency (Hz)	Percentage of the modal effective mass		
1	110.98	95.4	0	0
2	115	0	94.69	0
3	170.18	0	0	0
4	175.49	0	0	0.36
5	180.45	0	1.49	0
6	189.36	1.42	0	0
7	197.75	0	0	0
8	226.2	0	0	89.94
Total percentage of the modal effective mass		96.82	96.18	90.3

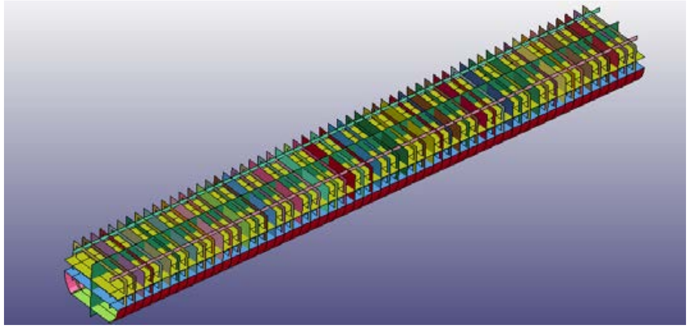


Shock response at	X directed shock-Deck mounted	X directed shock-Hull mounted	Y directed shock-Deck mounted	Y directed shock-Hull mounted	Z directed shock-Deck mounted	Z directed shock-Hull mounted
Total Displacement (mm)	0.5 $Disp_{DDAM-NRL-y-HULL}$	0.5 $Disp_{DDAM-NRL-y-HULL}$	0.5$Disp_{DDAM-NRL-y-HULL}$	$Disp_{DDAM-NRL-y-HULL}$	0.42 $Disp_{DDAM-NRL-y-HULL}$	0.83 $Disp_{DDAM-NRL-y-HULL}$
Maximum Von-Mises Stress (MPa)	0.54 $\sigma_{DDAM-NRL-y-HULL}$	0.54 $\sigma_{DDAM-NRL-y-HULL}$	0.5 $\sigma_{DDAM-NRL-y-HULL}$	$\sigma_{DDAM-NRL-y-HULL}$	0.32 $\sigma_{DDAM-NRL-y-HULL}$	0.63 $\sigma_{DDAM-NRL-y-HULL}$

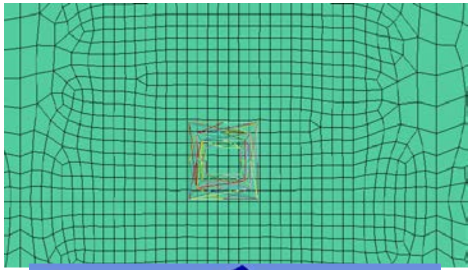
6.2. Transient Analysis of the Antenna

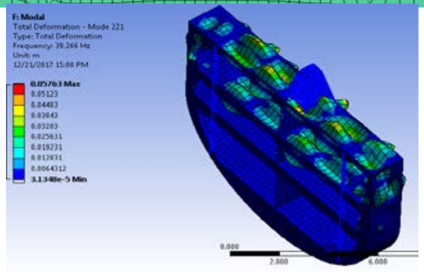
- A simplified ship structure
- Structural properties are similar to a frigate
- Added mass is applied by Lewis coefficients
- Three different transient analysis are carried out
- Global model (Coarse mesh) and section model (Fine mesh) approaches are applied
- Global models have only finer mesh around the equipment

Part	Dimension (m)
Length overall	Around 100
Breath	Around 12



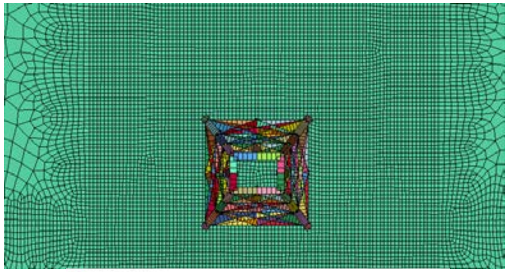
1:Global model - 200 mm element size around the equipment

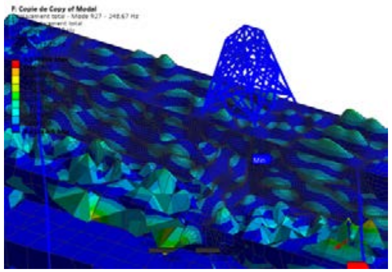




30 Hz

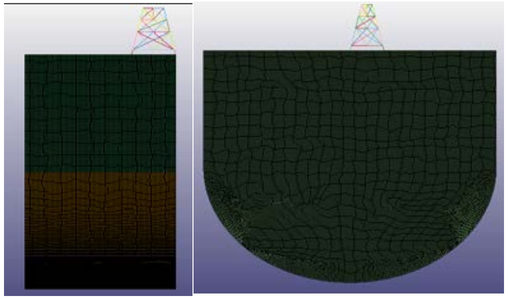
2:Global model - 50 mm element size around the equipment

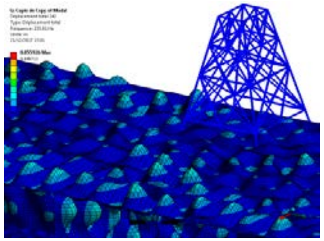




248 Hz

3:Section model - 50 mm element size all over the structure



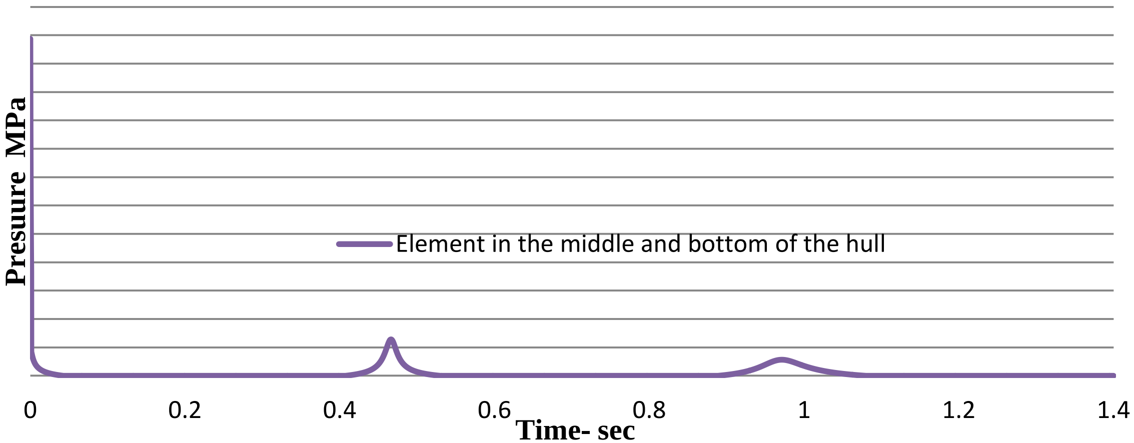


230 Hz

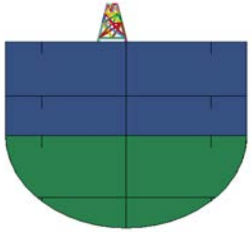
6.2. Transient Analysis of the Antenna

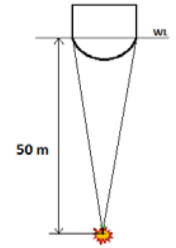
- Pressure field due to UNDEX is applied to the hull of the simplified ship

The maximum pressure load in the middle and bottom of the hull



	Initial conditions
mc	TNT charge mass, mc=500 kg
di	Distance from explosive to free surface, di=54.74
r	Distance from explosive to standoff point, r=50m
ρc	Density of the explosive, ρc= 1600 kg/m^3
SF	Shock factor= 0.447





- All simulations are carried out using elastic behavior law

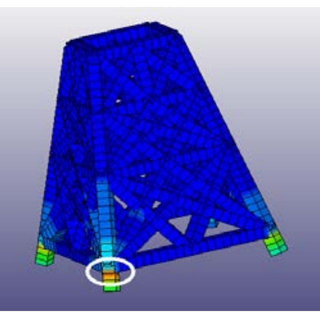
Transient Analysis	Global model, coarser mesh (0.2m) around equipment	Global model, finer mesh (0.05m) around equipment	Section model fine mesh (0.05 m)
Total response of the equipment (Max-Von-Misses stress) in MPa	1.95 $\sigma_{max\text{-}trans\text{-}section\ model}$	2.17 $\sigma_{max\text{-}trans\text{-}section\ model}$	$\sigma_{max\text{-}trans\text{-}section\ model}$

- Results in the global models are completely unrealistic.
- In the global models, the flexibility of structure is not modeled correctly in high-frequency
- The results in the section model seem to be more realistic

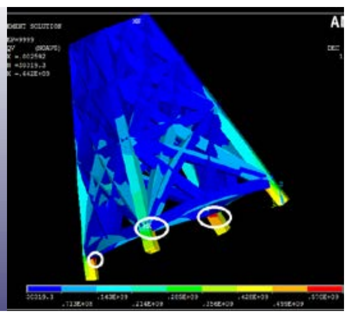
6.3. Comparison between the Transient Analysis and DDAM Analysis

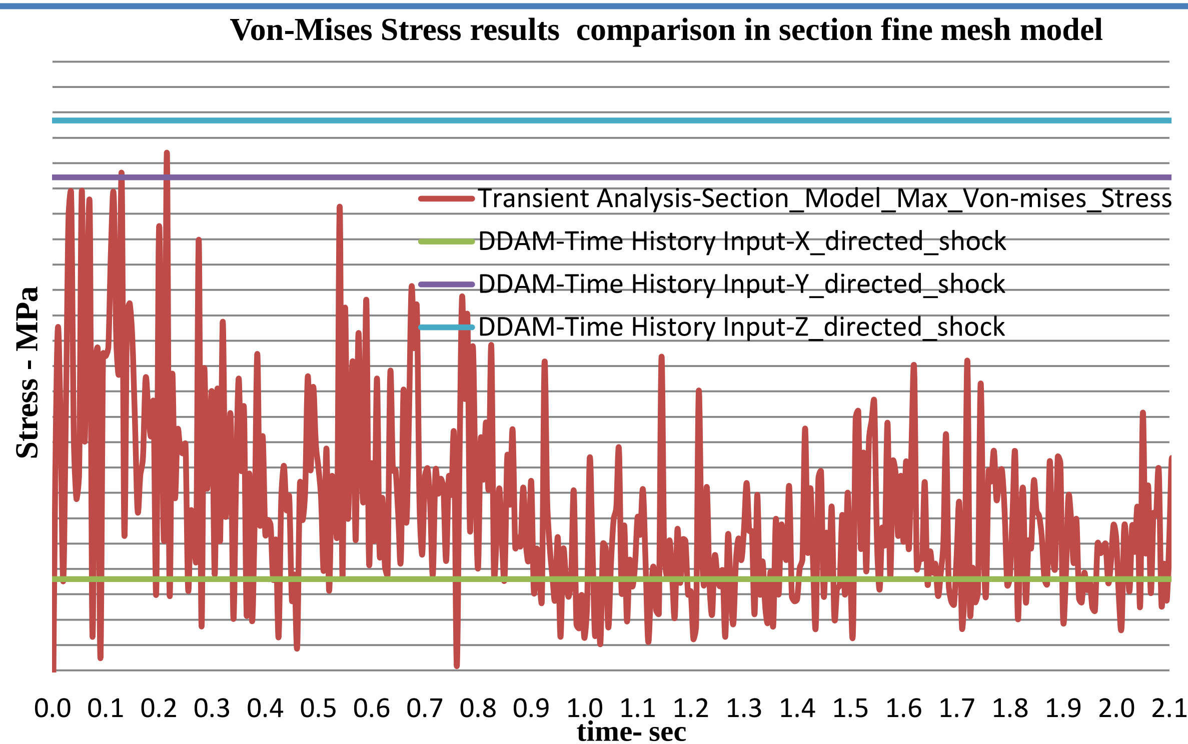
- Section model with fine mesh is only studied
- DDAM is an alternative method of the transient analysis

Transient-LSDYNA



DDAM-ANSYS





Section Model with fine mesh	DDAM Analysis from Time History Input-x directed shock	DDAM Analysis from Time History Input-y directed shock	DDAM Analysis from Time History Input-z directed shock	Transient analysis
Total response of the equipment (Max Von-mises stress) in MPa	$0.31\ \sigma_{max\text{-}trans\text{-}section\ model}$	$0.96\ \sigma_{max\text{-}trans\text{-}section\ model}$	$1.05\ \sigma_{max\text{-}trans\text{-}section\ model}$	$\sigma_{max\text{-}trans\text{-}section\ model}$

- DDAM gives approximately 5 - 10 % more conservative results than the transient analysis
- DDAM is a very powerful method to define the most critical areas of the structure
- DDAM is faster than the transient analysis

6.4. Conclusions for Shock Analysis of the Antenna Structure

- NRL Coefficient DDAM analysis uses shock design response spectrum

Final maximum stress values in three different shock analysis methods	NRL Coefficient DDAM-Y directed shock Hull mounted	(Section model fine mesh) DDAM Analysis from Time History Input-Z directed shock	(Section model fine mesh) Transient analysis
Total response of the equipment (Max-Von-Mises stress) in MPa	$0.77\ \sigma_{\text{max-trans-section model}}$	$1.05\ \sigma_{\text{max-trans-section model}}$	$\sigma_{\text{max-trans-section model}}$

Limitations of NRL-Coefficients

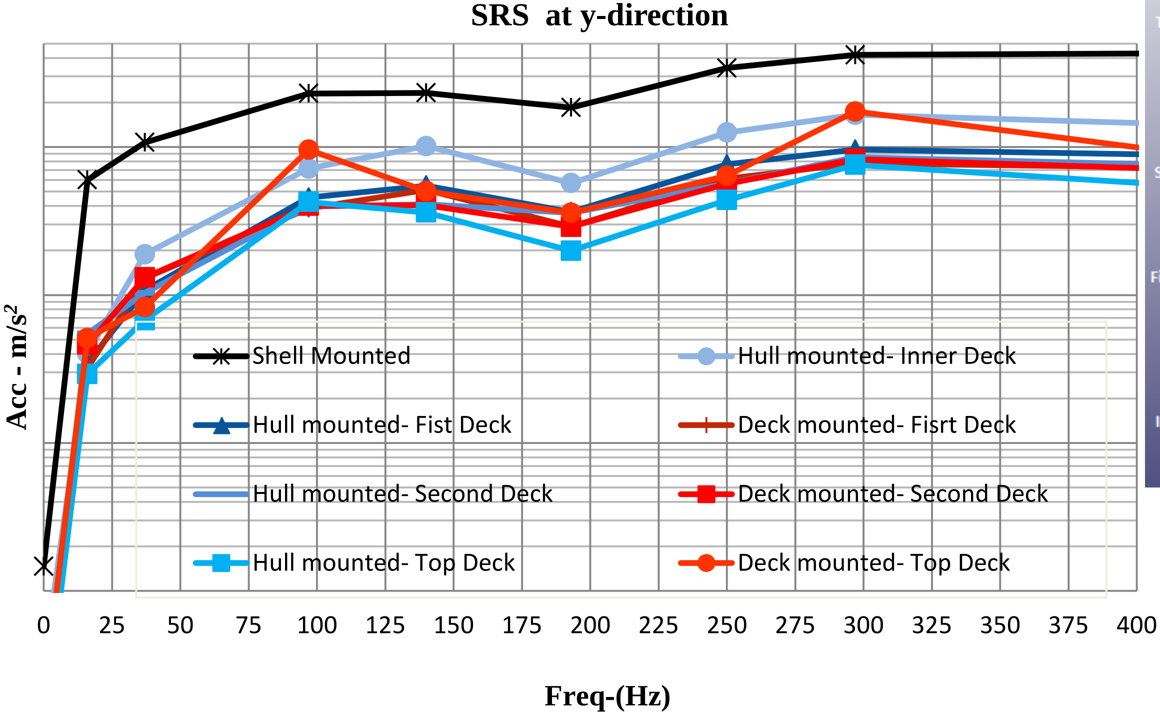
- No distinction between the type and size of ships
- No definition about shock factor
- Presumes that the shock input values are same anywhere at defined mounting system
- The coefficients are very old and published in 1963

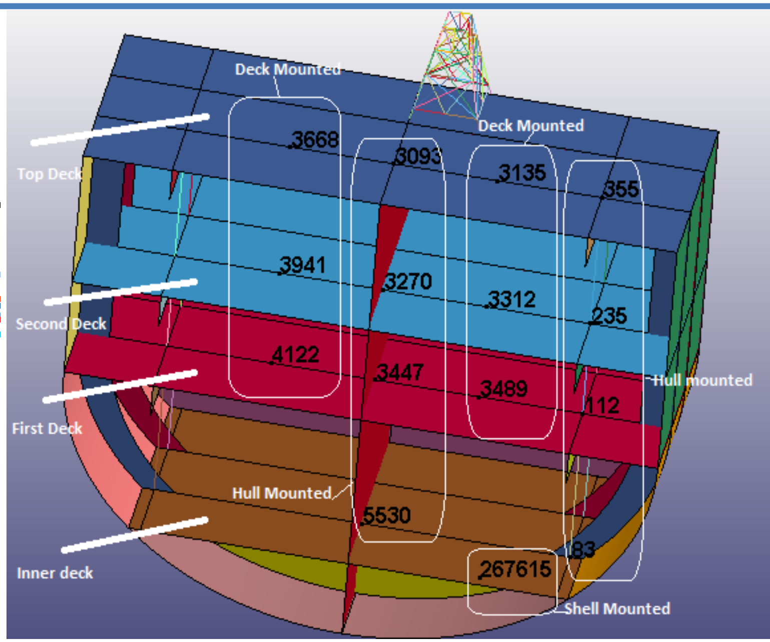
Deficiencies in the transient analysis

- The shock input signal is taken from a simplified ship structure model
- A ‘dry’ model with added water mass inertia by Lewis coefficient leads to very conservative results
- No damping is considered
- The propagation of the shock wave would not be same as in the global model of the ship.

7. SHOCK LEVELS IN DIFFERENT MOUNTING LOCATIONS

- Different mounting locations are considered in the section fine mesh model





- Shock levels decrease from the bottom to top deck of the ship
- Deck mounted systems give higher response than hull mounted systems
- Shell mounted systems have the highest response among all mounting systems
- SRS at Z direction has higher shock level than SRS at x and y-directions

8. CONCLUSION

- DDAM is the most convenient and fastest method for shock analysis of the equipments
- The available DDAM-NRL coefficients are old and not convenient for new type of the ships and warfare
- More realistic shock response spectra should be obtained for DDAM
- In order to get more realistic SRS and results, a transient analysis should be applied to refined enough mesh models
- DDAM analysis from time history input and transient analysis lead to have similar results
- The same methods can be applied for any type of equipment on any part of the ship

QUESTIONS & ANSWERS