Shock Transient Analysis on Wabtec Diesel Engines for Naval Vessels

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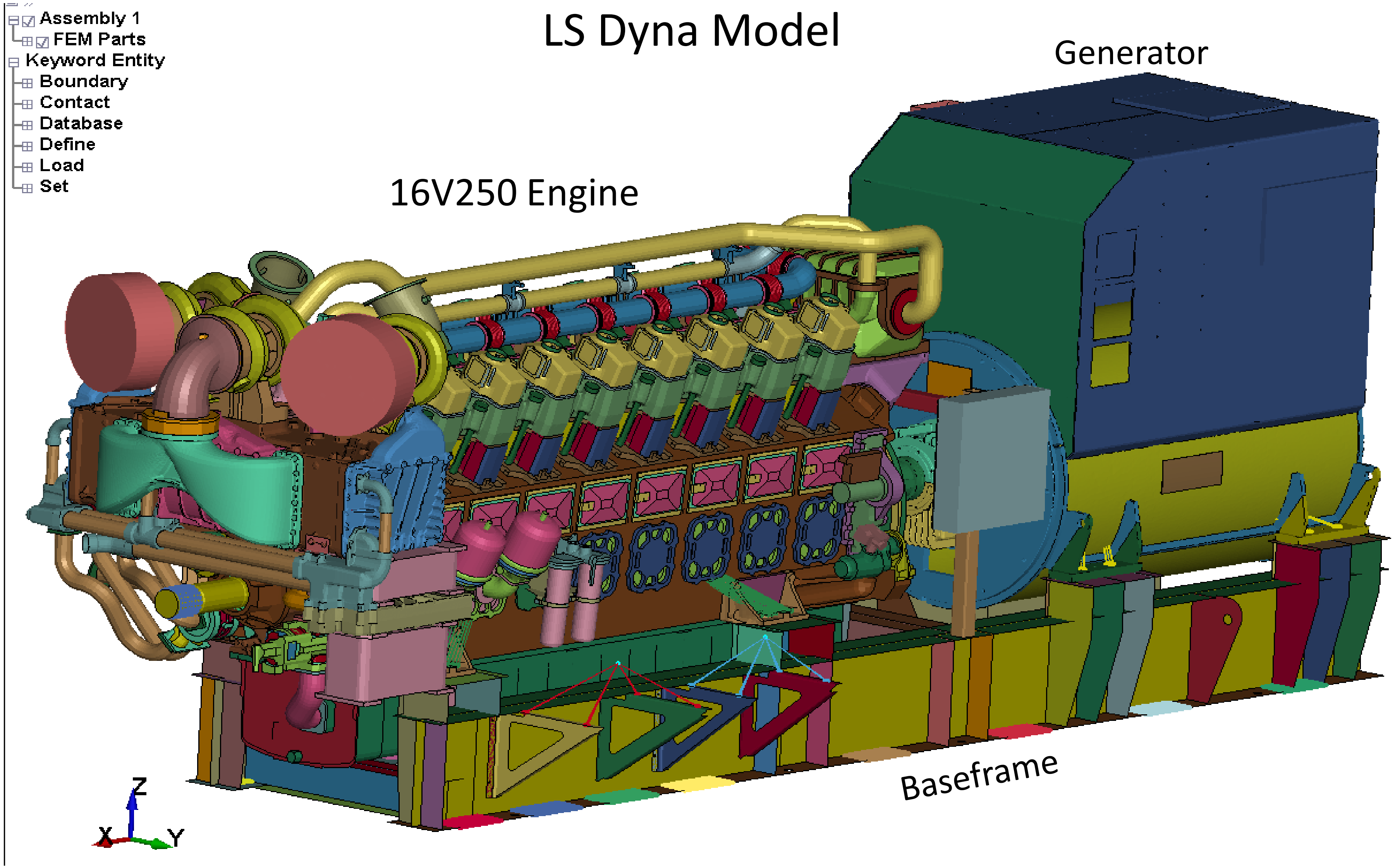
Wabtec CORPORATION

Marine Engine Barge Test Simulation



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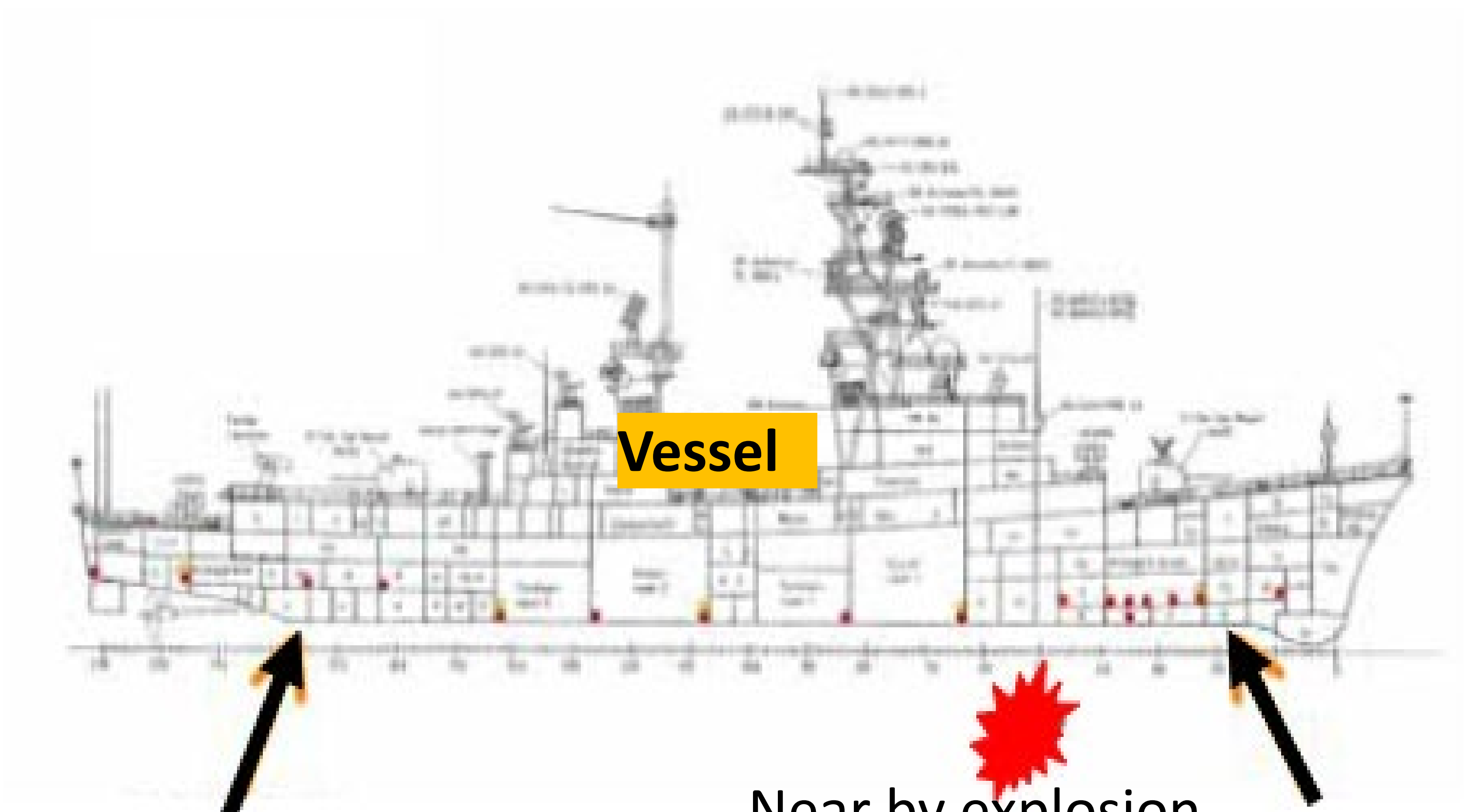
Marine Engine Barge Test Simulation - Overview

- For Naval applications (NVR)
- Show case the engine structural integrity - near to ship non-contact explosion.
- Barge Test
- MIL-DTL-901D/E

testing on barge

Marine Engine Barge Test Simulation - Overview Continuation



Measurement points

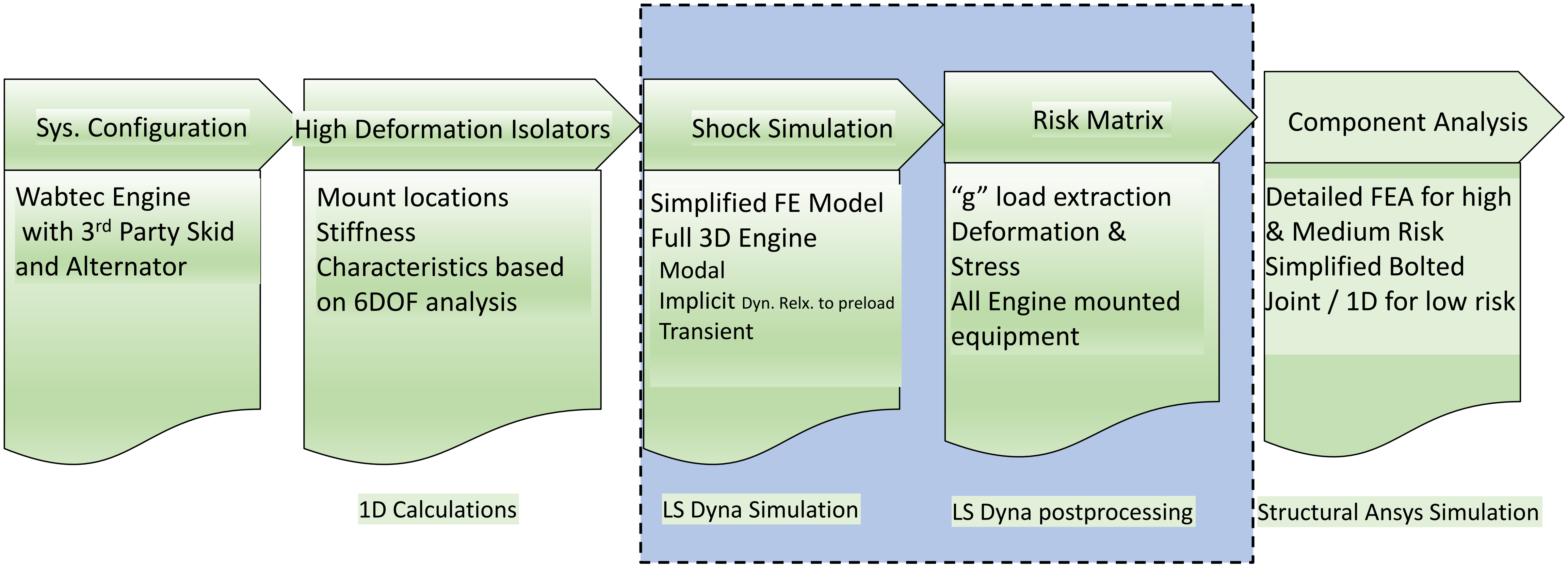
Near by explosion

Measurement points

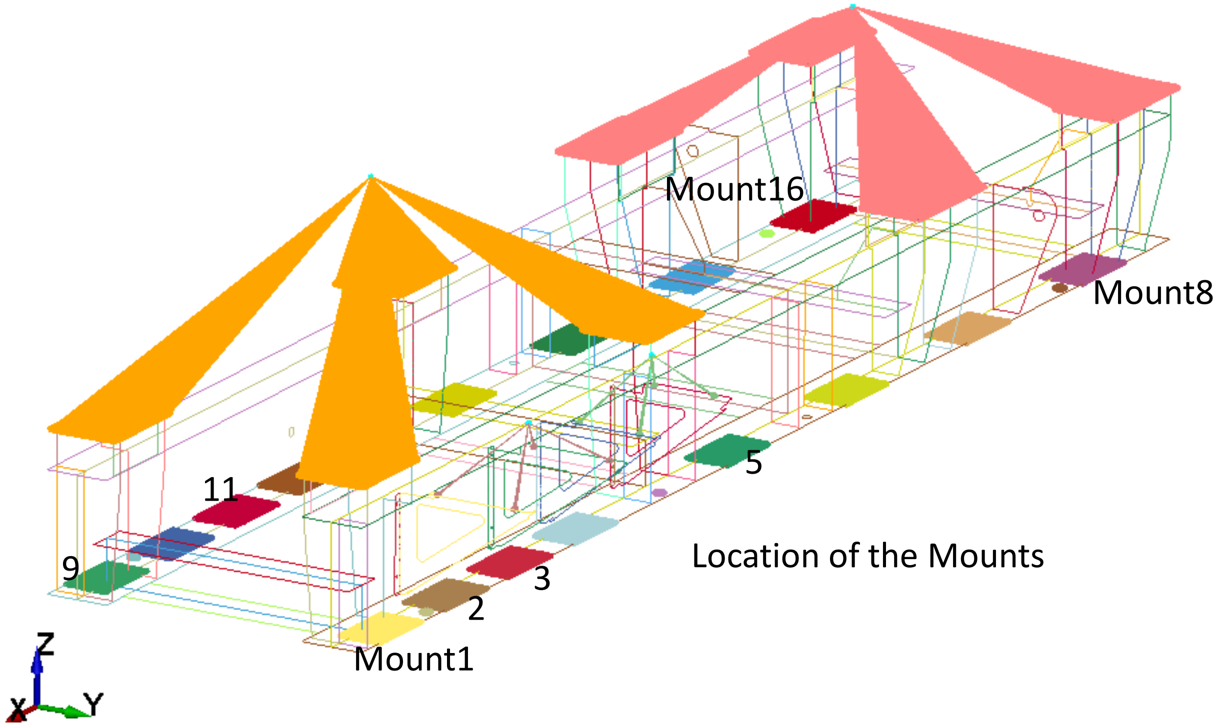
High Deformation Mount (HDM) - between the engine system and the Deck of the vessel

Marine Engine Barge Test Simulation : Process flow Chart

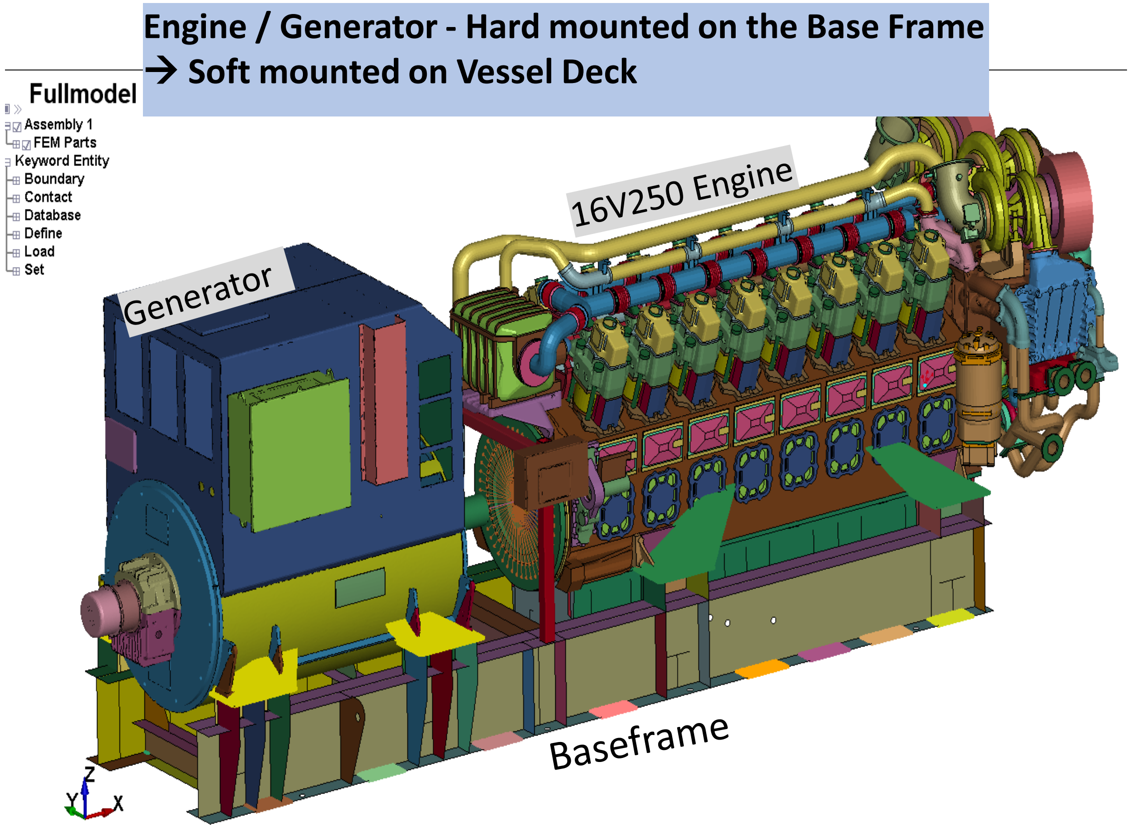
- Have engine ready for Barge Test / Shock Qualification
- Correlation with simulation



Marine Engine Barge Test Simulation : Two Stage Analysis



Stage 1 : Simplified model with engine and alternator as Inertia elements



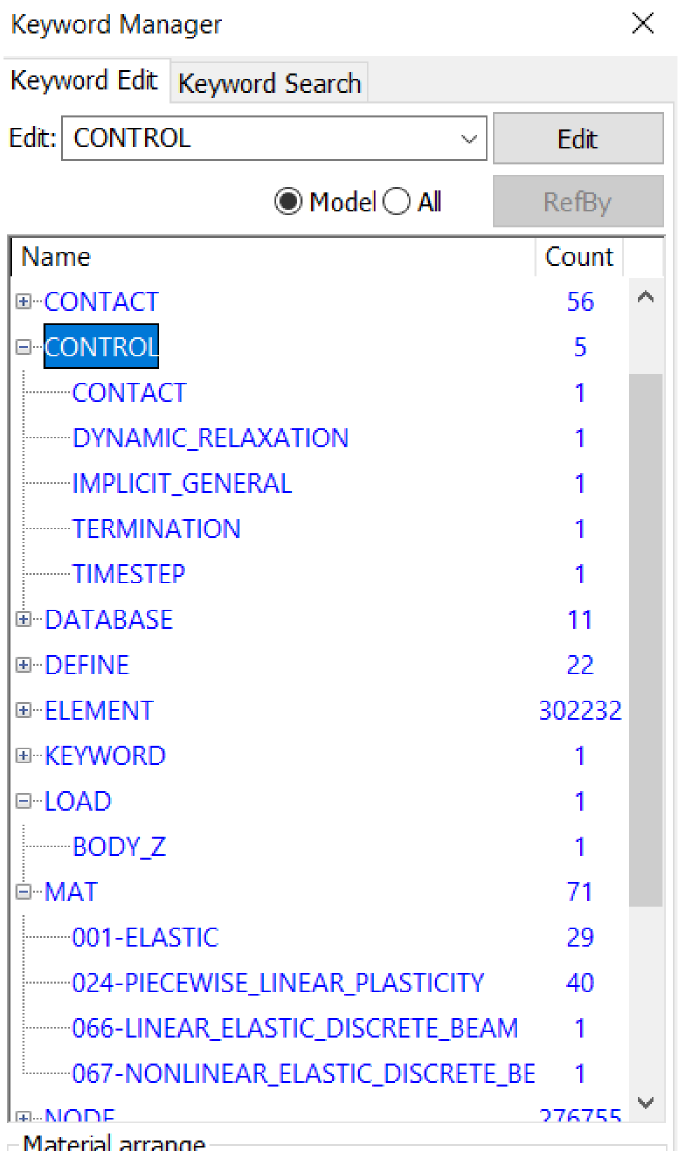
Stage 2 : Full 3D Engine and alternator simulated using SOLID elements

Total # Nodes:	~2.8mln
Total # Elements:	~2.4mln

Marine Engine Barge Test Simulation : LS Dyna Inputs

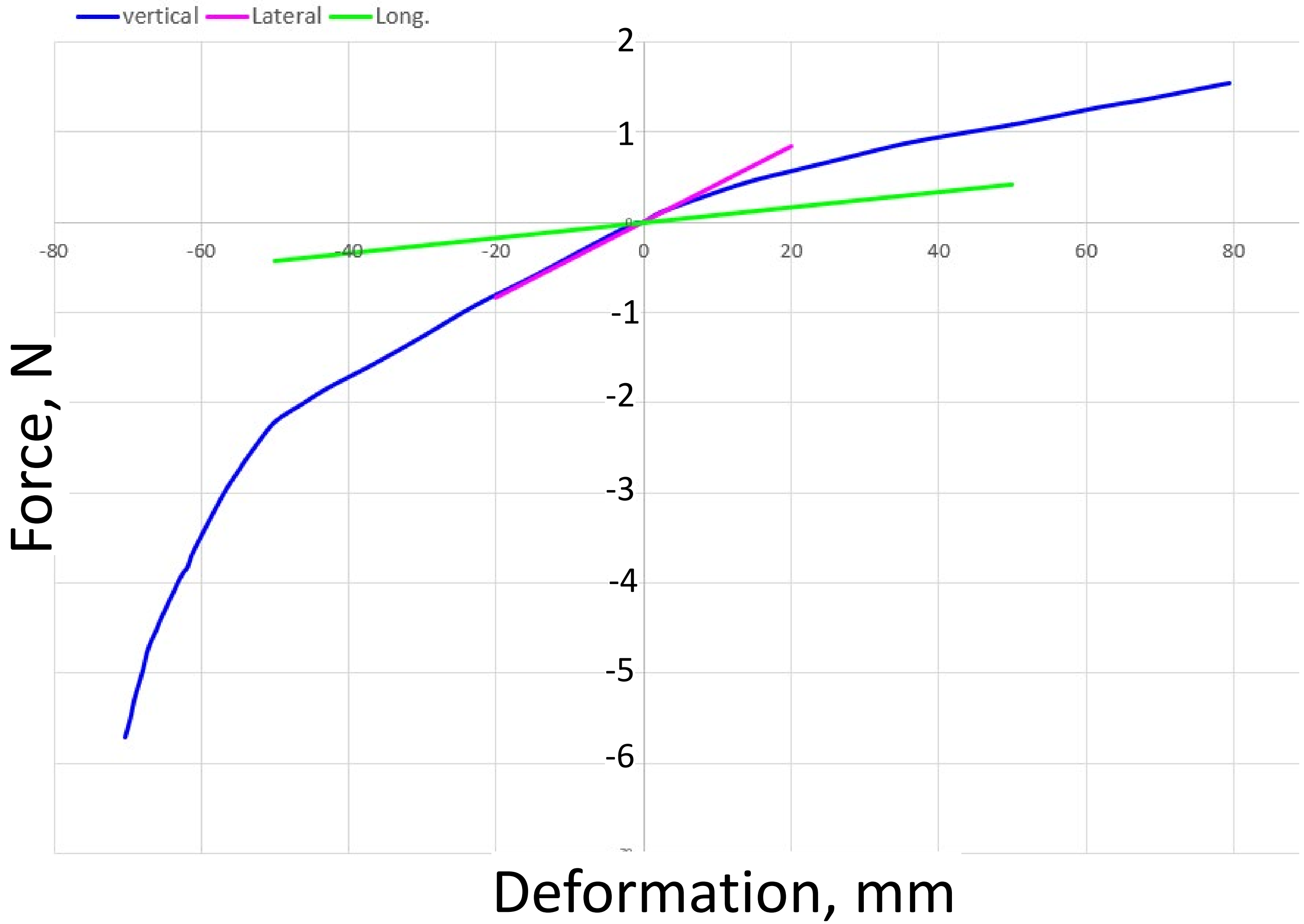
Pre and Postprocessing: LS Prepost V4.8
Solver: LS Solver R11.2.0

- SHELL / SOLID / INERTIA Elements
- Reuse of existing ANSYS Model.
- MAT024 - PIECEWISE LINEAR PLASTICITY and MAT001 – LINEAR ELASTIC.
- MAT067 – NONLINEAR ELASTIC DISCRETE BEAM – HDMs
- 25+ equipment - Merged nodes / Tied Contacts
- Modal Analysis in LS Dyna
- Dynamic Relaxation - to preload the model

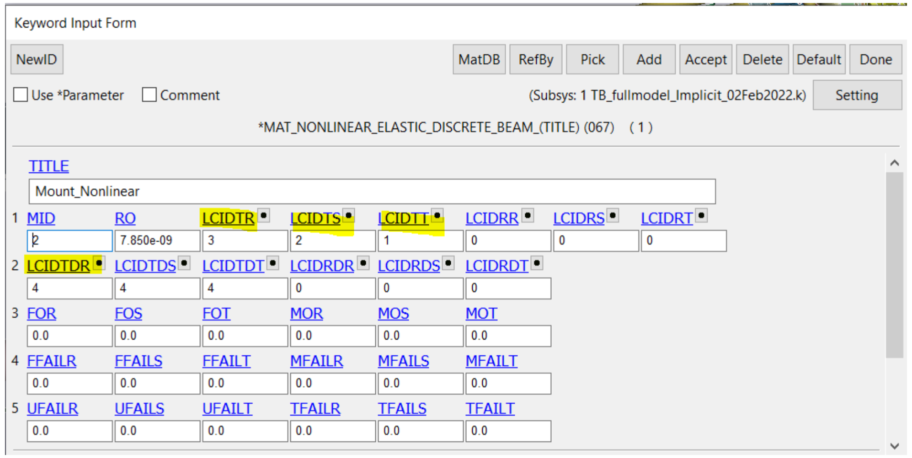


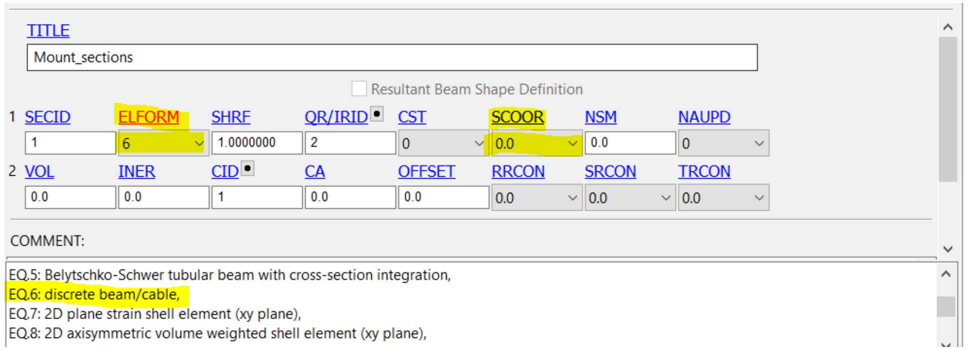
Marine Engine Barge Test Simulation : LS Dyna Inputs

High Deflection Isolator Mounts



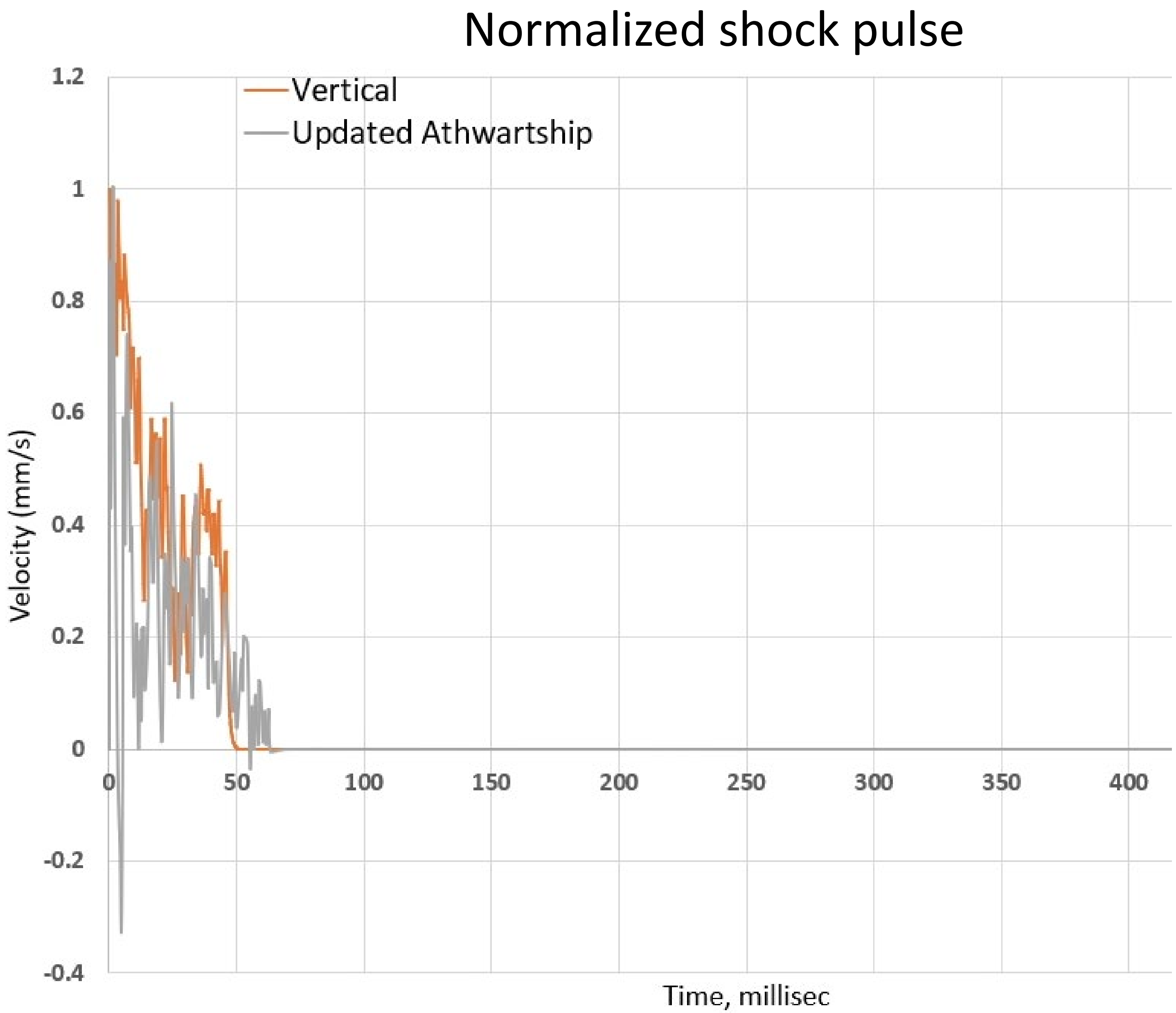
- Preliminary 1D calculation
- Normalized stiffness curve is shown here. Constant damping inputs were given.

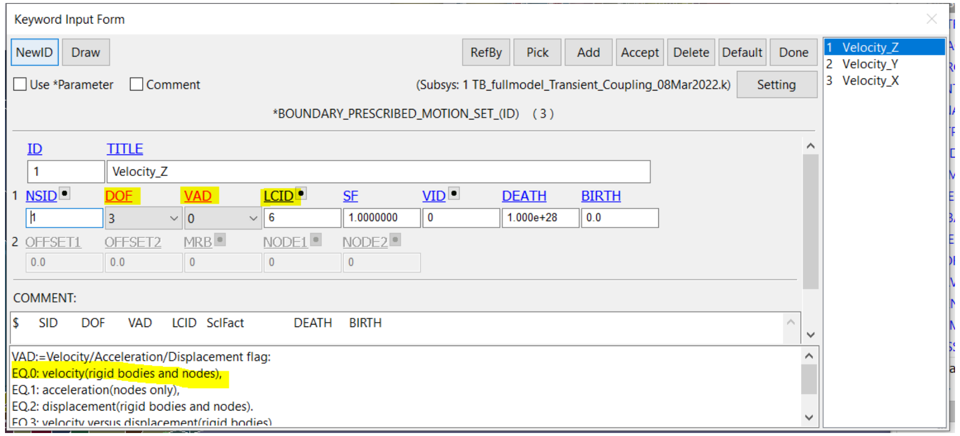




Marine Engine Barge Test Simulation : LS Dyna Inputs

High Deflection Isolator Mounts

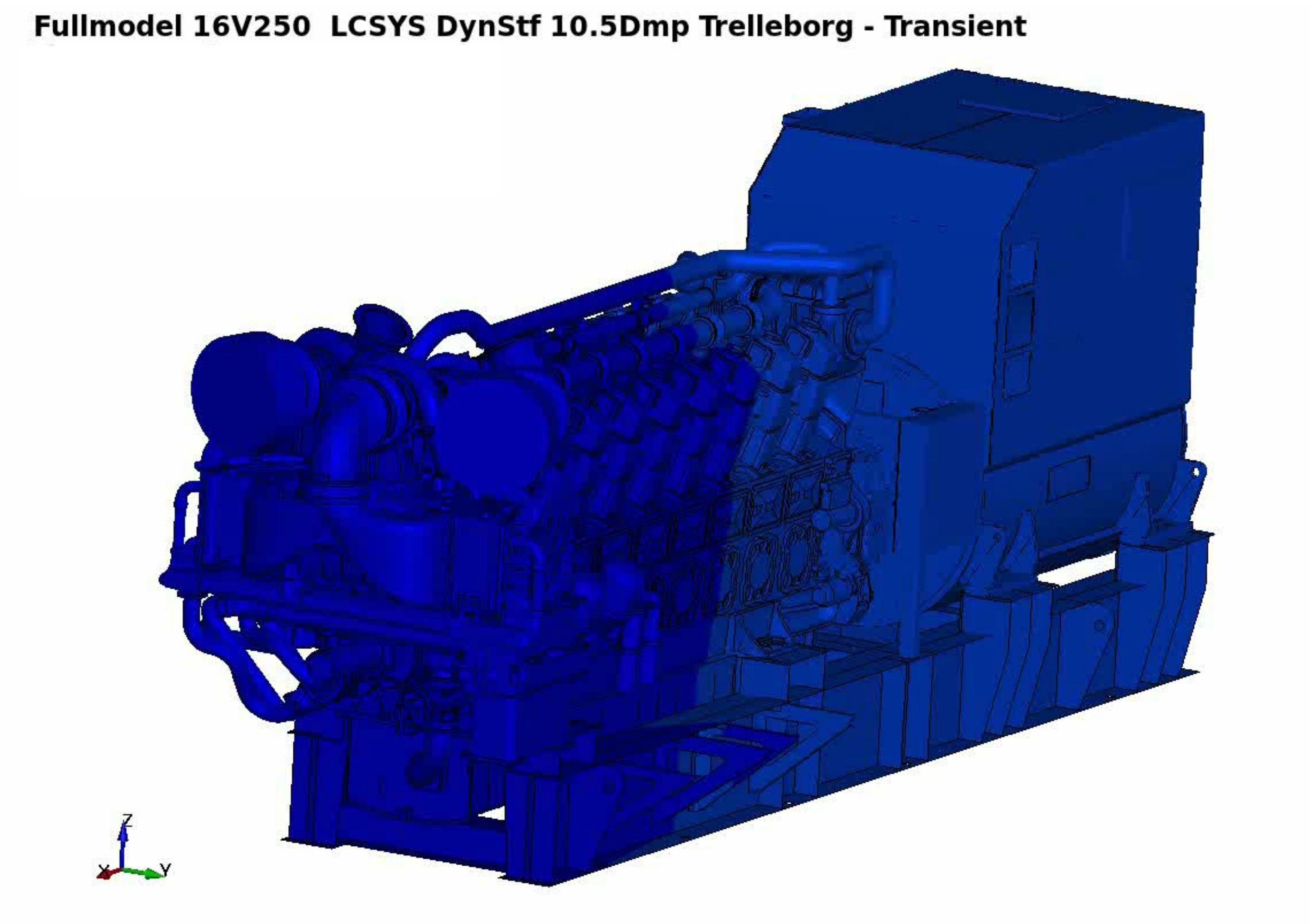


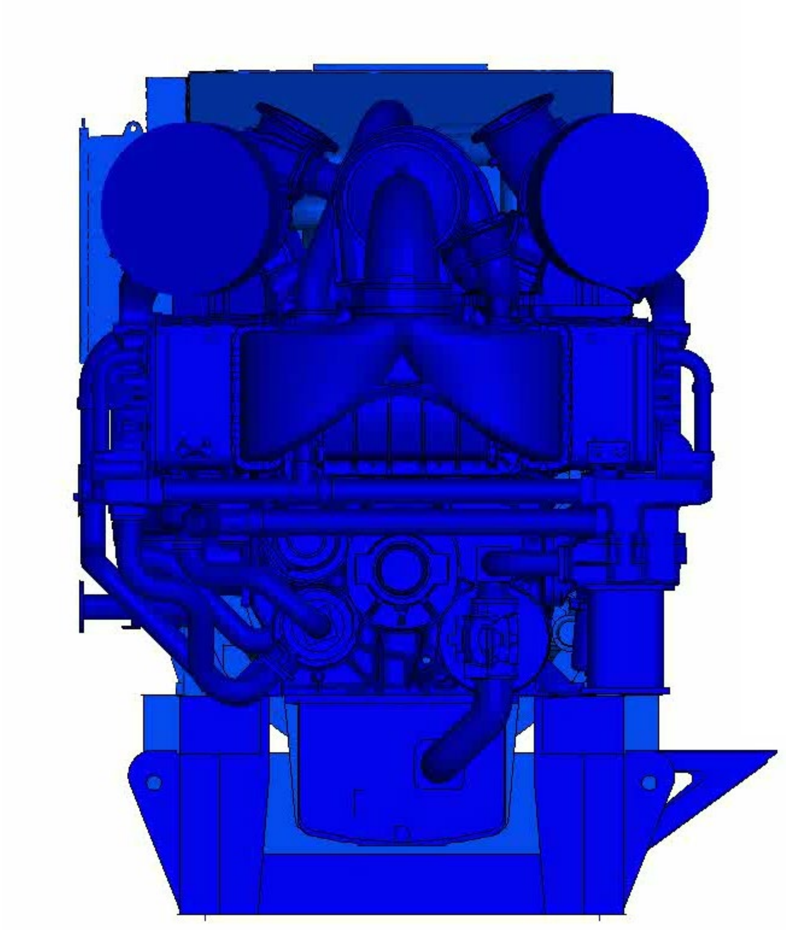


- BOUNDARY PRESCRIBED MOTION SET - Input velocity impulse -
- No secondary / tertiary motion is considered

Marine Engine Barge Test Simulation : Transient Results

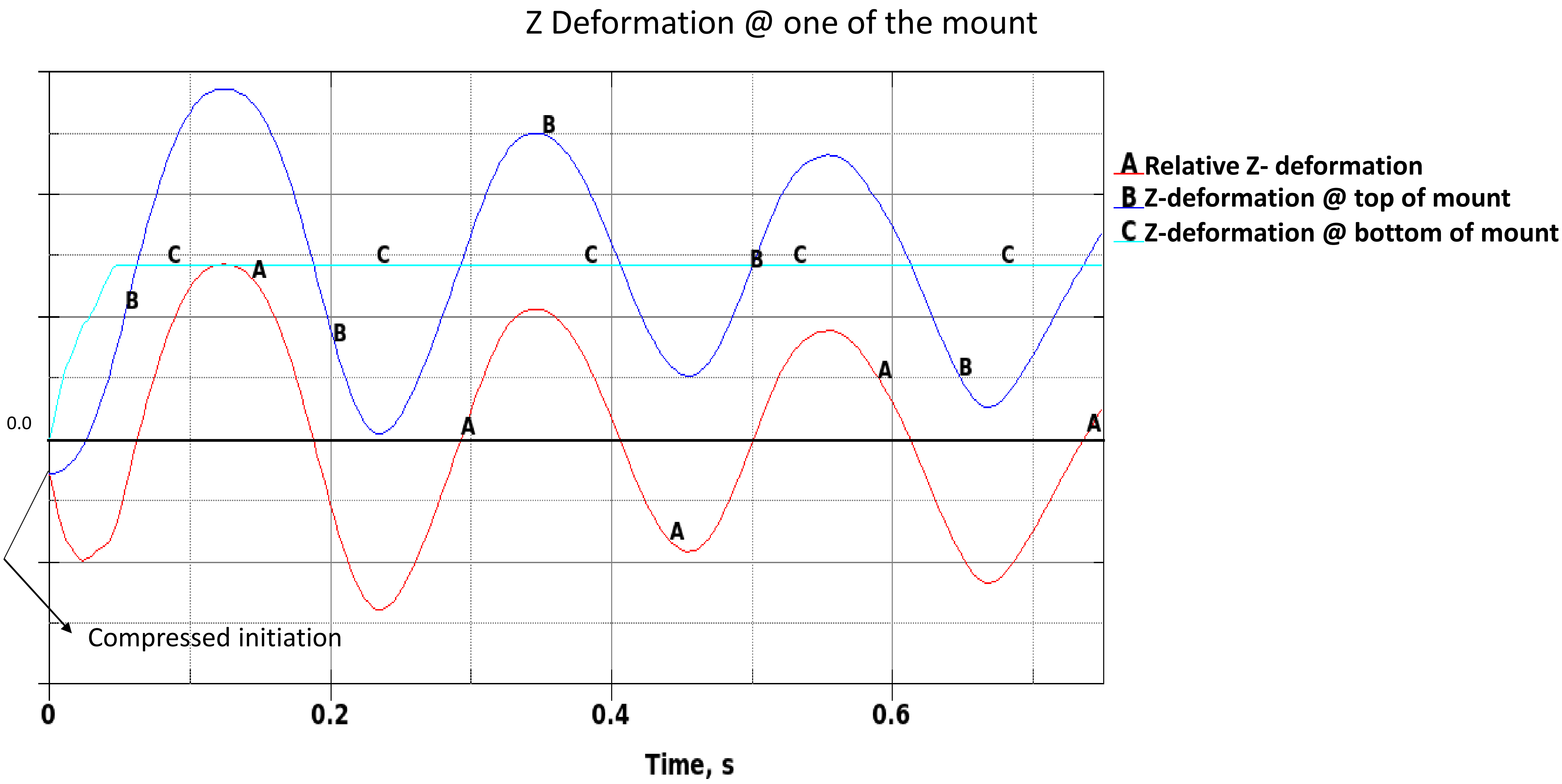
Z - Displacement, mm- Animation contour



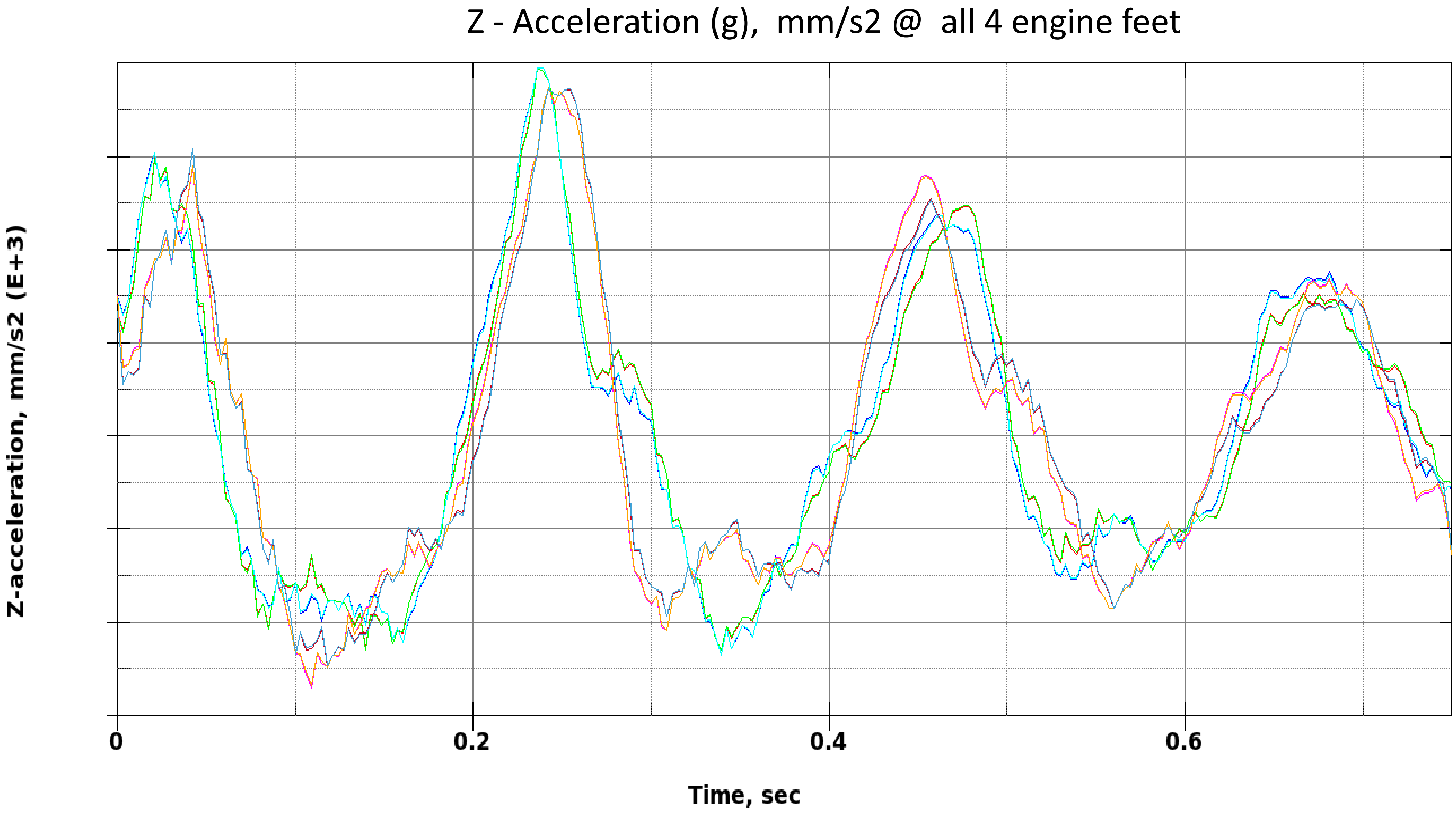


Deformation response of the system for 750ms for the shock impulse given for 50ms

Marine Engine Barge Test Simulation : Transient Results



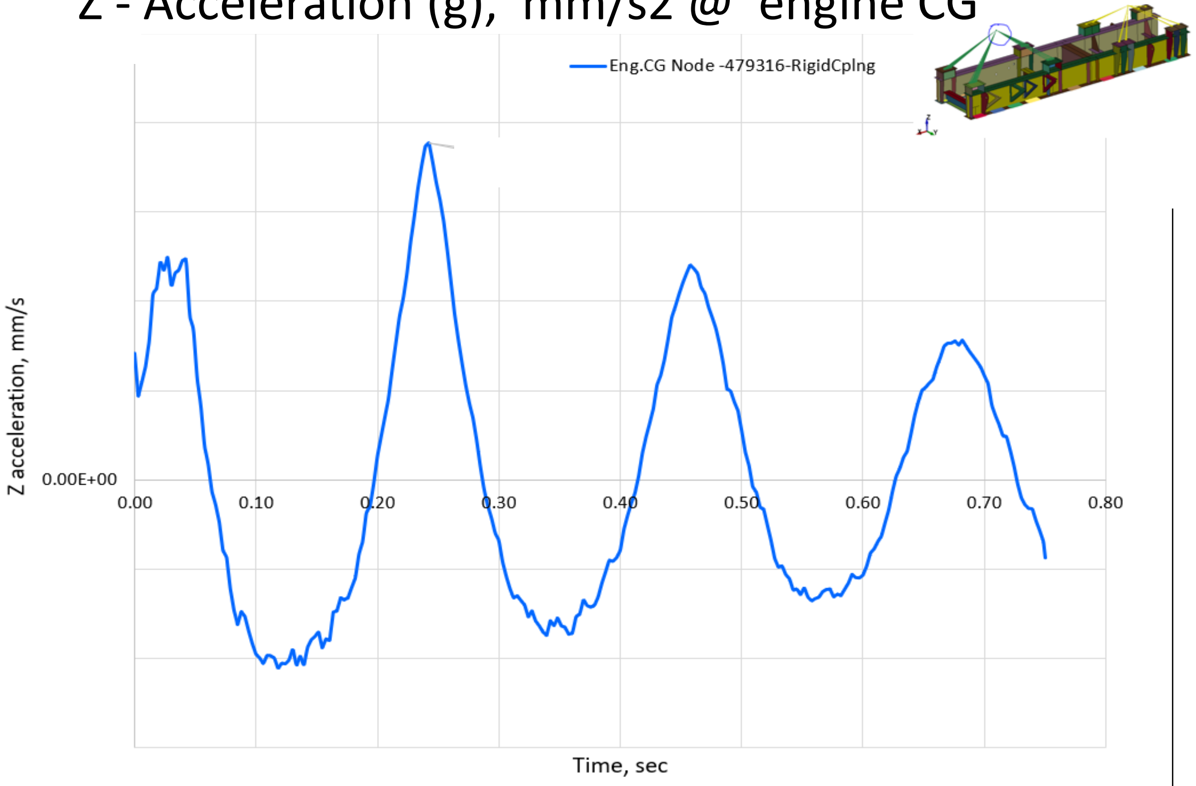
Marine Engine Barge Test Simulation : Transient Results



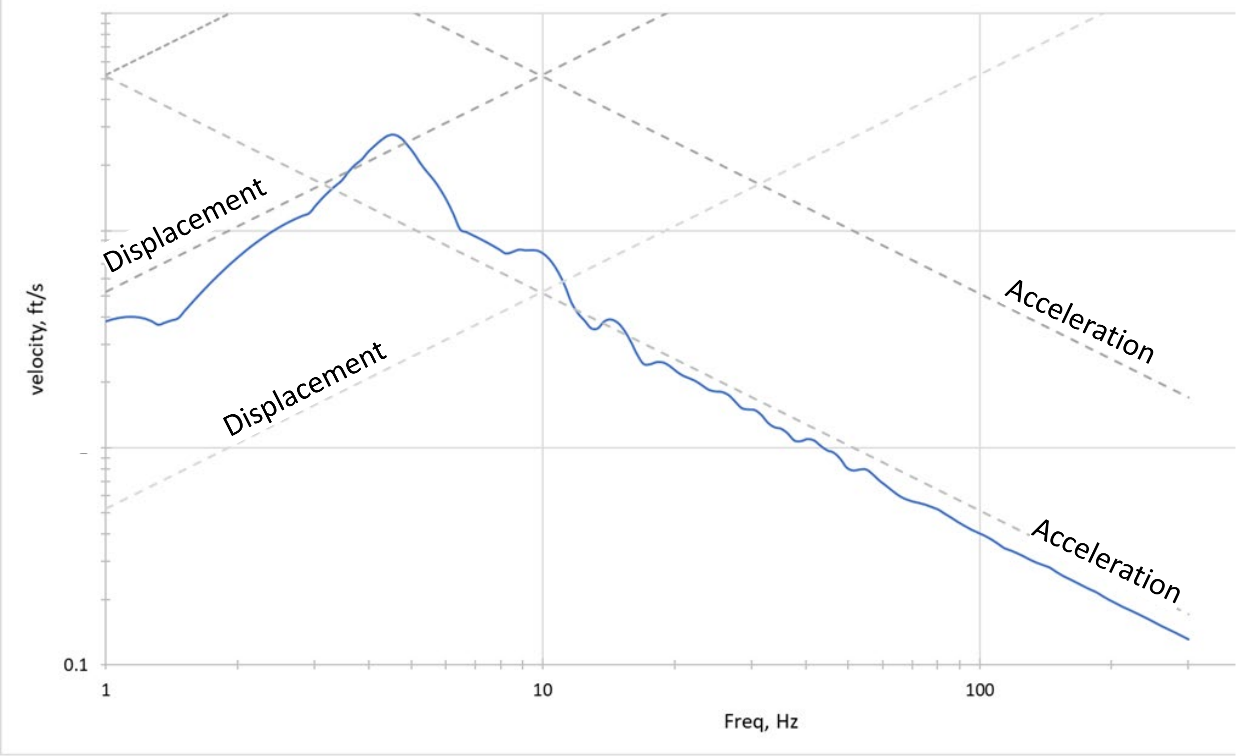
Marine Engine Barge Test Simulation : Transient Results

Response @ Engine CG

Z - Acceleration (g), mm/s2 @ engine CG

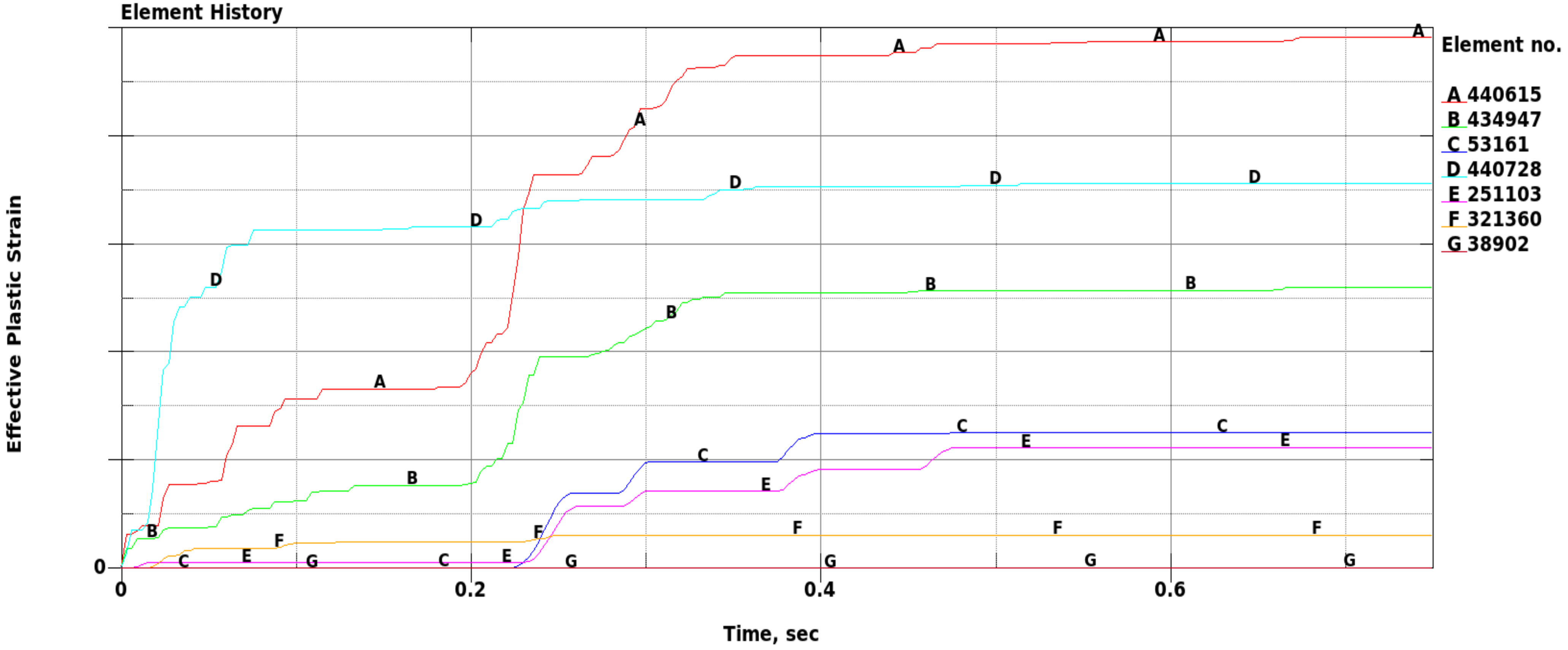


SRS - Velocity in frequency domain @ engine CG



Marine Engine Barge Test Simulation : Transient Results

Effective plastic Strain over time



Stabilization of the plastic strain over time

Marine Engine Barge Test Simulation : Infra & Risk Matrix.

Risk matrix :

Response acceleration

Stress/Strain magnitude

Wabtec's past analysis and field experience.

Sl. No	Equipment Name	Materia	Vendor/ Inhouse	"g" @ Moun Z	Y	Remarks / Risks	Recommended Action	Risk
1	Engine Feet	GJS500-7	Inhouse	6.2	2.6	Load is considered as global load for the entire engine as a single component. In LSDyna run, Feets shows stresses were within yield limit of 300MPa and no plastic strain is reported.	Engine Feet analysis done in the past to be looked at for "g" load analyzed in vertical direciton and the margins reported. Slip failure mode – even slips, the lips can hold it. Need to relook at the lip stresses in non-linear analysis.	high
2	Turbo Mounts (Pedestals)	GJS500-7	Inhouse	6.9	1.7	Max stress reported on the pedestals were less than 31MPa. Zero plastic strain reported. Casting parts show very low stress.	Check the past analysis done on the mounts with operating loads. Bolted joints of Turbo to Pedestals (Hold-down bolts -2)to be checked.	medium
3	Turbo Components	Steel	MAN	- do -	- do -	Max stress reported on blades : 110MPa. No plastic strain is observed. "g" loads measured at the pedestals to be considered for Turbo.	To be checked with Supplier	low
4	Heat Exhangers	Aluminum	Kelvion	7.6	1.9	considered as simplified boxes. No direct stress/strains can be extracted. 32MPa is maximum observerd in housings. Though aluminum mech. properties were applied, mass of the components were matched by adjusting the density. "g" loads extracted near the Heat Exchanger mounting bolts to IFE. Maximum of two Intercoolers and	To be checked with Supplier. Possibility of shaker test?	low
5	Oil Cooler & mounts	GJS 450	Alfa laval	6.62	2.92	Only the outer casings of oil cooler were modelled. No internal parts were considered, simplified as box. Though Mounts were considered with coarse mesh. G" loads were extracted at the mounting bracket bolts with IFE Max stress observed on the oil cooler mounting bracket is 55 MPa. Casting parts show very low stress, though coarse mesh is used on the mounting bracket.	Oil cooler byitself could not be evaluated in LSDyna. Need to be checked with supplier. Overhanging cast mount not evaluated in the past as static load concern was less. With Higher "g" load, this need to be evaluate the cast brackets with a better representation of coolers (non-homogenous model). Bolted Joints of the cooler to the IFE need to be looked at. Possibility of shaker test?	medium
6	EGR	GJS400-15	Kelvion	7.4	2.9	Max stress is 52MPa. No plastic strain based on yield considered, 300MPa. EGR cooler is fairly represented though the internal details were not captured accurately in LS Dyna model. Max stress seen near the pipe weld joint which is much lower than the yield. "g" loads extracted were at the EGR mounts.	EGR internal parts need to be assessed ? Need to confirm the material and check with supplier for higher "g" loads	low
7	EGR Mount brackets	GJS450-10	Inhouse	- do -	- do -	Stresses were less than 35 MPa Low risk as the casting mount show very low stress levels.	Check for any past analyiss done on the EGR mount brackets if available?	low
8	EGR Pipes	Steel	inhouse	7.62	4.9	Max stress of 41 MPa against the material yield of 250 MPa. No plastic strain. "g" loads extracted athe mounting points to crankcase (not on the pipe)	Material property to be confirmed. Pipe joints / interfaces with cooler are a known weak points. They need to be studied in detail if the higher "g" loads causing higher deflections and	medium
9	Water Pipes between HE and Inlet/Outlet to Waterpump	Steel	Inhouse	8	3.6	the joint. Though most of the joints shows relatively higher stress, except two joints, no plastic strain is reported any where on the pipes. All of these pipes were considered structural steel. Very low plastic strain of 0.9% considering yield of 250MPa. Maximum of "g" loads extracted out of many of the joints (HE & water pump) is reported in summary.	A submodel for the pipes might be required. **Depending on the EGR pipe analysis** risk would be re-evaluated and the need for analysis to be revisited. To be verified closely during testing on the joints for leakage. Material yield of these pipes to be confirmed.	medium
10	Exh. Manifold	HS Steel	Inhouse	6.9	3	Max stress of 109 MPa. No plastic strain consiering 350 MPa yield. Stress is at on the bellow region in LSDyna, which could be spurious. Considering manifolds alone, stresses were much lesser in the order of 25MPa. "g" loads extracted were at the cylinder head interaface and turbo interface. max value is reported.	HS Steel material need to be confrmed. Though low stress in "g" load alone, past analysis results margin to be relooked at including operating loads.	low
11	Oil filter & Mounts	GJS450	Alfa Laval / Boll n Kirch	6.9	2.72	were not captured, Filter housing and the mounting brackets were captured with 3D solid elements. Max stress of 43MPa on the filter mounting bracket. Yield of 290MPa for these parts, no plastic strain is observed.	Consiering a low stress values, any past analysis on the mounting brackets can be looked into. Need to get confirmation from filter supplier for "g" loads. Slip concern on the bolted joints – Bolt joint evaluation need to be looked into for higher "g" loads.	medium
12	Lube Pump	Steel	Rickmeier	7.5	4.8	Lube pump is modelled in simplified coarse mesh. No internal parts were captured. Max stress of 18MPa is observed. No plastic strain is seen as the material yield used is 250MPa. "g" loads were extraced at the mounting points on engine.	Need to be checked with the supplier. Rabbit fits were used and less risk on bolted joints.	low
13	Water Pump	Steel	Gilkes	7.3	4.5	Model with 3D elements for the housing. No internal parts were not considered in simulation. 48 MPa is the maximum stress observed on the pump housing. No plastic strain observed.	Need to be checked with the supplier. Rabbit fits were used and less risk on bolted joints.	low
14	SEA water pump	Steel	Gilkes?	7.1	2.4	In T4 MSD DL, SEA water pump is not available. However FE model used for simulation had it. Model with 3D elements for the housing. No internal parts were not considered in simulation. 59 MPa is the maximum stress observed on the pump housing. No plastic strain observed, considering 250MPa as yield of material.	Need for SEA water pump to be sorted out. To be checked with supplier for high "g" loads. Rabbit fits were used and less risk on bolted joints	low

Snapshot of Risk Matrix

INFRASTRUCTURE:

- Solved in On-Prem HPC as well as in AWS Cloud solution.
- 64 cores to 96 cores were used
- dp_mpp - double precision / multiprocessor
- Intel Xeon Platinum processors of 2.1GHz with 1TB RAM were used
- 5 to 7 days were solver time to complete the 750ms response.

Back up

~50 hours with 96 cores in hpc

Marine Engine Barge Test Simulation : LS Dyna Learnings.

- No ramping to be used to apply the self weight (pre-load) in transient analysis. 100% to be applied at time zero.

- SCOOR Parameter in isolator DISCRETE BEAM modelling in LSDyna has notable impact on the results. This is basically defining the location of the Triad for tracking the rotation of the discrete beam element. Unless required to be moved the Triad, keep them as default.

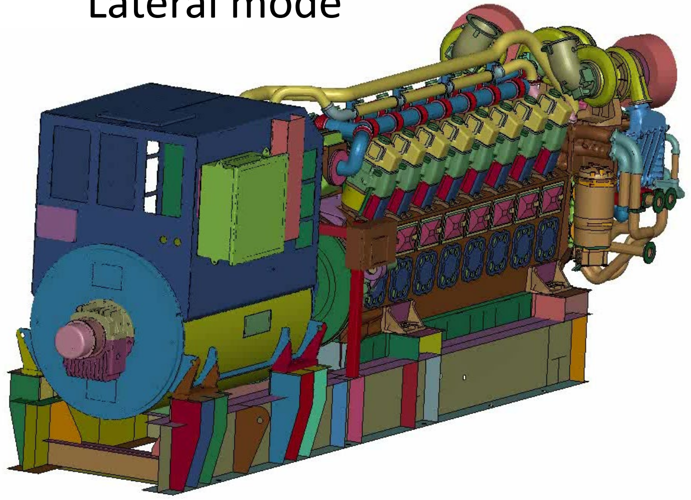
- Flexible coupling can be simulated using 066_LINEAR DISCRETE BEAM material model (spring) with stiffness input in required direction

- Time step adjustment: Parameter "DT2MS" in the control card *CONTROL_TIMESTEP to get the balance between solver run time to the added mass of the model (accuracy).
  "DT2MS" value used in this analysis is -1.03e-7
  "added mass" during the solution is 47e-3 kg on the entire assembly mass of 70 tonnes.

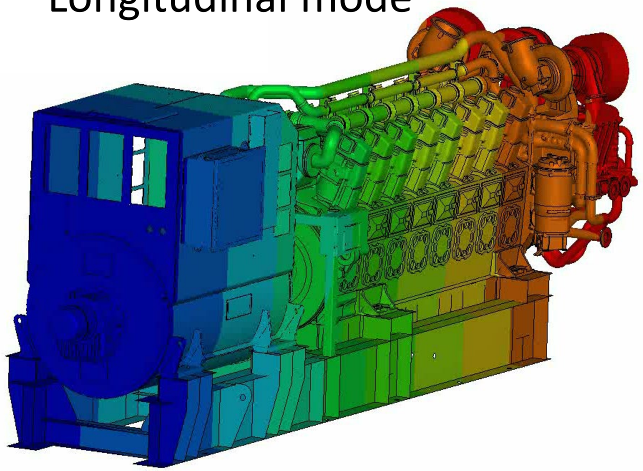
Marine Engine Barge Test Simulation : Modal.

Fundamental modes

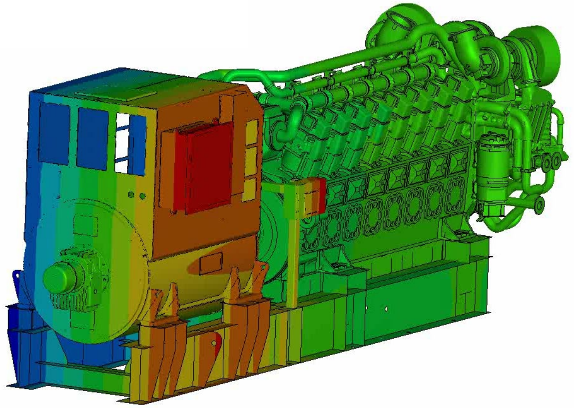
Lateral mode



Longitudinal mode

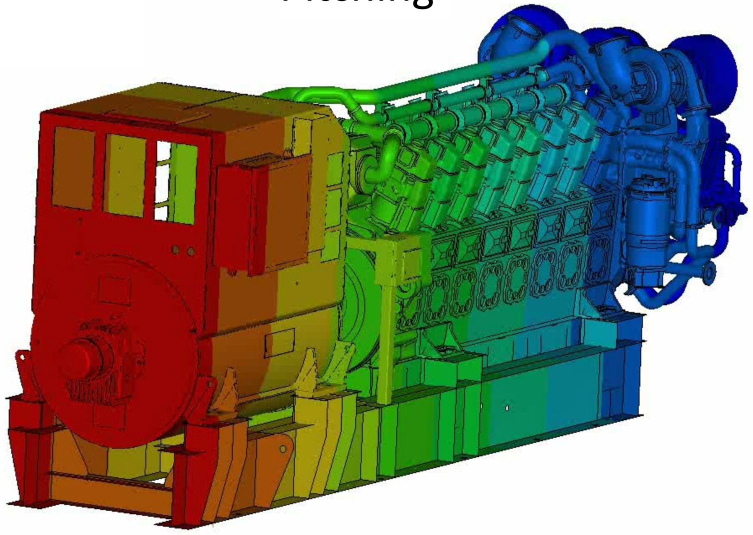


Yaw mode

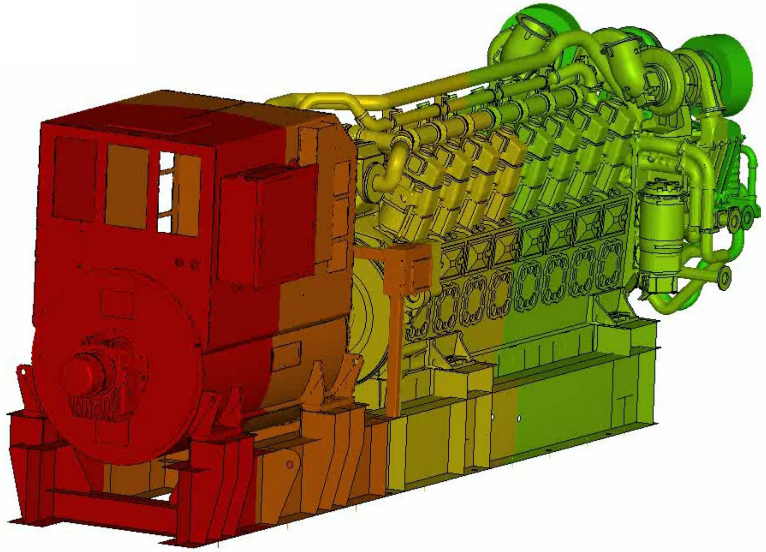


Frequency values were sanitized.

Pitching



Vertical mode



Rolling mode