Structural and Impact Analysis of Large Composite Container

Composite Analysis from Static to Impact to Transient Dynamic with LS-DYNA

LS-DYNA is well known in the automotive world for its ability to simulate extreme nonlinear transient events such as car crashes. In the aerospace world, it is the standard for turbine blade-out or aircraft seat crash analysis or bird strike. A common theme to its usage is the simulation of short duration events or one might say millisecond events. These types of simulations are solved using an explicit numerical technique. Although well-suited for these dynamic applications it is a tough fit for applications where the loading is static in nature and an equilibrium solution is required. For this type of analysis, an implicit approach is much better suited. With recent advantages over the last several years, LS-DYNA is now fully capable of both implicit and explicit type analyses using the same FEA model. In the example shown in Figure 1, our engineering team ran a complete suite of load cases from static pressurization, PSD spectrum analysis for aircraft transport, quasi-state rail impact at 4g and then multiple transient drop test cases from edge to flat bottom. A video walkthrough of this work is available by clicking on Figure 1. More details on this work can be found in our LS-DYNA Conference Paper “Broad-Spectrum Stress and Vibration Analysis of Large Composite Container”.

Figure 1: Example of glass-fiber vacuum-infused-process composite container

Idealization of Composite Structure to LS-DYNA FEA Model

Composite Shell Model with Sandwich Regions via Laminate / Hex Foam Core

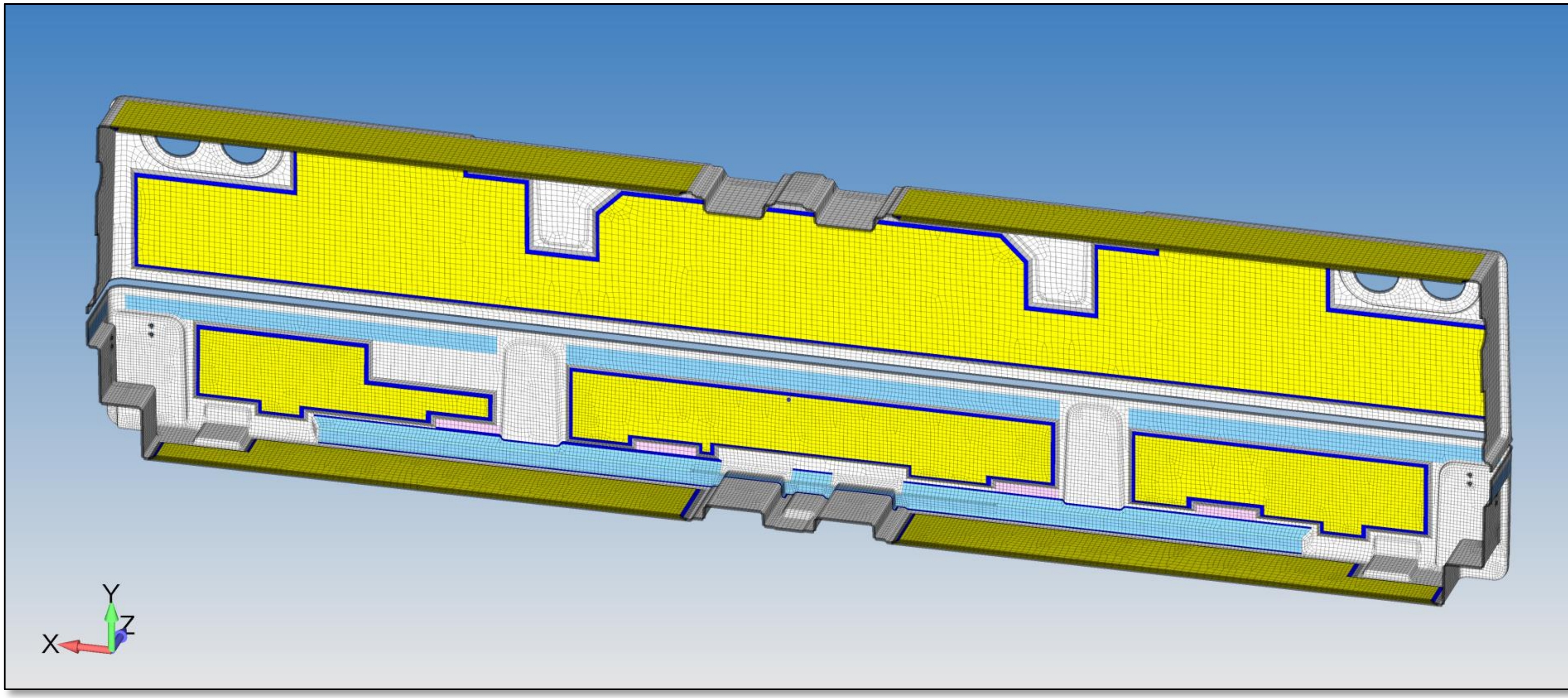
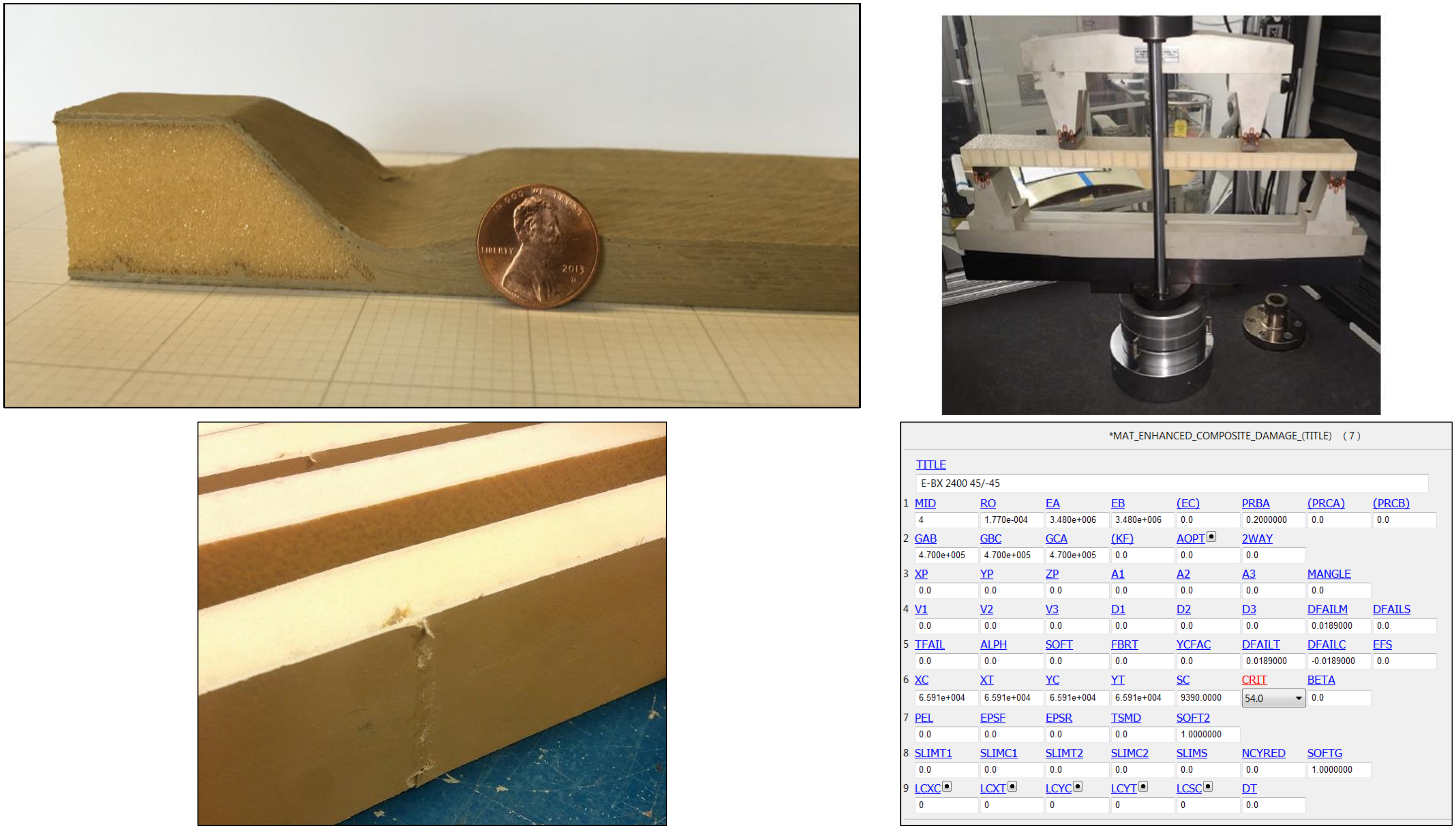


Figure 2: FEA model of composite container – built with FEMAP and analyzed with LS-DYNA

We should back up and mention that this was a FEA consulting services project using LS-DYNA. The reason we started with LS-DYNA is that the several of the load cases required drop and impact analysis. To avoid building two separate models, i.e., one for implicit (statics) and one for explicit (dynamic), we went out of the gate with LS-DYNA. The mesh was highly structured to obtain the highest possible explicit time step given the material mix of steel, aluminum, fiber-glass reinforced plastic (Glass-FRP or GFRP).

Laminate to *MAT_54 (*MAT_ENHANCED_COMPOSITE_DAMAGE)



*MAT_ENHANCED_COMPOSITE_DAMAGE_(TITLE) (7)

TITLE: E-BX 2400 45/-45

1	MID	RO	EA	EB	(EC)	PRBA	(PRCA)	(PRCB)
	4	1.770e-004	3.480e+006	3.480e+006	0.0	0.2000000	0.0	0.0
2	GAB	GBC	GCA	(KF)	AOPT	2WAY		
	4.700e+005	4.700e+005	4.700e+005	0.0	0.0	0.0		
3	XP	YP	ZP	A1	A2	A3	MANGLE	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
4	V1	V2	V3	D1	D2	D3	DFAILM	DFAILS
	0.0	0.0	0.0	0.0	0.0	0.0	0.0189000	0.0
5	TFAIL	ALPH	SOFT	FBRT	YCFAC	DFAILT	DFAILC	EFS
	0.0	0.0	0.0	0.0	0.0	0.0189000	-0.0189000	0.0
6	XC	XT	YC	YT	SC	CRIT	BETA	
	6.591e+004	6.591e+004	6.591e+004	6.591e+004	9390.0000	54.0	0.0	
7	PEL	EPSF	EPSR	TSMD	SOFT2			
	0.0	0.0	0.0	0.0	1.0000000			
8	SLIMT1	SLIMC1	SLIMT2	SLIMC2	SLIMS	NCYRED	SOFTG	
	0.0	0.0	0.0	0.0	0.0	0.0	1.0000000	
9	LCXC	LCXT	LCYC	LCYT	LCSC	DT		
	0	0	0	0	0	0.0		

Figure 3: Composite material modeling from test to verification to *MAT_54 material card

Although FEA composite material data can be constructed from manufacturer's data and or base properties using a rule-of-mixtures (e.g., Chamis Model) for glass or carbon plus the plastic, it is much nicer to have testing done and then blend the data together to create the material card. The LS-DYNA card was configured for progressive failure of the plies by specifying strength and failure strains under tension and compression.

Structured FEA Meshing for Optimum Implicit and Explicit Performance

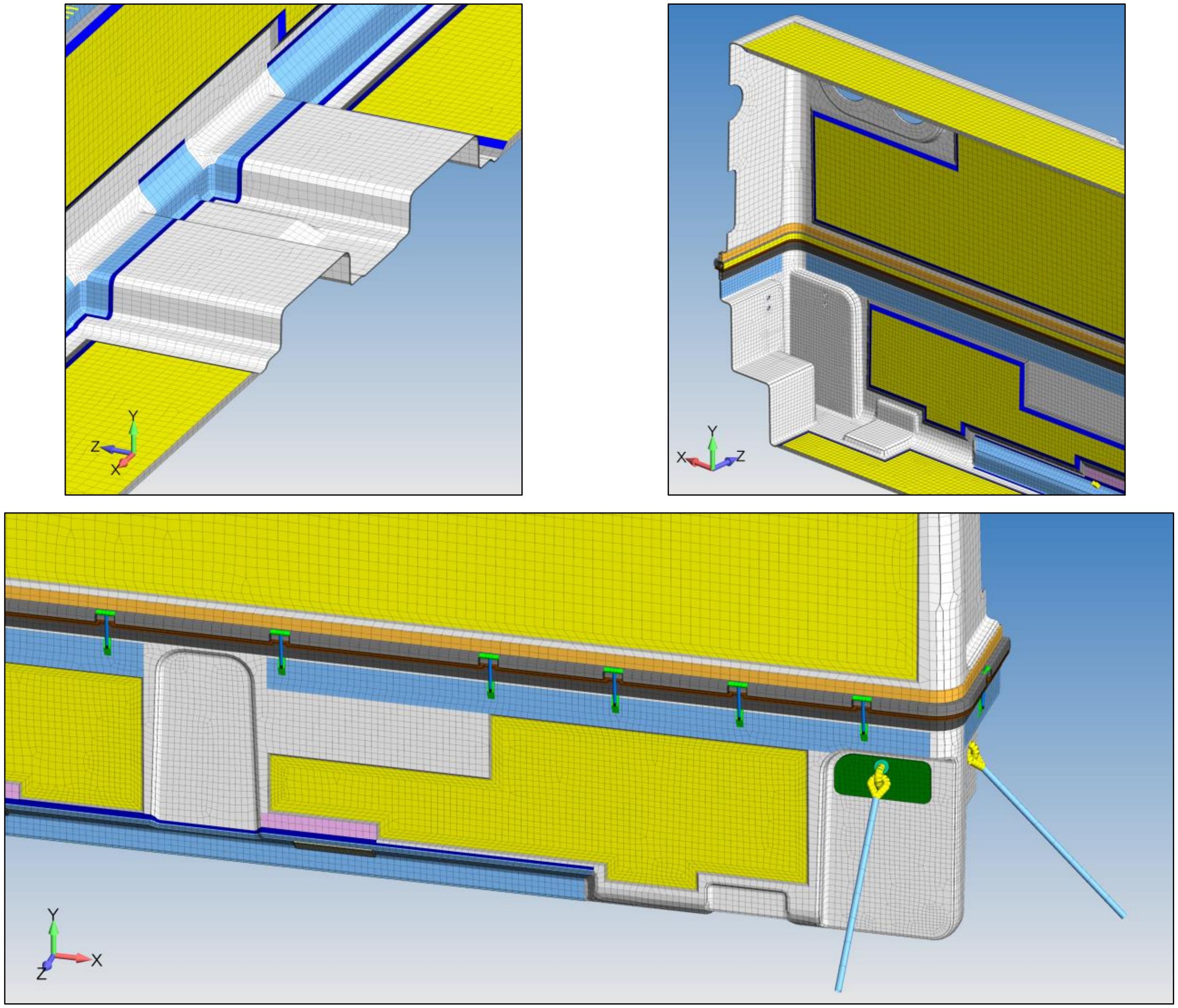
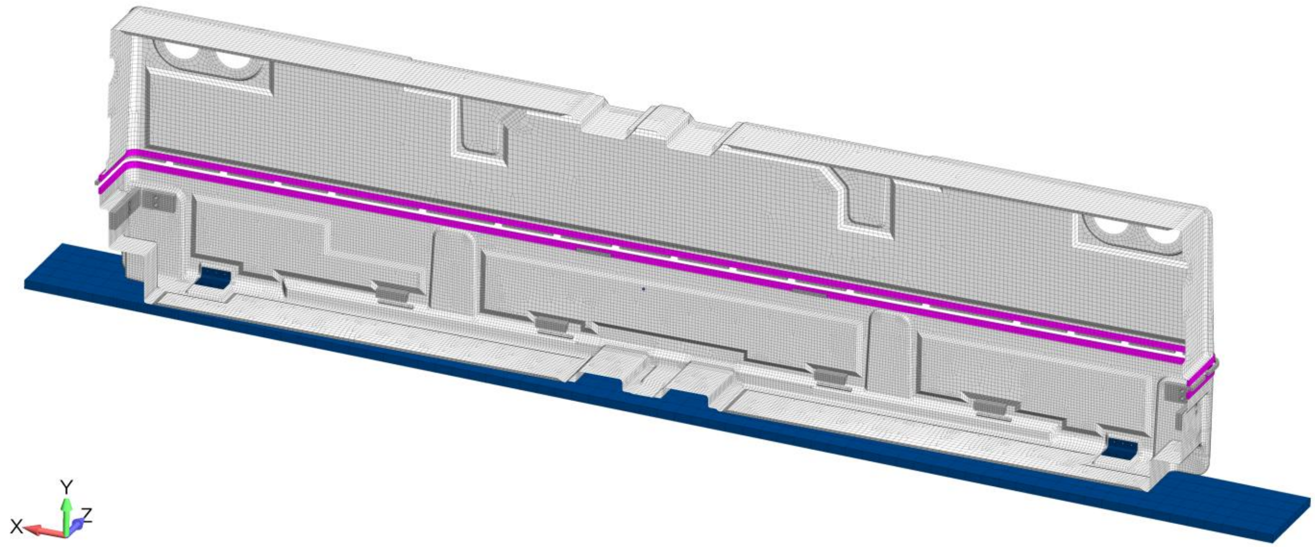
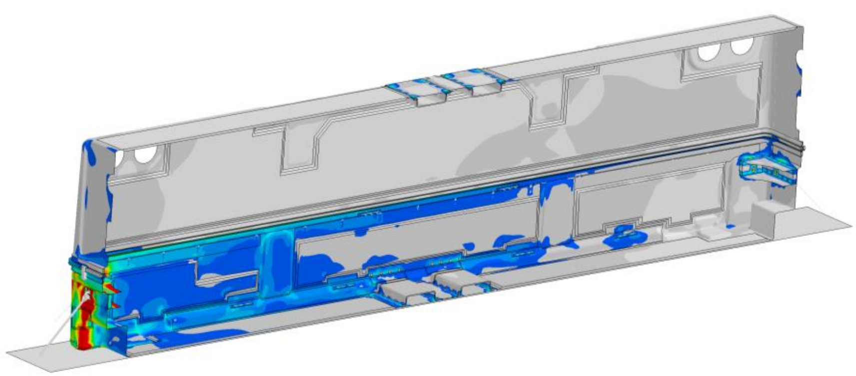


Figure 4: Laminate layups through transition regions requiring ply drop-offs

The FEA model used a wide range of material models: 6061-T6, Divinycell H100 foam core; shock isolation mounts (nonlinear springs), steel cables and roughly 8 laminate schedules.

LS-DYNA Scales for Quick Turn Around





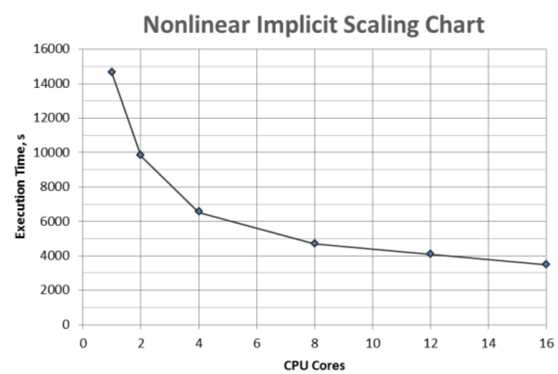


Figure 5: Analysis procedure from bolt preload / gravity to explicit impact / drop analysis with CPU scaling

The analysis required the application of bolt preload, closure latch preload (the container is split into two sections) and gravity prior to the drop test loading. To accomplish this load sequence in one analysis, a static implicit analysis was first performed and then automatically switched to explicit for the transient dynamic drop test. Failure or “no-pass” criterion was met by element erosion due to progressive failure of the composite shell.

PSD Analysis for Rail, Truck, Helicopter and Airplane Transport

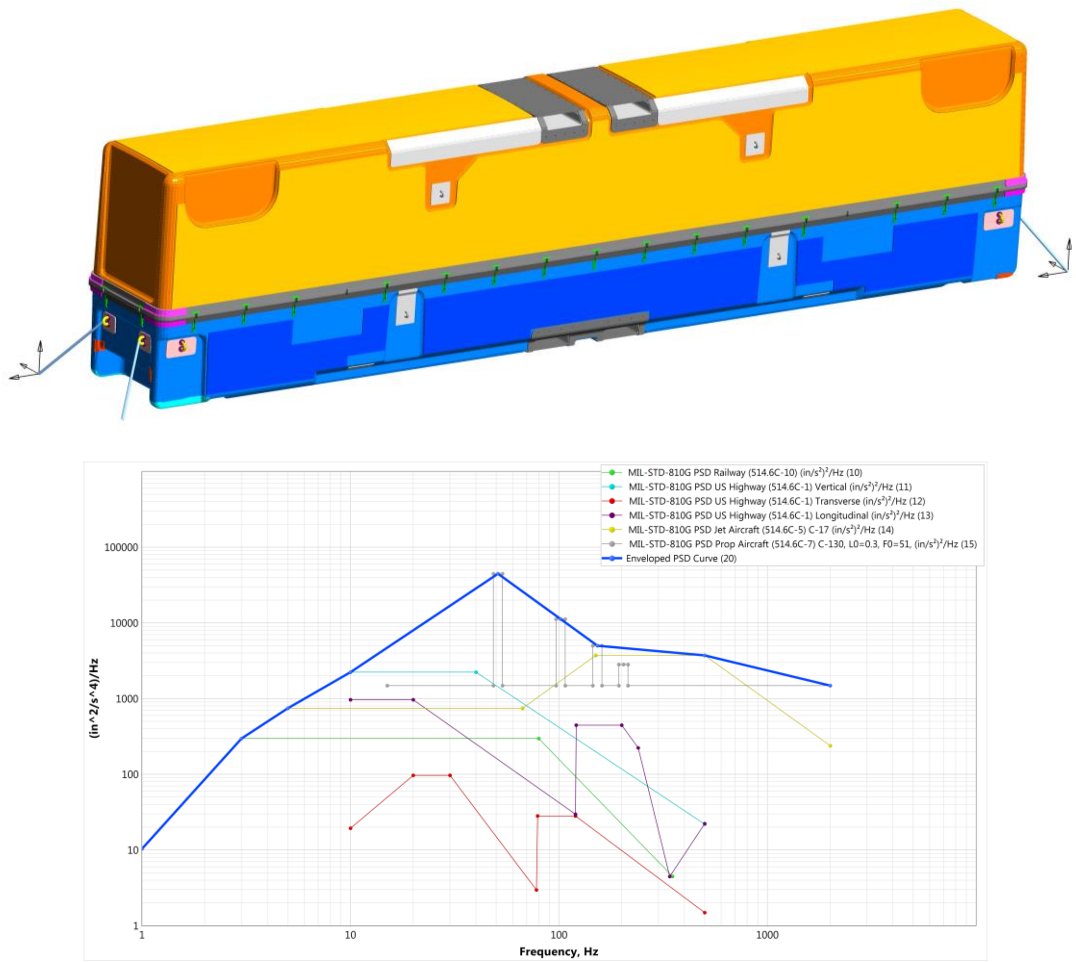


Figure 6: LS-DYNA PSD analysis was performed using an enveloped spectra

To cover transportation induced vibration loads, a PSD analysis was performed. In this analysis sequence, the container was initialized into its transport condition (i.e., bolt preloads, latch preloads and gravity) and then solved for up to 500 modes prior to the PSD calculation. For this 2.4 million DOF problem, PSD solution times were on the order of 80 minutes using 16 CPU-cores (LS-DYNA MPP Double-Precision).

LS-DYNA Implicit: Complete Composite Progressive Failure

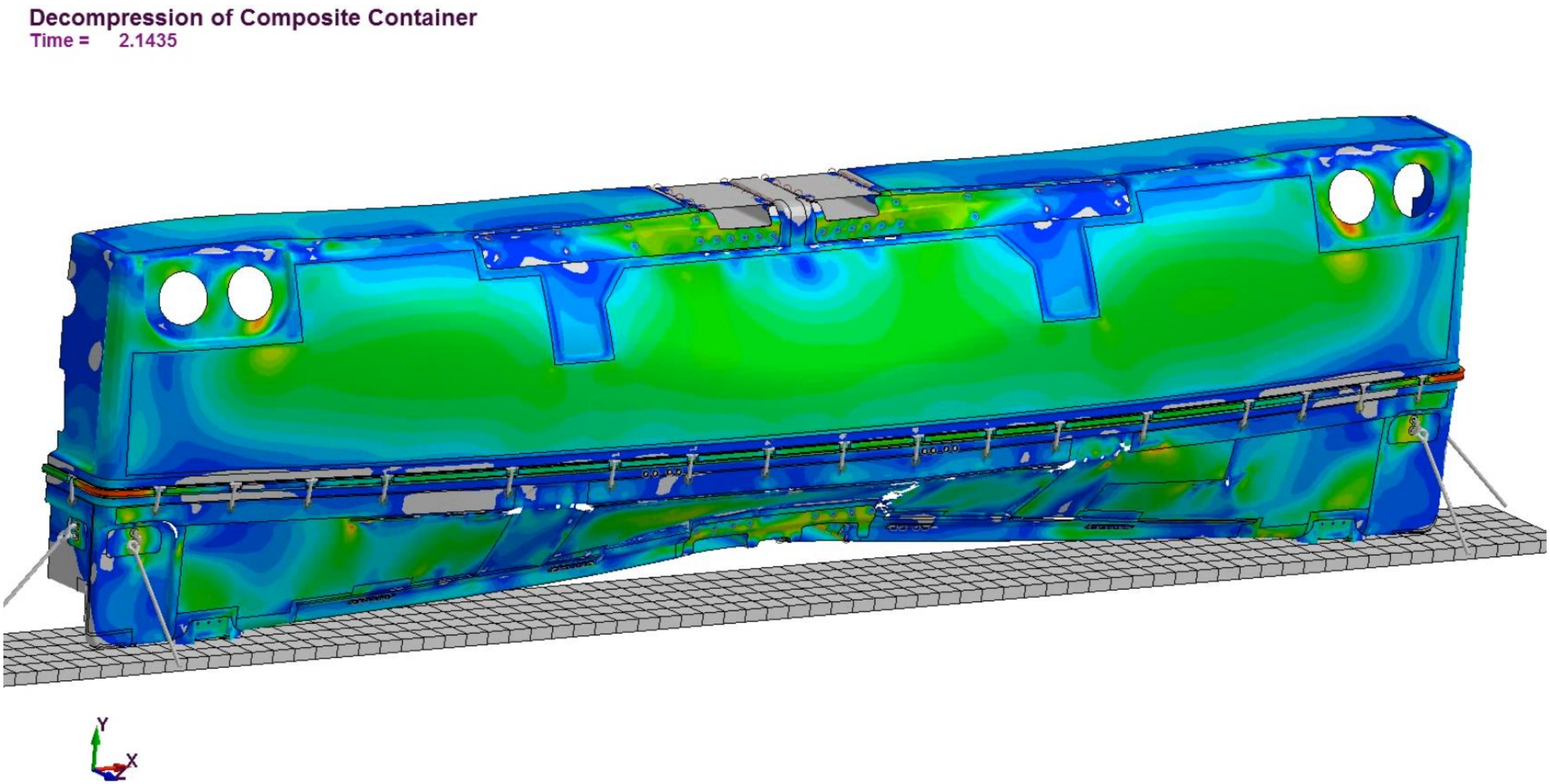


Figure 7: Static decompression loading of the composite container to complete failure

At the end of the LS-DYNA consulting services project we were able to make accurate (validated to test) predictions as to the absolute failure load of the composite container. The progressive failure capabilities of LS-DYNA were impressive since the load distribution from failed plies onto the rest of the structure allowed insight into the load line behavior of the structure under overload conditions. Moreover, this provided keen insight into how to optimize the structure since we never had to dig into the stress or strain states between plies – it either held together or failed providing a clean digital solution. The container is now in production.