The Hydrogen Economy – Go Green or Go Home

Why Simulation? Get It Right, Know Your Margins, In Service Confidence (Fracture and Fatigue)

The hydrogen economy is coming—not because of social interest or politics, but because of capitalism. Hydrogen is abundant, widely available, and an energy carrier whose combustion product is simply water. More importantly, hydrogen enables energy-to-energy conversion: energy can be used to produce hydrogen, and hydrogen can then be converted back into energy.

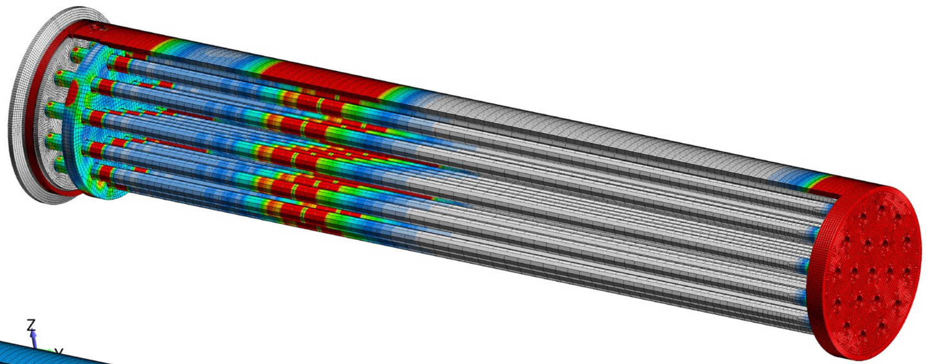
When surplus energy exists (from solar, wind, or future fusion systems), it can be converted into hydrogen and later used to power vehicles or systems where batteries are not efficient. Hydrogen has a vastly superior gravimetric (mass-based) energy density, offering over 50 times more energy per kilogram than even the most advanced solid-state lithium-ion batteries forecast to arrive around 2030. This fundamental advantage is what is driving the hydrogen economy.

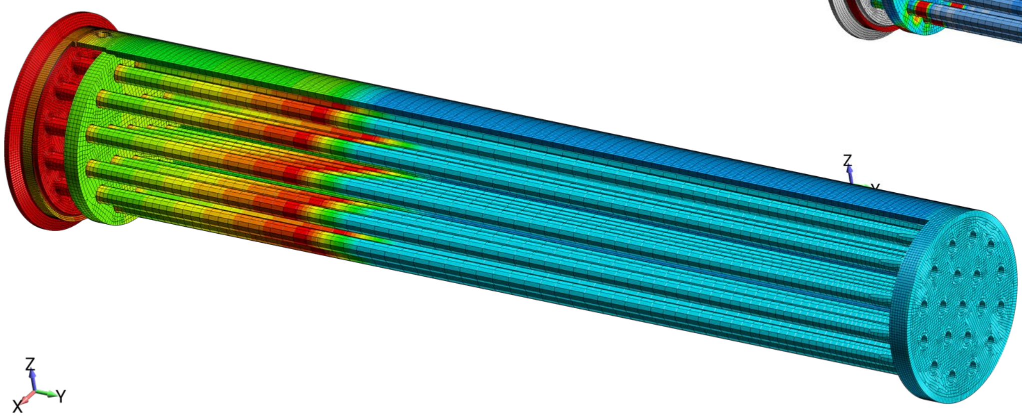
At its core, this is about energy efficiency, and Predictive is helping turn that efficiency into an engineering reality. This short note highlights our engineering consulting services related to hydrogen systems, including energy conversion, storage, and transportation.

Some of the First Steps Toward the Hydrogen Economy

Hydrogen Fuel Cell Thermal-Stress Analysis

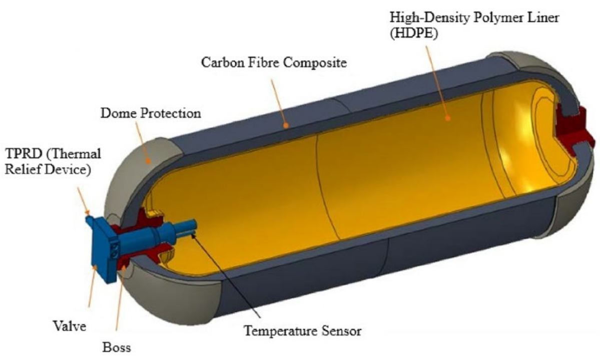
Thermal to Thermal-Stress

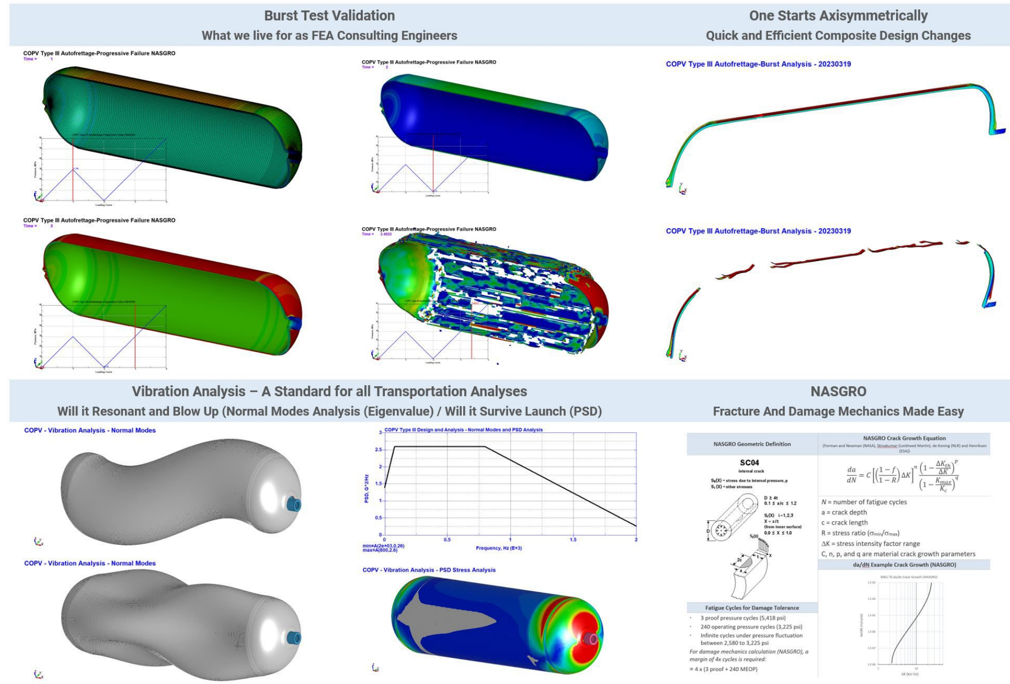




The ability to generate hydrogen from water or other fuel sources (e.g., methane) provides one of the great flexibilities of the hydrogen to generate energy from energy. Our work at Predictive was to verify the thermal-stress of the fuel cell and perform detailed weld-fatigue calculations at the connections. More can be found on this subject at [PredictiveEngineeirng.com]

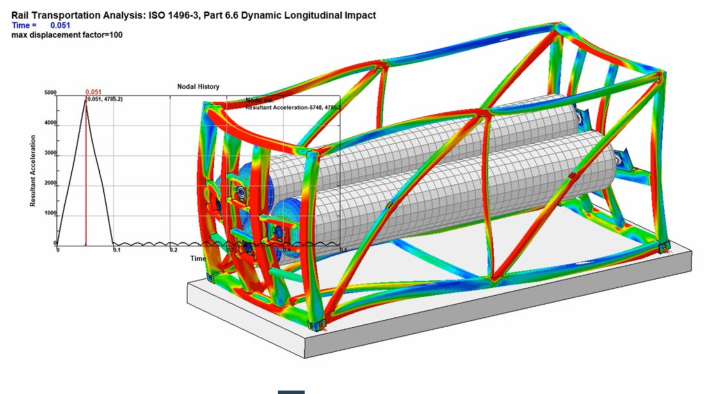
Efficient Methods for Storing Hydrogen for Aviation, Space, Marine and Automotive



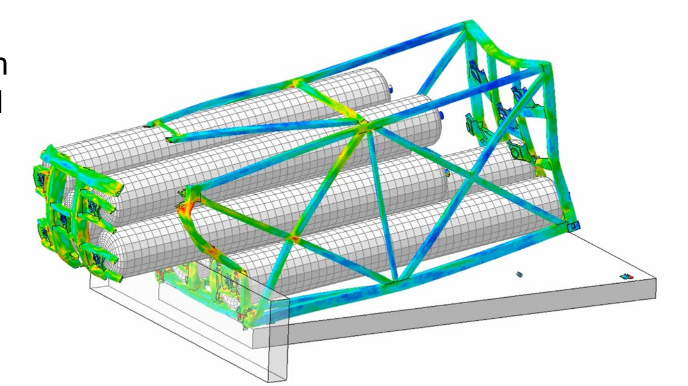


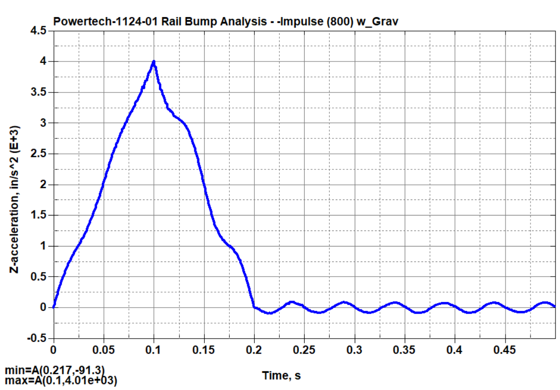
Composite Overwrapped Pressure Vessels (COPV) Type IV has solved one of the fundamental problems with hydrogen storage due to their lightweight and if failure occurs, it is a gentle process of fiber failure rather than an instantaneous burst. Simulation work at Predictive showed that our clients COPV Type IV was well designed and met their end-client's burst test requirements. Test data validated our analysis results to a near perfect match from initial loading to final failure. Additional information can be found at PredictiveEngineering.com

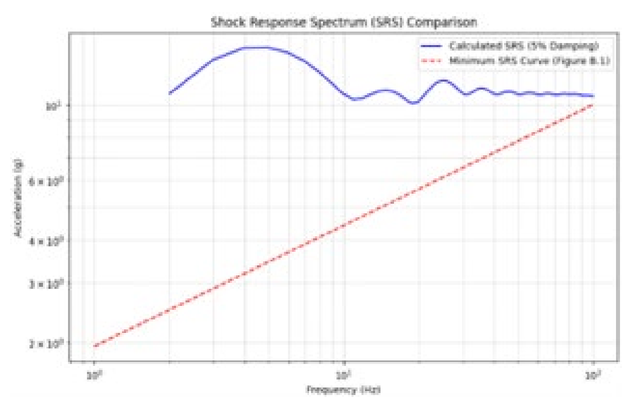
Transporting Hydrogen: Rail Transportation Frame – ISO 1496-3, Part 5



COPV vessels remain intact during 60 MPH Impact



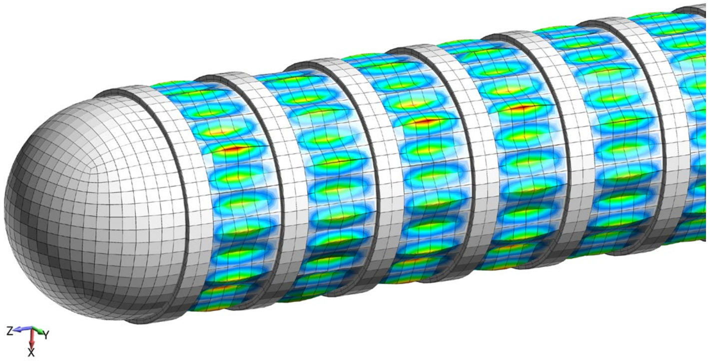




Impact analysis of rail transportation frame for hydrogen COPV type IV vessels per ISO 1496-3, Part 5. This specification requires that the frame has a SRS vibration response higher than a set curve. This requirement is met by taking the frame acceleration and converting it to a SRS response. Our client's frame passed with no problem.

Safe Storge of Hydrogen – Deep Burial While Meeting ASME VIII.2, Part 5

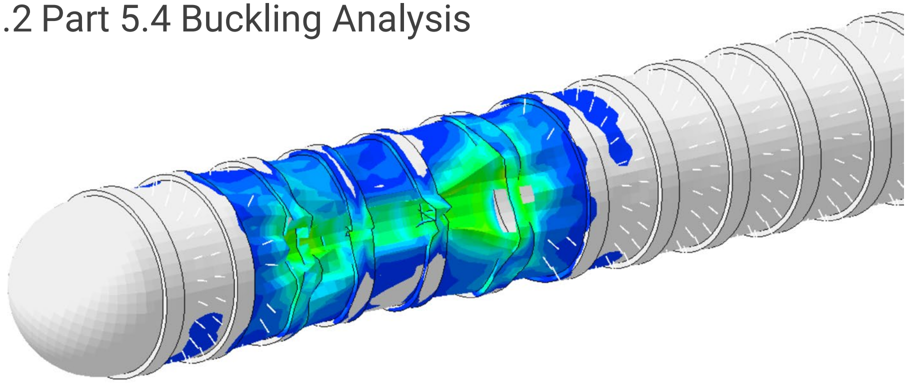
ASME VIII.2 Part 5.4 Eigenvalue Perturbation



ASME VIII-2 Fatigue Life Calculator

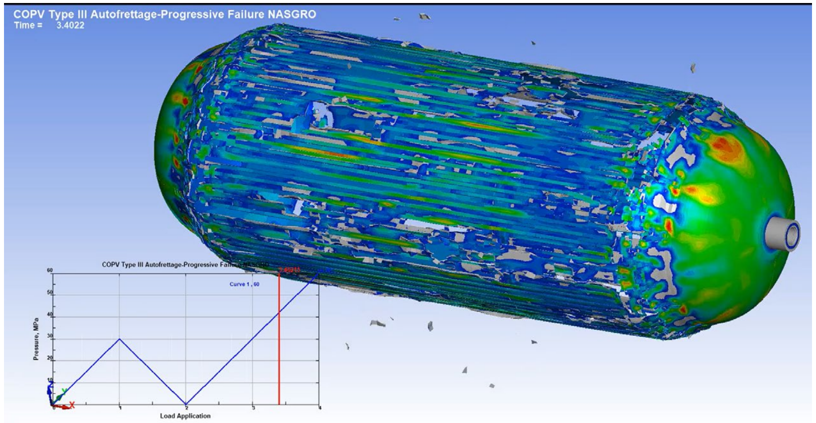
Input Parameters		
Alternating Stress, Sa (ksi):	18.5	
UTS Conversion Factor, Cus (1=ksi, 6.8	1	
Efc/Et (usually 1.0):	1	
Y = Sa/Cus * (Efc/Et):	18.5	
Coefficients (UTS ≤ 80 ksi)		
Coefficient	**Low Range (7 ≤ Sa < 31**	**High Range (31 ≤ Sa ≤ 580 ksi)**
C1	2.255E+00	8.000E+00
C2	-4.642E-01	5.832E-02
C3	-8.313E-01	1.501E-01
C4	8.635E-02	1.274E-04
C5	2.021E-01	-5.264E-05
C6	-6.941E-03	0.000E+00
C7	-2.080E-02	0.000E+00
C8	2.010E-04	0.000E+00
C9	7.138E-04	0.000E+00
C10	0.000E+00	0.000E+00
C11	0.000E+00	0.000E+00
X (log10 N):	5.086910566	
Number of cycles to failure, N:	122155	
Notes:		
1. Enter Sa in ksi (or MPa with Cus=6.894757).		
2. Coefficients from ASME VIII-2 Annex 3-F, UTS ≤ 80 ksi.		
3. Formula auto-selects coefficient set depending on Sa range.		

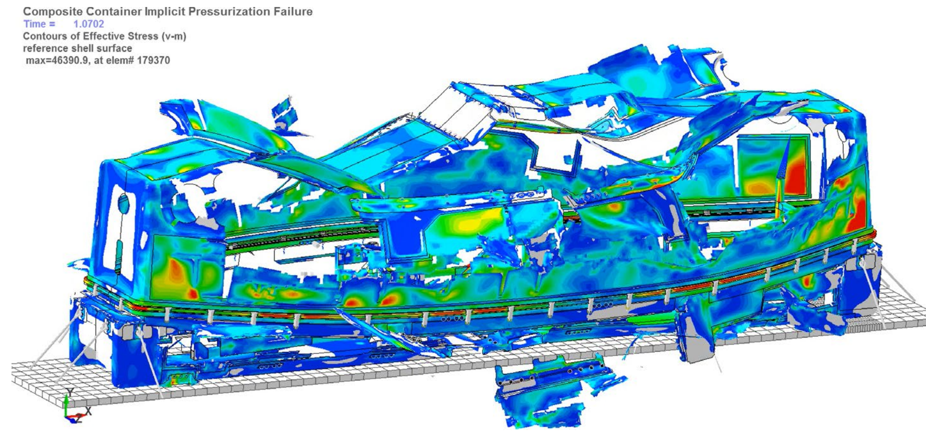
ASME VIII.2 Part 5.4 Buckling Analysis

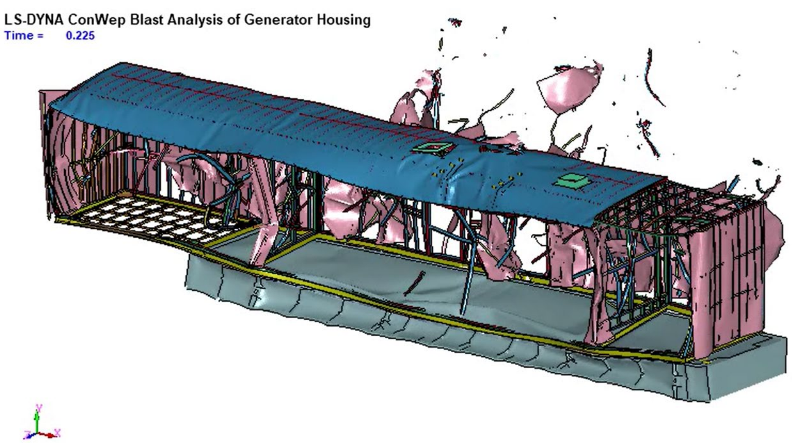


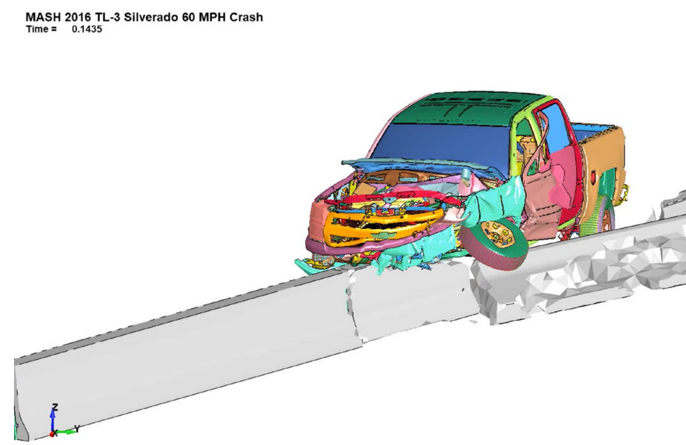
An innovative approach to hydrogen storage is to place the storage vessel deep underground and use the surrounding rock to support the vessel's high storage pressure. Predictive's work was to provide a comprehensive ASME Section VIII, Division 2, Part 5 verification of the vessel's design from surrounding rock geology to grouting methods.

Predictive Engineering's Broad Experience with Metals, Composites and Ceramics









Validated experience with composites, plastics, polymers and metals under explosive (ConWep) and Pressurized Burst Conditions. Material experts in ceramics, metals, engineered composites (polymeric and cement) – see Predictive Engineering Consulting Services for more stories.

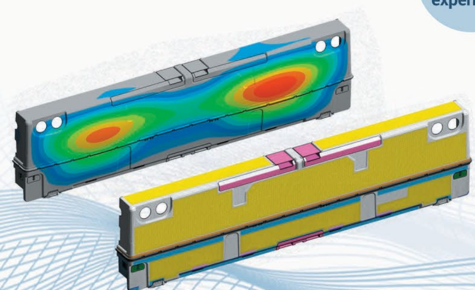
Predictive Engineering – The Advantage of Getting it Right the First Time

FINITE ELEMENT ANALYSIS
Predictive Engineering

Finite element analysis consulting services, software, training and technical support.

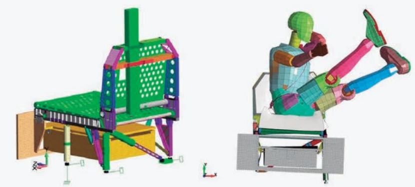
- Composites, Pressure Vessels, Vibration.
- **NASTRAN:** Linear Dynamics.
- **LS-DYNA:** Drop-test, Impact, Burst Analysis.
- **STAR-CCM+:** CFD Thermal/Flow Analysis.

+20 years experience



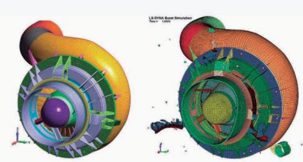
Project Examples

FAA 16G SLED TEST VERIFICATION

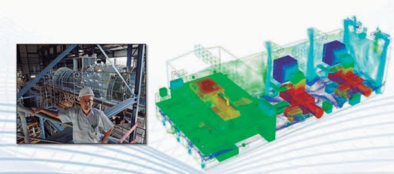


STRESS AND VIBRATION ANALYSIS OF SATELLITES

LS-DYNA TURBINE BURST SIMULATION



CFD STUDY ON CO-GENERATION POWER PLANT BUILDING



Our Services

FEA

Predictive Engineering brings to bear more than 20 years of finite element analysis FEA consulting experience in solving the most difficult mechanical engineering analysis challenges.
Our validated experience ranges from transmissions to submarines to satellites.

TRANSIENT NONLINEAR

At Predictive Engineering, we pride ourselves on the ability to idealize complex structures and systems into predictive numerical models. Our nonlinear, static and transient dynamic work has been validated against strain-gauges, drop and sled test results, accelerometers, crack growth and fracture and in extreme service environments.

ASME-BPVC

From seismic to buckling to cyclic service (fatigue), Predictive can assist in verifying the most challenging pressure vessel designs. Our hard-earned experience allows us to safely classify tanks and vessels as "fit-for-service" that would typically have required extensive redesign or re-work.

CFD

Our expertise in computational fluid dynamics (CFD) comes from hundreds of thermal-fluid projects in medical, aerospace, marine, HVAC (data centers), civil and automotive. This experience gives us the capability to quickly optimize and provide accurate digital prototypes.