Helius:MCT™ Case Study: Better Pressure Vessels with Composites

The Aerospace industry has always faced unique engineering challenges. These challenges have pushed the limits of current solutions, driving new technologies in design and manufacturing. Designs need to be lighter and stronger to achieve mission objectives while at the same time, programs must be reliable and low cost.

To meet these complex requirements, designers and engineers have looked to alternative materials, driving an expanded interest in composite materials. New advanced composite materials continue to be created with properties desirable for use in space flight. However, composites are not well understood by analysis and simulation technologies intended for metals. Traditional methods do not account for the unique makeup of the materials often resulting in grossly inaccurate results. Consequently, expensive manual testing and verification is still a necessary and significant part of the process. This lack of viable design tools has hindered adoption of composites.

The Challenge: Replace Aluminum with Composites

The Air Force had a specific challenge – to successfully design and build a tank for storage of cryogenic fuels on space craft that was lighter and stronger than the existing aluminum tanks. In order to achieve this goal, the design team recognized the need to use composite materials.

> **"We see great potential for Helius:MCT to substantially impact CTD's future spacecraft product designs."**
>
> **Naseem Munshi, President**
> **CTD Inc.**
> **Supplier of Composite Tanks**

Significant weight reduction can be achieved by switching from traditional metallic construction to lightweight, fiber-reinforced composite materials. However, designers have been unable to bring the all-composite pressure vessel concept to its full potential because current analysis tools lack the ability to accurately predict the thermo-mechanical response of these inherently complex materials. The introduction of Firehole Technologies' Helius:MCT™ solves this problem.

Composite tanks do not burst like typical pressure vessels. Rather, the matrix material cracks, creating leak paths through which the fluid can flow. Previously, simulation software was unable to accurately predict the complex interaction that occurs in composite materials. This forced designers to rely heavily on an iterative process of prototype building and testing, an expensive and time consuming process that rarely resulted in optimal structural design. In order to explore many different all-composite pressure vessel concepts, Air Force designers needed an analysis tool that could accurately and efficiently predict the behavior of composite materials. The team turned to Firehole Technologies, whose experience with advanced composite materials and partnerships with leading researchers had produced positive results on previous designs.

The Solution: Helius:MCT™ Composite Simulation

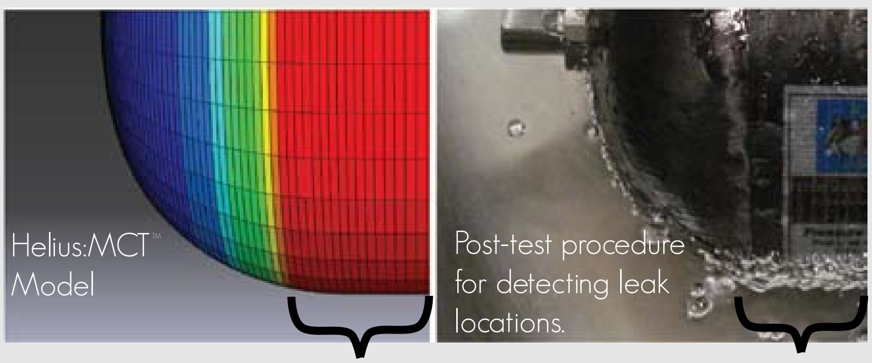
Helius:MCT™
Enhanced Composites Simulation

Helius:MCT is based on Multi-Continuum Technology (MCT) which allows composite material simulations to accurately and efficiently include material behavior at the fiber and matrix level. The inclusion of this multi-scale information enables Helius:MCT to correctly identify failure of individual material constituents and degrade the composite material accordingly. Using Helius:MCT to enhance structural analysis software, it is possible to predict the evolution of localized matrix cracking and, with acute accuracy, the point of failure.

The Air Force design team needed to understand how the tank would perform when filled and pressurized with cryogenic fluid. The desired insights included the location and pressure of initial matrix cracking as well as the location and pressure where leakage would occur. To validate the technology, results would be compared with experimental testing, using composite tanks manufactured by Composite Technology Development Inc. (CTD.)

Firehole Technologies performed a detailed finite element analysis of the all-composite tank. To demonstrate the accuracy of the material response predicted by Helius:MCT, the team performed the analysis using commercial FEA software with and without the enhancement of Helius:MCT technology. The results differed significantly.

Not only did the Helius:MCT model predict the pressure at which leakage occurred to within 2%, it also correctly identified the location of the leak as the cylindrical mid-section. Existing commercial software incorrectly predicted the curved shoulder of the tank as the site of failure and over-predicted the pressure by 100%.



Crack Saturation/Leakage Observed permeation

Conclusion : Improved Confidence, Better Designs

The results were compelling and provided the Air Force team with confidence in results to pursue the use of composite materials in their design. Using Helius:MCT, the influence of composite material type, manufacturing, and geometry are considered when creating the optimal composite design. This has lead to the development of an all-composite cryogenic pressure vessel that is 40% lighter, has 18% more volume and has 12 times the pressure capacity of the original metallic tank design.

Helius:MCT provides a tremendous increase in the predictive capability of finite element software without increasing the solution time or difficulty. This level of simulation capability permits designers to rapidly explore numerous composite design concepts while minimizing the need for expensive build and test programs. The design team can now make better, less-costly material selections while minimizing overall weight and maximizing the predictability of failure.