Helius:MCT Case Study

Optimizing Spacecraft Design with Advanced Composites Analysis

The Challenge:
Reduce Launch Costs by Optimizing Space Structures

Mission success is critical to the Air Force Research Laboratory's (AFRL) Space Vehicle's Directorate, requiring space structures to be designed to survive worst case flight conditions. The need to ensure flight success and lack of confidence in analysis tools has driven engineers to over-design many structures. This has led AFRL to question: How much have the structures been over-designed? Could the designs be optimized to reduce costs and still meet flight qualifications?

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AFRL launched a program to answer this question. "The genesis for the large structural failure program at AFRL Space Vehicle's Directorate was really to make a definitive statement regarding the ability of the aerospace community to optimize designs of large composite structures," states Jeffry Welsh, Chief of the Research, Development, Technology, and Engineering Division at AFRL.

The ISA sits atop the common booster of the Atlas V Rocket

The Solution:
Analysis and Test of ISA Structure

A definitive conclusion required both simulation and physical testing. Prior to costly physical failure testing, engineers used finite element (FE) simulation and analysis software tools to provide failure predictions. While many of these tools have been available for some time, they have not proven reliable for composite materials. Recognizing the need for improved FE tools, the AFRL turned to Firehole Composites composite analysis software, Helius:MCT, to analyze and predict catastrophic failure.

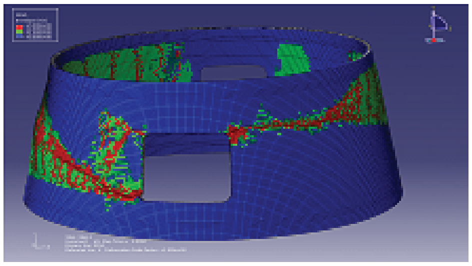
AFRL chose a newly designed Inter-Stage Adapter (ISA) for this program. The ISA sits atop the common core booster of the Atlas V rocket, adapting the booster's large diameter to the smaller diameter upper stage. The ISA design included an aluminum honeycomb core sandwiched between carbon fiber reinforced polymer composite laminates.

The most damaging flight load occurs when the maximum load is directly above the access door. The ISA qualification test simulated this load condition. Space flight qualification requires that a structure survives a test to 1.25 times the worst case flight load scenario. For the failure test, the loads were increased until a catastrophic failure was produced.

FIREHOLE COMPOSITES

Prior to the physical failure test, a progressive failure analysis was run using Helius:MCT. Firehole's progressive failure analysis provided a prediction of location and propagation of failure, with catastrophic failure predicted to occur at 187% of the flight load. The experimental test was then conducted under the same load condition. Catastrophic failure of the structure was produced at 183% of load - The Helius:MCT prediction was within 2.5% of the experimental failure.

Conclusive Results:
An Overdesigned Structure



The Helius:MCT failure state contour plot (red: fiber failure, green: matrix failure, blue: no failure) shown in an ABAQUS environment.

The results were compelling. “I had anticipated that most large aerospace composite structures were considerably overdesigned, and this program proved that,” said Welsh. Testing has shown that the original structure was 47% stronger than mission requirements. Thus, adequate strength could be achieved with a lighter ISA. This mass reduction could translate into a cost savings of as much as $500,000 per launch or a significant increase in payload.

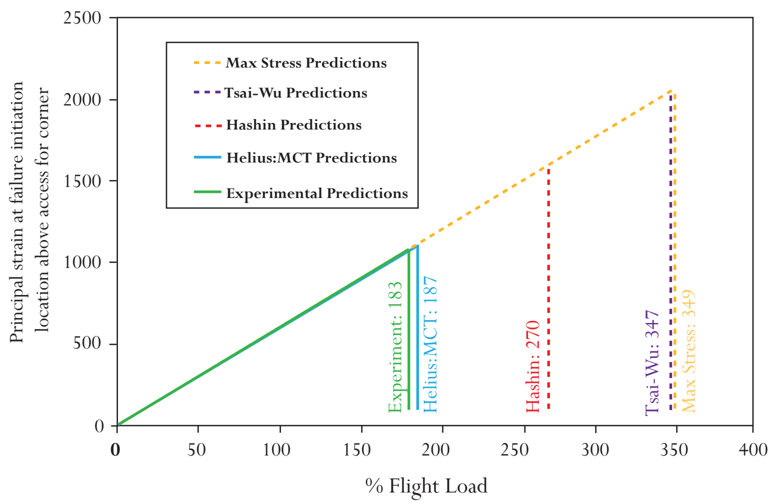
Superior Results with Helius:MCT

Not only did Helius:MCT prove that the ISA was overdesigned, it demonstrated its value as an accurate FE analysis software tool for composite materials during the design and analysis process. In addition to predicting the catastrophic failure load within 2.5%, Helius:MCT also accurately predicted the location and progression of failure.

“With innovative analysis technologies such as Helius:MCT from Firehole, I am convinced that these composite structures could remove as much as 40% mass, which translates into tremendous savings for many space applications.”

Jeffry Welsh
Chief of Research, Development, Technology, and Engineering Division
AFRL

Conic ISA Analysis vs. Experiment



Traditional composite failure criteria did not provide nearly as accurate predictions of the ISA failure. Using the same FE model as used to generate the Helius:MCT solutions, the Hashin criteria predicted failure at 47% greater than the experimental failure, and Tsai-Wu and Max Stress criteria predicted failure at 89% greater than the experimental failure. Additionally, Helius:MCT provided this improved solution in less time than the traditional solutions because of its ability to converge rapidly on a progressive failure analysis.

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