National Aeronautics and Space Administration

Additive Design and Manufacturing of SmallSat Structures (ADAMSS)

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Program: FY21 R&TD Strategic Initiative **Strategic Focus Area: Additively Designed and Manufactured Small Sat Structures**

Objectives

The objective of ADAMSS was to create multi-functional hardware for the Cupid's Arrow reference mission using additive manufacturing. The specific project objectives, over three years, were to demonstrate cost, mass, and schedule savings of 25% versus the conventional state of the art. The hardware identified for the task was an 11.1 liter propellant tank, to carry ammonia at a pressure of 380 psi. Further, the development of the design and materials is to be matured to a TRL 5 at the conclusion of th 3 year effort.

Background

Multi-functional structure offers a benefit for more efficient use of spacecraft mass, by combining multiple roles into a single piece of hardware. The reference hardware for ADAMSS, the 11.1 liter ammonia propellant tank, was conceived as both the propellant tank and the primary structure through which the spacecraft loads could be driven. In a typical spacecraft, the propellant tank serves a single function, with parasitic mass hits for the structural support brackets that hold it in place. ADAMSS seeks to invest that, by driving loads into the tank, which can be further improved using topological optimization to create a structural member responsive to the spacecraft's static and dynamic loadsets.

Approach and Results

For FY21, the two-piece design that had been successfully tested in FY20 was modified into a single-piece design, to eliminate the flange and buckling reinforcement features that the two piece design required. The research for FY21 focused on the use of topological optimization, fatigue characterization of the HRL 7A77 material, and higher-fidelity, flight like testing of the ADAMSS hardware. The major milestones were the creation of a single piece design that could be fabricated via laser powder bed fusion, a tabletop review of the technology, covering both detailed technology development and the progress towards a TRL 5, the fabrication of the single piece tank, and successful pressurization, vibration, and burst testing of the ADAMSS hardware. There were additional goals to review the mechanical data for advanced aluminum alloys (HRL 7A77), as well as to perform fractography on the 2-piece tank tested in FY20. The single piece tank design was successfully completed demonstrating a mass reduction from 9.3 kg (FY20 2 piece design) to 6.5 kg (including fittings) for the AlSi10Mg alloy. Further mass savings can be enabled by baselining an advanced alloy, such as HRL 7A77 or Elementum 7XRAM2. The testing of the hardware was conducted at Experior Laboratories and the following tasks were successfully performed: 1. proof pressurization to 570 psi with a 5 minute hold, 2. flight cyclic pressurization to 380 psi with a 1 minute hold, 3. x and y axis vibration testing to 30 g while pressurized to 380 psi, 4. sine burst testing while pressurized to 380 psi, and 5. a pressurization to burst test with failure in excess of 1500 psi (the pressure exceeded the gauge rating). All conditions passed per the test plan outlined in IOM 352G-JKC-2140.

Significance/Benefits to JPL and NASA

The use of multi-functional structure, copuled with a flexible, but flight-like design strategy, would enable significant cost and mass savings for SmallSats. Additionally, by driving design complexity and combining multiple parts into a single construct, a number of downstream costs (e.g. drawing release and review) are minimized, resulting in larger budgets for the design and implementation of these approaches. NASA is envisioning a future where SmallSats take on a greater role in planetary exploration, in conjunction with larger flight systems, and improving the efficiency of these systems will enable more mass/power for science returns, time on station, or myriad other design options, as well as significant flexibility in design and the potential to have radical alterations to the physical design of a spacecraft, which is enabled only by additive manufacturing.

Publications

None for FY21.

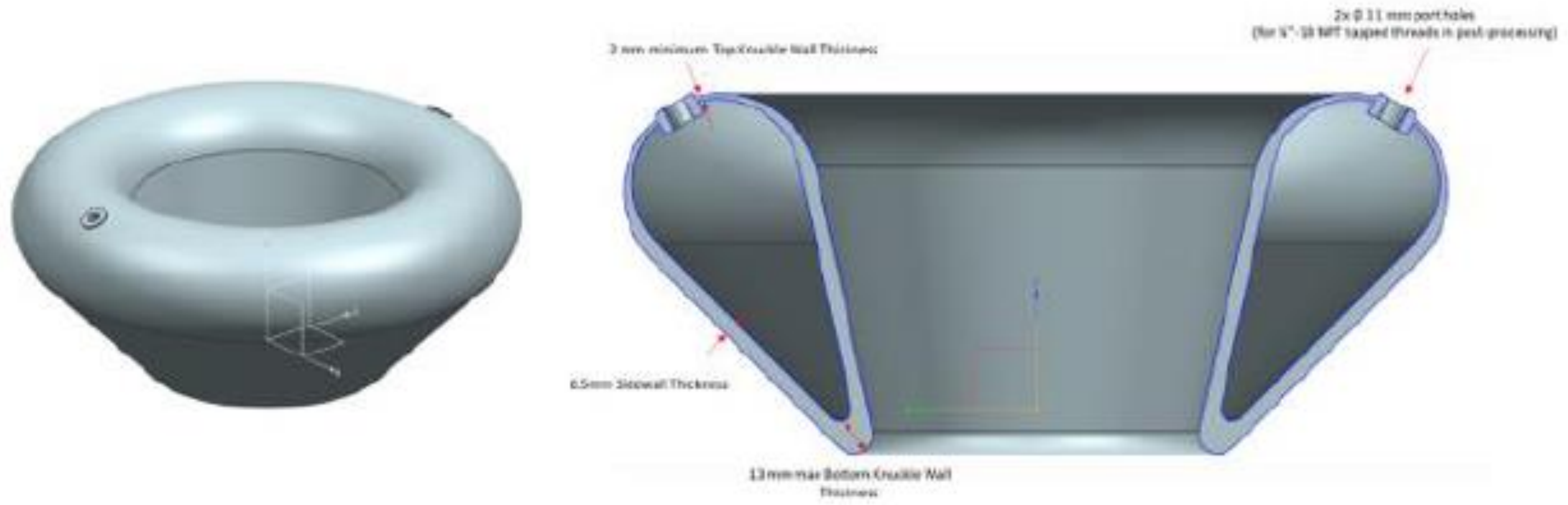

Figure 1: 1-piece design starting point with variable wall-thickness, based upon FY20 design

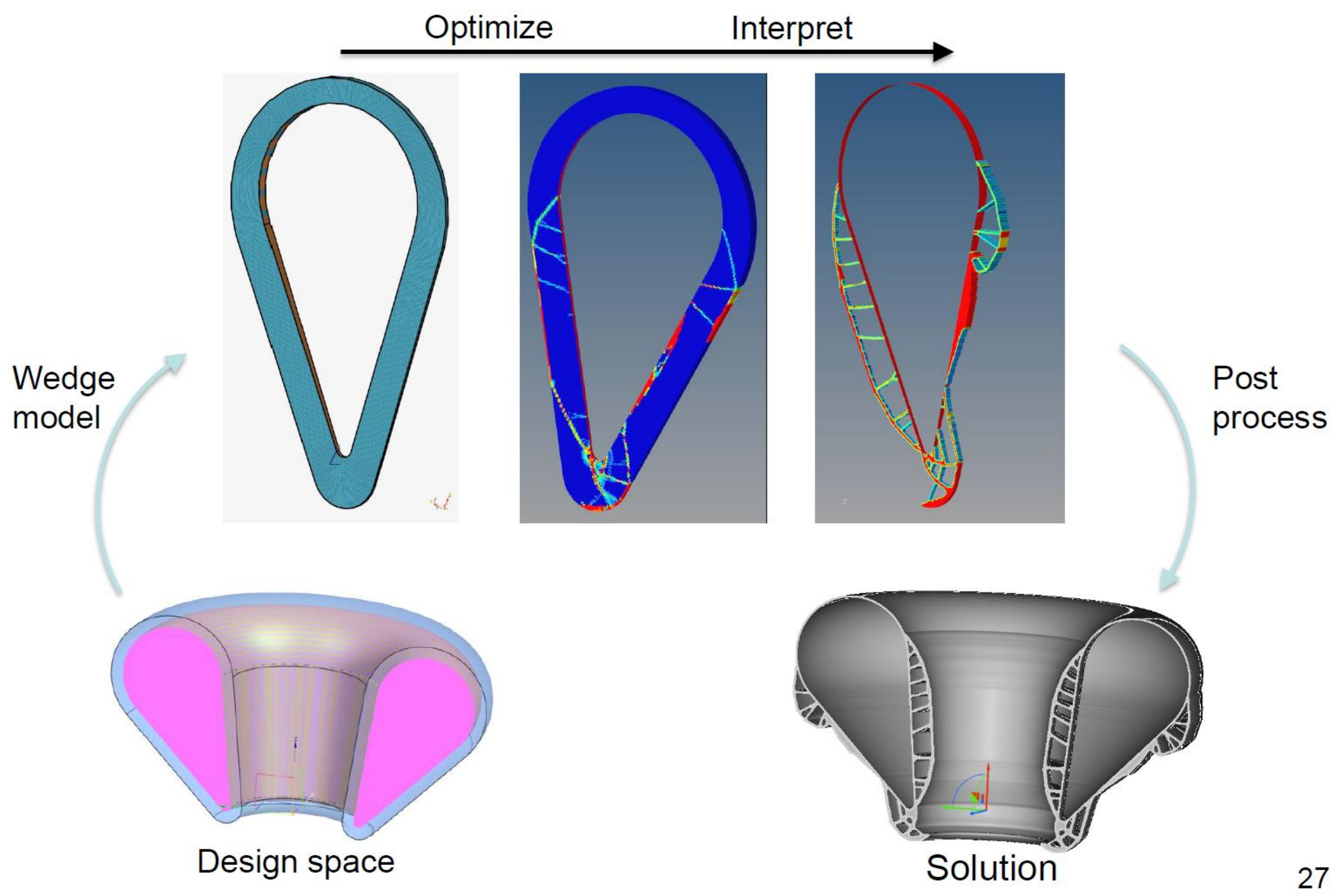

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Figure 2: Topological optimization approach demonstrating model iteration

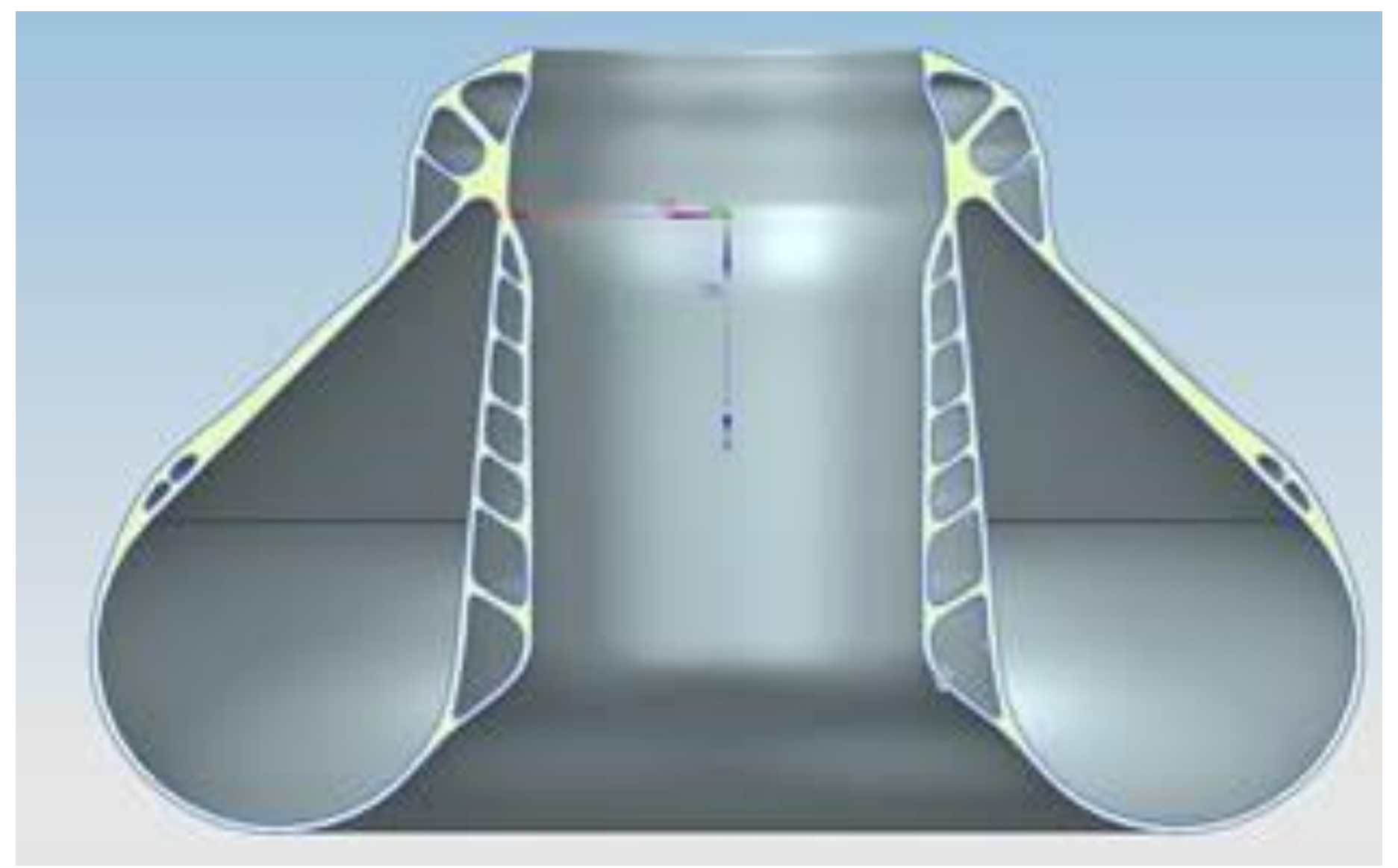

Figure 5: Cross-section of the final 1-piece design.

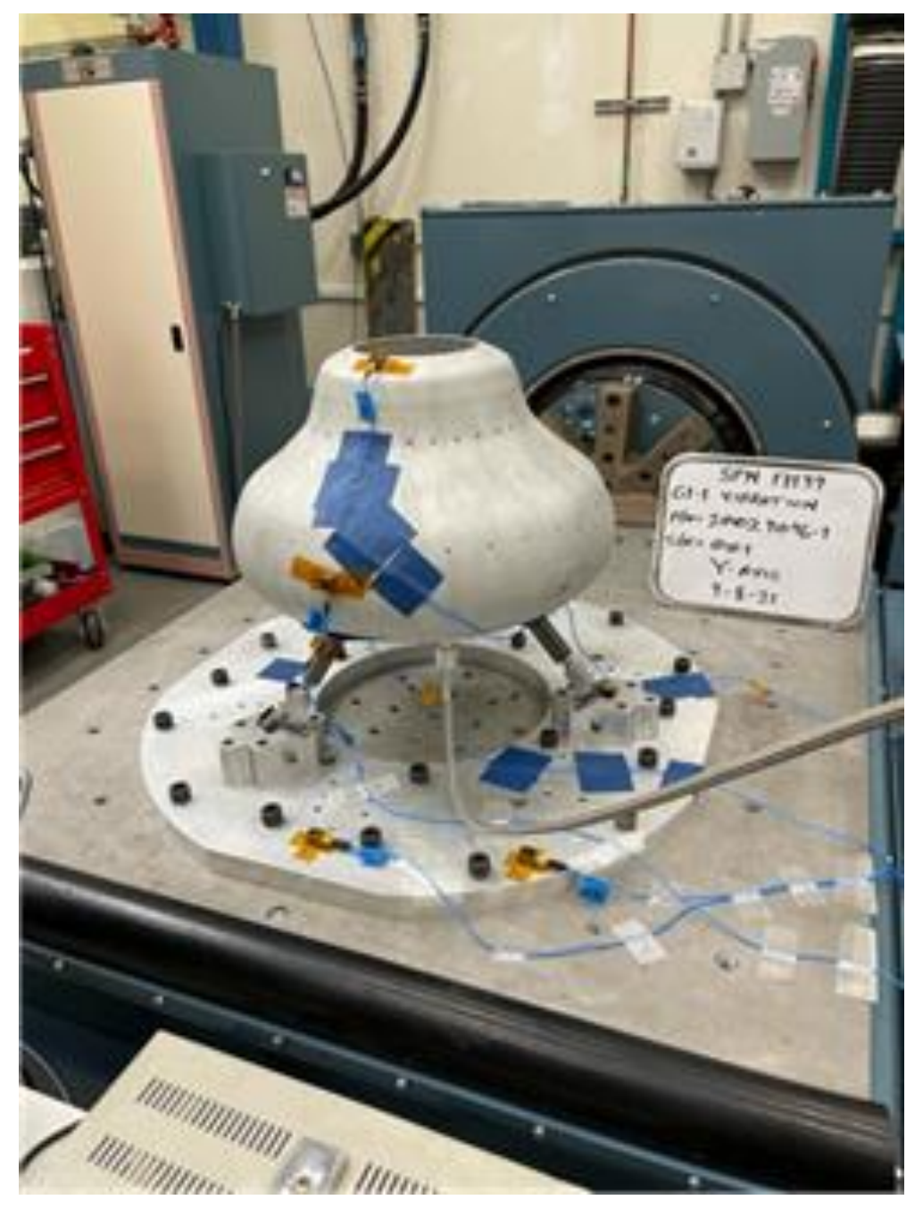

Figure 6: Hardware in test configuration with accelerometers for y-axis vibration testing at Experior.

Figure 3: Topological optimization results using axisymmetric (top), ¼ symmetry (middle) and 1/16th symmetry (bottom). Note the change in complexity in various features.

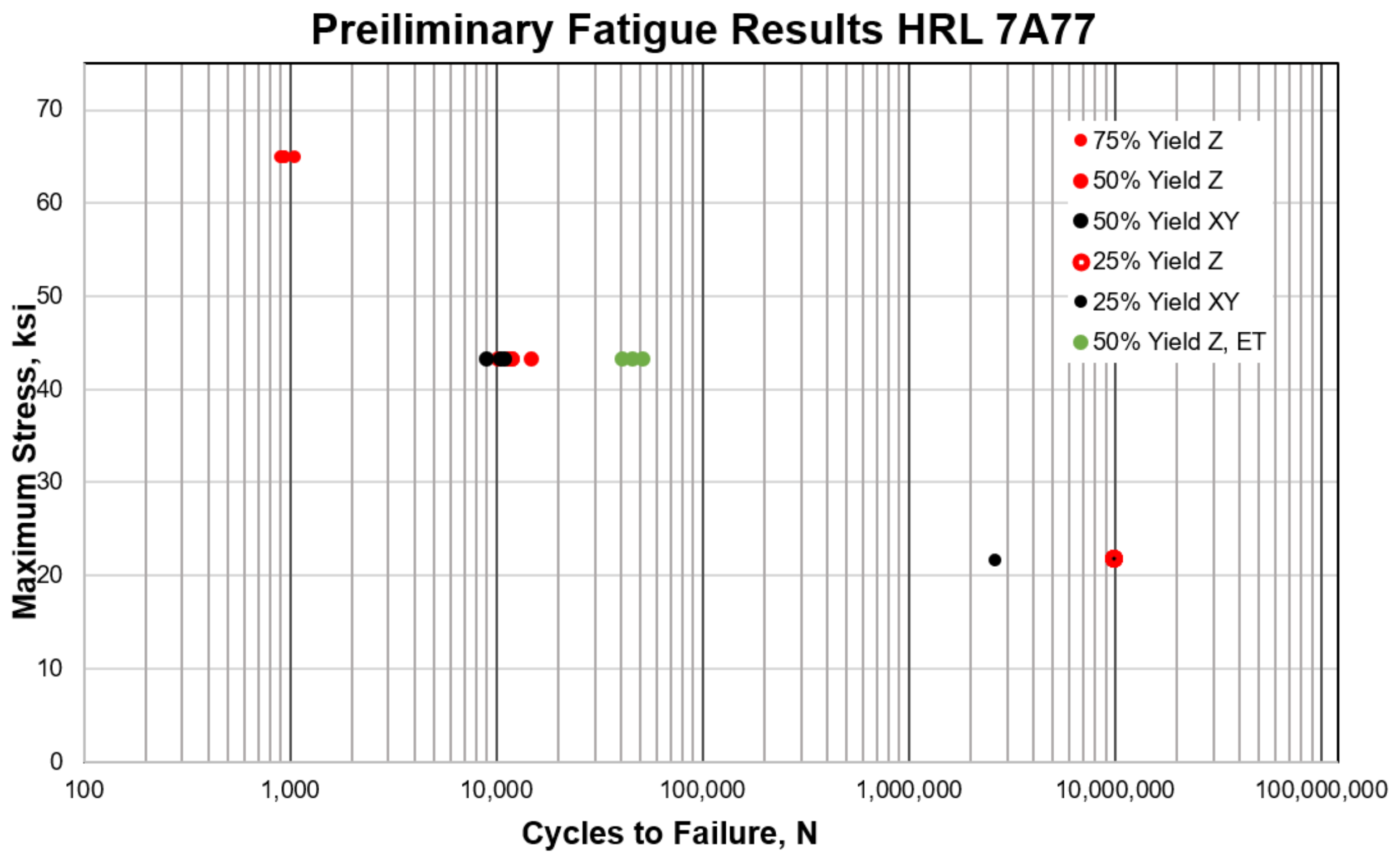

Figure 4: First of its kind fatigue testing data for HRL 7A77, demonstrating the effects of stress and test temperature.

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