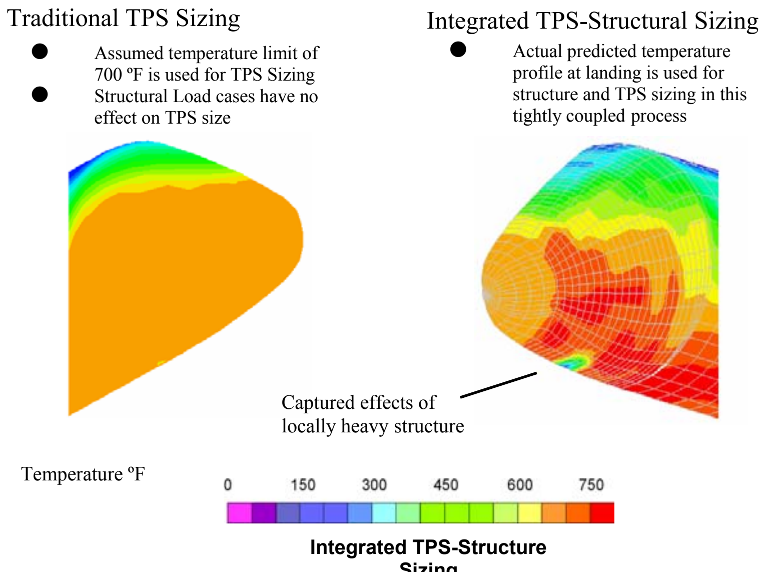
HyperSizer® TPS

HyperSizer Thermal Protection System (TPS) is an add-on module for the HyperSizer Structural Sizing Software, which was developed by integrating a powerful, NASA developed TPS analysis capability with HyperSizer.

NASA and the Air Force have indicated that a top priority for the near future is the development of next-generation Reusable Launch Vehicles (RLV), Space Access and Future Strike Vehicles (SA-FSV). One of the characteristics shared by these classes of vehicles is high Mach number ascent and reentry, resulting in substantial aero-heating, and a need for advanced lightweight structures and Thermal Protection Systems (TPS). The sizing and selection of TPS material in conjunction with structural sizing and material selection have been identified as critical steps during the RLV and SA-FSV design processes.



Structural Temperatures

There are several ways to analyze and size thermal protection systems and in many cases, both in government and in industry, sites will spend time and resources developing their own proprietary TPS analysis programs. Under contract to NASA, Collier Research Corporation has developed a TPS analysis and sizing program that is tightly coupled with the structural analysis and sizing program, HyperSizer®. This capability has now become an integral part of the HyperSizer software.

Two Main Purposes of the TPS Capability

One of the purposes of this new HyperSizer Integrated TPS-Structures capability is to provide a commercial quality TPS analysis and sizing program that will become a standard analysis method for 2nd and 3rd generation RLV's under the NASA Space Launch Initiative (SLI) program.

This capability runs in parallel on a network of computers and on multi-processor machines to efficiently support many RLV trade studies. With all TPS analysts using the same software, data can be exchanged between sites and analyses can be easily repeated. HyperSizer uses a true relational database management system to ensure data integrity and provides automatic archival of project data. As commercial software, HyperSizer also has the added benefits of robustness, user support and documentation.

The second purpose of the HyperSizer Integrated TPS-Structures capability is to combine the disciplines of TPS Analysis with Structural Analysis in a single program. This is necessary because the disciplines are so closely related where the mass of the underlying structure affects the TPS sizing, and the TPS sizing affects the structural temperatures, and thus the structural material properties.

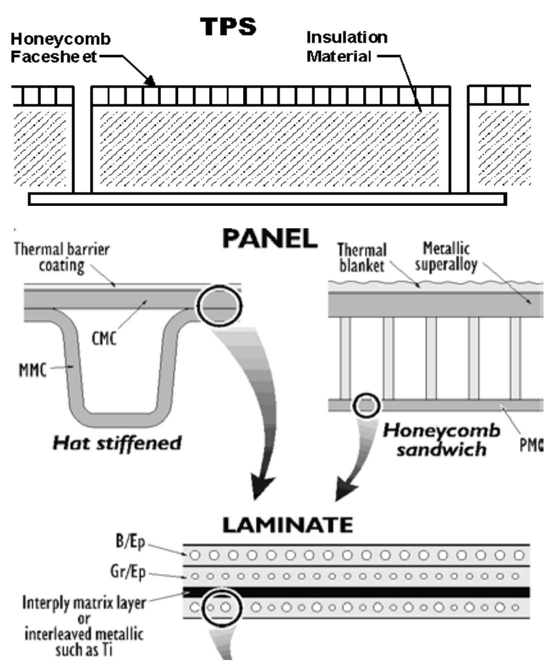


Figure 1: Sizing all aspects of the TPS-Structural System

New Technology in TPS-Structures Sizing

To solve a coupled TPS-Structural sizing problem, the thermal analysis methods from a NASA developed TPS Sizing program has been incorporated into the HyperSizer structural analysis and sizing software to form a tightly coupled Structures-TPS sizing and analysis capability. Because these two disciplines are so closely related, the only way to get a weight minimized design and accurate analytical solution is to tightly couple the two disciplines. The TPS-Structural optimization process, if

HyperSizer Structural Sizing Software Designs on the fly it is even performed in today's design processes, operates by manually passing data between analysis codes. Elimination of this manual data exchange will allow for better optimization, higher fidelity analysis results, and reduced design cycle time. Because the structure and TPS analyses are integrated at the HyperSizer kernel software level, this approach benefits the design process by eliminating the need to pass data between disciplines.

Benefits of Coupled Structural-TPS Sizing

- **A truly integrated analysis tool provides the correct solution**
- **A truly integrated optimization tool provides the lightest total TPS-structural weight**

Coupling the TPS-Structures optimization allows HyperSizer to optimize all aspects of the system simultaneously to obtain a lower total system weight. As shown in Figure 1, each individual piece of the system can be optimized including the honeycomb facesheet of the shown TPS concept, the insulation material and thickness, the structure facesheet and stiffener materials and thicknesses, etc. In addition, variables like stiffener spacing, panel height, and corrugation angle can also be optimized.

The coupled TPS-Structural sizing works by incorporating a fully transient, trajectory dependent heat flux profile, generated using a tool such as MINIVER (an Aero-Heating code from NASA Langley), selecting TPS materials, and sizing the thickness of the TPS using a one-dimensional transient finite element code. The transient heat transfer analysis of the TPS analysis automatically passes temperatures to the HyperSizer structural analysis module for structural analysis and sizing at various pre-defined loading points, or load cases. In the coupled analysis, the TPS analysis is performed with the correct backside structure, and the temperature of the structure is passed to the structural analysis at the time in the trajectory where each load case occurs.

TPS Applications

The HyperSizer TPS-Structures Integrated capability has been applied to several aerospace vehicles over the last three years and several contractors intend to use it as part of their SLI 2nd Gen vehicle design cycle.

As an example, a coupled structures-TPS optimization was performed using HyperSizer for a candidate 3rd Generation TSTO Launch Vehicle, shown in Figure 2. In this effort, Collier Research has worked closely with designers and project managers at NASA Marshall Space Flight Center to determine an optimum design for structures and TPS for the airframe, engine flowpath, cowl, and internal structure. During the optimization, many different materials were considered for the structure and for the TPS. The structural concepts included hot structure carbon-carbon and carbon-SiC hat stiffened, graphite epoxy hat stiffened, titanium hat-stiffened and isogrid stiffened. The TPS concepts considered were ceramic Alumina Enhanced Thermal Barrier (AETB) tile and Tailorable Advanced Blanket Insulation (TABI). A typical transient thermal profile from the TSTO Launch Vehicle is shown in Figure 2.

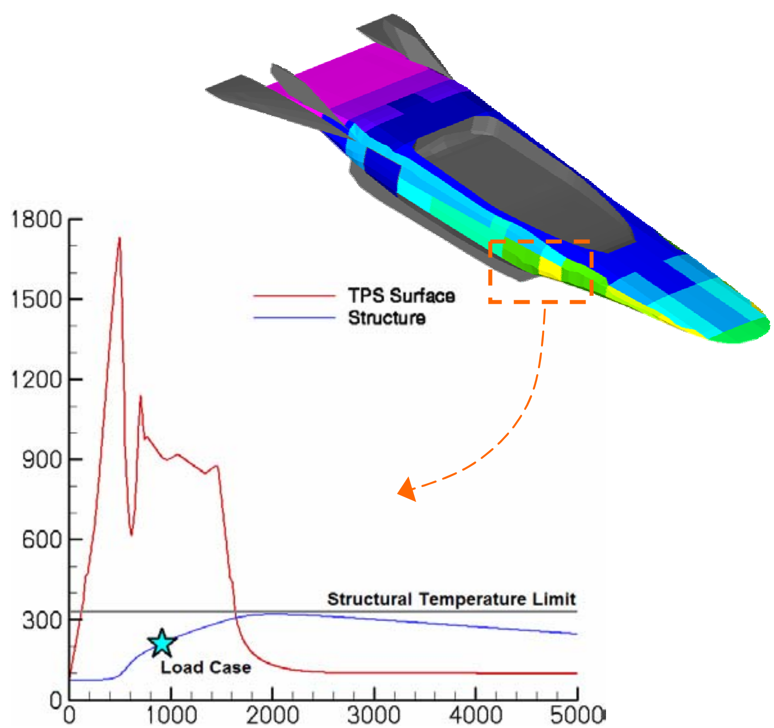


Figure 2: Transient Heating Profile

For the structural component analysis shown, which is on the vehicle sidewall behind the forward H_2 tank, the structure was analyzed at several load cases throughout the trajectory, including the Mach 8.5 vehicle pull up load case shown in the figure. The red line indicates the surface temperature of the TPS, which is exposed to the high speed flow, while the blue line indicates temperature of the structure, which has a temperature limit of 320°F. In the coupled analysis, the TPS analysis was performed with the correct backside structure, and the temperature of the structure was passed to the structural analysis at the structural load case points for consistent structural analyses with the correct temperature dependent structural material properties.

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