Thermochemical Ablation Analysis of the Orion Heatshield

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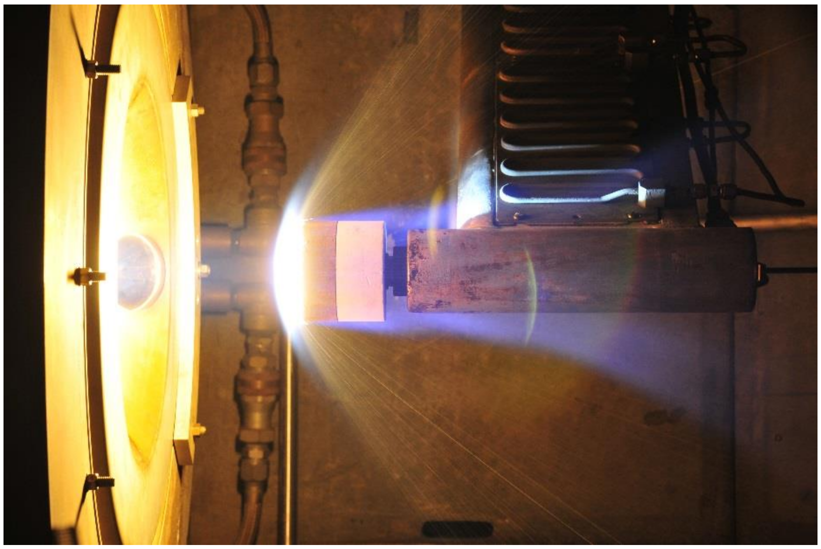
Abstract

The Orion Multi-Purpose Crew Vehicle will one day carry astronauts to the Moon and beyond, and Orion's heatshield is a critical component in ensuring their safe return to Earth. The Orion heatshield is the structural component responsible for absorbing the intense heating environment caused by re-entry to Earth's atmosphere. The heatshield is primarily composed of Avcoat, an ablative material that is consumed during the re-entry process. Ablation is primarily characterized by two processes: pyrolysis and recession. The decomposition of in-depth virgin material is known as pyrolysis. Recession occurs when the exposed surface of the heatshield reacts with the surrounding flow.



Arc jet test of molded Avcoat in CO_2 to simulate the atmosphere of Mars.

The Orion heatshield design was changed from an individually filled Avcoat honeycomb to a molded block Avcoat design. The molded block Avcoat heatshield relies on an adhesive bond to keep it attached to the capsule. In some locations on the heatshield, the integrity of the adhesive bond cannot be verified. For these locations, a mechanical retention device was proposed. Avcoat ablation was modelled in CHAR and the in-depth virgin material temperatures were used in a Thermal Desktop model of the mechanical retention device. The retention device was analyzed and shown to cause a large increase in the maximum bondline temperature.

In order to study the impact of individual ablation modelling parameters on the heatshield sizing process, a Monte Carlo simulation of the sizing process was proposed. The simulation will give the sensitivity of the ablation model to each of its input parameters. As part of the Monte Carlo simulation, statistical uncertainties on material properties were required for Avcoat. Several properties were difficult to acquire uncertainties for: the pyrolysis gas enthalpy, non-dimensional mass loss rate (B'_c), and Arrhenius equation parameters.

Variability in the elemental composition of Avcoat was used as the basis for determining the statistical uncertainty in pyrolysis gas enthalpy and B'_c. A MATLAB program was developed to allow for faster, more accurate and automated computation of Arrhenius reaction parameters. These parameters are required for a material model to be used in the CHAR ablation analysis program. This MATLAB program, along with thermogravimetric analysis (TGA) data, was used to generate uncertainties on the Arrhenius parameters for Avcoat. In addition, the TGA fitting program was developed to provide Arrhenius parameters for the ablation model of the gap filler material, RTV silicone.