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PARKER SOLAR PROBE STRUCTURAL-THERMAL ANALYSIS CHALLENGES

Abstract

The NASA Parker Solar Probe spacecraft, built by the Johns Hopkins University Applied Physics Lab will fly through the outermost part of the Sun's atmosphere taking in situ measurements and imaging to improve our understanding of the corona and the solar wind. The Thermal Protection System (TPS), a 4.5-inch thick carbon-composite heat shield, limits heat transfer to the spacecraft during its flight through the Sun's atmosphere, and casts a shadow which protects the spacecraft and its instruments from the harsh thermal environment. At a closest approach of 3.8 million miles from the surface of the Sun, the TPS has to withstand temperatures on its front surface of nearly 2500 F. The extreme thermal environment and TPS size limited the ability to do full scale TPS hot thermal testing. As a result, the TPS qualification program involved sub-scale hot bulk and gradient temperature testing and relied heavily on thermal-structural analysis. Operating temperature material property data is necessary to perform thermal-structural analysis. This analysis evaluates both mechanical survivability and thermal distortion of the TPS in the predicted on-orbit thermal environment. Performing standard material property tests at these elevated temperatures was challenging and resulted in higher than usual uncertainty in the test data. As a result of this uncertainty, a model correlation was performed to verify the temperature dependent properties used in the finite element model prior to performing the full-scale TPS thermal-structural analysis. This correlation used test results from both sub-scale hot and full scale cold TPS thermal testing. Thermocouple data was used as the input to the model to develop thermal load cases while LVDT and strain data was used to correlate model predicted distortion results. This correlation effort was critical to gaining confidence in the operating temperature material property data and allowed for a successful TPS qualification program.