The Evolution of the MSL Heatshield (Part II)

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ABSTRACT

Early in the development of the Mars Science Laboratory (MSL) thermal protection system (TPS) on the heatshield, the decision was made to use SLA-561V as the ablative material based on successful use on previous Mars entry heatshields and on stagnation arc jet tests at heating rates beyond the design levels. Because this heatshield will be the first to experience turbulent flow and high shear environments as it enters the Mars atmosphere, tests were performed in various arc jet facilities on flat plate, wedge and swept cylinder specimen configurations in order to ascertain the effects of shear on the material. In the course of these tests, a set of conditions within the flight envelope resulted in catastrophic failure in the SLA-561V. Descriptions of the SLA-561V failures were presented in Part I of this paper at IPPW-6. As a result of these failures, the decision was made to replace the material with Phenolic Impregnated Carbon Ablator (PICA), which had flown successfully on Stardust and was undergoing intense testing and characterization for the CEV Orion TPS Advanced Development Program (ADP). As with the Orion heatshield approach, the MSL PICA heatshield was designed to be constructed from multiple tiles with gap fillers.

Changing the TPS from a monolithic design to a tiled design proved to be a challenging design effort. Due to the compressed schedule, the detailed margined sizing analysis and the tile design were occurring in parallel. Therefore a decision was made to utilize the entire TPS mass budget and distribute it along a uniformly thick heatshield, except on the transition and shoulder tiles. The benefits of the mostly-uniform thickness were 1) the pre-existing structural design assumed a uniform TPS thickness and 2) it allowed for a minimum number separate tile designs and therefore fewer part drawings. The final design required only 27 separate tile drawings for the 113 total installed tiles. Extensive effort went into developing optimal bonding and gap filling techniques in order to develop the final processes used in manufacturing the heatshield. The MSL project planned and performed nearly 100 developmental tests on the heatshield material in arc jet environments as well as over 100 tests in thermo-structural environments, on acreage and gapped specimens, on specimens with flaws in the acreage or gaps, and specimens with repairs in the acreage or gaps, all in MSL relevant heating and/or loading conditions. With only 2 years remaining before the expected launch date and less than 18 months before the heatshield delivery date, the MSL team successfully developed and built a PICA flight heatshield.