Arc Jet Testing of 3D Mid-Density Carbon Phenolic [3MDCP] for Mars Sample Return

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Brief Presenter Biography: Jonathan Morgan is the arc-jet test lead for the Mars Sample Return (MSR) Earth Entry System (EES) Project, and has been with NASA since 2018 designing, testing, and characterizing Thermal Protection Systems (TPS).

Introduction: When accounting for the highest-heating trajectory with margin, dispersion, and greatest system mass, MSR-EES is predicted to experience the highest heat flux and pressure (approximately 3300 W/cm2 hot-wall, 200 kPa) of any earth entry vehicle to-date. To verify performance requirements are met by the forebody TPS, the material must be tested to validate model predictions and give confidence to stakeholder's expectation of performance. 3D Mid-Density Carbon Phenolic (3MDCP) is NASA's baseline material for the forebody heatshield of the MSR-EES. As part of the arc jet campaign to evaluate material performance, recent testing has completed in the Interaction Heating Facility (IHF) using a new facility setting to achieve the necessary environments.

Facility Setup: The IHF with the 3-inch nozzle is the only facility capable of achieving the necessary heat flux at ARC. With this nozzle, there are limited options in coupon design to achieve the necessary heat flux level and while maintaining large enough length scales for material assessment. Ultimately, 1-inch diameter iso-q coupons shown in Fig. 1 were designed and fabricated to achieve the necessary heat flux.

Figure 1. 1-inch diameter iso-q 3MDCP article (striped) assembled in carbon-phenolic holder (black).

Still, to achieve the heat flux, the facility must use high mass-flow settings which produces pressure forces on the article many times greater than what is predicted for flight.

Results: In total, 3MDCP was tested at five conditions ranging from a hot-wall heat flux of 2400 W/cm2 to 3700 W/cm2, with a stagnation pressure of 240 kPa to 640 kPa, respectively. This marks the first entry to characterize 3MDCP material recession at extreme conditions and is the highest heat flux and pressure combination available for a standard model design at ARC. Shown in Fig. 2, real-time recession estimates using the arcjetCV program determine that the centerline response of the model is reasonably linear for the exposure [1]. The early part of the exposure where data scatter exists is a result of residual sting arm motion after the model is placed in the flow.

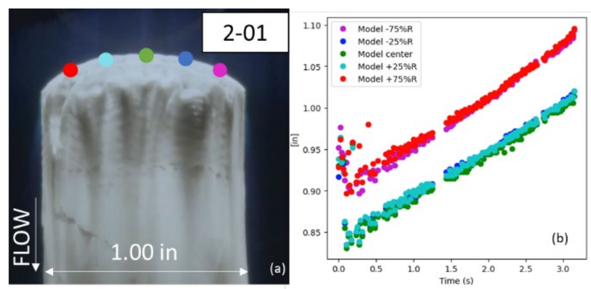

Figure 2. Image capture of 3MDCP exposed in IHF 3-inch nozzle (a). Real-time recession measurements depict model response across time at different radial stations.

Post-test laser scan recession estimates of the material show that the stagnation point recession, and thus the recession rate of the material is reasonably linear across the conditions tested, shown in Fig. 3.

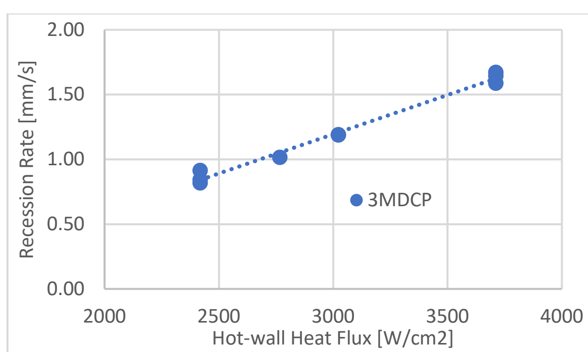

Figure 3.Recession rates for all conditions derived from laser scanner and facility calculated test durations.

Conclusions: 3MDCP tested at a range of environments, and bounding predicted conditions of the earth entry, shows linear recession at the centerline across test conditions and during the exposure. The material response, of each article will be further discussed in the final presentation, along with response model estimates from the Full Implicit Abator and Thermal (FIAT) response code. Follow-on tests are planned to further evaluate material performance and results will be incorporated to highlight material response in configurations that share geometric and material orientation relevance to the forebody heatshield design.

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References:

[1] Quintarte A. and Haw M. (2023) *AIAA, 2023-1012*. https://arc.aiaa.org/doi/abs/10.2514/6.2023-1912