Rotating arc jet test model: Time-accurate trajectory heat flux replication in a ground test environment

Bernard Laub and Jay Grinstead
NASA Ames Research Center
Moffett Field, CA 94035

Artem Dyakonov
NASA Langley Research Center
Hampton, VA 23681

Ethiraj Venkatapathy
NASA Ames Research Center
Moffett Field, CA 94035

Though arc jet testing has been the proven method employed for development testing and certification of TPS and TPS instrumentation, the operational aspects of arc jets limit testing to selected, but constant, conditions. Flight, on the other hand, produces time-varying entry conditions in which the heat flux increases, peaks, and recedes as a vehicle descends through an atmosphere. As a result, we are unable to "test as we fly." Attempts to replicate the time-dependent aerothermal environment of atmospheric entry by varying the arc jet facility operating conditions during a test have proven to be difficult, expensive, and only partially successful. A promising alternative is to rotate the test model exposed to a constant-condition arc jet flow to yield a time-varying test condition at a point on a test article (Fig. 1). The model shape and rotation rate can be engineered so that the heat flux at a point on the model replicates the predicted profile for a particular point on a flight vehicle. This simple concept will enable, for example, calibration of the TPS sensors on the Mars Science Laboratory (MSL) aeroshell for anticipated flight environments.

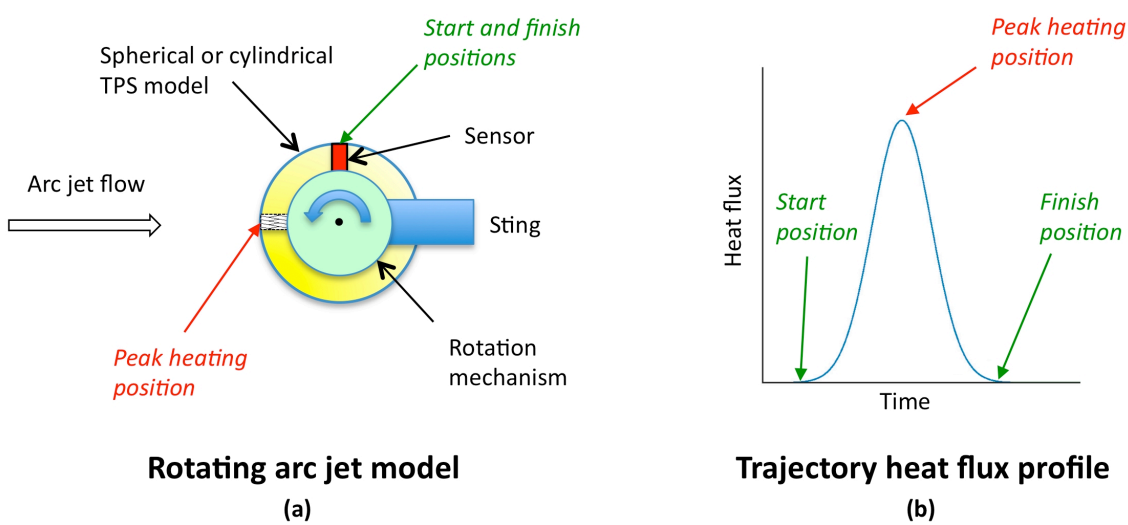

Figure 1: a) Schematic of rotating arc jet model concept. Embedded sensor encounters varying heat fluxes as model is rotated. b) Trajectory heat flux profile and correlation with rotating arc jet model positions.

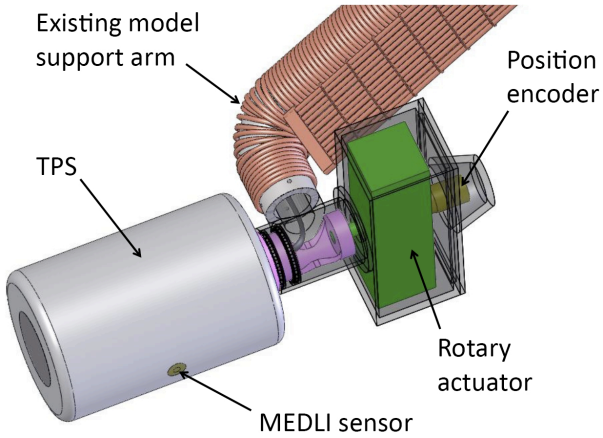

Figure 2: Rotating arc jet test model concept. Hydraulic rotary actuator is encoded to enable precise positional control for time-accurate heat flux profile replication.

During the test, the model is rotated such that the test model's sensor will sweep through points of varying heat flux: near zero when directed away from the flow, and the maximum when the sensor is rotated to the stagnation point. Since the flight profile spans from zero to a maximum and back to zero, the angular direction and instantaneous rate at which the model is rotated will be programmed to realize a time-accurate heat flux profile that maps to the predicted profile for a chosen location on the flight vehicle. The result is a "test-as-you-fly" heat flux condition at the sensor location on the test model, yet requires no change to the facility operating condition. Although the surface pressure at the sensor location cannot follow the flight profile in tandem with the heat flux, the material response will not be significantly affected by small differences in pressure.

The rotation of the cylinder will be accomplished with a programmable hydraulic actuator and position encoder. The transmission mechanism and encoder will be designed to interface with the model support arm and accommodate the sensor's instrumentation wiring. Figure 2 shows a design concept for a cylindrical model shape.

This approach will be applied first to validation of sensor performance for the MSL Entry Descent and Landing Instrumentation (MEDLI). We will present high fidelity rotating arc jet model simulations and analyses of test protocols to realize time-accurate correlation to MEDLI sensor points.