INTEGRATED SELF-HEALING THERMAL PROTECTION FOR HIGH-SPEED VEHICLES

Don King, Johns Hopkins Applied Physics Laboratory, USA
Don.King@jhuapl.edu
Dajie Zhang, Johns Hopkins Applied Physics Laboratory, USA
Steven Storck, Johns Hopkins Applied Physics Laboratory, USA
Daniel Eby, Johns Hopkins Applied Physics Laboratory, USA
Matthew Shanaman, Johns Hopkins Applied Physics Laboratory, USA

High speed aircraft and weapons rely on speed to penetrate enemy defenses before the adversary can successfully react. As adversaries improve their capabilities, there will be a proportionate need for the speed of our weapons and platforms to increase. Since the aero-thermal heating load roughly scales with the square of the Mach number, a doubling of vehicle speed results in roughly a quadrupling of the aero-thermal heating load. This generates a scenario where vehicle leading edges and propulsion components can experience extreme surface temperatures (> 2000 ^{o}C) in oxidizing environments.

Any damage to the vehicle thermal protection system (TPS) can prove fatal since high temperature gases can penetrate into the vehicle and cause catastrophic structural failure. Damage to the external vehicle TPS is driven by several factors: oxidation, thermal stresses, or kinetic impact from fragments (due to hostile weapons or the flight environment). Protection from these damage mechanisms and the ability to heal any damage to the TPS will significantly improve vehicle survivability.

Opportunities to solve this challenging problem exist via use of integrated structures to fulfill the various thermal, structural, aerodynamic, and materials requirements. A refractory metal sandwich structure fabricated by additive manufacturing (AM) technology, then coated with a TPS of ultra-high temperature ceramic (UHTC) materials and subsequently filled with an intumescent TPS material provides a unique integrated structure capable of surviving in high temperature oxidizing environments. The Johns Hopkins Applied Physics Laboratory has designed, fabricated, and tested such integrated AM fabricated structures capable of surviving and functioning in these high speed flight regimes. These integrated structures not only perform under increased thermal loads, but also provide increased post impact protection from damage via passive self-healing of damaged TPS regions.

Recent results from thermal analysis, impact simulation and tests, and TPS tests will be discussed. Aerothermal performance predictions for relevant (unclassified) flight trajectories will be shown. Performance results of integrated coupons evaluated via our high temperature test facility (capable of generating temperatures in excess of 2200 ^{o}C with aeroshear loads in an oxidizing environment) will be presented and linked to aerothermal model predictions (Figure 1). The mechanism for healing impact-damaged coupons will be demonstrated.

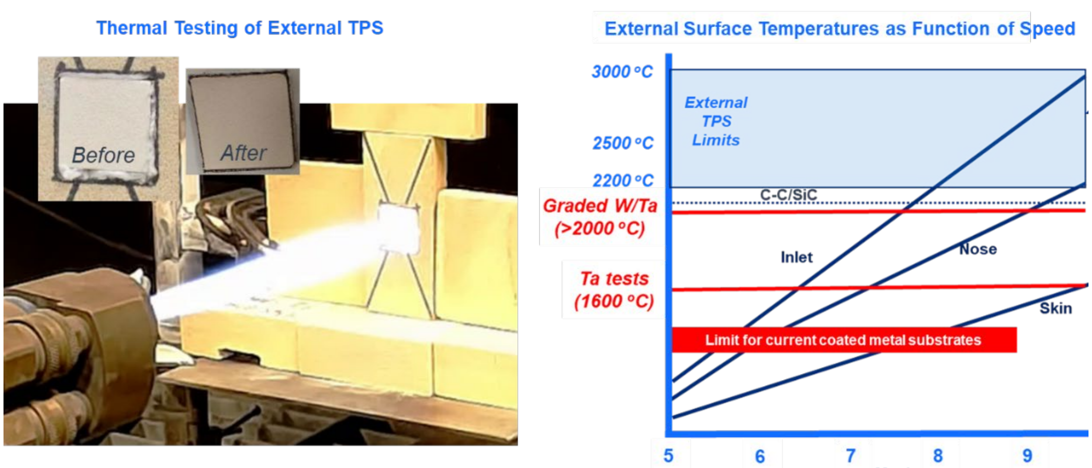

Figure 1 - Thermal Testing Correlated to Predicted Vehicle Temperatures