Heatshield Erosion due to Dust Particle Impacts on the Schiaparelli Capsule During Martian Entry

Grant Palmer[a], Aaron Brandis[a], Jeff Hill[b,*]

[a]*AMA, Inc., NASA Ames Research Center, Moffett Field, CA 94035, USA*
[b]*Aerothermodynamics Branch, NASA Ames Research Center, Moffett Field, CA 94035, USA*

Abstract

On October 2016, a capsule known as Schiaparelli, part of the European Space Agency (ESA) ExoMars mission, entered the Martian atmosphere. Measurements taken during the Schiaparelli descent will be used to validate computational models used to design the thermal protection system (TPS) of future Mars missions [1]. One of the unique features of Schiaparelli entry was the possibility of a major dust storm occurring during the entry. Major dust storms are unpredictable but more likely during the Northern Autumn timeframe. In 2001, for example, regional dust storms merged into a global dust storm that blanketed much of the planet. Even though Schiaparelli did not enter during a major dust storm, future Mars missions will have to account for the possibility of dust erosion (depending on the time of year) when estimating the thickness of the TPS. Because weight is always a critical factor in designing entry vehicles, accurate assessment of dust erosion is necessary to avoid over-design of the TPS.

This study will present computational results of heatshield erosion due to dust particle impacts on the Schiaparelli capsule if it had encountered a dust storm during entry. An uncoupled approach will be used where the particle trajectories are assumed to not impact the shock layer flow. The DPLR CFD code [2] will be used to compute Navier-Stokes flow solutions at 11 points along the entry trajectory. The particle trajectories through the shock layer are calculated by solving a set of coupled ordinary differential equations that make use of the underlying CFD solutions. The particle calculations continue until either the particle strikes the surface of the heatshield, miss the heatshield entirely, or disappear due to surface vaporization. Figure 1 shows a sample calculation where the particle velocity, shown in the circles, of 1-micron diameter dust particles decreases as the particles travel through the shock layer at the 40 km trajectory point. The particle trajectories begin to bend upward due to the effect of the underlying flow velocity.

Once the particle trajectory computations are complete, the information is passed to the Icarus material response code [3]. A dust erosion boundary condition has recently been added to Icarus that computes surface recession due to dust particle impacts. The initial implementation of this boundary condition uses the damage model of Papadopoulos, Tauber, and Chang [4] that is based on Apollo- and Shuttle-era experimental data. Under this model, the heatshield erosion is a function of the number density, velocity, and diameter of the particles at the point of impact. In addition to this model, more recent erosion models will also be implemented into the Icarus material response solver and comparisons between the models will be performed.

Keywords: Thermal Protection Systems, Planetary Entry, Dust Erosion

[*]Corresponding author.
Email address: grant.e.palmer@nasa.gov (Grant Palmer)

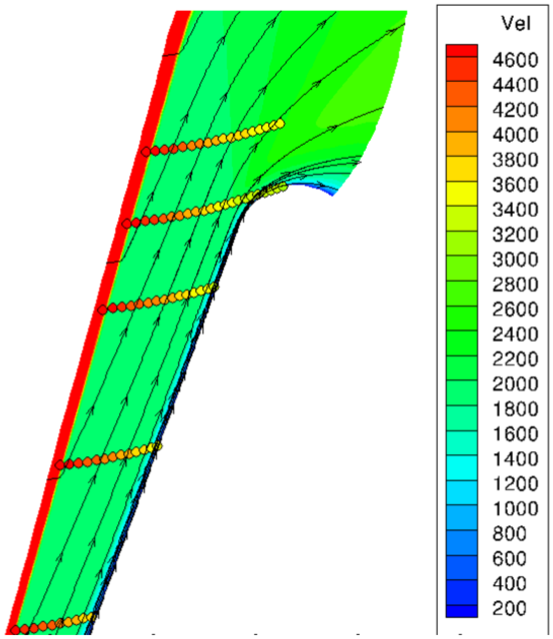

Figure 1: 1-micron diameter dust particle trajectories and velocity magnitude through the shock layer, 40 km trajectory point.

References

[1] A. Guelhan, T. Theile, F. Siebe, R. Kronen, T. Schleutker, Aerothermal Measurements from the ExoMars Schiaparelli Capsule Entry, Journal of Spacecraft and Rockets (2019). doi:10.2514/1.A34228.

[2] M. Wright, T. White, N. Mangini, Data Parellel Line Relaxation (DPLR) Code User Manual Acadia – Version 4.01.1, NASA TM-2009-215388 (2009).

[3] J. Schulz, E. Stern, S. Muppidi, G. Palmer, Development of a Three-Dimensional Unstructured Material Response Design Tool, AIAA Paper 2017-0667 (2017).

[4] P. Papadopoulos, M. Tauber, I-D. Chang, Heatshield Erosion in a Dusty Martian Atmosphere, Journal of Spacecraft and Rockets (1993). Doi:10.2514/3.11522.