URSI GASS 2020, Rome, Italy, 29 August - 5 September 2020

Dust and Atmospheric Effects on Light Gas Gun Hypervelocity Impact Experiments

Benjamin Estacio*(1), Sigrid Close(1)
(1) Department of Aeronautics and Astronautics, Stanford University, Stanford, California, USA.

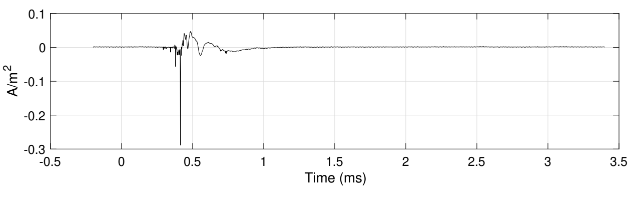
Extended Abstract

Plasma and associated radio frequency (RF) emission produced by hypervelocity impacts of dust and meteoroids are a source of scientific information and a potential hazard to spacecraft electrical systems [1]. A previously unexplored aspect of these impacts is the influence that non-vaporized ejecta, or dust, can have on both the plasma and RF emission. Although initially neutral, this dust can gain a charge through collisions with the plasma potentially forming a dusty plasma. Characterizing impacts with this dust production allows for assessing the threat they pose to spacecraft. This paper investigates the influence that a 0.5 Torr background pressure and dust had on the plume evolution of ground-based hypervelocity impact experiments using the NASA Ames Vertical Gun Range light gas gun. The effects of material and target charge on dust production and dynamics were explored.

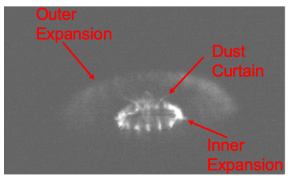
Results from high-speed cameras and plasma sensors are presented in this paper. Faraday cup plasma sensors were designed and built specifically for these experiments. Specific attention was paid to reducing secondary electron emission effects and attaining a fast rise time to capture any transients induced by charged dust. Plasma sensors were placed at 4 elevation angles to measure the spatial distribution of charge.

The background gas had a significant effect on the evolution of the impact plume, slowing it from its jetting velocity of 25 km/s down to 10 km/s. A Rayleigh-Taylor instability was formed in the propagating gases which altered the spatial evolution of the plume, as well as induced mixing which could create RF emission [2]. Matching first order theory to the observed onset distances and velocities confirmed the existence of this instability. From analysis of the gas dynamics the initial plasma density was found to be 1e23 particles/m^3.

Charged dust was confirmed by the Faraday cup measurements for both the regolith simulant and aluminum shots. The trace from the plasma sensor at 60° elevation and a high-speed camera frame from a shot on unbiased aluminum seen in Figure 1 are examples of dust observations. In the sensor trace the dust detections are the impulse-resembling peaks at approximately 0.4 ms after impact. Based on high-speed imagery, we observed that plasma was pulled along the trajectory of the expanding dust curtain. The measured signal from this dragged plasma lasted for 10 times longer than plasma that did not contain dust. Plasma with dust was highly negative with current densities measured by the plasma sensors of up to 0.1 A/m^2 — 10 to 1000 times more dense than measured on sensors at other elevations — putting spacecraft electronics at greater risk of RF interference and electrical discharges.



(a)



(b)

Figure 1. (a) is a trace from the 60° plasma sensor from an unbiased shot on aluminum that shows detection of both ions and electrons as well as charged dust. (b) is a frame from a high-speed camera of the same shot.

References

[1] S. Close, I. Linscott, N. Lee, T. Johnson, D. Strauss, A. Goel, A. Fletcher, D. Lauben, R. Srama, A. Mocker, and S. Bugiel, “Detection of electromagnetic pulses produced by hypervelocity micro particle impact plasmas,” *Physics of Plasmas*, **20**, 9, 2013, doi: 10.1063/1.4819777.

[2] M. Flaig and T. Plewa, “Self-generated magnetic fields in blast-wave driven Rayleigh-Taylor experiments,” *High Energy Density Physics*, **17**, pp. 46–51, 2015, doi: 10.1016/j.hedp.2015.01.005.