Accepted Manuscript

Rarefied Aerodynamics of a Deployable Re-entry Capsule

Stefano Mungiguerra, Gennaro Zuppardi, Raffaele Savino

PII: S1270-9638(17)30936-7
DOI: http://dx.doi.org/10.1016/j.ast.2017.07.007
Reference: AESCTE 4101

To appear in: *Aerospace Science and Technology*

Received date: 23 May 2017
Revised date: 6 July 2017
Accepted date: 8 July 2017

Please cite this article in press as: S. Mungiguerra et al., Rarefied Aerodynamics of a Deployable Re-entry Capsule, *Aerosp. Sci. Technol.* (2017), http://dx.doi.org/10.1016/j.ast.2017.07.007

Rarefied Aerodynamics of a Deployable Re-entry Capsule

Stefano Mungiguerra*, Gennaro Zuppardi, Raffaele Savino
Department of Industrial Engineering, Aerospace Division, University of Naples "Federico II", Piazzale Tecchio 80, 80125 Naples, Italy

Abstract

Several research activities have been already carried out in the field of low-ballistic coefficient re-entry capsules based on deployable umbrella-like aero-shield. The flexible aero-shield, made of ceramic fabrics, acts both as an aero-brake and a Thermal Protection System (TPS), making possible to perform a re-entry from orbital or suborbital conditions with relatively low values of the aero-thermo-dynamic loads.

Previous studies have already analyzed Aerodynamics of similar systems, identifying self-stabilizing configurations and creating a preliminary database of force and moment coefficients in different flight regimes.

This work is intended to provide a systematic overview of the aerodynamic behavior of a deployable capsule in the rarefied regime, where the differences between the re-entry trajectories from Low-Earth-Orbit and suborbital flight conditions are more evident. Particular focus is given to the longitudinal stability analysis, which demonstrates that, as the continuum hypersonic regime approaches, the capsule could show a stable equilibrium condition in the unfavorable reverse attitude. This unwanted equilibrium condition could be counteracted by moving the center of gravity out of the symmetry axis.

Keywords: Atmospheric Re-entry; Direct Simulation Monte Carlo Method; Deployable Capsule Aerodynamics; Longitudinal stability

1. Introduction

In recent times, deployable technologies have gained an increasing importance in the aerospace field, thanks to their key features that make them a light, low-cost alternative to more conventional planetary re-entry systems. The main characteristic of these technologies is the low ballistic coefficient, which makes possible performing an atmospheric re-entry with reduced thermal and mechanical loads. Furthermore, deployable capsules can be easily accommodated into the launch vehicles in the folded configuration and then deployed only when foreseen by the mission profile, with the flexible, high-temperature resistant fabric acting both as an aero-brake and a heat shield for the capsule's payload. Similar concepts make possible: 1) performing an exclusively aerodynamic de-orbiting maneuver without the need for a dedicated propulsive system [1], 2) helping to contrast the phenomenon of the Space debris [2], 3) providing small satellites of "in-orbit control" capabilities, by means of the aero-shield surface area modulation [3].

Examples of inflatable systems, proposed and already tested, are the European Inflatable Re-entry and Descent Technology (IRDT) [4] and the American Inflatable Re-entry Vehicle Experiment (IRVE) [5]. An inflatable Nanosat De-orbit and Recovery System has been specifically designed for CubeSat payloads by Andrews Space [6].

Beside those, different concepts for re-entry systems, based on mechanically deployable heat shields, exist. In 1990, a deployable capsule was developed using an umbrella-like heat shield, made of silicon fabrics, and called Parashield [7]. A similar satellite called Bremsat was studied in 1996 at the University of Bremen [8]. More recent concepts are the ESA's PARES [9], designed for a robotic mission allowing the recovery of a payload from the International Space Station, and the NASA's ADEPT (Adaptive Deployable Entry and Placement Technology) [10], conceived for a human Mars mission.

The present authors already analyzed the trajectory and the aerodynamic behavior of a deployable capsule during re-entry, both from Low-Earth Orbit and suborbital flight conditions [11-13]. In those studies, aerodynamic analyses have been carried out in both continuum and rarefied regimes. Low-Earth-Orbit (LEO)

* Corresponding author.
E-mail address: stefano.mungiguerra2@gmail.com