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Numerical assessment of the flowfield features at the exit of Scirocco plasma wind tunnel nozzle

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Abstract

The simulation of the aerothermal environment that a space vehicle experiences during the atmospheric descent is mandatory for the design of thermal shields of re-entry vehicles. In this framework, both numerical and experimental design approaches, as computational fluid dynamics and plasma wind tunnel simulations, are fundamental. Numerical and engineering analyses of the non-equilibrium flow of Scirocco plasma wind tunnel nozzle, aimed to get test chamber predictions, are described in this paper. A data interpolation code, named SINDA, developed at CIRA in order to support the experimental test activities performed in Scirocco, is presented. SINDA is able to evaluate several flowfield features at the nozzle exit sections, starting only from a limited set of numerical rebuilding of facility tests and using a spline based algorithm. Comparisons between numerical data and SINDA results show good agreement between each other.

Keywords: Computational fluid dynamics; Reacting hypersonic flow; Aerothermodynamics; Plasma wind tunnel; Nozzle flow

1. Introduction

The simulation of the aerothermal environment (e.g., pressure, heat flux and integrated heat load conditions) that a space vehicle has to withstand during the atmospheric descent is of essential interest for the design of thermal shields of re-entry vehicles [8]. This can be done, in a collaborative design approach, by involving both numerical and experimental approaches by means of computational fluid dynamics (CFD) and plasma wind tunnel (PWT) simulations, respectively [1]. For instance, as far as the atmospheric gas flows through the shock wave which envelops the planetary entering vehicle, it is heated to high temperatures and its composition changes as a result of thermo-chemical processes that take place within the shock layer [2]. So, from the experimental point of view, it can be simulated only in a high enthalpy facility by using very energized flows. On the other hand, when a PWT test is performed, it is of upmost importance to be able to compute the flowfield inside the nozzle, in order to ascertain the upstream conditions in front of the model being studied. To date, the world powerful PWT facility is Scirocco, located at Centro Italiano Ricerche Aerospaziali (CIRA). It is a hypersonic PWT based on an electric arc heater (EAH), with a maximum power of 70 MW. This facility allows to simulate experimentally the aero-thermal environment experienced by a space vehicle during an atmospheric entry [13]. For instance, plasma tests enable to verify the thermo-structural resistance characteristics of

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