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A POD-BASED REDUCED ORDER MODEL FOR THE SIMULATION OF SCIROCCO PWT NOZZLES

Abstract

The numerical simulations of the Scirocco Nozzles, able to reproduce critical flight conditions in order to qualify spacecraft components, is very time-consuming due to the very complex physical phenomena involved in. The solution of this flows require an high number of Degrees of Freedom (DOFs) if discretized with a Full Order Model, like a RANS code. From the point of view of the Industrial objectives of the Facility, a fast and accurate rebuilding analysis of a Test Campaign is hopeful and desired, in order to reduce the preparation time needed to design each test (reducing the 'time to market' of the Facility). This considerations represents good motivations to define and build a Reduced Order Model (ROM) of the PWT Nozzles, using the Proper Orthogonal Decomposition (POD) technique. The ROM is based on previous Full Order Model CFD simulations. In particular, a Database of 30 Aerothermal FlowFields of Scirocco nozzles was collected. This DB is presented in two previous works [1,2]. Each realization in DB is a sample of the Operative Envelope of the facility, parameterized in terms of two reservoir parameter: the stagnation Enthalpy, H0, and Pressure, P0. The numerical simulations was conducted with in-house CIRA code, H3NS, able to simulate three-dimensional subsonic, supersonic to hypersonic flows of a reactive mixture of perfect gases in thermal and chemical non-equilibrium. The Proper Orthogonal Decomposition is applied to the DB simulations, resulting in a new representation of this one, described by 'optimal' POD modes ('optimal' in average sense), and scalar POD coefficient, also note as 'evolutionary coefficient'. Defining a functional form of the relation between the scalar coefficients and the PWT reservoir parameters (H0,P0) with Kriging technique, it is possible to evaluate, in the limits of the Scirocco nozzle Envelope, every nozzle conditions with the POD-ROM model here defined, without additional NS computations. Furthermore, a Cross-Validation analysis of the ROM is performed, based on Leave-One-Out technique. This error analysis gives a way to a progressive refinement of the ROM, with further sampling of the envelope of the Facility, selecting regions with large errors. In this way, the POD subspace is enriched. In conclusion, the final tool is a flexible instruments able to compute the full aerothermal flowfield of the PWT nozzle with acceptable approximation, by-passing huge CFD computations.