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Title

Cold-Gas Experiments on Advanced Nozzles in Subsonic Counter-Flows

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Abstract

In recent years, there has been growing interest in Advanced Nozzle Concepts (ANCs) [1], such as aerospike, dual-bell and expansion-deflection nozzles, and their application to Reusable Launch Vehicles (RLVs). This is ascribable to their intrinsic altitude compensation properties, which could mitigate the additional propellant cost resulting from the vertical landing maneuvers based on retro-propulsion [2]. Additionally, design solutions recently investigated, such as film-cooling transition control for dual-bell nozzles and additive manufacturing techniques for regenerative cooling of aerospike engines, could overcome the current technical limitations of these architectures. Despite of a relatively low technology readiness level w.r.t. conventional bell nozzles, further investigations on ANCs in retro-flow scenarios could improve the understanding of retro-propulsion physics. Eventually, their adoption on the upcoming class of reusable launchers would advance the technology for full-recovery of the main stage, thus increasing competitiveness of Europe by lowering down costs of access to space.
The experimental campaign at Technische Universität Dresden (TUD) aims to verify the performance gains of three ANCs (i.e., aerospike, dual bell and expansion-deflection nozzles) by simulating the key phases of a typical landing-burn. This is obtained through various subsonic counter-flow regimes and ambient conditions, generated in the vacuum wind tunnel at TUD [3]. The advanced nozzles are tested with cold-gas (dry-air) and their performances are compared with reference models of conventional bell nozzles. Both the experimental setup and nozzle specimens are introduced, together with details on the test campaign outline. This manuscript concludes with insights on the first comparative results between advanced and conventional nozzles, together with a description of the method of analysis, process of the experimental data and connections with the CFD simulations on ANCs in retro-flow configuration. As final outcome, the experimental campaign aims to simulate the performance of ANCs during a landing maneuver as performed nowadays by private companies such as SpaceX or Blue Origin. Hence, it delivers early results on the feasibility of adopting ANCs as solution for the main propulsion system of the upcoming class of RLVs.
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