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SPACE PROPULSION SYMPOSIUM (C4)
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SECONDARY INJECTION THRUST VECTORING OF AN AXISYMMETRIC CD NOZZLE FOR SMALL SPACE LAUNCHERS & VEHICLES

Abstract

Secondary injection thrust vectoring capabilities are investigated as the segment part of the CNES "Perseus" project. Large reduction in mass, size and complexity comparing to the conventional hydraulic and electro-mechanical systems, faster dynamic response and smaller loss in the thrust specific impulse represent the main promising benefits. Perspectives of the fluidic thrust vectoring are of the special interest to the small satellite launching vehicles and systems as those intended by the "Perseus". Transverse gas injection into an oncoming supersonic flow is the problematic of many aerospace applications, ranging from the scram-jet combustors to the hypersonic vehicle reaction jets and fluidic thrust vectoring of a rocket engine. Induced strong bow shock inside the nozzle causing an adverse pressure gradient which separates the flow from the wall upstream of the secondary injection port. This supersonic cross-flow is then characterized with the complex three-dimensional structures including upstream and downstream vorticity zones, boundary-layer detachment and reattachment, shock interactions and mixing layers. To explore occurring phenomena and thrust vectoring possibilities full scale experimental and numerical investigation is conducted. Hypersonic blow-down wind tunnel EDITH of the ICARE-CNRS is used for the experimental test platform. Truncated ideal and conical contour types nozzle models for launchers upper-stage are designed. Visualization techniques as the Toepler's Z-schlieren are used for the qualitative analysis. The quantitative data are acquired via diagnostic tools for pressure, temperature and mass-flow-rate at every section of the modelled rocket engine installation (radial supply feeding system, chamber, nozzle and exterior ambiance) and at the inlet and chamber section of the secondary injection system. Two-frame complex force balance is constructed and used to measure forces acting on a nozzle in all three space directions. Effects of the secondary injection at the nozzle walls are diagnosed via 11 fast Kulite pressure transducers and via 32 pressure taps of the Scanivalve system sorted along the symmetry and iso lines of the nozzle wall. After the acquisition, the data is treated and compared with the numerical results. Numerical simulations are conducted using the solver of Bertin-CNES CFD code *CPS_C*. The code solves mass-averaged Navier-Stokes equations for compressible and reacting flows on the 3D numerical grid using the 2-equation turbulent models. The obtained results revealed influencing parameters as the position, shape and angle of injection. The investigation showed that significant vector side force and vector angle are possible to be achieved via fluidic thrust vector control system on the rocket nozzle.