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CFD ANALYSIS OF SUPERSONIC TURBULENT COMPRESSIBLE FLOWS WITH DETAILED PLUME STRUCTURE FOR SINGLE AND MULTI-NOZZLES FOR AEROSPACE VEHICLES DESIGN

Abstract

The numerical predictions of supersonic turbulent compressible flows with plume structure in clustered-nozzles have a significant role in robust aerodynamic design of aerospace vehicles for their controllability and maneuverability perspective. During flight trajectory, external pressure around vehicle is continuously being changed from ambient at ground to zero in space which is the most crucial parameter in robust aerospace design. Nozzle pressure ratios are continuously changing during ascending, cruising and descending phase. These also vary when throttling and thrust vectoring is being accomplished. During the ascending phase of flight, aerospace vehicles exhibit different exit pressure as compared to ambient pressure which changes behaviors and its performance. If exit pressure falls below the atmospheric pressure (over expansion) an irreversible phenomena like shock and flow separation occur inside the nozzle and plume structure changes. The over expanded nozzle is considered unsuitable to use as it causes a severe performance loss and such types of cases should be appropriately handled because they change the dynamic of vehicle drastically. In contrary, if exit pressure is greater than ambient pressure, nozzle is under-expanded and its plume expands and thickens significantly w.r.t. altitudes. These thickened plumes start interacting in clustered configuration, which is main source of reverse flow, base heating and performance loss. In this research, numerical simulations are conducted to study the nozzle plume behavior for different pressure ratios at various altitudes (air to space). Reynolds-averaged Navier-Stokes equations with different turbulence models are employed to compute configurations at various NPR (Nozzle Pressure Ratios 5 to 150) and altitudes (0km,3km,6km,9km,15km,21km,30km and 50km etc). The plumes of these configurations are studied both qualitatively and quantitatively and how they affect flow characteristics, thrust performance and vehicle dynamics by interacting with each others. A trend in change of flow structures, shock locations and plume-plume interaction intensity was observed and analyzed. The main focus of this research is to qualitatively describe clustered nozzles plume structure, shock-shock and plume-plume interactions.