Turbulent Jet Flow to Induce Entrainment for Atmospheric Rocket Flight

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Modern rockets pump thousands of tons of soot into the atmosphere, and as human space launches are primed to double again by 2030, the development of more cost-effective and sustainable launch systems is critical. Conventional rockets' specific impulse (efficiency of thrust) is limited by the mass of fuel it burns. However, many airplane engines achieve higher specific impulses by accelerating atmospheric air as well as their own reaction mass (fuel). Thus, this project aims to create a rocket nozzle that can leverage the acceleration of free-stream airflow around the engine to achieve 10% greater thrust than conventional De Laval nozzles while operating under the same conditions. The project employs the phenomenon of air entrainment, the nature of turbulent jet flows to draw in quiescent fluid, to achieve this goal. Rocket nozzle designs were created using Fusion 360 Computer-Aided Design software with the same major dimensions as a benchmark De Laval nozzle. Airflow around geometries was then simulated using SimScale Computational Fluid Dynamics software and post-processed to extract data related to the exhaust velocity and spinning motion (vorticity) of each nozzle. The final "dual slit" design had a statistically significant 66% increase in mass-flow rate as compared to the benchmark De Laval nozzle ($p<0.02$) and a positive correlation between vorticity and mass-flow rate indicates that air entrainment may be responsible for the extra thrust. Though this is an extremely specific case, with real-world testing technology has the potential to reduce the environmental and financial cost of future spaceflight.