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Viscous Effects in Supersonic Micro-Nozzle Flow WILLIAM LOUISOS, DARREN HITT, School of Engineering, University of Vermont — In this study we investigate viscous flow behavior in supersonic micro-nozzles. The supersonic flow field is characterized by $Re < 1000$ so that subsonic boundary layers can occupy a significant portion of the expander section. Numerical simulations are performed for realistic monopropellant flows in both linear and bell- shaped expanders. Emphasis has been on 2-D, adiabatic nozzles under steady and transient flow conditions. Steady simulations have revealed that viscous forces degrade micro-nozzle performance on multiple fronts. First, there is the reduction in flow linked to sizeable viscous subsonic layers near the nozzle walls. Compensating for this by increasing the expander angle, however, incurs performance reduction due to large transverse velocity components at the nozzle exit. Lastly, the under-expanded exit flow in a space environment results in premature flow turning near the nozzle exit due to the upstream propagation of backpressure information via the subsonic layer. For 2-D linear nozzles an expander half-angle of approximately 30° maximizes thrust production– a value roughly 2× that used in macro-scale expanders. Transient simulations reveal a lag in flow response during start-up as flow inertia must initially overcome viscous forces; in contrast, no lag is observed during shut-down as viscous forces aid in the flow reduction. Additional impacts associated with 3-D geometry and heat transfer through the nozzle walls will also be discussed.

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