

Abstract

The Peregrine Solid Rocket Motor (SRM) has experienced failures during static firing tests. Previous computational fluid dynamics (CFD) analysis and examination of recovered Peregrine hardware have led to the conclusion that these failures are caused by failure of insulation between the Peregrine propellant grain and the outer casing near the joint between the grain and the converging portion of the converging-diverging nozzle. The hypothesized mechanism for this failure is mechanical erosion by alumina particles entrained in the swirling global circumferential flow (GCF) in the converging part of the Peregrine nozzle. To understand the development and behavior of this GCF, quasi-steady CFD simulations were conducted in which each simulation had a different number or configuration of propellant grain slots (PGSs). Burn rate coefficients were modified in order to keep the total mass flow rate constant between simulations. GCF was observed in all simulations with more than one PGS. Angular momentum in the aft enclosure (the combined converging nozzle and nozzle joint volume) was greatest in the 4-Slot and 3-Slot simulations, and decreased in the 5-Slot simulation. Axial velocity in the Peregrine bore decreased monotonically with increasing PGS count. Heat transfer to the converging nozzle surface was greatest in the 3-Slot and 4-Slot simulations, while heat transfer to the nozzle joint was lowest in those simulations. The 3-Slot and 4-Slot simulations show the highest erosive burning potential on the aft grain surface. To determine whether the GCF effects were an artifact of quasi-steady simulations, a time-varying 3-Slot ignition simulation was conducted. Its results were similar to the quasi-steady 3-Slot simulation, with similar magnitudes of GCF and surface heat transfer. Though previous Peregrine 1.1 simulations showed a high rate of particle impacts on the nozzle joint surface, Peregrine 2.0 simulations showed only half as many impacts in that location. The low rates of heat transfer and particle collisions in that region suggest that changes to the Peregrine geometry between Peregrine 1.1 and 2.0 influence the internal flow field, and that GCF is not the only factor influencing interactions between the flow field and the nozzle joint. Further research is needed to determine how the flow field evolves as the grain recedes.