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# COLD FLOW SIMULATION OF COMPOUND SWIRLING OXIDIZER INJECTION FOR HYBRID ROCKET PROPULSION

**Abstract**

Hybrid rockets consist of two different types of propellants. Though hybrid rockets have many advantages such as throttlabitliy and non-explosiveness, and they do not progress to their practical use due to the challenges on the performance. One of the most critical problems is low thrust due to low fuel regression rates. In order to solve this disadvantage, recently, hybrid rockets using swirling oxidizer injection such as Swirling Oxidizer Flow Type (SOFT) hybrid rocket by Yuasa et al. have attracted researchers' attention. They demonstrated that this type increases fuel regression rate 3 times larger than the conventional types. This method was intended to enhance heat transfer to solid fuel using a large tangential velocity of oxidizer flow. Ozawa et al. have applied the dependence of regression rates on swirl strength to control both thrust and maintain the optimal O/F by arranging an axial injector with an oxidizer feed branch independent of swirling injector. They designated this type as "Altering-intensity Swirling Oxidizer Flow Type (A-SOFT)" hybrid rocket. They demonstrated that various fuel regression rates to change the oxidizer mass flow and swirl strength with a fixed configuration of the combustion chamber. Although the concept of A-SOFT was demonstrated, the injectors have not been optimized to provide the smooth controllability for various oxidizer mass flow rate and axial-tangential flow rate ratio. The goal of this research is to propose the optimal design of the injector for A-SOFTs using computer fluid dynamics (CFD). As the first step of the research, the cold flow of oxidizer provided by the injector by Ozawa et al. is simulated for various axial and tangential oxidizer flow rates. Because it is known that typical Reynolds Averaged Navier-Stokes (RANS) models do not provide proper eddy viscosity for swirling flows, this research adopts Large Eddy Simulation (LES) as the turbulence model. The results of the LES for various axial and tangential oxidizer mass flow rates are compared to each other from the aspects of the similarity of the flow field and velocity on the edge of the boundary layer. In addition, the results of LES are also compared with those of RANS carried out as a preliminary study. The results of RANS showed that the two flows were largely separate and the interaction or mixing between the oxidizer flows from the two injectors was hardly observed.