Flow Field 3D Waverider Optimization of a Variable Hypersonic Scramjet

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Hypersonic travel provides numerous opportunities for faster travel through the atmosphere. This leads to potential benefits such as fast trade, increased access to space, quicker emergency response, new high-speed military technology, and more. It can be said that the heart of any hypersonic vehicle is its engine: the scramjet. Scramjet engines provide a highly efficient method of hypersonic travel through precompressed air driven by shock waves at supersonic velocities. Thus, these engines remove the need for turbomachinery. However, scramjets still lack efficiency in their inlet throat airflow capture, suffer from poor lift-to-drag ratios, exhibit slow transverse fuel injection and combustion rates, poor thermal protection, and inefficient fuel mixing. In this study, we present a novel methodology for inversely carving a hypersonic “waverider" scramjet out of a predetermined 3D flow field, allowing for scramjet geometry optimization from given design hyperparameters. To correct various scramjet inefficiencies, a conical shock wave was used to replace turbomachinery compression instead of an oblique shock wave. A series of equations were generated from the modified Taylor-McColl relationship to define optimal conical shock geometry using non-uniform rational B-splines, allowing for efficient scramjet modeling. A novel hyperparameterized osculating freestream surface was designed which produces shock waves that allow for compression to occur prior to inlet entry. Subsequently, an artificial genetic algorithm optimization was designed” to develop an effective scramjet geometry. Optimal scramjet geometries are obtained for various design parameters and are subsequently tested using computational fluid dynamics, Euler numerical approach, and wind tunnels.