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Author: Mr. Christian Bach
Technische Universität Dresden (DTU), Germany, christian.bach1@tu-dresden.de

Mr. Martin Propst
TU Dresden, Germany, martin.propst@tu-dresden.de
Mr. Jan Sieder-Katzmann
TU Dresden, Germany, jan.sieder-katzmann@tu-dresden.de
Prof. Martin Tajmar
TU Dresden, Germany, martin.tajmar@tu-dresden.de
Mr. Bernhard Bust
Technische Universität Dresden (DTU), Germany, bernhard.bust@mailbox.tu-dresden.de
Ms. Sarah Schöngarth
Technische Universität Dresden (DTU), Germany, sarah.schoengarth@mailbox.tu-dresden.de

HOW TO STEER AN AEROSPIKE

Abstract

As an alternative to classical bell nozzle designs, aerospike propulsion systems have been developed and tested since the 1950s. They have been in discussion for the upper stage of Saturn V and later for the Space Shuttle Main Engine. In the form of a linear plug construction, the nozzles were the single-stage-to-orbit propulsion system of choice of the X-33 Mission at NASA during the 1990s, which is also known as Venture Star. Nevertheless, there still is a lack of ground and flight test data that would enable a verification of analytical or numerical flow predictions. This lack of data leads to a low technical readiness level (TRL), which is the reason that still there has not been an operational deployment of an aerospike rocket on a space mission. However, in recent years, aerospike engines experience a renewed and growing interest because of their well known altitude adaptive properties and further advantageous performance characteristics towards comparable bell nozzles. Still, one putative disadvantage of aerospike engines is that traditional thrust vector control cannot be applied. Conventional bell nozzles are gimballed as a whole. Due to the large diameter of aerospike engines close to the diameter of the launch vehicle, swiveling of the whole engine around a single flexible joint is rather challanging. This steering method is also not desired, because it would foil the advantage of a well distributed thrust load transmission and thus any savings in thrust frame mass. Therefore, advanced TVC methods have to be considered. While thrust vectoring for aerospike engines with combustion chamber segments can be achieved with differential throttling, a different solution must be found for smaller single-chamber engines. A promising approach is aerodynamic thrust vectoring by secondary injection (Secondary Injection Thrust Vector Control – SITVC). Here, the main exhaust flow is diverted by injecting a secondary fluid flow from the central spike orthogonally to the spike surface. While previous works have demonstrated the advantages over conventional TVC methods and the feasibility of SITVC for aerospike engines by means of numerical flow simulations and shallow water flow experiments, this paper presents concepts for the actual technological realisation of the SITVC. Therefore, fundamental trade-offs for engine types, propellants, engine cycles, cooling cycles, combustion chamber layout and the injection site itself are discussed, including an analysis of the state of the art of aerospike engines. Furthermore, engine design concepts are being presented, which implement the above mentioned design factors.