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DESIGN, EVALUATION AND TESTING OF AN ETHANOL/LOX SOUNDING ROCKET PROPELLED BY A REGENERATIVELY COOLED ROCKET ENGINE WITHIN THE STUDENT INITIATIVE WARR

Abstract

By developing a bi-liquid cryogenic sounding rocket, members of the student initiative WARR e.V. (German for *Scientific Workgroup for Rocketry and Spaceflight*) have sought to verify educational approaches and project design in aerospace technology development. Project Nixus, initiated in 2020, shall allow young engineers to gain both theoretical knowledge and hands-on experience in the aerospace domain, giving them the skillset demanded in the growing new-space industry. This has been achieved by focusing on three major aspects.

Foremost, the team has developed a reusable, regeneratively cooled rocket engine, additively manufactured in Inconel 718. Being propelled by liquid oxygen and an ethanol-based fuel, the engine delivers a thrust of 3.5 kN. Secondly, using a model-based systems engineering approach, it has been possible to evaluate early design uncertainties, enabling parallel development of the complete rocket. Finally, the project has promoted knowledge exchange with other student teams, further contributing to student rocketry.

The three-year development plan for the propulsion subsystem included the design, manufacturing, and testing of a sub-scale engine prior to the completion of the actual flight hardware. This engine was designed to be capacitively cooled to reduce complexity and sufficiently robust to allow the team to gain comprehensive testing experience. A particular focus was put on design verification of the triplet impinging injector. In parallel with hot fire tests of the sub-scale chamber, the flight engine was developed.

The propulsion system has proved to work successfully in multiple hot fire test campaigns on the ground test infrastructure. The gathered results show the engine operate at its nominal load point, achieving a chamber pressure of 25 bar. Additionally, the analysis of the gathered data has indicated combustion efficiencies exceeding 95%. Most notably, the propulsion system was integrated into the Nixus EX-4 rocket and successfully completed the integrated commissioning hot fire tests, leading to a launch attempt at the European Rocketry Challenge (EuRoC) 2023 and the achievement of the EuRoC Design Award.

Although there are some open points regarding the scientific evaluation, it has been shown that the presented development approach is not only feasible, but also exceptionally instructive from an educational point of view.