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DESIGN AND ANALYSIS OF A NOVEL SWIRL-PINTLE COMBINED FUEL INJECTOR FOR IMPROVED PERFORMANCE OF LIQUID ROCKET ENGINES

Abstract

The use of liquid propellants in rocket engines offers several advantages, including high thrust-to-weight ratios, enhanced specific impulse, and the ability to adjust thrust levels. These propulsion systems are advantageous mainly due to the usage of fuel injectors. This study demonstrates a brand-new fuel injector design that combines the benefits of swirl-coaxial and pintle injector types that are already in use. While the former has proven effective in delivering high atomization and mixing of the propellants for stable combustion, the latter is renowned for its ability to provide larger mechanical throttling of bipropellant flow rates. The proposed design consists of two coaxial cylindrical systems with separate swirls for the fuel and oxidizer, inspired by the famous RD170 injector, which was slightly modified to accommodate a solid rod-like structure or the pintle rod, that passes through the inner cylinder with a flat face, facing outwards at the exit of the injector. Thus the position of the pintle face directly determines the flow rate of the exiting fuel-oxidizer mixture thus ensuring mechanical control of the flow rate without altering the flow parameters in the propellant supply lines.

The study focuses on maximizing the benefits of both injector types while overcoming their respective drawbacks. The flow pattern and other fuel properties departing the injector are studied and understood using numerical simulations and multifluid flow analysis, and the results are studied to enhance injector performance. Greater control over the flow rate of bipropellants and better atomization rates could be made possible by combining pintle and swirl-coaxial injectors, leading to more effective and stable combustion. This was proved by analyzing the injector performance using advanced flow simulation softwares utiling VOF to DPM spray analysis models and the impact of the injector design on the engine's performance improvement was also verified utilizing the NASA CEA software.

The suggested fuel injector concept is a significant advancement in the field of liquid fuel-based rocket propulsion systems. This research provides an in-depth examination of the design, modeling, and analysis of this special rocket fuel injector utilizing design calculations, numerical simulations, multifluid flow, and chemical equilibrium analysis.The proposed design has the potential to revolutionize the liquid rocket engine sector by incorporating pintle and swirl-coaxial injector technologies. This will give the space community, robust insights for the development of more effective and reliable fuel injectors that will support the growth and expansion of space exploration.