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ENHANCING COMBUSTION EFFICIENCY THROUGH INJECTOR DESIGN IN HYBRID ROCKET ENGINES

Abstract

The injector design is a key aspect in the performance of hybrid and liquid rocket engines. These components are responsible for regulating the mass flow of the oxidizer through the combustion chamber, which directly influences the final thrust curve of the engine and its specific impulse (ISP). Since there are different configurations and geometries for injectors, it is crucial to analyze their performance to select the most efficient option based on the specific characteristics of each engine.

In this study, two types of injection patterns, namely shower head and impinging, will be evaluated both theoretically and experimentally, comparing their performance in a hybrid rocket engine using nitrous oxide and paraffin as propellants. The main goal is to determine the advantages of one geometry over the other, characterizing atomization and how this affects the oxidizer and fuel mixing ratio during combustion. From the gathered information, it will be possible to identify which geometry offers the highest efficiency for a predetermined engine.

Thermodynamic conditions were established before and after each injector design, along with the required mass flow. Additionally, measures were proposed for subsequent analysis and validation. Parameters to assess atomization performance were also defined, complemented by CAD geometry designs and simulations using Computational Fluid Dynamics (CFD) to validate their operation.

Finally, based on the data obtained from these processes, the necessary information was gathered to conclude that in a hybrid rocket engine powered by nitrous oxide and paraffin, optimizing the atomization process of the oxidizer flow in impinging injectors significantly improves combustion efficiency and allows for controlling the regression rate of paraffin. This is crucial to prevent the solid fuel from being consumed uncontrollably and faster than planned.

In this way, by optimizing combustion, a significant cost saving is achieved, strengthening the sustainability of the system. The reduction in propellant consumption not only decreases operational costs but also opens new opportunities for space exploration. By expanding access to space, it facilitates the participation of more countries, even those with limited resources, creating a more competitive scenario in the race for space exploration.