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Hypersonic Air-breathing and Combined Cycle Propulsion, and Hypersonic Vehicle (7)

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NUMERICAL ANALYSIS OF ROCKET STAGED COMBUSTION WITH AIR-STAGED AND FUEL-STAGED SUPPLIES FOR HIGH-COMBUSTION PERFORMANCE AND LOW-POLLUTANT EMISSIONS

Abstract

Amongst the various methods and techniques applied to enhance rocket ballistic and combustion performance, solutions with low-pollutant emissions remain those of first choice. The objective of this study is to investigate, theoretically and thermodynamically, the main parameters controlling staged combustion and the performance achieved through different propellants combination with varying mass fractions, while providing an overview on the current and future challenges that can encounter the future aerospace exploration and transportation missions using such systems. Staged combustion can be applied in two different ways, air staged supply and fuel staged supply. Using the Rocket Propulsion Analysis, Python, Matlab, and Fluent at different levels of the numerical work, both ways have been investigated. In the first method, combustion air is supplied via two sections, primary and secondary flows. The mass fraction of primary air mixed with fuel is varied, when it is between 0.7-0.9, it occurs at relatively lower temperatures, oxygen-deficient, fuel-rich zone, leading to only moderate amounts of Nitrogen Oxides (NOx) formation. As for the secondary air mass fraction, it is also introduced into the combustion zone with different values, varying with the primary air fractions variation. Thus, under some specific conditions, complete combustion, and Nitrogen (N2) formation, by limiting the formation of thermal NOx, can be achieved. The location of the injectors and the chamber design are of a paramount importance to achieving combustion efficiency. For fuel staged combustion, or fuel biasing, it consists of fuel-rich and fuel-lean zones, whether from upper-stages to lower ones or from the center to the sides, to achieve some emissions control and complete combustion. It also occurs at relatively lower temperatures, while oxygen is well balanced and NOx emissions are reduced. However, the efficiency of a rocket in terms of spacecraft propulsion depends on the achievable exhaust velocity and mass ratio; thrust is mostly important for the first stage of a launcher. All these parameters are defined by the rocket design and propellants combination.