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ROCKET PERFORMANCE OPTIMIZATION FOR AEROSPACE PROPULSION AND SPACE TRANSPORTATION

Abstract

Much of the efforts in rocket design for aerospace propulsion and space transportation target the increase of the exhaust velocity, which is the most important performance indicator, as it determines the final velocity, the mass ratio, and it is the major contributor to thrust development. One should note that the magnitude of the exhaust velocity is dependent on molecular and chemical properties of the propellant, which means molecular weight and combustion temperature, and the expansion ratio of the engine, which means the nozzle design. Indeed, if the length of the nozzle increases, the exhaust pressure will decrease, which will also affect the exhaust velocity; thus, the exhaust nozzle should be optimized to make the exhaust pressure equal to the ambient pressure. The main requirement for all propellant combinations is to maximize the energy release per kilogram; in other words, the lower the mass for a given energy release, the higher will be the ultimate velocity of the vehicle. This also implies that the mass flow rate depends on the density, i.e. $\sqrt{\frac{M}{T_c}}$, while the exhaust velocity depends on the energy contained in the hot gas, i.e. $\sqrt{\frac{T_c}{M}}$. For instance, for multistage rockets, usually engines with high thrust, or propellants with high molecular weight, are used for sea level; while engines with high exhaust velocity, or propellants with low molecular weight, are used for altitude. From this, the main performance parameters can be defined as the thrust coefficient (nozzle performance) and the characteristic velocity (propellant and combustion performance), the first parameter reaches its optimum when the exhaust pressure is equal to the ambient pressure while the second parameter is defined by the choice of propellant combination. The objective of this work is to investigate different combinations of fuels and oxidizers, for different types of propulsion, i.e. liquid, solid and hybrid propulsion systems. The selection criteria are based on the best propellant combinations that can provide the rocket engine with the best performance for the considered application. Rocket Propulsion Analysis is used to obtain the combustion composition, analysis of nozzle flows and calculation of engine performance, Python is used for algorithms implementation and the Python package: Proptools is a Python package for preliminary design of rocket propulsion systems. Relationships defining thrust, velocity and specific impulse involving the combustion temperature, molecular weight, density of the propellant combination, specific energy and energy densities are also established.