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ENERGETIC HYBRID ROCKET PROPELLANTS FOR UPPER STAGE PROPULSION

Abstract

Rocket engines for upper stages generally use liquid propellants which are desirable because of their reasonably high specific impulse and control. A higher specific impulse implies lower duration to achieve design cruise velocity for a given rocket initial and instantaneous mass. In rockets three main liquid bipropellant combinations are used – cryogenic liquid oxygen liquid hydrogen; cryogenic oxygen and hydrocarbon (semi-cryogenic combination) and the Earth-storable propellants. Since the past few decades, cryogenic propellants viz., liquid hydrogen and liquid oxygen are widely used for upper stages due to their high specific impulse. An aspect of concern is the high pressure cryogenic storage tanks that must be able to withstand high pressure thus making fuel tanks bulky needing heavy insulation to store propellant thereby, reducing performance and practicality. The over-dependence on cryogenic propellants has necessitated active research efforts for efficient alternatives. As an attractive alternative, the combination of Dinitrogen Tetroxide (N2O4) and Monomethyl Hydrazine (MMH) is used for many space applications owing to an extreme storage stability and hypergolic nature. The combination is extensively used in orbital maneuvers, reaction controls, and launch vehicle propulsion. The relatively high density of MMH and N2O4 leads to lower volume of the propellant tanks allowing possible use of lightweight centrifugal turbo-pumps to pump the propellant from the tanks into the combustion chamber, which means that the propellants can be kept under low temperature such as insulation from heat sources viz. engine exhaust air friction during flight. Also, the hypergolic nature of the propellant combination dismisses the need of an ignition system. However, the propellant combination yields low performance (moderate specific impulse). Present work addresses issue of an imperative alternative to the conventionally used cryogenic bi-propellant combination of Liquid Hydrogen (LH2) and Liquid Oxygen (LOx) for upper stage rocket propulsion. Combination of Dinitrogen Tetroxide (N2O4) and Monomethyl Hydrazine (MMH) is selected as the base composition for enhanced upper stage performance and carbon is added as an energetic additive (for increasing its performance) by using standard NASA-CEA complex chemical equilibrium program (NASA-CEA®). The performance is evaluated in terms of variation in specific impulse evaluated as a function of chamber pressure and supersonic nozzle expansion ratio.