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NON-UNIFORM HEATING IMPACT ON SPECIFIC IMPULSE IN NUCLEAR THERMAL PROPULSION ENGINES

Abstract

One potential game-changing technology for future crewed missions to Mars is Nuclear Thermal Propulsion (NTP). NTP rocket engines offer higher specific impulse than chemical engines, which allows for shorter mission travel times. However, NTP engines typically experience non-uniform heating profiles caused by different heat generation rates in the fuel elements over the cross-section of the engine core and difficulty in dissipating heat generated near the center of the core compared to the edge of the core. These effects can lower the engine performance. This study defines the causes of non-uniform heating and evaluates the impact to specific impulse. Previous investigations examined heat generation profiles from specific engine designs, which required extensive neutronics calculations and simulations to achieve appropriate accuracy. An alternative method is to utilize mathematical distribution models of heating profiles. This study generates computational normal, bimodal, and skew distributed heating profiles, based on previously studied profiles, to compare the impact various distributions have on the specific impulse. The conducted analysis finds considerable agreement between the mathematical heating profiles and historical studies specific impulse results, which lead to the development of correlation equations between heating factor standard deviation and engine specific impulse. The correlations reveal that engine performance, specific impulse, decreases as the variation in heating factor increases. An option to address this issue, coolant channel orificing, delivers improved engine performance at lower propellant mass requirements. Developing a method which quickly estimates the impact of non-uniform heating is necessary for preliminary engine design and will lead to further investigation of improved strategies to address this issue, such as mass flow orificing or fuel loading.