Paper ID: 72246
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IAF SPACE PROPULSION SYMPOSIUM (C4)
Interactive Presentations - IAF SPACE PROPULSION SYMPOSIUM (IP)

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COMPUTATIONAL MODEL FOR PERFORMANCE PREDICTION OF A NITROUS OXIDE / EICOSANE HYBRID ROCKET ENGINE

Abstract

A computational model is developed to predict the performance of a nitrous oxide / eicosane hybrid rocket engine, based on basic thermodynamics and gas dynamics assumptions. The model aims to assist the development of the McGill Rocket Team's first hybrid rocket engine: it is used to determine the propellant quantities required to bring an amateur rocket with a dry mass of approximately 50 kg to a target apogee of 3048 m (10,000 ft). The transient solver programmed in MATLAB considers: a self-pressurizing nitrous oxide oxidizer tank in quasi-steady liquid-vapour equilibrium; a one-dimensional shower head injector; a combustion chamber containing a hollow cylindrical paraffin wax fuel grain assumed to be in quasi-steady chemical equilibrium; and a one-dimensional nozzle flow model. The liquid-vapour mixture in the oxidizer tank is assumed to obey Raoult's law, and semi-empirical correlations for nitrous oxide properties are used to resolve the transient tank state. The oxidizer discharge to the combustion chamber is resolved with an axial shower head injector discharge model, which couples the oxidizer tank feed-forward pressure to the chamber feedback pressure. An empirical model is considered in the combustion chamber to predict the fuel grain regression rate, with ballistic coefficients found in the literature. The chamber combustion gas properties are computed with the PROPEP chemical equilibrium code, and conservation of mass along with the ideal gas equation of state are used to predict the transient chamber pressure. The one-dimensional converging-diverging nozzle solver assumes ideal isentropic gas expansion, while also accounting for the possible formation of a normal standing shock wave in the nozzle diverging section. Instantaneous performance parameters such as theoretical thrust and specific impulse are analyzed for different operating conditions. The model is compared against the McGill Rocket Teams's hot fire test data, and its validity is assessed.