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MODELING AND SIMULATION OF IN-ORBIT CENTRIFUGAL CASTING OF A PARAFFIN WAX GRAIN INSIDE A 3U CUBESAT

Abstract

Continued interest in paran wax as a high-performing hybrid rocket fuel motivates the investigation of the use of paran for small satellites. Shorter-chained paran waxes have been used as phase change materials for thermal insulation onboard satellites dating back to the Apollo missions, but paran has yet to be leveraged as an in-space propellant (1). The purpose of this research is to explore the possibility of using paran wax as fuel to deorbit small satellites, potential mean to tackle space debris mitigation.

Experiments conducted by the Space Enabled Research Group have been characterised by the use of paran as working uid, with rotation rates ranging from 50-1500 rpm, and initial temperature of 75-100 C. The expectations are that the microgravity environment will reduce the rotation rates required to cast the wax into the desired shape (2).

The work conducted by the authors investigates the possibility of performing centrifugal casting of paran into annular shapes while the spacecraft is in orbit. The adopted strategy considers using the wax as thermal insulator and, at the end-of-life, recast it as fuel to allow a controlled reentry of the satellite.

The workow is conceived such that the wax will be melted and conveyed into the combustion chamber, which - spun by a DC motor - allows the wax to be shaped into a hollow cylinder, one of the most ecient shapes to burn the wax (3). Future extensions of this research will involve the design of a thermal bus capable of melting and conveying the wax inside the combustion chamber.

This work is developed under the assumption that the wax is already inside the combustion chamber, and the simulations conducted take into account the grain formation mode and the reentry trajectory design.

The generated model is based on the propagation of a quasi-ISS orbit including all relevant perturbations, coupled with the true attitude measured by onboard sensors. Then, these two are coupled with a multi-node thermal model used for a transient thermal analysis, which considers direct solar radiation, Earth albedo, infrared radiation and internal power dissipation.

It is shown that the stability of the spacecraft can be maintained with minimum eort, especially due to the low inertia of the rotating device. Also, with passive thermal control, the wax endures the eclipse-sunlight cycles and is kept below its melting temperature. The deorbit of the spacecraft can also be accomplished by considering the theoretical performances of the paran wax engine with one burn only, optimised to lower the altitude of the spacecraft enough to induce atmospheric reentry.

References

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