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Microgravity Experiments from Sub-Orbital to Orbital Platforms (3)

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DESIGN AND ANALYSIS FOR CENTRIFUGAL CASTING OF WAX ON SUBORBITAL AND ORBITAL PLATFORMS

Abstract

Centrifugal casting of paraffin and beeswax has been shown to reliably yield hybrid rocket fuel grains with superior structural integrity compared to those produced via drip casting [1]. As waxes are increasingly considered as fuels for in-space propulsion, the ability to centrifugally cast wax in the microgravity environment of low Earth orbit requires in-depth investigation. Prior work demonstrated the successful miniaturization of the centrifugal casting process for both laboratory and microgravity experimental setups [2-4]. Those papers reported results from two parabolic trajectory aircraft microgravity flights with the Zero G Corporation alongside tabletop experiments.

Currently, four microgravity flights are scheduled for the upcoming year: a third aircraft flight scheduled for 2021, two suborbital spaceflights onboard the Blue Origin New Shepard vehicle, and a 30-day mission within the Destiny module of the ISS scheduled for launch in summer 2021. The initial New Shepard flight experiment is constrained to a 2U form factor, while the second flight experiment will benefit from the 25X greater volume of a single payload locker.

This paper describes the approach to design and analysis for each of these three experimental platforms and details the adaptations made to the centrifugal casting experiments to meet various environmental demands, including mass, volume, power, and thermal requirements. Notably, the casting experiment requires local temperatures in excess of 50 deg C to melt the wax prior to casting, and extensive thermal modeling was conducted in order to ensure that neighboring experiments were not adversely affected.

An image analysis technique was developed and employed in each case to automate the process of determining instantaneous solidification rates in the molten wax for various centrifuge rotation rates. The solidification rate influences material properties of the wax and is corroborated by a parallel in-depth modeling study conducted by Ngetich et al. [5].

[1] Stober, K.J. et al., "An Investigation of the Centrifugal Casting of Paraffin Wax in the Laboratory and in Microgravity," AIAA 2019-4012

[2] Stober, K.J. et al., "An Investigation of the Laboratory-Based and Microgravity Centrifugal Casting of Paraffin Wax," IAC-19-A2.3.1.52725

[3] Stober, K.J. et al., "Centrifugal Casting of Paraffin and Beeswax for Hybrid Rockets," AIAA 2020-3736

[4] Stober, K.J. et al., "Leveraging Microgravity to Investigate Earth- and Space-Based Centrifugal Casting of Wax," IAC-20-A2.3.4.58780

[5] Ngetich, G.C. et al. "Centrifugal Casting of Paraffin Wax: Numerical Simulation...", Submitted, IAC-21-C4.4