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

Author: Dr. Javier Stober
Massachusetts Institute of Technology (MIT), United States, stober@mit.edu

Ms. Maria Regina Apodaca Moreno
Mexico, regina_apodaca@ciencias.unam.mx
Dr. Gladys Ngetich
Massachusetts Institute of Technology (MIT), United States, gladysn@mit.edu
Ms. Anika Kamath
Massachusetts Institute of Technology (MIT), United States, akamath@mit.edu
Ms. Dinuri Rupasinghe
Massachusetts Institute of Technology (MIT), United States, dinurir@mit.edu
Prof. Danielle Wood
Massachusetts Institute of Technology (MIT), United States, drwood@media.mit.edu

EXPERIMENTAL STUDY OF WAX FUEL FORMATION DURING SPACEFLIGHT

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 [2-6]. Those papers reported results from three parabolic trajectory aircraft microgravity flights with the Zero G Corporation alongside tabletop experiments. Currently, four microgravity flights are scheduled for the upcoming year: a fourth aircraft flight, 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 spring 2022. 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. Furthermore, additional flights afford the opportunity to test both rotating and non-rotating casting experiments, as well as non-casting wax-based experiments. 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. [7].

[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] Stober, K.J., et al., "Design and Analysis for Centrifugal Casting of Wax on Suborbital

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