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DESIGN AND DEVELOPMENT OF A CENTRIFUGAL CASTING EXPERIMENT FOR THE ON-ORBIT MANUFACTURING OF WAX-BASED PROPELLANTS

Abstract

The Space Enabled Research Group at MIT has a long-running research program investigating the use of paraffin waxes as solid fuel grains in hybrid propulsion systems for in-space propulsion. Our research focuses on manufacturing these fuel grains in space through centrifugal casting, wherein a tube containing paraffin wax is heated to melt the wax, then cooled while rotating. This process creates an annular-shaped solid fuel grain that can be combusted with a liquid oxidizer injected through the hollow centre. Our research focuses on both scientific and engineering aspects of this in-space manufacturing process. Engineering interests cover the systems design and operations of the components required to facilitate rotation and heat exchange in the materials. Scientific interests cover aspects of the fundamental behavior of materials in space, such as the effect that microgravity and vacuum conditions have on fluid flow and heat transfer.

The research program has progressed over several years to demonstrate centrifugal casting of waxes in different microgravity environments. Previous works by the authors have presented findings from numerical thermal/fluid dynamics simulations, ground-based laboratory experiments, reduced-gravity parabolic flights, and suborbital launches. These results have demonstrated the validity and performance of some aspects of the centrifugal casting process. However, the short-duration of microgravity experienced in parabolic and suborbital flights were not sufficient to demonstrate the full melting/casting cycle.

This paper describes the design and operations planning of a modified version of the experiment to be hosted on the International Space Station, within the Space Tango CubeLab facility. This orbital platform will provide extended periods of microgravity, allowing testing of full cycles of melting/casting to ambient temperatures. Multiple melting/casting cycles will be tested to investigate the influence of rotation rate and temperature control conditions on the casting process. The operations have been designed to run the melting/casting processes as separate experiments, with parameterized inputs to give full control over experimental conditions. The CubeLab facility provides two-way communication to a flight computer, allowing tele-operational control of the experiment, and relaying of experimental data in near-real time. This will allow us to adapt experimental runs based on results from preceding experiments. This version of the experiment has seen significant improvements in the mechanical design, creating a more compact design with increased structural stability of the rotating components. This version also introduces new components including a fan and temperature controller, to provide greater thermal control during the melting and cooling phases.