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Additive Manufacturing of High Solids Loading Hybrid Rocket Fuel Grains

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ABSTRACT

Hybrid rocket motors offer many of the benefits of both liquid and solid rocket systems. Like liquid engines, hybrid rocket motors are able to be throttled, can be stopped and restarted, and are safer than solid rocket motors since the fuel and oxidizer are in different physical states. Hybrid rocket motors are similar to solid motors in that they are relatively simple and have a high density-specific impulse. One of the major drawbacks of hybrid rocket motors is a slower burning rate than solid rocket motors. Complex port geometries provide greater burning surface area to compensate for lower burning rates but are difficult and expensive to manufacture. Additive manufacturing can reduce manufacturing costs of these complex port geometry fuel grains. It has also been shown that the addition of energetic materials, such as aluminum, can increase the burning rate and density-specific impulse of the rocket motor. Previously, additive manufacturing was restricted to plastics or fast-setting paraffin wax, both with low solids concentrations. This paper investigates the process of printing hybrid rocket fuel grains and the differences in physical characteristics between printed and conventionally cast samples. Using a proprietary printing system, we have successfully printed 80% solids loading aluminum and HTPB fuel samples. Material creep was significant and resulted in samples bulging and sagging as well as gaps between print lines being filled in more completely. The finish and cross sections of printed samples were of comparable quality to cast samples. This indicates that the manufacturing process has not significantly affected the physical characteristics of the fuel samples.

KEYWORDS

Hybrid rocket, propulsion and combustion, additive manufacturing