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TPMS-Based Catalyst Beds for Space Propulsion Produced via Multi-Material Additive Manufacturing

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ABSTRACT

High-test peroxide (HTP) is a green and sustainable propellant that can be catalytically decomposed into steam and oxygen. Higher concentrations of HTP produce more energetic reactions, which can reach temperatures of up to 1000 °C. The decomposition products can be utilised in space propulsion systems by ejecting hot gases at high velocities. Traditionally, catalyst beds are produced by depositing active materials onto pelletised ceramic supports, which are then placed inside a packed-bed reactor. However, the steep thermal gradients generated during HTP decomposition often cause attrition, damaging the pellets and reducing system lifespan. Monolithic beds offer an alternative that can achieve low pressure drop, eliminate attrition, provide uniform conditions across the length of the catalyst bed, increase surface area for a given volume, and enhance reactivity. Yet commonly used geometries, such as honeycombs, can suffer from channelling, where unreacted HTP leaves the catalyst bed due to the lack of tortuosity. Furthermore, several processes are required to coat the catalyst supports, usually involving the application of a washcoat followed by an impregnation step with the active material. Additive manufacturing (AM) enables the creation of complex catalyst bed geometries combining low pressure drop, high surface area, and high response time, such as triply periodic minimal surfaces (TPMS). Aditionally, AM also allows the catalyst to be incorporated directly into the feedstock, rapidly producing a functionalised catalyst bed without the necessity of multiple coating steps.

This work investigates the use of material extrusion to 3D-print TPMS-based catalyst beds for HTP decomposition. A multi-material feedstock containing ceramic nanopowders and a thermoplastic binder was used. Alumina (• -Al_2O_3) was incorporated to enhance the strength of the parts, while Mn_2O_3 served as the catalyst material. Printed green parts were thermally debound and sintered at different temperatures. Material characterisation was carried out using

a wide variety of analytical techniques, the mechanical properties were studied, and a screening process was utilised to study the decomposition rate of hydrogen peroxide on the sintered catalysts.

The results show that this manufacturing method can rapidly produce a functioning complex catalyst bed, offering a promising route to improved performance in space propulsion systems.

KEY WORDS

Additive manufacturing, catalysts, space propulsion, triply periodic minimal surfaces

BIOGRAPHY

Dario Manca is a PhD student from the Chemical and Process Engineering Department of the University of Canterbury in New Zealand. He graduated in 2019 as a materials engineer from the University of La Plata in Argentina. He worked as a process and quality engineer in the steel-making industry for ArcelorMittal France for almost four years. His interest in aerospace led him to pursue a PhD, studying catalysts for the decomposition of hydrogen peroxide.

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