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M3Or2F-02: [Invited] Additive Manufacturing of Cryogenic Materials

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The use of pure copper and Inconel 718 as cryogenic materials has been well known in the cryogenic materials space. Despite their potential, little is known about the use of these materials in cryogenic environments and their ability to withstand these conditions when manufactured using Additive Manufacturing (AM) methods. AM has emerged as a promising production method due to its ability to produce complex geometries and near net-shape parts. Copper being a highly conductive material for electrical applications and Inconel 718 as an engineering material both offer a widespread range of use cases in cryogenic applications.

In this paper, we demonstrate the Cold Gas Spraying (CGS) of copper and the Selective Laser Melting (SLM) of Inconel 718 as the AM processes of choice for each respective material. The main distinction between both processes is that CGS is useful for rapid deposition of material in the range of several kg/h whereas SLM is limited to a range of several hundred g/h. However, CGS can only yield bulk structures while SLM allows to produce intricate fine structures due to the nature of each processes'approach.

The development of the CGS process has been a rapidly evolving field in recent years. The process involves the acceleration of metallic powders to high velocities, which are then deposited onto a substrate to create a dense, solid structure. Originally developed as a coating process, it has been used to fabricate a wide range of materials, including metals, ceramics, and intermetallics, and has proven to be a promising alternative to traditional manufacturing methods such as casting and welding.

One of the challenges in the field of cold spray has been the ability to produce bulk specimens of large height. This has limited the use of CGS to produce e.g. tensile specimens in build direction, which are critical for the characterization of material properties and for the validation of material models. In this work, we present the development of a CGS process that can produce bulk material of up to 160 mm height to obtain such specimens in build direction. The process was optimized through a series of experiments to achieve the desired material properties. The microstructure of the specimens was then characterized. The results showed that the CGS process was able to produce bulk specimens with a high degree of uniformity and with mechanical properties that are comparable to those of traditionally manufactured materials. We show how we overcame the boundaries of thin layer application to produce bulk material from many consecutive layers.

On the other hand, the SLM process involves the use of a laser beam to melt and solidify Inconel 718 powder layer-by-layer to create a solid part. In this process a powder bed is lowered after each consecutive layer and new powder applied on top of it. No process development was needed to be able to obtain specimens for material testing. However, an important aspect in question was the post SLM heat treatment for a material originally designed for operating in environments of elevated temperatures.

The results presented here give insight into how to tweak processes and/or post-processing to obtain materials from AM and make them usable in cryogenic environments.

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