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ADDITIVE MANUFACTURING OF COPPER COMPONENTS FOR THE SPACE SECTOR: TECHNOLOGY COMPARISON, OPPORTUNITIES AND CHALLENGES

Abstract

Continuous technological developments in the field of additive manufacturing (AM) have made this innovative production paradigm a key enabling technology for the space sector, suitable to rethink the way space systems are designed and manufactured. AM techniques have demonstrated a high potential to enhance space system performances, leading to additively manufactured parts that have already achieved flight heritage. However, the actual AM potential goes much further, opening new possibilities for next generation launchers, mega-constellations, new space exploration missions and long-term human settlements in space. In this framework, one material with several possible applications in the space sector is copper. AM of copper allows combining the design freedom enabled by AM with the excellent conductivity properties of the material, which is a key issue for advanced thermal management solutions and high-performance propulsion systems, radio-frequency equipment, on-board electronics, and payloads. A detailed analysis of space environment requirements for copper AM applications is needed to adequately design future missions, according to space standards. However, AM of copper, and pure copper in particular, is affected by a range of challenges that need to be tackled. They include high reflectivity and low photon absorption, oxygen pickup, high thermal gradients and thermal variations that may lead to dimensional and geometrical distortions, high tendency of copper powder to sinter even at relatively low temperatures, etc. These issues reduce the "printability window" in AM, i.e., the window of process parameters where defect-free parts can be produced, and they make production of complex copper shapes still a challenging task that requires several process optimization iterations. This study explores the potentials and the challenges of copper and pure copper parts manufactured via AM methods for space applications, and it compares different AM processes, including laser- and electron beam-based powder bed fusion processes and bound metal deposition. This study reviews the state-of-the-art, including patents and scientific literature, on copper AM applications, including those that are potentially relevant for the space environment and it investigates the pros and cons of different technologies, with a special focus on the capacity to achieve defect free parts and on part qualification methods. From this last perspective, being copper a dense material, non-destructive inspection via post-process x-ray computed tomography is difficult. Thus, opportunities to anticipate the qualification during the process, while the part is being printed, taking advantage of sensor data that can be gathered on a layer by layer basis, are presented and discussed.