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A topographical methodology for in-situ process control in Laser Powder Bed Fusion (LPBF) Metal 3D Printing

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The heat evolution and thereby the densification rate in Laser Powder Bed Fusion (LPBF) Metal 3D Printing may vary during the print depending upon the build geometry variation along the height. Such variations in densification, even at fixed print parameters, are a major cause of defective parts in metal AM, as well as the poor consistency of print quality form part to part. We present a cutting-edge process control methodology in LPBF Metal 3D Printing via in-situ surface profiling. i.e., enabling a real-time correction of heat input (i.e., via adjusting the laser power and/or velocity) maintaining the densification rate regardless of print geometry variations along the build direction, Z, i.e., thus eliminating the Z-dependency of densification. The proposed methodology correlated the in-situ generated high-resolution surface profiles of the build's individual layers to its densification. The obtained surface profile of each layer is assessed and analyzed, providing a set of representative scalar values, that are experimentally verified to correlate well to the build's internal densification. Building upon the well-known relationship between the print parameters (e.g., laser beam velocity and power) and densification, our methodology can incorporate Machine Learning (ML)-enabled feedback loops for a real-time process control during the print, i.e., via algorithms trained for a given set of input material. The proposed methodology can enable an LPBF system to dynamically track and control the surface profile evolution in situ, in accordance with a known trend linked to the corresponding evolution of internal densification. The proposed methodology not only caters to the needs of research-oriented institutions but also offers a robust solution for industrial R&D application. It can potentially mark a significant leap in the field of LPBF Metal 3D Printing, offering unprecedented control and insight into the printing process.

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