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In-situ monitoring of LPBF metal process using a dual wave-length thermal camera compared to numerical simulations and experimental measurements

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ABSTRACT

Characterizing the melt pool and temperature field is critical in the laser powder bed fusion (LPBF) additive manufacturing for controlling the printing process and avoiding defects. However, complex nature of the LPBF process makes challenging relating thermal signatures of the process to the laser scanning strategy and powder bed characteristics.

This study aims to measure the temperature distribution in a powder bed during the LPBF process to quantify the impact of process parameters, such as laser power and scanning speed, on the temperature field-sensitive material characteristics, including chemical composition, material microstructure and residual stresses. To enable the temperature measurements for different materials while minimizing the dependency on the powder bed emissivity, a dual wave length Stratonics pyrometer with two CMOS sensors operating at bandwidths of 750 and 900 nm in a co-axial configuration was integrated into an EOS M280 LPBF system. Next, single-track printing experiments were conducted with IN625, CoCr, and 316L stainless steel powders, chosen for their distinct thermal and physical properties. Twenty single tracks of each material were printed using laser power ranging from 80 to 370 W and scanning speed, ranging from 400 to 1600 mm/s, and a comprehensive dataset of radiation intensity images was collected during printing. These images were then processed by calculating their pixel-by-pixel ratios, which were subsequently converted to temperature using Wien's approximation of Planck's law.

Image processing techniques, including dark image subtraction and filtering, were applied to generate the temperature field images for each material and each printing condition. Correlating the temperature distributions with the materials' melting points enabled the detection of solidus-liquidus regions and the measurements of melt pool widths and lengths. These in-situ observations were experimentally validated by post-printing measurements of the melt pool widths, using optical microscopy. Additionally, the melt pool lengths measured from the thermal images were compared with the results of numerical simulations conducted for the same materials and printing parameters using the Ansys software. This comparison allowed for the refinement of threshold parameters and the improvement of measurement reliability.

Once validated, these in-situ measurements provide insights into the maximum temperatures achieved in the melt pool and temperature gradients in the heat affected zone. Ultimately, these data will be integrated into LPBF models capable of predicting the vaporization of alloying elements and the material microstructure, thus enabling the production of high-density parts with controlled characteristics.