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The crucible method: A new technique of generating process maps for laser powder-bed fusion

Laser powder-bed fusion (LPBF) is an additive manufacturing process fusing metal powder layer-by-layer to form complex 3D components. LPBF is seen as a rapid evolution of machine design (more and higher power lasers, improved laser control and build preparation software) giving increased density of built parts, better inter- and intra-build repeatability, all leading to better mechanical properties. The traditional method to create process maps via post-mortem examination of solidified single line tracks aims to understand how the laser interacts with the powder to form single line tracks directly onto a baseplate. Control of process parameters such as speed, power and beam diameter are integral to choosing optimal laser penetration whilst avoiding evaporation, keyhole melting or balling defects. This method is limited as the substrate may be of a similar composition but microstructurally dissimilar and controlling additional parameters such as the powder layer thickness is difficult. A new crucible method is described and compared to the traditional method using Ti-6Al-4V and 316L with advantages, which include: i) high-throughput, high-quality topographical and cross-sectional metallography to be easily obtained. ii) tracks to be built in-situ on a previously deposited substrate is more representative of the process at all layers. iii) tight control on the powder depth and additional parameters. The crucible method predicted a much less severe transition between conductive and keyhole modes of melting than direct deposition of single tracks onto a baseplate, with shallower re-melting of lower layers. The crucible method also predicted a more forgiving transition between continuous and discontinuous tracks.

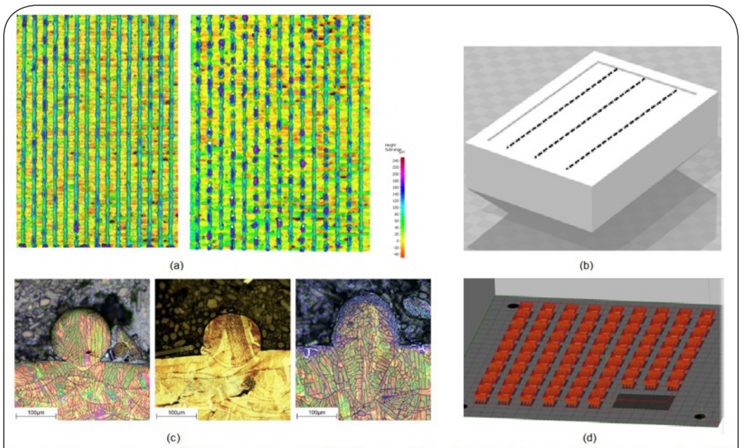

Figure 1 - (a) Topographic scans of Ti-6Al-4V tracks formed at 200W (500 mm/s and 750 mm/s), (b) Single Crucible with 3 tracks, (c) examples of 316L tracks formed in crucible as balled (200W and 700 mm/s), optimal (150W and 300 mm/s) and keyhole (175W and 200 mm/s), (d) multiple crucibles

Recent Publications

1. J A Cherry et al. (2014) Investigation into the effect of process parameters on microstructural and physical properties of 316L stainless steel parts by selective laser melting. International Journal of Advanced Manufacturing Technolology. 76(5-8):869-879.

2. N P Lavery et al. (2017), Effects of hot isostatic pressing on the elastic modulus and tensile properties of 316L parts made by

powder bed laser fusion. Materials Science and Engineering: A. 693:186-213.

3. H W Mindt et al. (2016) powder bed layer characteristics: the overseen first-order process input. Metallurgical and Materials Transactions A. 47(8):3811-3812.
4. H.W. Mindt, M. Megahed, N.P. Lavery, A. Giordimaina, & S.G.R. Brown (2016), Verification of Numerically Calculated Cooling Rates of Powder Bed Additive Manufacturing. In TMS 2016: 145th Annual Meeting & Exhibition: Supplemental Proceedings. (pp. 205-212), Nashville, TN, USA.
5. A M Philo et al. (2018) A Multiphase CFD Model for the Prediction of Particulate Accumulation in a Laser Powder Bed Fusion Process. In: CFD Modelling and Simulation in Materials Processing. TMS 2018. Pages 65-76.

Biography

Adam M. Philo is a Post-Doctoral Research Assistant in the College of Engineering at Swansea University. He has a background in Aerospace Engineering and Mathematics and hold an Engineering Doctorate which was completed with Renishaw's Additive Manufacturing Products Division. His research interests are predominately in the field of computational modelling of the laser powder bed fusion process. These are multiscale and multi-physical in nature and involve a variety of fluidic, thermal and structural analyses.

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