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Neutron tomography and neutron diffraction characterization of junction properties in CoCrMo and SS 316L PBF-LB functionally graded materials

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Additive manufacturing (AM) offers distinct benefits over conventional manufacturing methods, most notably in design flexibility and material utilization. Complex geometries and internal features can be realized with AM that would be infeasible to produce by subtractive techniques, giving engineers unprecedented design freedom. A further key advantage is the ability to integrate multiple materials into a single component, combining different material properties in ways traditional processes cannot.
In this framework, the objective of this study is to investigate the junction properties, by utilizing advanced neutron techniques, of functionally graded materials (FGM) made of CoCrMo and SS 316L realized by Powder Bed Fusion –Laser Beam (PBF-LB).
The FGM samples were manufactured by utilizing powder separators and therefore mixing in-operando the two different powders. In this way, multi-material components possess a variation in composition of the materials within the same building layer and not between different layers. This can be advantageous for many reasons since it is well-known that properties of AM parts heavily depend on their orientation with respect to building direction. In this work, neutron diffraction was employed to measure residual lattice strains across the materials transitions. Furthermore, in contrast to standard X-ray tomography, by leveraging the high disparity in the neutron attenuation coefficients between Co and Fe, which are the primary constituents of CoCrMo alloy and stainless steel 316L, neutron tomography served the purpose of not only characterizing defects and porosities, but also the effective location of the two dissimilar materials thus highlighting the internal morphology of the interface regions.
Diffraction results showed a peak shift indicating proper designed spatial variation in materials composition. Residual strain measurement revealed compression in pure materials, and a variation compression-tension-compression in the interface zone. Neutron tomography highlighted a peculiar interlocking layered morphology in the transition regions.
The integration of neutron diffraction and neutron tomography was instrumental in achieving a comprehensive, non-destructive characterization of strain evolution and internal mixing morphology in FGM components. In particular, both the residual strain field and the complex interlocking interface can be key in enhancing the mechanical fatigue and fracture behavior of innovative FGM structures.

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