Kinetic rather than thermal energy for additive manufacturing of load bearing elements: cold spray set against SLM freeform fabrication

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ABSTRACT

Cold gas dynamic spray, as an emerging method, relies on high plastic deformation and adiabatic shear instability, which occur upon impact. In cold spray process, high kinetic energy is achieved through accelerating microparticles to supersonic velocities by preheated gas passing through a convergent-divergent nozzle. Recent advances in the field of cold spray have put forward the potential of this deposition technique to be used as a non-thermal additive manufacturing process with significantly high deposition rates. Selective laser melting (SLM), on the other hand, is an additive manufacturing technology that allows layer-by-layer building of metallic components using laser source to fuse the melted powder particles together. It has been widely used for near net shape fabrication of parts from various alloys and composite materials with outstanding mechanical performance. In this study, we used the additive manufacturing potential of cold spray for fabrication of freestanding three-dimensional Inconel 718 samples, which is a challenging material for cold spray due to its high hardness and limited deformability. Additionally, we fabricated samples with similar geometry using SLM technique. Our previous study validated the potential of cold spray to be used as an additive manufacturing technique for fabrication of Inconel three dimensional objects [1]. In the present study, however, we focus on evaluating the static and high cycle fatigue characteristics of cold spray Inconel deposits as well as their fracture behavior and compare them with those of samples fabricated by an industrial scale SLM system.

Microstructural characteristics, distribution of residual stresses, porosity and structural integrity of the cold spray deposited samples were compared with those of samples obtained by SLM before and after different heat treatments. The optical micrograph of cold spray samples' cross section (Fig. 1 (a)-(c)) present highly deformed splats as the characteristic features of cold spray process. Fig.1 (a) shows a dendritic structure inside the splats, similar to the original tree-like microdendritic structure of the rapidly solidified powder crystals. This dendritic structure tends to fade after heat treatments (Fig. 1 (b) and (c)) developing a more uniform and homogeneous microstructure. Fig. 1 (d) and (e) represent the microstructure of the as-built SLM sample on cross sections parallel and perpendicular

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to the build direction respectively. Fig. 1 (d) illustrates the development of layers comprised of arc-shaped molten pool boundaries with an average max height of 115±22 µm. Columnar dendrites were observed generally growing along the build direction, mostly traversing through few melt layers. The general appearance of the section parallel to the scanning plane, Fig. 1 (e), showed a cellular and dendritic structure organized in a way that highlight the direction of multiple laser tracks with 33° rotation between the adjacent layers. The results of static and axial fatigue (R=0.1) tests, reported in Fig. 2, indicate the notable efficiency of cold spray for fabrication of freestanding objects for structural components, with similar characteristics to those obtained from laser based additive manufacturing technique and even comparable to bulk material properties. The low working temperature of cold spray method, suggests it as a promising additive manufacturing method that can address many challenges regarding laser based techniques.

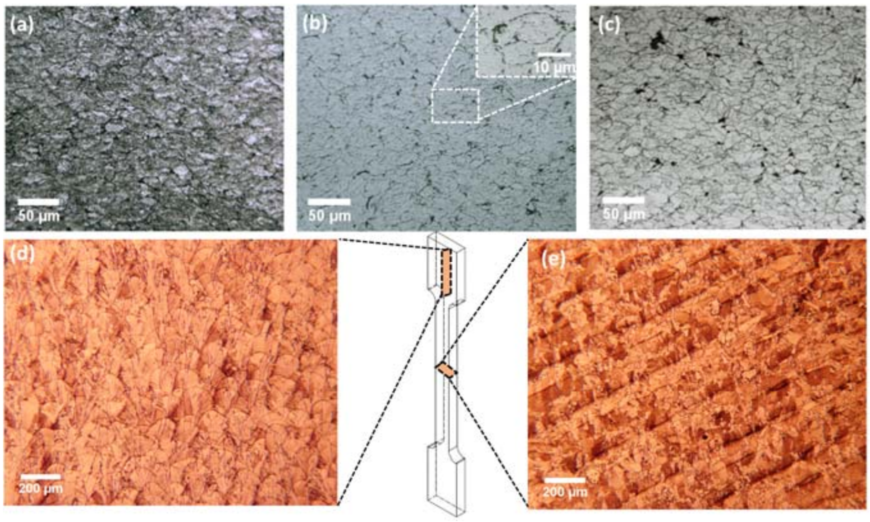

Figure 1: Optical micrograph of samples cross sections after chemical etching (a) CS (b) CS-HTA (c) CS-HTB (d) SLM-as built parallel to the build direction (e) SLM-as built perpendicular to the build direction (CS: cold spray, SLM: selective laser melting, HTA and HTB: different heat treatments)

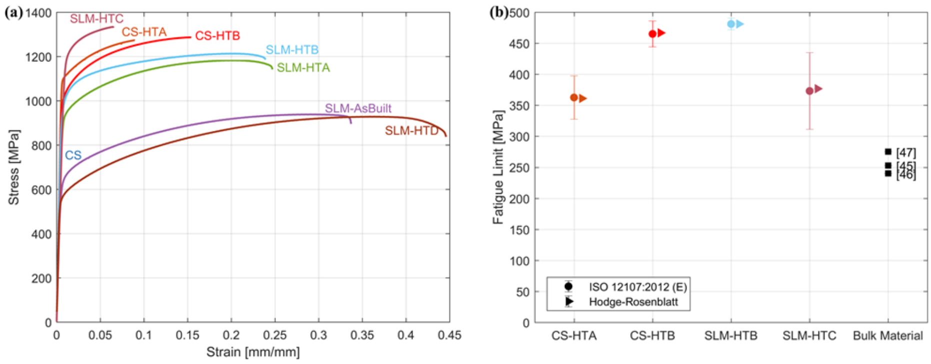

Figure 2. (a) Stress strain graphs of CS and SLM samples before and after various heat treatments (b) fatigue strength corresponding to 2 million cycles for CS and SLM samples compared to the bulk material fatigue test data available in the literature (CS: cold spray, SLM: selective laser melting, HTA to HTD: different heat treatments)

References

[1] S. Bagherifard, G. Roscioli, M.V. Zuccoli, M. Hadi, G. D'Elia, A.G. Demir, et al. Cold Spray Deposition of Freestanding Inconel Samples and Comparative Analysis with Selective Laser Melting, Journal of Thermal Spray Technology,26, 1517–1526, 2017.