Microstructural Modification in IN718 Deposits Using Nanoparticles: Transitioning from Columnar to Equiaxed

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Abstract

We explored the refinement and equiaxing of grain structures in Inconel 718 (IN718) deposits fabricated through the directed energy deposition (DED) process. The primary challenge addressed was the grain coarsening observed in traditional DED processes, which often leads to compromised mechanical properties. Our approach involved the incorporation of ZrO2 nanoparticles into the IN718 powder. This mixture was homogenized using a swing planetary mixer. To optimize the deposition process, we varied the laser power and energy density. The most notable results were achieved under the conditions of 250 W and 1000 mm/min, where the IN718-ZrO2 deposits exhibited a desirable equiaxed grain structure. To understand the underlying mechanisms, we measured and analyzed factors such as volume energy density, Marangoni convection, and contact ratio. Our findings indicated that an increase in these parameters was conducive to grain refinement and the formation of equiaxed grains. Further analysis using Transmission Electron Microscopy (TEM) revealed that the addition of ZrO2 nanoparticles induced nucleation behavior, leading to the formation of L12-Al3Zr intermetallic compounds. This process, characterized by heterogeneous nucleation and grain boundary pinning effects, was instrumental in promoting grain refinement and the formation of equiaxed grains. Moreover, the refined and equiaxed grain structure of the deposits resulted in reduced anisotropy and a significant improvement in hardness. There was a uniform enhancement in hardness, ranging from 26 to 48 Hv, encompassing all regions from the surface to the interface. The transition from columnar to equiaxed grains is primarily attributed to the heterogeneous nucleation mechanism facilitated by ZrO2 nanoparticles. This research not only demonstrates the successful refinement and equalization of grain structures in IN718-ZrO2 deposits but also highlights the enhanced hardness achieved through this cost-effective and readily accessible approach.

Keywords: Inconel 718 (IN718) Deposits, Directed Energy Deposition (DED) Process, ZrO2 Nanoparticles, Grain Refinement and Equiaxed Grain Structure, Hardness

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