HÖGSKOLAN VÄST

Electron Beam-Powder Bed Fusion of Alloy 718:

Effect of Process Parameters on Microstructure Evolution

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Abstract

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Additive manufacturing (AM) is the technology of building 3D parts through layer-by-layer addition of material. Of the different types of AM techniques, electron beam-powder bed fusion (EB-PBF) has been used in this study. EB-PBF can build parts by melting metallic powders using an electron beam as the energy source. Compared to conventional manufacturing processes, EB-PBF offers a convenient approach and enhanced efficiency in producing customized and specific parts in the aerospace, space, automotive, and medical fields. In addition, the EB-PBF process is used to produce complex parts with less residual stress due to the high-temperature environment within the process.

This thesis has been divided into four stages. In the first stage, the behavior of Alloy 718 during the EB-PBF process as a function of different geometry-related parameters is examined by building single tracks adjacent to each other (track-by-track) and single tracks on top of each other (single-wall samples). In this stage, the focus is on understanding the effect of successive thermal cycling on microstructural evolution. In the second stage, the effect of the position-related parameters–including the distance or gap between samples, height from the build plate (in the Z direction), and sample location on the build plate (in the X–Y plane)–on the microstructural characteristics, are revealed. These three position-related parameters can have significant effects on the defect content and niobium-rich phase fraction. In the third stage, the correlations between the main machine-related parameters, geometric (melt pool width, track height, remelted depth, and contact angle), and microstructural (grain structure, niobium-rich phase fraction, and primary dendrite arm spacing) characteristics of a single track are delineated. The results obtained in stages one to three were used as a guideline for the reduction of the internal–external defects and columnar-to-equiaxed transition (CET) in the grain structure of a typical cubic part. The final stage reveals two different strategies that were developed using machine-related parameters (scanning speed, beam current, focus offset, line offset, and line order number) to tailor the grain structures. All investigated parameters with respect to the proper selection of the processing window played a critical role in the solidification parameters (thermal gradient, growth rate, and cooling rate) on the solidification front, which could induce formation of more fine equiaxed grains.