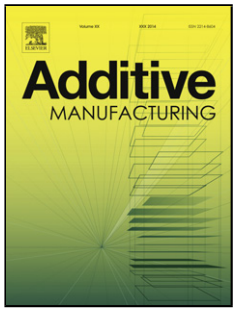

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Metallurgy of Additive Manufacturing: Examples from Electron Beam Melting

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Abstract

The metallurgy of selected metal and alloy components fabricated by additive metallurgy using electron beam melting (EBM) is presented for a range of examples including Ti-6Al-4V, Co-Cr-Mo super alloy, Ni-base super alloy systems (Inconel 625, 718 and Rene 142), Nb and Fe. Precursor and pre-alloyed powders are preheated and selectively melted using a range of EBM process parameters including beam scan strategies, beam current variations, and cooling rate features. Microstructures and residual mechanical properties are discussed for selected systems in contrast to more conventional wrought and cast products. Novel features of EBM fabrication include columnar microstructural architectures which result by layer-by-layer melt-solidification phenomena.

Keywords: Electron beam melting (EBM), Ti-alloy, Superalloys, Nb, Fe, Optical and electron microscopy characterization, Mechanical properties.

1. Introduction

Recent reviews involving laser and electron beam melting applied to the additive manufacturing of metal and alloy components have generally outlined their non-equilibrium physical and chemical nature which contributes to unique and novel metallurgical phenomena [1-3]. In this context, additive manufacturing (AM) utilizing laser or electron beam melting reduces the need for tooling such as moulds and jigs, although AM can fabricate more optimized and complex patterns than metal and alloy casting; especially applicable in automotive, aerospace, electronic and medical/biomedical (including dental) product manufacturing. AM also allows for low volume production of customized metal parts and reduced capital investment and transportation costs since production can occur closer to the consumer. Complex monolithic geometries involving little or no joining operations accommodating rapid design changes enable flexible production and mass customization strategies using AM technologies involving laser and electron beam processing of pre-alloyed powder beds by incremental (layer) manufacturing. This differs dramatically from more conventional powder metallurgy (PM) processing. [4]. The incremental powder layer interaction with laser and electron beams is also fundamentally different from surface or near surface processing of bulk metal or alloy products [5], although there are some similarities in regard to heat treatment and melting.

The incremental layer-by-layer melt and solidification phenomena associated with the laser and electron beam AM of metal or alloy powders differs fundamentally from more conventional metallurgical processing, including directional solidification involving a continuously moving melt/solidification front [6]. In addition, traditional metallurgical processing of bulk melt/solidification products involving thermo-mechanical treatment regimens can be facilitated to some extent in the AM of the same products by adjusting and optimizing beam scan parameters and scan sequencing strategies to achieve desired microstructural features incrementally rather than by bulk cast or wrought product post treatment.