A Novel, Low-Cost, Highly Alloyed Cast Iron Powder for High Performance Binder Jet Components

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1 Abstract

A new low cost, highly alloyed cast iron powder (designated MC15-5) has been developed, exhibiting beneficial features and characteristics for industrialization and use in high temperature or wear resistant applications. This alloy combines technical performance and commercial value, exhibiting desirable microstructure, near theoretical density, high hot hardness, and exceptional wear resistance in binder jet-produced samples. The unique combination and levels of Cr, Mn, and C (nominally 15, 15, and 5 wt%, respectively) eliminate or reduce the need for expensive alloying elements such as Mo, W, and V.

Binder jet fabrication of MC15-5 test samples is described, and the specific metallurgical and performance aspects characterized and measured. The ease of achieving >99% theoretical density using relatively wide and coarse powder size distribution (comparable to conventional press and sinter PSD) and the presence of a liquid phase indicate high sinterability. Thermodynamic modeling tools were used to predict the phase structure, and the powder characteristics, microstructure, density, macrohardness, microhardness, hot hardness, and wear resistance are measured and characterized. Of particular interest are the complex multi-phase microstructure and its transformation during post-sinter thermal treatment.

2 Introduction

Metal additive manufacturing (AM) processes, also referred to as rapid prototyping, 3D printing or freeform processes, are a class of manufacturing techniques that allow significant design freedom. Parts are built layer-by-layer from a computer-aided drawing (CAD) file and various types of feedstocks such as wires, powders, or sheets. ASTM classifies AM processes in 7 different categories, four of which are used for the production of metallic parts [1]. These categories are: powder bed fusion, direct energy deposition, binder jet and sheet lamination. These processes have the advantages of reducing material waste, reducing lead times, reducing stockpiles and have unrivaled design freedom [2]–[4]. While their use is currently limited by comparatively high feedstock cost and low production volume capability, notable advancements in these areas are driving increased adoption and industrialization of most AM technologies.

Binder jetting is an AM process that can be used to produce metal parts. Liquid binder material is selectively deposited onto a powder bed using an inkjet-type print head to form layers. These layers correspondingly bond by binder hardening or curing processes to strengthen the bonds between the binder and the metal particles; a fresh powder and binder layer is subsequently delivered to the build-bed, and the process is repeated until the programmed component bed design is completed. The juxtaposition of these layers produces green three-dimensional (3D) parts. After carefully removing the loose powder from the binder treated green component (a process called depowdering), the as-printed parts are subject to a de-binding process (chemical and/or thermal) to remove the binder material, followed by a sintering cycle to generate structural integrity and metallurgical bonding of the powder particles. Depending on part design, purpose, and sintering cycle, near full density (>99% of theoretical density) can be achieved by binder jetting technology. Typically, the gradual heating and cooling of binder jetting thermal processing produces parts relatively free of residual stresses, unlike other metal AM processes such as Laser Powder Bed Fusion (LPBF) or Electron Beam Melting (EBM). In addition, binder jetting is not limited only to weldable alloys and new alloys are continually being added to those proven successful for binder jetting portfolios [5].