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Novel post-processing procedure to enhance casting molds manufactured by binder jetting AM

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ABSTRACT

The significant improvements made in additive manufacturing (AM) techniques since their beginnings, coupled with its intrinsic advantages, have resulted in a technology that stands out as most suitable for applications in leading sectors today. In addition to some of the properties of the parts, there are also some inherent aspects of AM techniques that hinder their applicability. In this respect, the application of calcium sulfate parts manufactured by binder jetting (BJ), as expendable casting elements, is limited by both the high quantity of volatile substances, due to the BJ process, and their low compression resistance. In this work, a novel part post-processing procedure is presented. This procedure consists of applying various heat treatments, in combination with a vacuum infiltration process using an Epsom salt solution. The procedure reduces the volatile content of BJ AM parts and enhances the compression strength with little modification to the part geometry. This post-processing substantially improves the applicability of BJ AM parts as expendable casting elements. After presenting this novel procedure and analyzing the significant enhancement of the properties of the AM calcium sulfate parts (i.e. permeability, the reduction of volatile content and reduction of compressive strength), a case study is presented with an expendable mold for aluminum casting. This procedure allows for a safer casting process, improves the part's surface quality and reduces the internal porosity of the cast parts.

1. Introduction

Additive manufacturing began to develop in the 1980 s. At that time, it was named rapid prototyping and consisted of a set of techniques that allowed parts to be manufactured quickly and easily from their digital models, by means of adding layers of material [1,2]. The development of new techniques, the use of new materials and the application of new post-processing procedures to the manufactured parts, improved the properties of the products, allowing these sets of techniques to be referred to as a technology in their own right: Additive Manufacturing (AM). The main advantage of AM is the high degree of product customization and complexity it allows without significantly increasing the cost, which enables mass production of individual customized parts [3]. In addition, the AM enables quicker new product development, with low or no redesign penalty, as well as improving supply chain efficiency thanks to a decentralized and on-demand manufacturing [4]. Despite the design demands of some of these techniques [5], as well as the need to use models to optimize parts quality [6], AM is of great interest to several leading industrial sectors such as aerospace, automotive and medical.

One of the AM techniques that has received the most attention in recent years is known as Binder Jetting (BJ), based on conglomerating powder particles by means of a binding substance [7–10]. This technique can be applied to different materials such as calcium sulfate, silica, or alumina [11–13]. As an additive manufacturing process, this technique consists of the consecutive deposition of the different layers in which the digital model of the part has been previously sliced. The deposition of each layer begins by spreading a layer of powder on a platform using a scraper or a roller. Then, by means of a print head, micro-droplets of a binding substance are selectively projected on the positions where the powder particles need to be bonded, i.e. the area inside the perimeters belonging to the corresponding layer, obtained by the previous slicing of the digital model. This allows the conglomeration of the powder reached by the binder, forming a thin layer with the desired geometry. The platform is then lowered by a distance equivalent to the layer thickness used in the slicing. This process is repeated for successive layers in which the part model was sliced. After manufacturing all of the layers, a three-dimensional part is obtained that

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