Available online at www.sciencedirect.com

ScienceDirect

Procedia Manufacturing 21 (2018) 638–646

Procedia MANUFACTURING

www.elsevier.com/locate/procedia

15th Global Conference on Sustainable Manufacturing

Influence of Binder Quantity on Dimensional Accuracy and Resilience in 3D-Printing

M. Kafara [a]*, J. Kemnitzer [b], H.-H. Westermann [b], R. Steinhilper [b]

[a]*Bayreuth University, 95447 Bayreuth, Germany*
[b]*Fraunhofer IPA, Project Group Process Innovation, 95447 Bayreuth, Germany*

Abstract

Driven by an increasing number of variants and high quality standards in all production processes high efficiency and flexibility are necessary to fulfill the customer needs. In this context additive manufacturing has become one of the most innovative technologies in manufacturing and offers a high potential for the efficient use of resources. Especially for small-scale production like individual mold making it can be more cost and time efficient than conventional methods. Therefore, the additive manufacturing method of 3D-Printing is used in the field of mold making for castings.
The provided case study shows the influence of the binder quantity used in 3D-Printing on dimensional accuracy and resilience of manufactured test specimen. A special focus was on the analysis of the dimensional accuracy by measuring deviations. It was performed by using optical metrology based on stripe light projection. The aim was to define the optimum operating point as compromise between accuracy and resilience.

Peer-review under responsibility of the scientific committee of the 15th Global Conference on Sustainable Manufacturing (GCSM).

Keywords: 3D-Printing, Additive Manufacturing, ; Mold; Mold core; Rapid Tooling; Small Scale Production; Casting

1. Introduction

Additive manufacturing is a technology of huge significance in today's manufacturing industry because of its ability to decrease the design and manufacturing time in addition to its geometrical freedom and sustainable potential [1]. This makes it a desirable technology for applications in different industry sectors including engineering,

* Corresponding author. Tel.: +49 921 78516-410; fax: +49 921 78516 105.
E-mail address: markus.kafara@uni-bayreuth.de

2351-9789
Peer-review under responsibility of the scientific committee of the 15th Global Conference on Sustainable Manufacturing (GCSM).
10.1016/j.promfg.2018.02.166

aerospace, automotive. Especially in manufacturing small lots, complex parts or in lightweight design there is already a preference for additive manufacturing over conventional manufacturing like milling, turning or casting. [2]

Nowadays a wide range of additive manufacturing technologies and materials are available which are assignable to Rapid Prototyping as well as to Rapid Manufacturing and Rapid Tooling. Rapid Prototyping is understood to mean the manufacturing of design prototypes and functional models. In contrast, the manufacturing of consumable end products is known as Rapid Manufacturing. The manufacturing of tools and molds falls within the area of Rapid Tooling. Nowadays primarily tool inserts, individual production aids and mounting devices are made by additive manufacturing. The present work refers to the investigation of new materials and the belonging 3D-Printing processes in mold making. Additive manufacturing processes can be quicker and more economic than conventional manufacturing processes, especially in individual manufacture. These factors are advantageous for manufacturing molds because time-to-market, availability and low costs are decisive for the competitiveness. [3]

The processed material form helps to distinguish the different additive manufacturing technologies. The most common material forms are powder, filament and liquid plastics. One of the most known additive manufacturing technology is Fused Deposition Modeling, which processes plastic filament. The thermoplastic filament melt in a heated nozzle and is then applied to the buid platform. Stereolithography makes it possible to create complex components out of a light-curing liquid plastic, for example, an epoxy resin or a synthetic resin, which is cured in layers by a laser. Metallic or plastic powder materials can be processed by Selective Laser Sintering (SLS) or Melting (SLM) and 3D-Printing. In this case the powder material is applied layer-wise onto the build platform and locally sintered or fused by a laser. The 3D-Printing technology uses inkjet print heads to deposit a liquid binder onto a layer of powder. Processible materials can be ceramic, metal, sand or plastic powders. Thus the presented work focusses 3D-Printing, it is explained in more detail within the state of the scientific knowledge. [4]

All additive technologies have in common that they are relatively new compared to conventional methods. Therefore, a great deal of research and development is still necessary for widespread usage, especially in the fields of process stability, reproducibility and properties of new materials. This paper addresses the increase in scientific knowledge in the area of dimensional accuracy and resilience of salt-based materials in 3D-Printing. Finally, 3D-Printing and the investigated materials may used in future for mold making, which nowadays particularly in small-scale production consists of very elaborate processes.

2. State of the scientific knowledge and need for action

2.1. 3D-Printing

The 3D-Printing technology has been developed at the Massachusetts Institute of Technology (MIT) in the USA and subsequently licensed to many companies for commercial purposes [5]. Components are produced by the layer-wise application of a binder to a powder layer. The powder materials processed are based on a variety of materials such as metals, salts, ceramics, plastics, sand or gypsum [6]. The present work focusses the use of salt-based powder material. The main components of a common 3D-Printing system are the powder feed supply, the build platform, powder feed roller, the excess powder container and the print head, as shown in Fig. 1.

The print head has two degrees of freedom (in the x- and y-directions), the powder feed supply and the build platform can be moved by their pistons in z-direction. By lifting the powder feed supply, a small amount of powder is conveyed upwards, which is spaced out evenly by means of a powder feed roller as a thin layer on the build platform lowered by one layer thickness. [7] Excess powder is collected and can be reused in the next print-job. In the subsequent step, the binder is applied by means of the print head to the areas to be solidified. The binder connects the powder particles among each other as well as to the layer already printed. By using colored binders, colored