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Influence of structure on mechanical properties of 3D printed objects

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Abstract

Additive Manufacturing (AM), the relatively young manufacturing technology of layer-based automated fabrication process for making three-dimensional physical objects directly from 3D CAD data set was originally called Rapid Prototyping (RP) when the first commercial process – Stereolitography was entered the market in 1987. This technology is still frequently called Rapid Prototyping. The main objective of research was to determine the impact of sample's structure on the tensile strength of 3D printed samples. Test samples were prepared on a Z Corporation's 3D printer model Z310, with variations of internal geometrical structure. Results of tensile test revealed that the honeycomb structured samples exhibit the highest strength.

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Keywords: Additive Manufacturing; Lattice-shaped structures; Rapid prototyping; Tensile strength; Three-dimensional printing

1. Introduction

3D printing or additive manufacturing is a process of making three dimensional solid objects from a digital file. The creation of a 3D printed object is achieved using additive processes. In an additive process an object is created by laying down successive layers of material until the entire object is created. Each of these layers can be seen as a thinly sliced horizontal cross-section of the eventual object. Today, there are many different additive manufacturing techniques with high accuracy and large choices of materials available on the market. The most successfully developed techniques are: Stereolithography (SLA), Selective Laser Sintering (SLS), Laminated Object Manufacturing (LOM), Fused Deposition Modeling (FDM), 3D Printing etc. [1,2]

Some of common advantages of existing additive manufacturing techniques are: speed (model building in one day); manufacturing flexibility (almost any geometry can be replicated); high degree of control over part microstructure; wide variety of engineering materials (plastic, metals, and ceramics). They also have some common shortcomings such as: lack of required mechanical properties depending on material combination; lower accuracy (can be improved by additional machining); high computational demands and limited bio-compatibility (important in manufacturing of medical products). Yet, most of listed shortcomings can be successfully avoided in particular case with proper selection of techniques and materials [2].

In our research we have been concentrated on three-dimensional printing (3DP) technique. This process combines a layered approach from RP technologies and a conventional ink-jet printing. It prints a binder fluid through the conventional ink-jet print head into a powder, one layer onto another, from the lowest model's cross-section to the highest (Figure 1). After printing, the printed models are dried in a building box, then removed from the powder bed, de-powdered by compressed air, dried in the oven and infiltrated for maximum strength.

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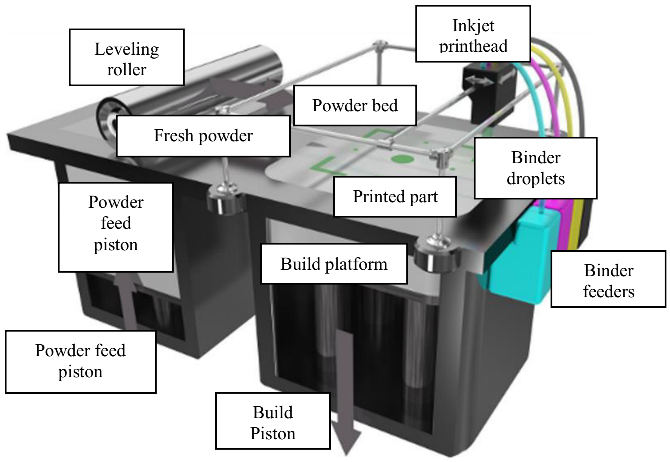

Fig. 1. 3D Printer main components [3]

3D printing technique delivers slightly less details and a rougher surface and it is also less accurate comparing to other AM technologies (e.g. stereolithography, polymer jetting/printing techniques) [4]. The models obtained by 3D printing are not transparent too, but this AM technique is fast and cheap and therefore widely accepted in many areas of application. A comprehensive overview of the capabilities of 3DP processes is presented and evaluated in [4]. It shows the application of 3D printing beyond concept modeling. There are many other studies dealing with various aspects of 3DP processing characteristics, cost evaluation and accuracy, e.g. [5–7].

2. Equipment and materials for experiment

The machine, 3D printer, used for these experiments, was the model Z310, a product of Z Corporation, recently acquired by 3D Systems Corporation. It is a low-cost monochrome 3D printer suitable for RP education or for small and medium sized companies. The printer firmware version was 10.158 and test samples were prepared in printer software ZPrint version 7.10.

There are several base materials, i.e. powder types, available for the above mentioned 3D printer. For our experiment we used a plaster-based powder zp130 with an appropriate binder zb56. The powder zp130 is recommended for the accuracy and for delicate models. It is a mixture of plaster, vinyl polymer and sulphate salt [8]. After drying, the samples were infiltrated with the infiltrant, cyanoacrylate-based adhesive Loctite 406.

In our experiments we used models derived from standard specimens for tensile tests defined in ISO 527:2012 standard. Three different hollow lattice-shaped structures were considered: honeycomb, drills and stripes (Figure 2). Also, one set of standard compact full-bodied specimens were printed and tested as a control set, analogous to control group in randomized controlled trial.

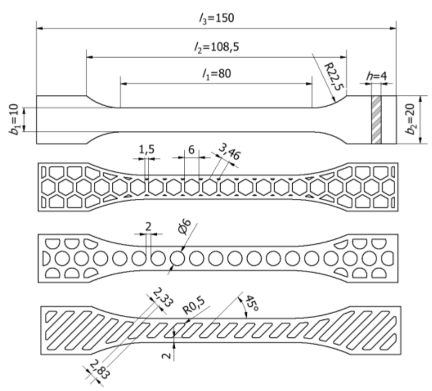

Fig. 2. 3D Sample structure types and dimensions (full, honeycombs, drills, stripes)