

Slurry-based additive manufacturing of ceramic parts by selective laser burn-out

Hwa-Hsing Tang^{a,1}, Hsiao-Chuan Yen^{b,*}

^a Graduate Institute of Manufacturing Technology, National Taipei University of Technology, Taipei 10608, Taiwan

^b Department of Mechanical Engineering, National Taipei University of Technology, Taipei 10608, Taiwan

Received 27 August 2014; received in revised form 10 October 2014; accepted 15 October 2014

Available online 30 October 2014

Abstract

This study proposes a novel process of slurry-based additive manufacturing of ceramic parts by selective laser burn-out (SLB). The process employs the slurry layer to replace the sheet material used in the process of laminated object manufacturing (LOM) and computer-aided manufacturing of laminated engineering materials (CAM-LEM). A part of binder and solution in the fresh slurry layer permeated into the dried green layers to achieve a good binding strength; then the green part was built with laser irradiation to burn out binder. Two scanning modes were used; the outline scanning traced out the outline of the predefined part slice geometry, and cutting scanning facilitated removal of excess material. Consequently, the new process benefits the fabrication of the large parts as LOM and CAM-LEM possessing. Many accessory facilities used in LOM and CAM-LEM are not required. The feasibility of the new process is verified through the fabrication of the alumina parts.

© 2014 Elsevier Ltd. All rights reserved.

Keywords: Additive manufacturing; Ceramic; Selective laser burn-out; Alumina

1. Introduction

The material used in the additive manufacturing (AM) process can be divided to three categories. One is the powder, another is the slurry, and the other is the sheet material. Selective laser sintering (SLS) and three-dimensional printing (3DP) are well known AM processes using powder. A variety of ceramic powder has been used to fabricate ceramic components with the process of SLS.^{1,2} The feasibility of fabricating ceramic parts with 3DP has been explored in industrial and biomedical applications.^{3–6} Because appreciable densities can be achieved by the use of ceramic slurry, many slurry-based processes have been reported. Stereolithography (SL) is employed to create ceramic green bodies with the photocurable ceramic slurry.^{7,8} A series of slurry-based technology, which uses aqueous slurry to

fabricate ceramic components with laser sintering or fusion, has been studied,^{9–15} such as ceramic laser fusion (CLF), ceramic laser sintering (CLS), and ceramic laser gelling (CLG). The slurry deposition technology (LSD) combines elements of the tape casting and slip casting process to build up of the layers and selectively sinters with laser.¹⁶ LSD allows the step-by-step generation of ceramic components without the use of non-ceramic binders.¹⁷ The strategies for an improved microstructure of laser-sintered bodies fabricated by LSD are introduced.¹⁸ One of the important features of the slurry-based process is the inherent support for overhanging or undercutting geometry. The processes using sheet material are laminated object manufacturing (LOM) and computer-aided manufacturing of laminated engineering materials (CAM-LEM). The LOM involves layer-by-layer lamination of sheet material, cuts using a CO₂ laser. The contour scanning mode leads to a better building rate. The feasibility of fabricating ceramic parts with different ceramic sheet materials has been reported.^{19–21} The CAM-LEM can rapidly create high-integrity ceramic components directly from solid CAD model, and enables production of parts with complex internal geometries which are difficult to manufacture by the conventional process.^{22,23} Except for 3DP, the aforementioned

* Corresponding author at: Department of Mechanical Engineering, National Taipei University of Technology, No. 1, Chung Hsiao East Road, Section 3, Taipei 10608, Taiwan. Tel.: +886 2 27712171x2086; fax: +886 2 27317191.

E-mail address: hcyen@ntut.edu.tw (H.-C. Yen).

¹ Graduate Institute of Manufacturing Technology, National Taipei University of Technology, No. 1, Chung Hsiao East Road, Section 3, Taipei 10608, Taiwan.

processes consist of two main steps, i.e., layer fabricating and selective laser scanning. In the slurry-based processes, the selective laser scanning refers to the selective irradiation of the layer by a laser beam scanning, which locally sinters the powder contained in the dried layer according to the predefined part slice geometry. LOM and CAM-LEM use sheet material to build the three-dimensional parts. The sheet material must be prefabricated by an accessory apparatus. Laser beam selectively scans outline of the predefined part slice pattern to cut the sheet material for separation of the green part and excess material. Obviously, compared with other processes, LOM and CAM-LEM possess the advantage of high build rate. Nevertheless, easy storage and delivery are the advantages of the processes using powder or slurry.

In LOM and CAM-LEM, adhesive must be laminated on the bottom side of the sheet. The adhesive is heated and melted with a heater roller to stick the fresh layer and the previous layer together; thus, the green block is built layer by layer. However, the laminated binder between the sheets leads to the micro-structure of the green part being imperfect. The sheet material in CAM-LEM also can be coated solution to dissolve the binder during the layer stacking, and then press with a pressing apparatus to tighten the sheets. Nevertheless, not only dissolving the dried binder is time consuming but also controlling the binding strength is difficult. The binding quality will influence the micro-structure of the green parts, and relate to the sintering strength of the sintered parts. Frequently, pressing is applied to tighten the layers when the part is completed. Such treatment is unnecessary in the slurry-based processes.

The aim of this study is to propose a new process to succeed the advantages and eliminate the drawbacks of the slurry-based and sheet material processes, the new process will employ the slurry composed of ceramic powder and binder to replace the sheet material used in LOM and CAM-LEM. A green block with good binding strength can be achieved without additional pressing because the binder contained in the fresh slurry layer permeates into the solid green block underneath the fresh slurry layer. Not only the prefabrication of raw material is not required but also laser scanning only traces out the outline of the green part. No hatch scanning of the part slice pattern is required; thus, the time-taken of scanning can be shortened dramatically; the build rate of the 3D green part can be increased. The new process will benefit the fabrication of the large parts and eliminate the required accessory apparatuses for the sheet material prefabricating and the green part pressing in LOM and CAM-LEM.

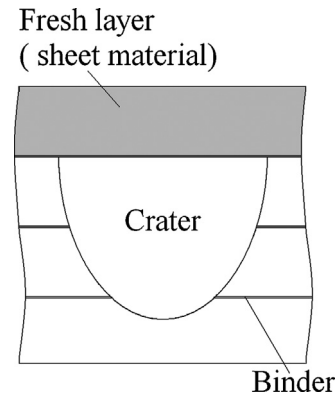


Fig. 1. Schematic of the fresh layer in LOM.

The main difference between the new process and LOM or CAM-LEM is the type of material. The new process employs the slurry layer to replace the sheet material used in LOM and CAM-LEM. In LOM, the new sheet material bridges the crater caused by laser cutting as shown in Fig. 1; thus, no craters appear on the surface of the green block.

A CO₂ laser beam produces a crater as shown in Fig. 2(a). In the slurry-based processes, scanning with high energy density leads to ablation and creates a linear crater along the track of the scanning. Fig. 2(b) illustrates a part of slurry of the fresh layer flows into the crater during the process of casting. After layer drying, the conspicuous crater is formed on the layer surface as shown in Fig. 2(c). Such crater is harmful to the interior construction of the green part, and then the part may not be built. A method, named selective laser burn-out (SLB), was developed in the present study to eliminate this phenomenon.

2. The principle of the new process

2.1. Selective laser burn-out

Selective laser burn-out is the process of selectively removing the specific ingredient in the material from a solid surface by irradiating it with a laser beam. At low laser flux, the specific ingredient in the material is heated by the absorbed laser energy and evaporates, and the structure material still remains. In this paper, polyvinyl alcohol (PVA-the binder) was evaporated by laser beam irradiation because of the low evaporation point, and the alumina powder was remained.

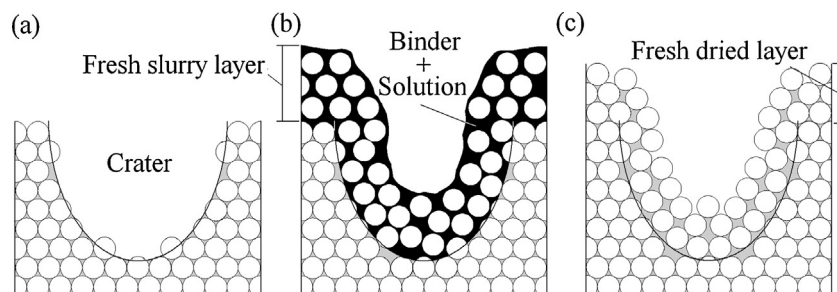


Fig. 2. Schematic of the slurry in the crater caused by ablation.

Download English Version:

<https://daneshyari.com/en/article/1474340>

Download Persian Version:

<https://daneshyari.com/article/1474340>

[Daneshyari.com](https://daneshyari.com)