Research on Porous Ceramic 3D Printing Process Based on Laminated Template Method

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***Abstract*—This paper proposes a new 3D printing lamination process to prepare porous ceramics with tight bonding between layers. The ceramic slurry is prepared by mixing alumina powder, organic binder and deionized water, nylon mesh cloth is used as organic template, scraper is used to scrape the ceramic slurry into the organic template, and the organic template layer is dried and laser scanned to obtain a single The green layer is obtained by laminating the layers and then sintering the ceramic body to obtain a porous ceramic. The results show that the compressive strength of porous ceramics prepared by this method can reach 43.12Mpa, the tensile strength between layers can reach 2.2Mpa, the diameter of ceramic through-hole is 70μm. The pore size and pore spacing of the ceramic green body processed by the process can be controlled, and the adhesion of adjacent layers of the ceramic body is improved, thereby improving the compressive strength of the ceramic material.**

Keywords-Laminate Manufacturing; Organic Template; Porous Ceramic; Material Properties

I. INTRODUCTION

Porous alumina ceramics have the advantages of good wear resistance, high porosity, strong permeability, low thermal conductivity and low dielectric constant. They are widely used in biological implantation, filtration, thermal insulation, catalytic carrier, and sound absorption reduction and other aspects.

Porous ceramic 3D printing methods include Fused deposition modelling[1],Selective laser sintering/melting[2], and frozen slurry-based laser selective gasification[3],Frozen slurry-based Laminated object manufacturing[4] and the like. The pores of the porous ceramic material prepared by the above method are controllable and the material preparation efficiency is improved[5,6], but the separation of the parts is prone to interlayer separation[7], the interfacial interface pores and the sintering shrinkage are uneven, and there is a significant step effect between the layers[8]. Reduce the interlayer bonding force of the material, and limit the physical properties such as compressive strength and flexural strength of the part[9,10].

Aiming at the above problems, this paper proposes a porous ceramic 3D printing process based on the laminated template method, which aims to prepare porous ceramics with tight interlayer bonding, controlled pore size control, compressive strength and flexural strength. The ceramic slurry is scraped into the organic mesh template by a doctor blade, and the surface of the ceramic green body is heated and dried by infrared drying, and the peripheral contour of the ceramic green sheet layer is scanned and cut by using a laser to the first layer of the organic mesh template ceramic sheet. As the substrate, the layers are stacked to obtain a ceramic green body, and the ceramic green body is subjected to post-sintering treatment to obtain a porous ceramic material having a regular controllable pore structure and tightly bonded between layers. In this paper, the effects of different blade angles and blade speeds on the uniformity of the cross-section of organic grid template ceramic sheets were investigated. The laser processing parameters were investigated to test the physical properties such as compressive strength and interlayer adhesion of ceramic blanks.

II. EXPERIMENTAL MATERIALS AND METHODS

A. Experimental materials

Table 1 shows the reagents and raw materials required in the experiment, wherein the alumina powder has an average particle diameter of 0.5 μm. The viscosity of sodium carboxymethyl cellulose is 600-800 cps, and the organic mesh template is a nylon mesh having a mesh density of 576/cm^2, a wire diameter of 0.1 mm, and a thickness of 0.2 mm.

TABLE I. THE MAIN RAW MATERIALS AND REAGENTS OF THE EXPERIMENT

Table Head	Table Column Head		
	Level	***purity/%***	***Solution mass fraction/%***
Reagents / raw materials	Analytical purity	≧99	70%
Sodium hydroxymethyl cellulose	Analytical purity	≧99	3%
Deionized water	Chemically pure		
Organic grid template			

B. *Sample preparation*

The experimental platform constructed in this paper consists of a network feeding device, a feeding device, a paving and drying device and a laser cutting scanning device. The supply network device is mainly used for the supply and recovery of the organic grid template; the feeding device is used for transporting the ceramic slurry onto the surface of the organic grid template of the lifting platform; the spreading device is composed of a scraper and a lifting platform for completing the organic template The laying of the material layer; the drying device mainly dries the material layer by the infrared searchlight; the laser scanning device is composed of a laser tube and an XY table for realizing the scanning of the laser.

The processing flow is shown in Figure 1: (a) preparing the raw materials. (b) preparing the ceramic slurry. (c) transporting the organic template to the top of the printing platform. (d) applying the ceramic slurry to the organic template by a doctor blade. (e) heating and drying the organic template by means of an infrared heating lamp. (f) scanning and cutting the organic template according to the desired target shape. (g) descending the platform by one step; repeating step cg to obtain a ceramic green body. Finally, the ceramic green body is subjected to post-sintering treatment to obtain a porous ceramic.

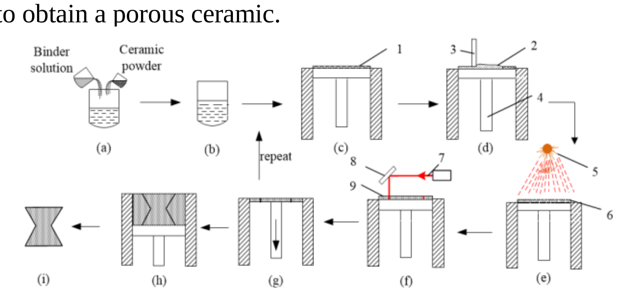


Figure 1. Process flow chart (1- organic template;2- ceramic paste;3 -scraper;4- lifting platform;5- heater;6- template sheet;7- laser;8-reflector;9- scanned material).

C. *Sample characterization*

The ceramic blank body layer was prepared by setting different blade angles and blade speeds. The cross-section morphology of the ceramic body layer was observed by CX31 optical microscope. The laser power and scanning speed were crossed by 70% ceramic layer body using CO^2 laser. In the experiment, the laser parameters were used to observe the surface structure and cross-sectional morphology of the laser layer; the compressive strength and interlayer bonding strength of the material were tested using a DDL300 electronic universal testing machine.

III. RESULTS AND DISCUSSION

D. *Ceramic green body lamination process and pore structure analysis*

A ceramic body is prepared by using a slurry having a solid content of 70% by weight, and the lamination process is as shown in Fig.2:(a) scraping the slurry into the organic template to obtain a ceramic green body layer.(b) preparing the ceramic body layer; The green body layer is heated and dried.(c) laser scanning and cutting the green body layer.(d) repeating the organic template laying, repeating step ac. Fig.3 is a structural view of a ceramic body obtained by the lamination method before and after sintering.

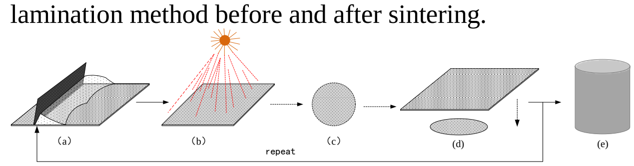
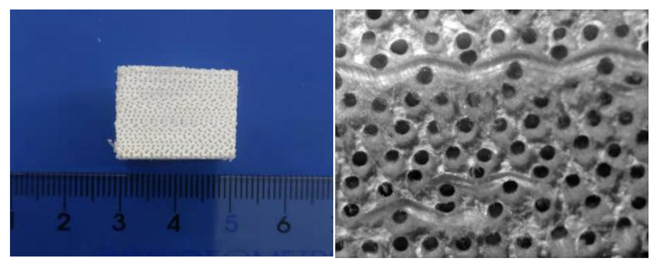
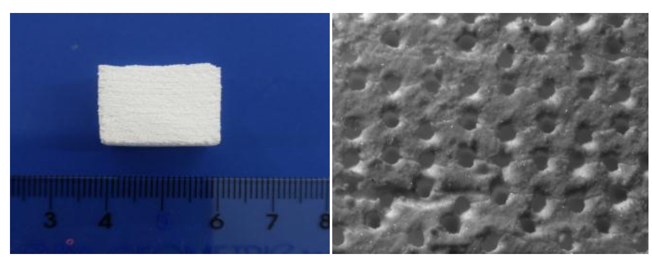


Figure 2. Schematic diagram of laying process of ceramic body material.



(a)



(b)

Figure 3. Schematic diagram of ceramic green body: (a) Before sintering (b) After sintering.

It can be seen from Figure.3 that the ceramic body prepared by the method has a complete structure after the sintering, the sample layer is tightly combined, and the pore distribution is uniform. The pore spacing of the sintered ceramic body is measured to be about0.14 mm, and the pore diameter is about 0.14 mm. The size is around 0.07mm.

E. Analysis of the uniformity of the section of the material by the blade parameters

The scraper scrapes the ceramic slurry into the organic mesh template. The angle of the scraper and the organic mesh template and the moving speed of the scraper have a certain influence on the flatness of the layer. The working principle and the force analysis of the ceramic slurry As shown in Figure 4.

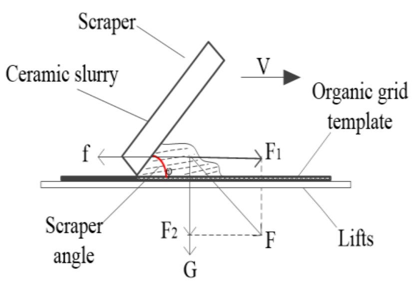


Figure 4. Scraper processing principle diagram

As can be seen from Fig.4, the component force of the blade pressure F in the vertical direction and the gravity of the ceramic slurry act on the organic mesh template, so that the ceramic slurry is squeezed into the pores of the organic mesh template. The larger the F is, the larger the amount of ceramic slurry is scraped into the organic mesh template, that is, the smaller the groove of the green body is, the more flat the material layer is, and the blade pressure F is affected by the blade and the template angle and the moving speed of the blade.

Design the crossover experiment between the blade angle and the blade speed. Select the angle between the scraper and the organic mesh template=15degree,30degree, 45degree,60degree,75degree, 90degree. The ceramic slurry is scraped into the organic template at a fixed speed of V=150 mm/s, and the ceramic layer body is dried by an infrared drying lamp; when the blade angle is obtained. When the blade running speed V=50mm/s, 100mm/s, 150mm/s, 200mm/s, 250mm/s,300mm/s is selected, the ceramic slurry is scraped into the organic template at the above speed, and the infrared drying lamp is used. The ceramic layer body is dried. The cross-sectional morphology of the layers prepared by different parameters was observed using an optical microscope, as shown in FIG. The depth of the groove of the cross section of the layer is measured, and the depth of the groove of the section of the layer is changed as shown in Figure 6.

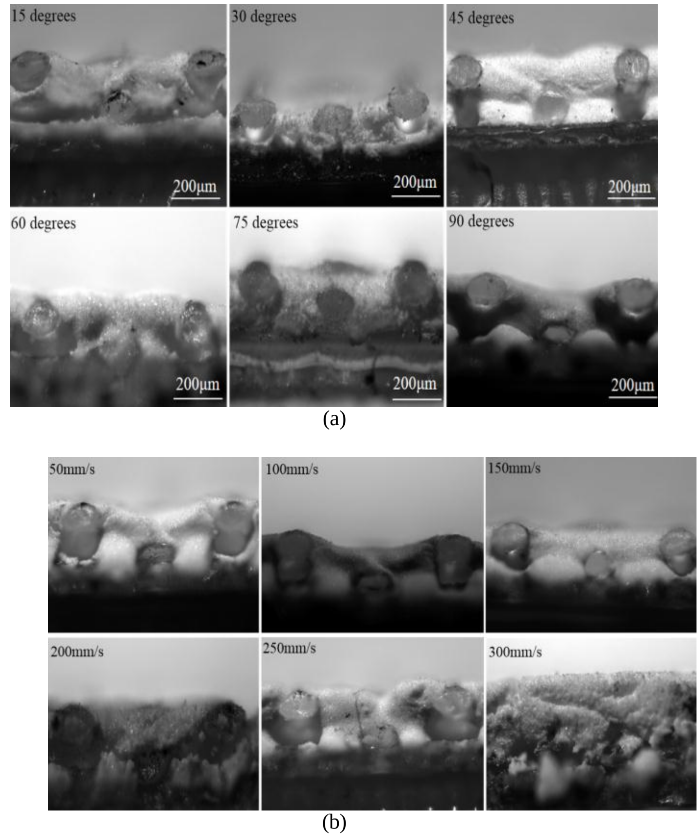


Figure 5. Schematic diagram of the cross section of the material layer: (a) Scraper different angle (b) Scraper different speed.

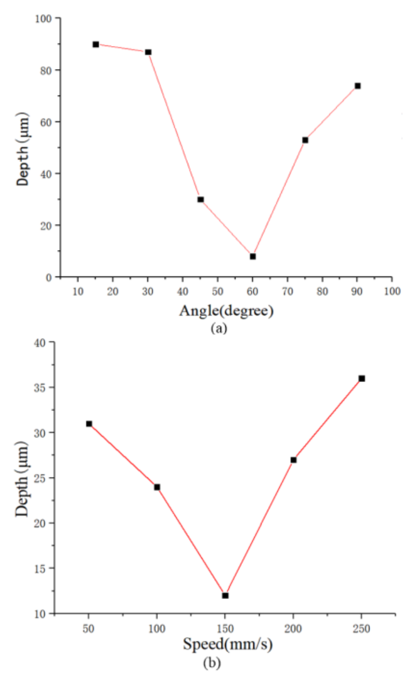


Figure 6. Schematic diagram of the depth change of the section of the material layer: (a) Scraper different angle (b) Scraper different speed.

It can be obtained from the analysis in Figure 6 that the blade speed is constant when the blade angle is from 15 Change to 60 degree During the process, as the angle of the blade increases, the depth of the groove section of the green body layer gradually decreases, when the blade angle is from 60 Change to 90 degree During the process, as the angle of the blade increases, the depth of the groove section of the green body layer gradually increases; when the blade angle is 60 degree, When the blade speed is changed from 50mm/s to 150mm/s, the groove depth of the blank layer is gradually reduced; when the blade speed is changed from 150mm/s to 250mm/s, the section of the blank layer is concave. The groove depth is gradually increased. When the blade speed is 300 mm/s, the slurry covers the organic mesh template, resulting in the thickness of the layer being increased to 0.35 mm.

In summary: when the blade and the organic grid angle is60 degree When the speed is 150mm/s, the groove depth of the blank material layer is the smallest, that is, the ceramic slurry enters the organic mesh template depth Y, and the green body layer is the most uniform.

F. *Analysis of the influence of laser processing parameters on the scan line*

The ceramic green body three-dimensional parts are assembled by two-dimensional pattern lamination, and the dried single-layer blank body layer is subjected to laser cutting of the two-dimensional pattern by a CO2 laser in order to obtain a desired size and shape.

Due to the influence of the degree of interlayer bonding of the groove depth layer of the material layer, since the organic template belongs to a non-uniform material, the organic template layer is scanned by different laser power and scanning speed, and the unevenness of the section thickness of the layer is different. Cross-experiment was designed for different laser power and scanning speed. The cutting morphology of the surface and section of the layer was observed by optical microscope. As shown in Fig. 7, the cutting depth of the layer was measured, as shown in Fig. 8.

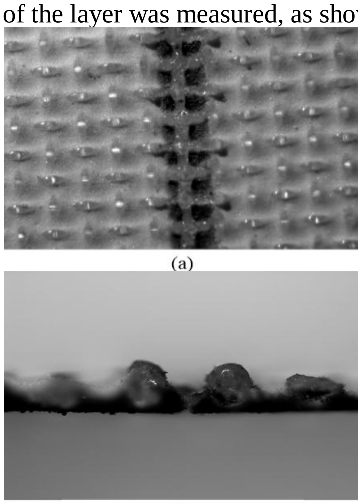


Figure 7. Sketch of the blank: (a) Surface topography (b) Sectional morphology

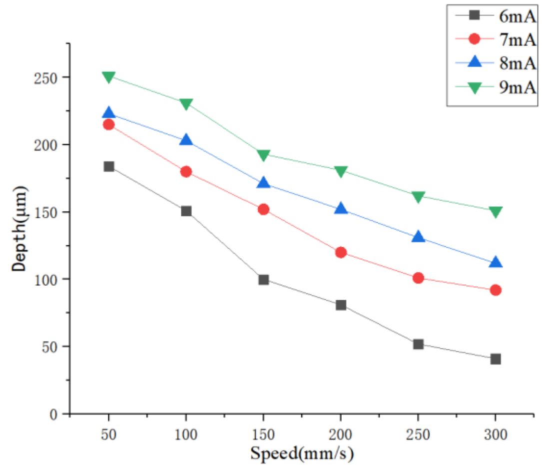


Figure 8. Schematic diagram of section depth change of laser cutting material layer

It can be obtained from Fig. 7 that the laser cutting power 30w and the cutting speed 300mm/s, the cutting depth of the material layer is the smallest, which is not enough to separate the desired shape layer from the raw material; when the laser cutting power P=41w, and the laser When the cutting speed is 100mm/s, the laser cutting layer has the largest depth, which can separate the desired shape layer from the raw material.

In the processing process, as the laser power increases, the laser scanning cutting speed is increased, the cutting depth of the material layer is larger, and the processing efficiency is improved. At this time, the material layer has a relatively flat cross section and a high degree of interlayer bonding.

IV. Processing experiment

The processing experiment was carried out using a 70 wt% solid content ceramic slurry. The blade angle is 60. The blade speed was 150 mm/s, the thickness of the ceramic green layer was 2 mm, the drying temperature was 210 °C, the laser power was 41 W, and the scanning speed was 100 mm/s. The ceramic green body is obtained by lamination manufacturing, and the ceramic green body is subjected to post-sintering treatment to obtain a ceramic green body. The compressive strength of the sample measured by an electronic universal tester was 43.12 MPa, and the tensile strength between layers was 2.2 MPa.

V. Conclusion

The method is different from the conventional LOM process, and it is not necessary to prepare the sheet in advance, and a porous ceramic material having tight interlayer bonding, controlled pore structure, compressive strength and improved tensile strength between layers can be prepared. The properties were tested to obtain a porous ceramic having a compressive strength of 30.12 MPa, an interlayer tensile strength of 2.2 MPa, a through-hole diameter of 70 μm, and a pore spacing of 140 μm. During the scraping process, different blade angles and blade speeds affect the amount of ceramic slurry entering the organic mesh form. When the blade and the organic mesh template angle are 60 degrees and the blade running speed is 150 mm/s, the amount of ceramic slurry entering the organic mesh template is the largest. As the laser cutting power increases, the depth of the laser cross-section cut increases.

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