Research on The Application of Ceramic 3D Printing Technology

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Abstract: Ceramic 3D printing technology is using computer aid design techniques to model and produce ceramic products. The basic principle is through X, Y, Z axis of the ceramic 3D printer displacement layer to create the computer-designed 3D ceramic shape, and combined with traditional pottery hand-made techniques to finally complete it. Analysis and utilize the advantages of ceramic 3D printing technology, in order to inject new vitality into the traditional ceramic production industry.

1. Introduction

Each step of Ceramic modeling process is through countless experience of precipitation. The traditional skill passed down from generation to generation, so that we still can use it to continue to product new ceramics. With the development of science and technology, the technology of making and producing ceramics is also advancing and changing. Traditional ceramic production techniques also have their inherent limitations. For example, it needs a certain production experiences and production basis to complete a ceramic product. Ceramic materials are more fragile easily to produce defects before burning them. The traditional ceramic techniques have certain requirements for modeling the clay body. It is difficult to find a new way for innovation.

In the process of traditional ceramic product design, the first step is drawing a sketch which is contented and expressed of the main idea through pictures. Besides it also should be considered about the working process and material’s costs. Ceramic product design techniques are developed from handmade pottery skills, along with the industry technology movement people began to use three-dimensional models into the mass ceramic production. Although it was advantaged to promote the development of ceramic product design, the accuracy of the three-dimensional model is not precise enough and the working time are increased. Also, it constantly modifies the model to extend the product procession. Otherwise, ceramic production designers need to communicate with different participates in the production process, express their ideas and explain the former design drawings or models. It can be seen that the traditional design process is very cumbersome. Two-dimensional drawings or sketches cannot express all angles of production. In the process of hand building a three-dimensional model, we also need to consider materials and equipment and skill factors etc. Both these two ways are lack of time and efforts, and the products cannot achieve the designers’ desired.

Alone with the development of computer technology, ceramic designers encouraged to use variety of new techniques to design ceramic model. Ceramic 3D printing technology is a currently developing new technology. It can easily though computer and ceramic 3D printer to product ceramic design productions. Ceramic 3D printing technology is flexible and the data of the objects are editable. This
technology can easily sculpt the objects shape, and the product procession is much shorter than the traditional way. The sketch drawing and modeling time are reduced. The influence of materials and technology on the hand-made model are avoided. Using of computer modeling software design a digital object, through ceramic 3D printer directly product a real clay object. It is a new ceramic production design revolution, and it can reduce the waste of human and material resources in different aspects.

Today, the production of 3D model is the basis of ceramic product design. Through the prefabricated 3D modeling, the designer normally can confirm the final ceramic design production shape. 3D printing models can more intuitively reflect designers' ideas by computer and 3D modeling software. It can also provide technical support to make the design idea clearly and convenient especially for later functional expression. For example, designers or engineers are operating 3D software to build ceramic models which can be quickly converted into STL formats and sent to ceramic 3D printers to print during a multifaceted objects design process. The digital 3D model techniques provide technical support for the production of ceramic design that are able to design more complicated appearances of ceramic production. In order to improve the aesthetic appearance of ceramic products, the application of curves and the smoothness of production surface are become significance. It is necessary for 3D technology design and sculpt the curves and print them out to see the effect. From this procession, designers can constantly by adjust the data of the program to flexibility modulate the final production’s surfaces.

2. Ceramic 3D printing molding technology

2.1 Principle of ceramic 3D printing molding
3D printing technology is actually the general term for a series of quickly modeling techniques. The basic principle of the technology is laminated manufacturing. Particularly, there is rapidly shift needle within full of materials forms a cross-sectional shape of the work piece by transmit data from computer in the X-Y axis, and the Z axis coordinates uninterrupted shift forms the thickness in order to sculpt integrated 3D printing.

Figure 1. Designers are using 3D modeling software to create ceramic 3D printing models.
Compared with the traditional pottery process like throwing technique, plaster casting technique, hand modeling, 3D printing technology transform the three-dimensional process of ceramic forming into a discrete stacking process which is formed from point to line, from line to surface, from surface to body. The 3D printing technology is greatly reducing the complexity of manufacturing, and breaking through the restriction of traditional techniques. The ceramic 3D printing technology can quickly create complex shapes and structural features in terms of shape complexity beyond those forms were difficult or even impossible to sculpt in the traditional modeling techniques. Expanding the imagination and making it possible and practically for ceramic designers, pottery masters or artists to imagine and create ceramic innovations.

2.2 Spray-extruded and stacked molding technology

This technology uses extrusion needles to continuously extrude paste-like clay which is working cavity under constant pressure, and accumulates layer by layer after curing in the air to final resulting a ceramic shape. This printing technique can use multiple needles and spray different kinds of paste clay at the same time, even it can print a variety of colors to form the colorful ceramic bodies. This technology originated from 3D printing in the construction industry. An American scholar, Joseph Pegna, proposed a construction method for constructing a free-form component by cement materials that could add up cement layer by layer and selectively solidify in 1997. Behrokh Khoshnevis, a professor at the University of Southern California, proposed a building 3D printing technology which is called Contour Crafting to enable to building layered stacking of concrete through large 3D extrusion devices with needles of smears in 2001. Studio Under studio, from Israel's Fire Dragon Institute of Technology, has developed a color ceramic 3D printing technology that blended specially colored powders into ceramic clay and then printed them out with extruded needles to produce colorful ceramics.
2.3 Layered bonding overlay molding technology

This technique is selective cohere ceramic clay by spraying the binder to achieve the accumulation of molding ceramic objects. The specific process of the technology is after the completion of the upper layer bonding, the molding cylinder drops a distance, equal to the thickness of the layer from 0.013 to 0.1mm, the powder cylinder rises a height and a number of powders are introduced and pushed by the paving roller to the forming cylinder. The layer is flattened and compacted by the needle under the control of the computer. Then following the construction section of the forming data, the machine selectively sprayed and adhesive the next construction level. The excess powder is collected by the powder collection device when the powder roll is laid. So that powder, powder roll and spray binders are sent back and forth in cycles, to result in the bonding of a three-dimensional powder objects. The place where the binder is not sprayed will become the dry powder, which support the forming process and is easier to remove after forming. This technology is simple to operate, the product has a high porosity rate. A wide range of original material applications, the surface of the holder is smoothly. The disadvantage of this technique is that the mechanical strength of the product is not strong enough. The products are normally need to be repaired in post-production phase. An Italian engineer Enrico Dini, who was working in Monolite company in UK, proposed a binder that accumulates into a type D(D-Shape) layer-by-layer selective bonding sandstone powder outside the device in 2007. Later, he successfully printed a sculpture with a height of 1.6m in 2009.

2.4 Selective laser-burning technology

This technique is a mixture of ceramic powder and a certain binder powder together, and molded by 3D
printer by melted from the laser to adhesive powder from the lower melting point powder in order to bonding the ceramic powder together. The specific molding process is 3D printer feeder rise then move the powder roller, lay a layer of powder material on the working platform. Then the laser is beaming by the laser devices, under the control of the computer it is burning some of the selected areas of the powder according to the profile of the section. It melts the powder of the binder to form an integrated printing layer. The working platform will drop a certain height after the first layer completed, and the powder roll will lay the mixture powder to prepare burning in the next layer and move in circles to stacking a ceramic form. This technology is ideal for the molding of composite prints based on polymeric polymers, composite ceramics, glass, fibers, metals and other powders.

![Figure 6. The forming schematic of selective laser-burning technology.](image)

3. Advantages and disadvantages of the ceramic 3D printing technology

Nowadays, the ceramic 3D printing technology is becoming a usual product or model technique by using computer and ceramic 3D printer to make 3D objects. This technique can accurately reflect the designer's thinking through 3D software and digital expression, and then combine them together to create the 3D models from imagination to finally printing accumulated layer ad layer texture by the 3D printer. If people want a smooth surface, they may polish their printed works in post-production phase. The technique is not only saving the working times, but also reduces costs and saving human and material resources.

Compared with traditional ceramic design methods, ceramic 3D printing technology has a more obvious advantage. It is not only can better displayed the designer's ideas by digital techniques, and more convenient to modify the form to saving the working time and material costs which were mostly spend in the traditional ceramic design or hand-made technologies. But also, it is improving production efficiency and accuracy by using computer and digital technology to interchange human’s images into three-dimensional forms which are directly transferred from ceramic 3D printers.

Today, ceramic 3D printing technology is usually using wet clay as the printing material in ceramic product design. But wet clay has certain defects, for example that is difficult to form and is not strong enough and easily to deform during the printing process. Perhaps the harder clay materials can be applied to avoid this problem later. Another problem is the layer thickness of ceramic 3D printing which normally is 10 mm, and it cannot guarantee the quality and speed of printing. The technician need research how to reduce the thickness to improve the accurate of printing, and after air-drying its appearance still can be polished to ensure its smoothness. Furthermore, ceramic 3D printing technology also has certain disadvantages that are the technology form the rough surface which qualities are not exquisite besides the appearance of them with irregular textures. Although the uniquely textures can highlight the characteristics of the ceramic itself, it cannot meet the requirements of smooth surface for functional use. To improve the smoothness of surface, the appearance of printed ceramic needs to be polished in post-production phase.

In addition, the ceramic 3D printing technology is still fresh vitality in many aspects. The appearance of printed objects excesses or lack of material during the printing process. Some materials will appear wiredrawing or remaining on the surface, so after the production should be further improved like
strengthen polishing. So that forming a smooth and available model, or removing the floating ash from the surface then to take the glaze is still necessary. Otherwise it will not achieve the desired effect until the glaze is finished ready to put into the kiln burning. Therefore, the ceramic 3D printing process need more rely on manual work to increase labor and material resources. Another aspect is the modeling process of computer and 3D software remaining a high intelligence operation which are need to be constantly coordinate between designer and operator. That may increase the workload.

In summary, the advantages of ceramic 3D printing technology application are still greater than the disadvantages in the future of ceramic product design. Ceramic 3D printing technology is the perfect combination of traditional ceramic manufacturing techniques and modern intelligent manufacturing techniques. This technology innovates the new intelligent ceramic manufacturing methods, new ceramic product processes and new modeling techniques to transfuse new vitality into the traditional ceramic industry. It is true that due to the short application time of this technology in the ceramic industry, there are still some weakness such as deformed or crack etc. The author believes that with the further popularization of ceramic 3D printing technology development process in the future, with strengthen the research on materials and modeling process, ceramic 3D printing technology will bring a new development for the innovation of ceramic art and design. People need pay more attention and further explore this technology in order to enhance the artistic effect and economic benefits of ceramic art and design.

![Figure 7. A ceramic 3D printing Art works made by Dutch designer Olivier van Herpt.](image)

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**References**

[1] Shi H., Wang T., Wang A., Liang C., Wang X., Zhang R., (2018) The current situation of ceramic 3D printing technology development and research and development trends. J. Ceramics, 16-19.

[2] Zhao B. (2018) Delicate and Elegant Chinese ceramics. Beijing Institute of Technology Press, Beijing.

[3] Baidu Library, (2019). Introduction to Ceramic 3D Printing Technology. https://wenku.baidu.com/view/fdfde066814d2b160b4e767f5acfa1c7ab00825e.html.
[4] Profound Visual View, (2019). The Application and Research of 3D Printing Technology in the Field of Ceramics. https://baijiahao.baidu.com/s?id=1623900068338411793&wfr=spider&for=pc.
[5] Sohu News, (2018). Ceramic 3D Printing, Beyond Your Imagination. http://www.sohu.com/a/239886531_320432.