Application of 3D Printing Technology in Ceramic Product Design

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Abstract. With the innovation of computer 3DPT (3DPT), the shape composition of ceramic product design is also constantly improving, and the analysis of ceramic product system design based on 3DPT is becoming increasingly important. In the construction of the entire ceramic product design system, how to reduce the ceramic manufacturing cost of the improved system and improve the product cycle efficiency is currently a key issue that needs to be urgently solved. Through relevant research on traditional ceramic product design methods, this article utilized the main application fields of 3DPT and its specific process analysis in ceramic products, and explored the advantages of 3DPT in ceramic shape design. Based on the discussion of the data results, the following conclusion can be drawn: six ceramic samples were selected through simulation experiments, and the design of ceramic product systems based on 3DPT improved the manufacturing price of single pieces compared to traditional schemes, with a comprehensive average reduction of 102 yuan in single piece price. At the same time, there were improvements in product cycle efficiency, and the overall average increase was about 15.5%. This indicated that the design of a ceramic product improvement system based on 3DPT has good results in practical applications.

Keywords: Ceramic Products, 3D Printing Technology, Ceramic Design, System Design

1 Introduction

The current design methods for ceramic products are constantly developing, and the updating speed of ceramic shapes is accelerating. People's research and discussion on it has entered a new stage. The main goal of this article is to improve the ceramic product design system by analyzing the application modules of 3DPT in ceramic products. Therefore, constructing a ceramic product system based on 3DPT is very important.

There are many theories related to the design methods of different ceramic products. Based on the combination of digital media technology and digital expression art, Yu L independently conducted personalized artistic design of ceramic products by combining numbers to better meet customers' private ceramic customization needs. Finally, starting from the advantages of digital media technology in ceramic product design, he comprehensively conducted research on the application

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of digital media technology in ceramic product design [1]. In recent years, with the widespread use of bamboo wood and ceramic combination design techniques, Qun Y classified and explained the application routes and design methods of bamboo wood materials, metal materials, and plastic materials through an overview of their design purposes. Combined with the application of cross-border materials in personalized ceramic design, Qun Y analyzed the design principles through some typical cases. Finally, the experimental results demonstrated that it has a certain improvement effect [2]. From the perspective of Transdisciplinarity, Qi Q analyzed the similarities between Mr. Wu Guanzhong's painting method and the design method of Chinese ceramic products, and believed that the artistic conception of Chinese aesthetics should be integrated based on the traditional Chinese aesthetic ideas, so as to create artistic ceramic products with oriental beauty and touching feeling [3]. Sun X analyzed the use of computational aids for the design of ceramic products and used three-dimensional methods to process the design. On this basis, he explored the current status of 3DPT in the field of ceramics, and then summarized the machine usage principles and characteristics in the ceramic 3D printing process through personal design and experiments. Finally, several sets of ceramic shapes were designed and produced using ceramic 3DPT. The results indicated that ceramic products using 3DPT have lower design costs and higher plasticity [4]. Fu WT focused on analyzing the creation and expression of Zen charm in ceramic lamp design. By analyzing, strengthening, and categorizing the Zen charm characteristics and design elements of these ceramics, a new perspective and method were provided for the design of ceramic lamps. The research aimed to promote the design of ceramic lamps and improve their artistic competitiveness and vitality [5]. Based on the trend of green design becoming a modern product, Hu XB discussed the connection points between green design and modern ceramic product design. At the same time, he conducted in-depth research from various aspects such as energy, resources, and lifecycle design in modern ceramic product design. He also explored how to use VR technology to build a display platform for ceramic product design, provide human-machine interaction feedback design information and achieve green design under VR technology [6].

The combination of 3DPT and ceramic product design has prompted the field of ceramics to re optimize the design scheme of artistic ceramic products [7-8]. The use of various research theories and methods above can effectively reduce the manufacturing cost of ceramic products, but there is a lack of analysis on product cycle efficiency.

The application analysis of 3DPT in ceramic product design is a major focus of this paper. In thi`s article, relevant research on traditional ceramic product design methods was utilized for improvement, and simulation experiments were conducted to reduce the manufacturing cost of ceramic products and improve product cycle efficiency. The final results showed that the ceramic product system design based on 3DPT has good results in practical applications.

2 Methods and Exploration of Ceramic Design

2.1 Exploration of Ceramic Product Design

Ceramic is a collective term for pottery and porcelain, which has a long cultural history and high artistic value in ancient China. The design of ceramic products reached its peak in Jingdezhen, and is famous worldwide for producing a large number of high-quality and beautiful artistic white porcelain and decorative porcelain [9-10]. With the innovation and development of science and technology, ceramic product design is constantly decorating and beautifying people's lives. This not only enhances the interactive experience between the public and artifacts, but also plays a very positive role in human life. At the same time, the design of some national ritual ceramics is also a proof of a specific stage in history. Based on the relevant knowledge and theoretical achievements of domestic ceramic product design, the methods and specific content of modern ceramic product design are shown in Figure 1.

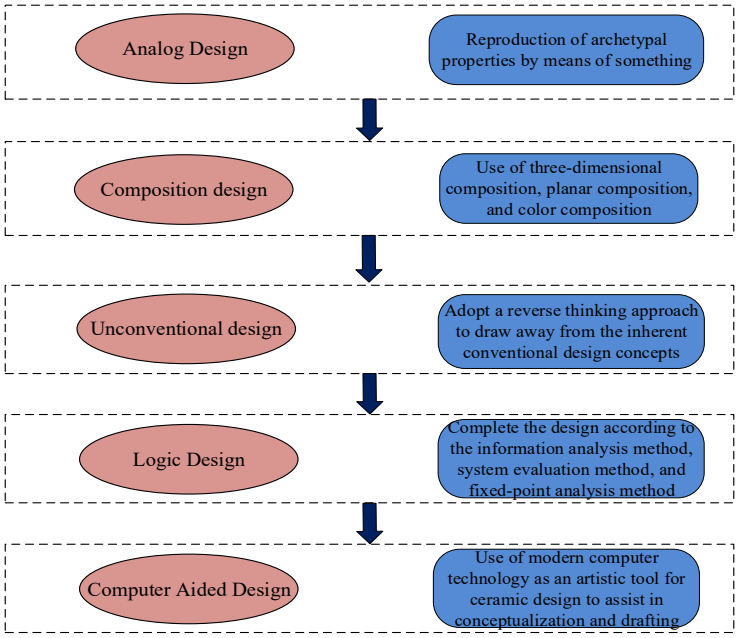

Fig.1 Method of Modern Ceramic Product Design

It can be seen from Figure 1 that the design methods of ceramic products mainly include simulation design, composition design, unconventional design, logic design and Computer-aided design. In addition, there are integrated design method and optimization design method. The first four ceramic product design methods mentioned above are relatively traditional design methods, which focus on the change of product design thinking, or a step improvement of ceramic engineering design process. This paper focused on ceramic products based on Computer-aided design, which is also the mainstream research trend of modern ceramic product design. Using computer technology as an artistic means of ceramic design to complete conceptual

drawings is more efficient. Therefore, based on traditional ceramic product design, introducing 3DPT for optimization and improvement is of great significance.

2.2 Application of 3DPT in Ceramic Design

3DPT, also known as a rapid prototyping manufacturing technology. Its main working principle is to use adhesive matching materials that can connect two materials on the basis of digital model files or 3D drawings, and construct products through printing layer by layer in sequence. In traditional 3DPT, it is usually used for manufacturing models or mold production processes, and is gradually being used for direct manufacturing of products after updates and changes in computer technology [11-12]. The main application areas of 3DPT are shown in Table 1.

Table 1. Main Applications of 3DPT

Applications	Description
Industrial Applications	World's first printed bicycle made with 3D printer
Medical Applications	Enables rapid modeling of human organs as well as the development of bone printing technology
Daily Life Applications	Application to food manufacturing equipment to print out food through computer software
IT Applications	Printing a wide range of sensors on highly translucent plastic at low cost

From Table 1, it can be seen that 3DPT is gradually being popularized in various fields, gradually approaching daily life applications from the initial production of precision instruments [13-14]. The advantage of 3DPT is that it does not require harsh factory environments or precise operating procedures. The operation of some small objects only requires traditional printers similar to computers. At the same time, printers with 3DPT would greatly increase the inclusiveness of personalized product production, and can play a huge role in private demand [15-16]. Based on this, this article proposed the use of 3DPT for the design and research of ceramic products. The specific process of the application of 3DPT in ceramic products is shown in Figure 2.

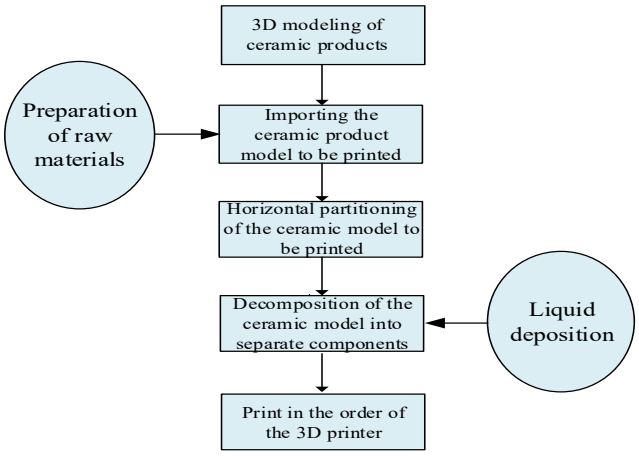

Fig.2 Flowchart of the Application of 3DPT in Ceramic Products

In summary, determining the 3D model production of ceramic products is the primary and most important step of 3DPT in ceramic product design. Next, by importing the ceramic product model to be printed and dividing it horizontally, the ceramic model to be printed can be separated for printing and finally liquid deposition can be achieved [17-18]. Based on the steps of the entire 3DPT, the entire ceramic 3D model can be divided into various horizontal partitions. Combined with the analysis of ceramics integrated with 3DPT in the following text, it is beneficial to gain a deeper understanding of their improvements compared to traditional ceramic production [19-20].

3 Construction of Ceramic Product Design System

3.1 Ceramic Modeling Design Integrating 3DPT

After a research discussion on theories related to ceramic product design methods and the application of 3DPT in ceramic design, the analysis of the improvement of 3DPT in ceramic modeling design compared to traditional ceramic product modeling is continued. The shape of ceramics determines their basic form and functional purposes. The design and production of some ceramic flower products not only have the practical function of holding plants, but also have the decorative function of carving patterns. 3DPT can make these advantages more apparent while reducing costs. The advantages and contents of 3DPT in ceramic shape design are shown in Table 2.

Table 2. Advantages of 3DPT in Ceramic Shape Design

Design Advantages	Content
Inheritance of traditional ceramic shapes	Inheriting the exquisite craftsmanship and vivid and delicate patterns of traditional porcelain
Cultural aesthetic filling and strengthening	The artistic beauty of the appearance shows a modern sense of rhythm and rhythmic transformation
Enhancement of post-modern art presentation	It shows the standard of pragmatism and mainly shows strong diversity
Increased technical difficulty and tolerance for error	It is possible to reach a stage that is difficult to solve by traditional processing.

From the advantages of 3DPT in ceramic shape design discussed above, it can be seen that 3DPT inherits traditional ceramic design and exquisite craftsmanship. On this basis, it shows the modern sense of rhythm and rhythm transformation, thus reaching the standard of Pragmatism with a strong diversity. These improved advantages have important reference value for the design of ceramic products. When it comes to ceramic product design, it is often necessary to balance the cost of the ceramic production process with the difficulty of the design process, and 3DPT better meets these needs. Therefore, it is necessary to use 3DPT for ceramic product design in some aspects.

3.2 Ceramic Product System Design Based on 3DPT

Based on the relevant research on traditional ceramic product design methods, combined with the application and process flow of 3DPT in ceramic product design, a ceramic product design system based on 3DPT is constructed by analyzing the advantages of 3DPT in ceramic shape design. At the same time, according to ceramic design practice, it is divided into design method module, digital model module, production process module, and ceramic product module. Therefore, the architecture of the ceramic product design system based on 3DPT is shown in Figure 3.

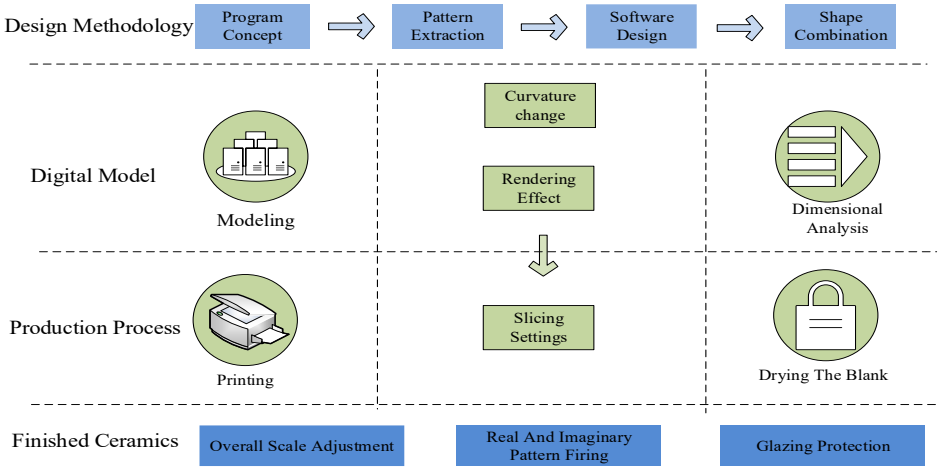

Fig.3 Architecture of Ceramic Product Design System Based on 3DPT

According to the architecture of the ceramic product design system designed in Figure 3, the entire ceramic product design is a comprehensive aesthetic and practical value artwork. Subsequently, the calculation of the proportion of raw materials in ceramic design is carried out to better perform glaze and firing. The main raw materials in ceramic raw materials are silicon dioxide, aluminum oxide, and iron oxide. Firstly, the proportion of silicon dioxide content in ceramic raw materials is calculated as follows in Formula (1):

$$a = M_1 \div (M_1 + M_2 + M_3) \tag{1}$$

Among them, M1, M2, and M3 represent the mass of silicon dioxide, aluminum oxide, and iron oxide in the ceramic matrix, respectively. The proportion of aluminum oxide content in the ceramic matrix is calculated as follows in Formula (2):

$$b = M_2 \div (M_1 + M_2 + M_3) \tag{2}$$

The proportion of iron oxide content in ceramic raw materials is calculated as

follows in Formula (3):

$$c = M_3 \div (M_1 + M_2 + M_3) \tag{3}$$

4 Simulation Experiment Results

After completing the construction of a ceramic product design system based on 3DPT, in order to test the actual effectiveness of the system in specific cases, simulation experiments were conducted.

This experiment selected six types of ceramics as sample parameters, named daily ceramics A, artistic ceramics B, sanitary ceramics C, architectural ceramics D, chemical ceramics E, and textile ceramics F, and used them as a dataset for training and testing. 100 rounds of data testing and analysis were conducted using Monte Carlo method within a certain period of time. The product manufacturing cost and product cycle efficiency of the 3DPT-based ceramic product design system on six ceramic samples were obtained and compared with the results of traditional ceramic product design methods. The results of applying the improved ceramic product design system and traditional methods for single piece manufacturing cost are shown in Figure 4.

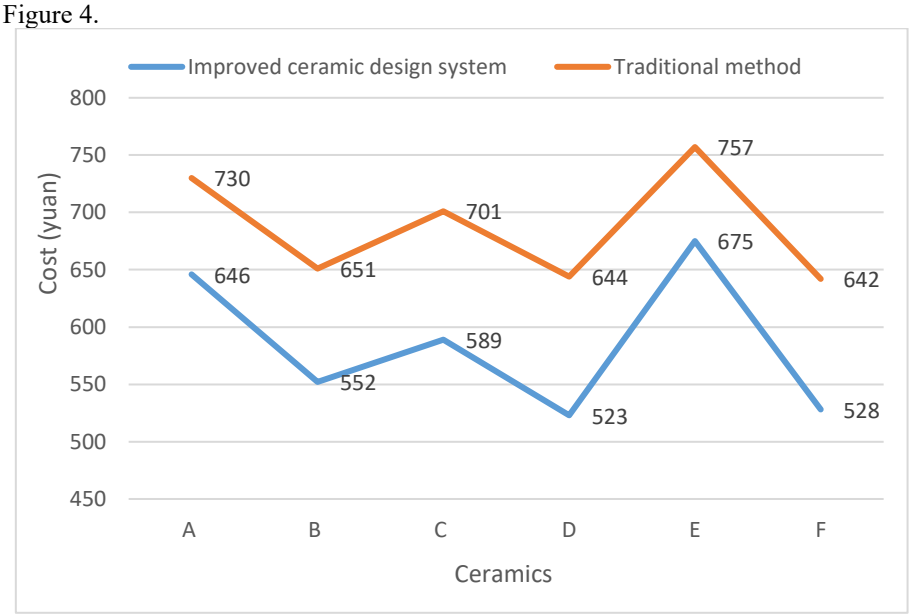

Fig.4 Improvement of Ceramic Design System and Single Piece Manufacturing Cost of Traditional Methods

In Figure 4, the blue line represents the manufacturing cost of a ceramic product design system based on 3DPT, while the orange line represents the manufacturing cost of a single product using traditional ceramic design methods. The ceramic product design optimization system using 3DPT on architectural ceramics D had the

best effect in improving product manufacturing costs, reducing it from 644 yuan to 523 yuan, with a reduction of 121 yuan. The manufacturing cost of other ceramic samples for a single product decreased by 84 yuan, 99 yuan, 112 yuan, 82 yuan, and 114 yuan from left to right, indicating a comprehensive average reduction of 102 yuan in the manufacturing cost of the ceramic product design optimization system. This indicated that the application of a ceramic product design system based on 3DPT is an improved solution in terms of manufacturing costs.

After discussing the manufacturing cost results of the above products, simulation experiments were continued. Based on the analysis of the product cycle efficiency of the ceramic product design system, the improvement in product cycle efficiency of the ceramic product design system using 3DPT compared to traditional methods is shown in Figure 5.

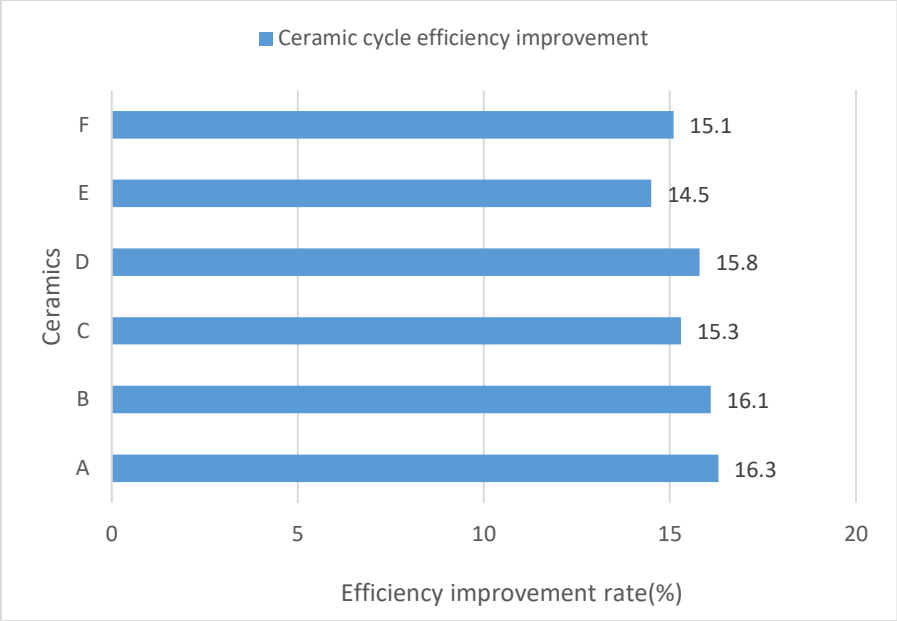

Fig.5 Improving the Product Cycle Efficiency of Ceramic Design Systems

In Figure 5, the blue column represents the improvement in product cycle efficiency of the ceramic product design system based on 3DPT. The product cycle efficiency of each ceramic sample increased, with each group of different samples increasing by 16.3%, 16.1%, 15.3%, 15.8%, 14.5%, and 15.1% from bottom to top. The overall average improvement in product cycle efficiency of the improved ceramic product design system was about 15.5%. This indicated that the ceramic product design system based on 3DPT has a good application effect in terms of product cycle efficiency.

5 Conclusions

In the context of the rapid development of science and technology and ceramic design methods, a ceramic product design system based on 3DPT can be widely applied to the personalized needs of the ceramic market. This article was based on the relevant research on traditional ceramic product design methods. By analyzing the main application fields and specific processes of 3DPT in ceramic products, and utilizing the advantages of 3DPT in ceramic shape design, simulation experiments were conducted on it. It was concluded that the ceramic product design optimization system based on 3DPT has good application effects in product manufacturing costs and product cycle efficiency. This article aimed to provide a ceramic product design system based on 3DPT for China through theoretical and empirical research. Due to the small number of ceramic samples selected and the insufficient analysis of 3DPT in ceramic shape design, the ceramic product design system designed in this article still has many defects and deficiencies. Further improvement and improvement would be made in future research.

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