Computer-Aided Design of Ceramic Product Modeling based on NURBS Method

Huiling Liu[1] and Feng Li[2]

[1]Art & Design Department, Taiyuan Institute of Technology, Taiyuan 030008, China, liuhl@tit.edu.cn
[2]Shanxi Muxiang Decoration Engineering Co., Ltd., Taiyuan 030006, China, jiufenglifeng921@126.com

Corresponding author: Huiling Liu, liuhl@tit.edu.cn

Abstract. NURBS function can help to express design thinking and creativity in computer, and realize three-dimensional modeling of ceramics. Based on the discussion of NURBS surface modeling method, this paper mainly studies how to make computer-aided design for ceramic modeling, and pay attention to the surface shape in ceramic modeling, taking practical application cases as reference and analogy. This paper aims to study the application of NURBS modeling method in the modeling design of daily-use ceramics, and explore a design idea that inspires designers' thinking through modeling method in software. Firstly, this paper studies the modeling characteristics of software, analyzes the advantages of surface modeling, and then talks about the similarities between the components of daily-use ceramics and sub-object elements in three-dimensional modeling, expounds the significance of introducing computer three-dimensional modeling technology into the modeling design of daily-use ceramics, and illustrates how to establish the relationship between the modeling elements in the software and the basic elements of daily-use ceramics with examples of surface modeling of software. This paper explores the modeling of work surface and summarizes some skills used in practical operation. At last, it summarizes how the basic elements and modeling methods of design software influence and inspire designers' design ideas in the modeling design of daily-use ceramics, and predicts the application of computer 3D modeling technology in the modeling design of daily-use ceramics in the future.

Keywords: NURBS modeling; Household ceramics; Modeling design; Computer aided design
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1 INTRODUCTION

NURBS is a modeling method to generate curved objects. As an excellent modeling method, NURBS can create realistic and vivid modeling in computer. The introduction of NURBS greatly enhances the surface modeling function of CAD/CAM system, so it has been widely used in various fields. At present, NURBS has been chosen as the main method of geometric description in industrial manufacturing industry, and NURBS has become the basic geometric expression form of many CAD/CAM systems and the international standard of data exchange. The powerful NURBS surface modeling system has good basic functions such as scanning method, skin method, rotating surface and stretching surface. In addition, the surfaces can be connected, trimmed, deformed and simplified. These functions can well express the ideal 3D model [1]. The software can repeatedly modify the model, establish data or parameters, and realize realism through the built-in lighting simulation system, all of which play a vital role in the completion of later products.

It plays a role in the early conception and scheme implementation stage of NURBS modeling for ceramics, sculptures, metal utensils, industrial products, and uses the free-form surface modeling function of NURBS to express contours and shapes with curves and surfaces in the internal construction space, so as to provide excellent data and shapes for the final industrial products or artistic works. This topic mainly studies the modeling method of design software, and puts it into daily ceramic modeling design. It demonstrates that in the development stage of modern ceramic design, the intervention of computer design has a profound influence on traditional ceramic design. At the same time, it explores the advantages and methods of the design software to interpret complex shapes in the daily ceramic modeling design, so as to inspire the designers' design ideas, improve the design level and open up a new way for computer-aided ceramic modeling design.

Porcelain is a great invention of China. Underglaze color painting is a traditional ceramic decorative art in China. It has a long history. As early as the mid-Tang period in the 8th century AD, the Tongguan Kiln in Changsha, Hunan Province made an important contribution and pioneered the new technology of high-temperature underglaze color painting. Since then, "the black and brown painting in the famous Cizhou Kiln in Song Dynasty and other northern folk kilns, as well as the underglaze decoration techniques of blue and white and underglaze red in Yuan, Ming and Qing Dynasties, can be said to have developed under the influence of Changsha Kiln, and opened the way for underglaze color painting." The history of underglaze colored porcelain in China for hundreds of years has left a wealth of cultural relics, and a great deal of information has been provided in modeling, decoration, composition, brushwork and so on, which has provided many useful inspirations and valuable experiences for the future creation and design of underglaze colored porcelain.

2 RELATED STUDIES

D'Uva and Eugeni [2] utilize a kind of algebraic surface computer technology and a kind of computer language that uses object standardization. Explain the related application of computer-aided design in ceramic product modeling design. Wei et al. [3] proposed a new way to engrave tools with precision machining into ceramic modeling design. This can effectively use the NURBS fitting algorithm to engrave the required complex parts on the surface brilliance contour in the ceramic design. So as to generate a unique new NURBS double loop fitting technology. Zhang and Wang [4] used the NURBS interpolation technology to update the parameters in the design in real time, which can effectively change the feed rate fluctuations and reduce the ceramic contour error. In addition, a new type of NURBS interpolator is introduced. Compared with the traditional design method of simulation research, it highlights the advantages of NURBS. And design an interpolated continuous NURBS curve. Audoux et al. [5] believe that NURBS is a recognized modeling method, and almost all modern 3D design software can include this design function. Using NURBS technology, we can

create a visualized calculation model on the computer. This model can also be well used in the design of porcelain shapes, and experiments have proved to have good results. Combining practical experience, fitting examples and analyzing computer-aided curved surface model design in porcelain design on the basis of predecessors. Safdari et al. [6] used computer-aided practical methods to model ceramic samples. And the original structure of ceramics and its strength and damage type were studied. As shown in Figure 1, using the computer-aided design of complex structure-based materials, the performance of the designed ceramics will be analyzed, thus showing that the computer-aided design of ceramics is a scientific idea.

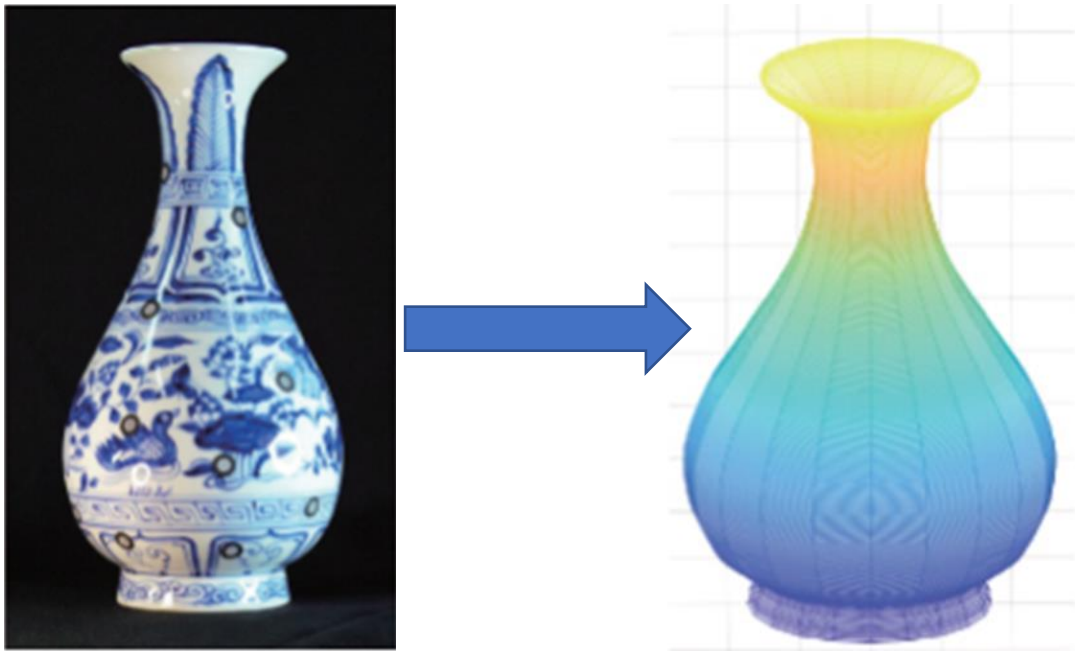

Figure 1: Software model diagram.

Nowadays, computer-aided design software is more and more used in ceramic modeling design, and 3D technology has been widely used in the field of ceramic modeling design because it can accurately and truly show the shape of products. The 3D software converts 2D drawings into 3D models, then endows materials and arranges scenes, and finally gets the product design renderings through rendering.

In developed countries, computer 3D modeling technology is widely used, such as aerospace industry modeling, automobile modeling, 3D animation modeling and other fields. However, in China, the application of 3D modeling technology in ceramic product design started late. Some advanced enterprises that have introduced computer 3D modeling technology ahead of time are ahead of the industry, while some enterprises are consciously introducing computer 3D technology to enhance their competitiveness in the face of increasingly fierce market competition. However, due to the commercial competition, there are relatively few published papers in the manufacturing enterprises engaged in this line. Based on the research of modern CAD technology and engineering analysis method in sanitary ceramic product design, according to the characteristics of sanitary ceramic product design and the principle of application-oriented and user-oriented, the design method of sanitary ceramic product is analyzed, and the overall structure model of sanitary ceramic CAD

system is established. Based on the feature 3D solid modeling technology, aiming at the complex structural characteristics of sanitary ceramic products, a method of dividing them into multiple functional parts and making parametric modeling for each part according to a certain order is proposed. Many sets of sanitary ceramic product designs completed in this sanitary ceramic CAD system have achieved good results [7].

3 COMPARISON BETWEEN COMPUTER-AIDED CERAMIC MODELING DESIGN AND TRADITIONAL CERAMIC MODELING DESIGN METHODS

3.1 Traditional Ceramic Modeling Design Method

Computer-aided design is a method for designers to design with the help of computers. It is characterized by a good combination of people's creative ability and computer's high-speed computing ability, huge storage capacity and logical judgment ability [8]. In ceramic product design, many heavy tasks, such as very complicated mathematics and volume shrinkage ratio calculation, putting forward various design schemes, comprehensive analysis, comparison and optimization, output of product drawings and production management information, which can be completed by computers. Designers can judge and modify the intermediate results of product appearance design, so as to finish the design work more effectively [9]. Computer aided design capability greatly improve the design quality, reduce the labor of designers, shorten the design cycle, reduce the product cost, and create favorable conditions for developing new products and new processes. At present, it is being welcomed and valued by manufacturing enterprises and professional designers in our country, and it has been gradually popularized and applied.

(1) Make a design plan. This is the first step in designing ceramic shapes. After understanding the market and customer needs, we need to work out a design plan for these needs to meet the requirements of the target customers.

(2) Sketch the concept. After the scheme is made, it is necessary to draw the conceptual sketch, and the traditional way is the floor plan expression. There are sketches, color effect drawings, plane projection drawings, engineering dimension drawings, etc. This kind of plane drawings can hardly truly show the design effect of products, and every detail change needs to be redrawn.

(3) Making an effect model. To truly show the three-dimensional effect of the product, it is necessary to make a certain proportion of effect models, which take a long time to make, have high cost and are difficult to modify after making, thus prolonging the design cycle of the product.

Ceramic ware for daily use is a three-dimensional shape occupying a certain space. As far as its appearance is concerned, it is composed of the most basic elements-point, line, surface and body. These elements, in ceramic modeling, can be expressed as abstract conceptual elements or concrete visual elements [10]. Elements such as points, lines, surfaces and bodies are reflected in concrete ceramic shapes, and they are manifested in various forms of sharp corners and end corners, line edges and lines, inner and outer walls, whole and partial, etc. Various changes of ceramic shape, such as turning point, ups and downs, cohesion and explanation, are all made up of these basic elements, which are combined in different ways and embodied in the form seen by vision.

3.2 Computer-Aided Ceramic Modeling Design Method

The process of creating ceramic modeling by computer modeling is generally divided into the following three stages:

(1) Analysis entity stage. This is a very important step. The established ceramic modeling must first consider what features this ceramic product is made of, which features should be taken as basic features, and determine the scale and proportion. The order in which the model is created has a great influence on the modeling. Generally, drilling, rounding and chamfering are done later.

(2) Establishing model stage. After analyzing the basic characteristics of ceramic products, modeling is carried out, and various modeling methods such as rotation, extrusion and stretching are used to complete the basic modeling. After the modeling of basic features is completed, the further improvement of the modeling should be considered. For example, considering that the surface is covered with glaze, the edge should not be too sharp and chamfering must be considered. In the process of building the model, the perfection of details can truly and effectively reflect the effect of the product.

(3) Complete two-dimensional graphics. After the 3D solid modeling is completed, the 3D renderers or plug-in renderers of 3D software can be used to generate 2D renderings.

Using NURBS modeling method to build ceramic products can play a convenient and fast role. Computer-aided design carries out real simulation in two-dimensional space or three-dimensional space. Before making the physical model, we can create the initial scheme in the software and complete the model in a short time. We can use the historical recording function of the software to repeatedly modify and observe the model style, As shown in Figure 2 which can vividly show the true effect of ceramic modeling and give different materials and texture maps to ceramic products.

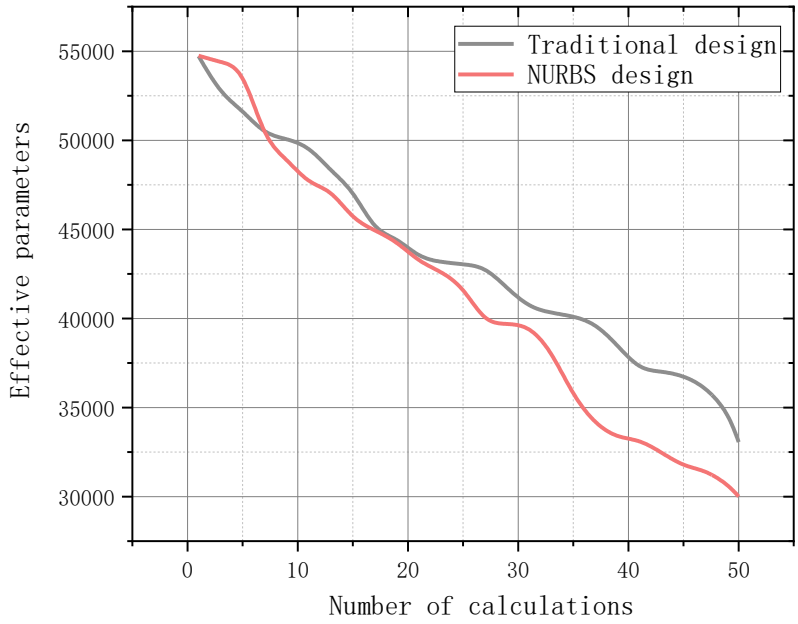

Figure 2: Comparison of NURBS and traditional design.

NURBS's free-form surface is mainly presented visually, and new digital means are used to express ideas and ideas. Although it is not a real physical model, it has too many advantages in the implementation and rapid expression of the scheme, and it has played a great role in the formation of our ideas and the conception of creativity, greatly improving the quality and efficiency of its design. As shown in Figure 3: three-dimensional technology plays a very important role in product design. If necessary, the computer can create the model and initial design of the product, and fully visualize the product. Although it is not a real model substitute, 3D rendering can more easily submit product designs to customers. Different from real models, 3D models have the advantage that they only

need to be modeled once, but they can be textured many times. Using different materials to create the same product can process different images within a few minutes, and it is easy to change a part of the model without creating the whole model from scratch.

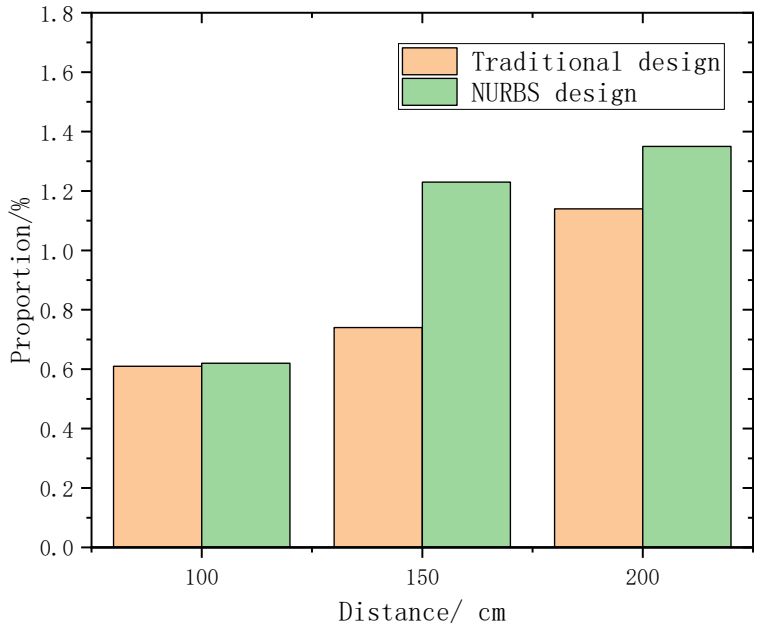

Figure 3: Model length ratio.

4 ANALYSIS OF RESULTS

4.1 Curved Surface in Ceramic Modeling

In ceramic modeling design, the composition of curves and curved surfaces is an indispensable expression and application form of ceramic modeling design. The design of curves and curved surfaces can make the modeling have a sense of rhythm, and the design of streamline can not only make people feel happy and comfortable in the experience of contact with objects, but also show the characteristics of movement and life. Studying the curves and surfaces of ceramic modeling can help us quickly find the correct NURBS surface modeling method, and help us better understand the structure of ceramic modeling. The modeled surfaces of ceramics are mainly divided into geometric surfaces and free-form surfaces.

The composition of geometric surfaces has certain standards and rules, usually consisting of parabola, arc line and multi-curve of regular circle, ellipse or above. Its surface feeling is very regular and unified, giving people a sense of bright pleasure and order. Geometric curved surface, as a form of ceramic modeling, is rarely seen in traditional ceramic modeling design in the past due to the influence of production technology, molding technology and aesthetic concept. With the technological innovation of industrial production and the improvement of people's aesthetic consciousness, geometric curved surfaces in ceramic shapes produced in modern industry are more common. Geometric surfaces are characterized by clear direction of surfaces and fixed change of forms.

Compared with free-form surfaces, they are simple in sense of form and easy for people to understand and master. Free-form surfaces are rich in shapes in ceramic modeling, with subtle details in changes. "C" shape and "S" shape are more common in the sense of surface form, and they are also presented in other more complex surface forms.

NURBS model building method, points form lines, and the movement connection between lines will form faces. The appearance of ceramic ware is also composed of the most basic elements-point, line and surface. These elements not only have abstract conceptual elements in ceramic modeling, but also contain specific visual elements. Therefore, before the model is created, we can conceptually divide the surface shape, and then select the corresponding NURBS modeling method to create it. NURBS modeling method is relatively basic and representative. Combined with ceramic modeling, it can be found that most geometric surfaces, "C"-shaped and "S"-shaped free-form surfaces are formed by the outer contour around the axis. Simply put, they can be realized by the rotation function of software. However, in addition to the main body of modeling, there are many other modeling details that need to be expressed, such as the spout, lid and handle of ceramic teapot, etc. As shown in Figure 4: these modeling can't be realized by a single rotation method, but the scanning method and skin method mentioned in the article can be used. This series of NURBS surface modeling methods provide the possibility for other modeling, and the more complex and varied free-form surfaces need more methods and steps.

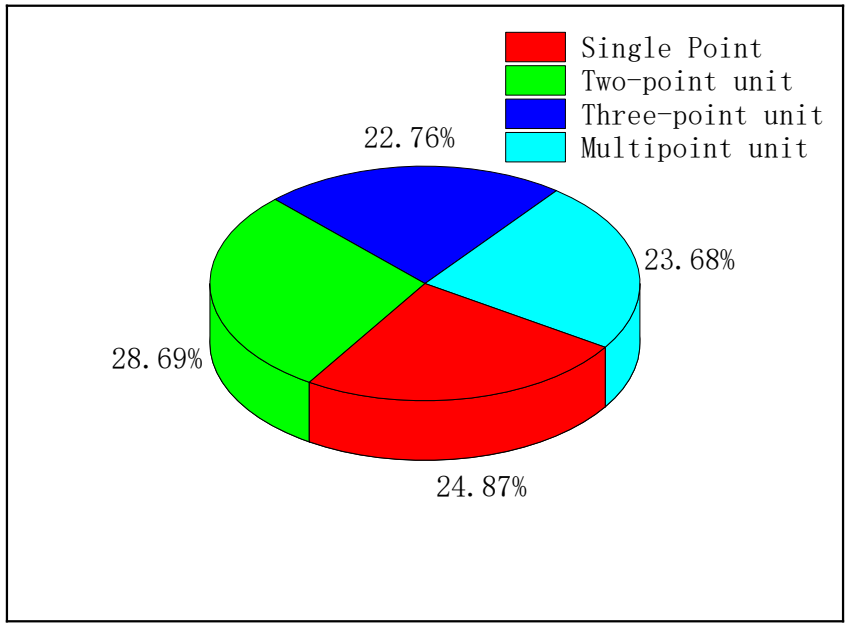

Figure 4: Number of units at each point.

Finally, the shape generated by NURBS can be rendered later. With the improvement of computer digital technology, a variety of post-rendering software is born. Post-rendering can be made into photo-level real effects, as shown in Figure 5 which can not only be used as reference samples of ceramic schemes, but also be used for reference production or mechanical production in the real production stage.

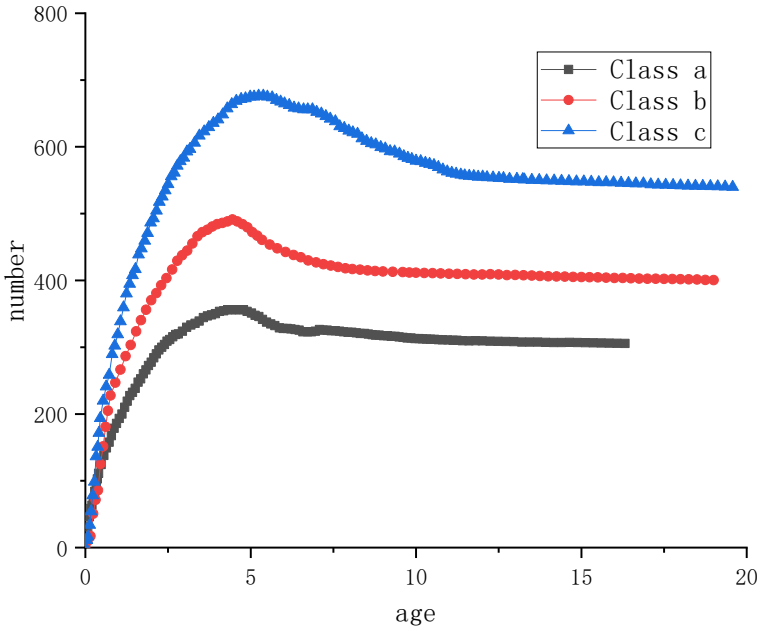

Figure 5: Three types of ceramic designs are popular among teenagers.

Among NURBS, the most important ones are B-curve and surface. B-surface is the extension and extension of B-spline, which has some excellent properties of B-curve. It retains the advantages of Bezier method, and at the same time overcomes its defect of no local properties due to global representation. It was put forward to solve the problem of connectivity when describing complex shapes. It was put forward by Schoenberg. In 1972, De Boor and Cox independently gave standard algorithms for B-spline calculation. At present, B-spline method has a unified, universal and effective standard algorithm and powerful supporting technology, only free curves with powerful functions can be designed, which is one of the widely used methods of digital shape description so far, as shown in Figure 6. At present, it has become the basis of rational B-spline method for defining international standards of industrial products, so B-surface theory is adopted as the basis of ceramic modeling design.

4.2 Ceramic Surface Feature Design

The decoration, carving and tracing on the surface of ceramic products need to be re-designed on the curved surface. From the angle of geometric design, the essence of surface design of ceramic products is the design of curves on curved surfaces. Point-to-surface projection is the basis of the design of curve points on a curved surface.

Projection to parametric surface is a basic work of curve design. This kind of method includes two parts: calculating projection and reverse solution. Because the surface design of ceramic products needs a lot of interactive work, the whole calculation process needs to meet the fast convergence speed to improve the design efficiency. Therefore, the geometric iterative algorithm of point-to-point parametric surface projection and reverse solution. This method is based on local double circular arc approximation, and the projection point is estimated by the test point as the

beginning of iteration. In each iteration, a double circular arc is built locally approach the original surface from the current projection point. Then, the test points are projected to the constructed double circular arc to calculate the projection points and their parameters of the next iteration. Because the local double circular arc approximates a whole.

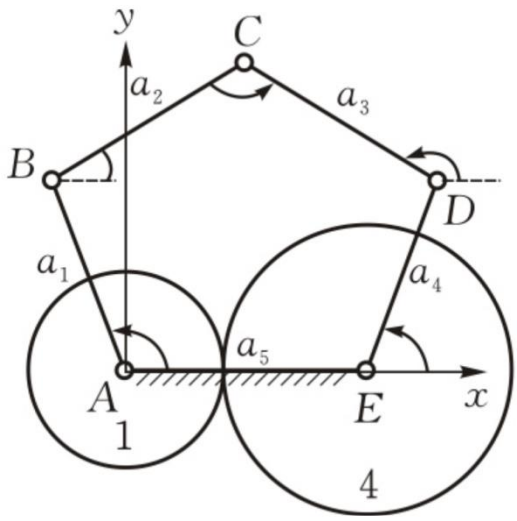

Figure 6: Curve structure relationship.

The approximate space has been expanded, so that each iteration has a larger step size. This method can not only reduce the number of iterations, but also make the iteration get rid of the poor initial value quickly and improve the robustness of the method. It can be seen from Figure 7. The whole iterative process is controlled by the user input precision, which is convenient for application. It can be seen that this method has better approximation accuracy and larger approximation step than traditional similar methods.

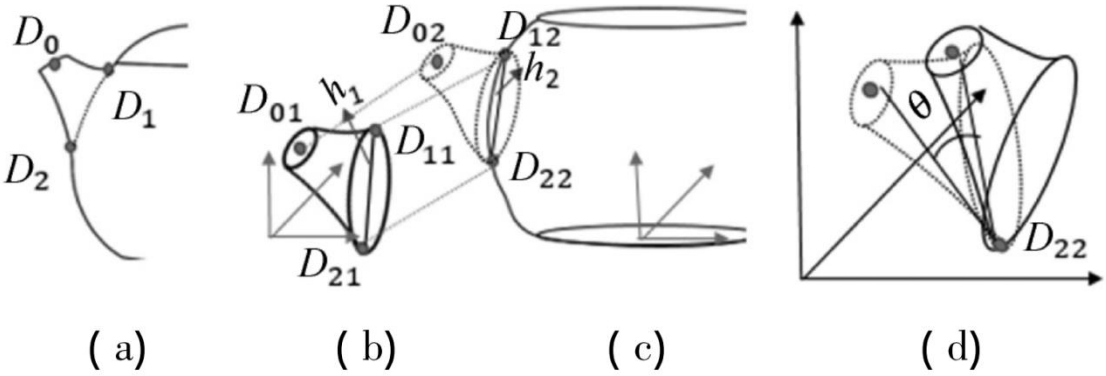

Figure 7: Spout splicing operation indication.

In order to ensure the correctness and design efficiency of ceramic product surface design, the advantages and disadvantages of this method are measured by three standards: convergence correctness, convergence speed and dependence on initial values. It can be seen that under the

same step calculation mechanism, this method has obviously improved convergence correctness, error iteration times and calculation time. Experiments show that the point-to-curve projection algorithm needs fewer iterations and the convergence rate is only 50%-70% of the original method, compared with Newton iteration method, first-order method and second-order method and other projection calculation methods based on single point approximation, which proves that the algorithm has advantages in convergence rate and quality, so it can well support various surface design applications of ceramic products.

In fact, modeling design is an important aspect to realize artistic value. On the other hand, the node database provided by modeling design lays a data foundation for 3D finite element analysis of product pressure. Through 3D finite element analysis, products with high stress resistance can be obtained, which can reduce the cracking and porcelain explosion of products during drying, firing and baking, or design lightweight products under certain stress conditions, which can save mud, fuel and cost. Excellent modeling design has high economic value.

5 CONCLUSION

Ceramic products are one of the widely used design products in our daily life, and also an important carrier of our culture. This paper discusses the aided design and visualization technology of ceramic products, how to improve the quality and efficiency of innovative design of ceramic products, how to use the modeling technology of free surface and free curve in aided design to accurately and efficiently express the shape and texture of ceramic products, and how to reverse construct the shape and texture to reuse the design and improve the design efficiency. How to evaluate and reflect the design quality of ceramic products by using geometric continuity through the visualization of ceramic products, form the design closed loop of ceramic products and improve the design quality. How to generate product prototype intuitively and quickly according to customer's demand through natural semantic-driven ceramic design, and form a demand-driven design pattern. The work introduced in this paper has constituted the key technology of 3D aided design and visualization of independent intellectual property rights in China, and will strongly support the development of digital ceramics and solid ceramics in China.

Huiling Liu, https://orcid.org/0000-0001-9403-7223
Feng Li, https://orcid.org/0000-0001-5501-3595

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