

Furniture Design Based on 3D Printing Technology

Yuting Fu¹ Yi Yang²

^{1,2} *Hubei Institute of Fine Arts, Wuhan, Hubei, China*

ABSTRACT

In the period of continuous development and technological progress, new materials and new methods will affect the design concept of furniture. 3D printing technology is developing more and more rapidly, so discuss whether other means can be used to design and make furniture. From the perspective of personal design, it is more personalized to use 3D printing technology to make furniture. 3D printing technology meets the people's demand for customization, breaks through the limitations of traditional furniture design, and uses new materials and technologies to achieve the desired effect. Based on 3D printing technology, this paper deeply understands the application of furniture design, studies and integrates the current situation of Chinese and foreign furniture products, and integrates the use and innovation of 3D printing technology. However, all seats need to conform to ergonomics. The combination of culture and new technology and the presentation of Ming furniture in a new form are in line with the public's aesthetic. In order to meet people's needs for personal products, 3D printing technology can accelerate the transformation from sketches to real objects by changing materials and technologies more effectively. If people need to adjust after designing the product, they can print a small model for experiment. This can avoid the problem that there is no way to modify the material objects after they are made, which not only saves costs but also speeds up work efficiency.

Keywords: *3D printing technology, Furniture design, Ergonomics.*

1. INTRODUCTION

In recent years, 3D printing technology has played a major role both in China and foreign countries, and has been included in the national high-tech development plan. Therefore, industries related to 3D printing technology have received corresponding resources and preferential policies in many large cities in China. Therefore, China should strengthen the research and development of cutting-edge technologies and equipment such as material manufacturing, so as to accelerate the development of competitive industries and strategic industries.

In the construction industry, many engineers and designers are slowly beginning to accept that building models can be printed through 3D printers, and then adjust and modify the scheme. These models are made quickly, cost less, and will not have much impact on the environment, which meets the requirements of designers and the masses. At the same time, it can save a lot of materials and avoid the need to adjust after the construction is completed. Traditional manufacturing incurs many

unnecessary expenses. In terms of cost, time and precision, 3D printing technology is more suitable for large-scale production, and 3D printing technology has brought countless benefits to the manufacturing industry [1]. In recent years, 3D printing technology has also been used in many aspects of the medical field. When simulating surgery experiments, 3D printing technology can be used to print the model of human internal organs to study whether it can be solved by surgery. The application of 3D printing technology has produced great medical value in the process of surgery, and has brought great help to the medical field. Before the operation, the accident can be reduced by demonstrating the model and adjusting the operation plan [2]. In orthopedics, people can see where the patient's bone is damaged by scanning. Doctors can build a model by computer calculation and print it out with 3D printing to see whether it matches before surgery [3]. In dentistry, a dental model can be built through pre scanning to see where the teeth are missing, and a detailed repair plan can be developed to reduce costs. In light industry, people specializing in food have begun to

use 3D printing technology to print chocolate. Various shapes can be made from the built models. At present, 3D printing technology has been applied in the jewelry industry [4]. The designer will import the designed model into a 3D printer and print it, so that different jewelry materials can be displayed through different 3D printing materials. In today's daily life, many designers apply 3D printing technology to furniture design. The author thinks that the demand of modern people is people-oriented, and the products designed need to meet the needs of people, rather than focusing solely on the design effect of furniture. This paper is mainly based on the characteristics of modern furniture design and the application status of new technologies and new materials. It puts forward the principle and application mode of 3D printing technology. Through research and exploration of the specific application of 3D printing technology in furniture design, it analyzes the current and needs to be improved areas of 3D printing technology in the furniture industry. It is necessary to carry out in depth study of 3D printing technology and furniture design methods to meet the needs of modern consumers for personalized customized furniture [5], and keep improving their own design [6].

Therefore, at present, China's 3D printing technology is leading in the world. The rapid development of laser direct sintering technology almost meets the mechanical performance requirements of special parts. It was reported that Huang Weidong's team of Northwestern Polytechnical University used this kind of technology to manufacture metal parts, and also used 3D printing technology to repair aeroengine blades. In addition, under the guidance of Professor Wang Huaming of Beihang University, their team created a special research on aircraft aviation engines. Therefore, China has entered the forefront of the field of 3D printing of metal materials. With the steady development of 3D printing technology, 3D printing technology will be applied to all areas of life [7].

2. CURRENT RESEARCH LEVEL AND STATUS IN CHINA AND FOREIGN COUNTRIES

The development and application of 3D printing technology in the production of traditional Chinese furniture and models are also increasing in China. The development of traditional furniture product design includes some important stages such as

conceptual development, drawing of design drawings and isolation of artificial products. However, the production of traditional furniture takes a long time, costs a lot. At present, major furniture design companies have gradually integrated 3D printing technology into the design and development of furniture. The main processes such as 3D printing products, color processing, and product fine-tuning have been carried out, gradually reducing some limitations of furniture products, and solving the problem that furniture can only be demonstrated through design drawings after the completion of traditional space design. At the same time, designers can also intuitively carry out the first processing analysis of furniture, and can save costs while processing and modifying. After that, the dyeing, finishing, product processing and other processes become easier and more efficient, maximizing the integration of products and solutions.

The development and application of 3D printing technology in foreign countries are increasingly mature, and its subdivision technology has been very advanced. Photocatalysis of plastics such as SLA and DLP is highly automated in the melting process, which can produce good modeling quality. However, most of the plastic parts are resin with limited strength. This technology can be temporarily used in a simple furniture model, and can only be used as a model. It cannot be used in production. The 3D injection molding printing technology is based on a certain line layer and designed with micro engineering principle to form a layer by layer effect with 3D profile. Famous overseas companies use 3D printing technology to provide customers with personalized services. The design products include sofa, table, seat and other furniture products with simple design and novel design [8]. These models are usually made of black and white PLA. After 3D printing, all works are hand polished and combined. It takes 5 to 7 hours to complete each work. They created a luxury to show the value of their company's products and let customers feel the difference between new technology and traditional craft.

Now, many foreign countries have applied 3D printing technology in automobile manufacturing, electronic technology, medical field, aviation technology and other fields. In addition, they also provide personalized customization services in 3D printing technology, and make physical products for sale through a unified platform based on the opinions of mobile phone customers. The exploration of 3D printing technology in China is a

little later than that in foreign countries, but many Chinese researchers and experts in the field of industrial design have paid attention to the emerging technology of 3D printing with the rapid development of 3D printing in various fields abroad.

3. FEASIBILITY ANALYSIS OF 3D PRINTING TECHNOLOGY IN FURNITURE DESIGN

3.1 Application in 3D Printing Technology Design

Traditional furniture manufacturing uses most common materials such as wood, plastic, metal, glass, etc., and the processing method is mainly in the form of producing quantitative materials. However, 3D printing is a typical additive manufacturing technique, and first of all, such changes can make the structure of furniture from a single structure to a very complex structure. In addition, there are perforated chairs with irregular holes inside, which can make it more elastic. However, the pores of the foam are not the most desired size. Due to the lack of rigidity of pure foam materials, the quality of users needs support. The 3D printer form can be shaped at one time. It will have better effect if no other materials are needed except for printing materials. 3D printing technology can continuously produce excellent furniture in terms of function, beauty and shape. This degree of freedom exceeds the traditional shrink production mode, and 3D printing technology has great benefits for the application in the furniture field.

3.2 Ergonomic Analysis of 3D Printing Technology Furniture Product Design

Recently, a new science, called ergonomics, has emerged. It applies scientific knowledge such as physiology, psychology and medicine to study the relationship between machinery and human beings in group machine systems and improve the overall labor effect of the system. The elements of ergonomics are often one of the methods for enterprises to improve competitiveness. "Human engineering factors" are factors that need to be considered when designing industrial products. As shown in "Figure 1", according to ergonomic standards, the optimal values of each part of the chair are as follows.

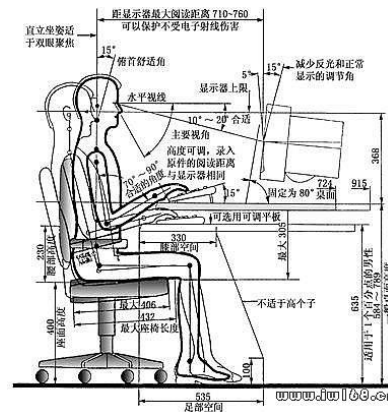


Figure 1 Body size. (Seat height: 380mm-450mm. Seat width: 380mm-480mm. Seat depth: 420mm-450mm.) <https://www.iw168.cn>

4. APPLICATION OF 3D PRINTING TECHNOLOGY IN FURNITURE PRODUCT DESIGN

4.1 Design Trend of 3D Printing Furniture

At present, 3D printing technology mainly focuses on the manufacturing of small customized furniture. Due to the high cost of 3D printing technology, the short-term use of 3D printing greenhouse products focuses on the adaptability and craftsmanship of furniture. This technology has the upper hand in the furniture manufacturing industry, for example, simplifying the furniture production process and saving time and materials. It is what the manufacturing industry needs in the future. The development of 3D printing furniture industry in the future will break the boundaries of traditional manufacturing technology and transform into a unique production mode. It is not a large number of furniture production, but the integration of industrial clusters, design, materials, technology and value chain.

4.2 Principle Analysis of 3D Printing Technology

As a comprehensive application technology, 3D printing technology integrates advanced technology into digital model, precision machinery, electromechanical control technology, information technology and other fields. 3D printer is the core equipment of 3D printing, and is a complex mechanical system integrating machinery, control and computer technology, mainly composed of high-precision mechanical systems.

3D printing technology mainly refers to additive molding technology. From the perspective of molding technology, 3D printing technology has broken through the traditional manufacturing molding method. Through the combination of high-speed automatic forming system and computer data model, it is completely unnecessary to manufacture and machine the traditional mold, and can produce various prototypes with complex shapes.

At present, the printing methods used in 3D printing technology include melt deposition, selective laser sintering (SLS)/laser direct sintering (DLS), electron beam free-form manufacturing, selective laser melting molding, layered solid manufacturing, stereo lithography, and digital light processing. The most commonly used methods are melt deposition, selective laser sintering (SLS)/direct laser sintering (DLS), stereo lithography and digital light processing. Melt deposition is the process of stacking thermoplastic materials layer by layer under the control of PLC. The forming material and supporting material are transported to the corresponding nozzle through the wire feeding mechanism, heated to the melting state in the nozzle, and moved along the shape and internal path of the table under the direction of the control system. At the same time, the adhesive material and supporting material that will extrude the molten material into a viscous shape are selectively coated on the table to quickly harden to form a contour. Following the composition of the plaque layer, the nozzle rises to the set height and then applies another layer. Selective Laser Sintering (SLS)/Direct Laser Sintering (DLS) technology uses small particles, such as plastics, ceramics and synthetic blocks in three-dimensional shape, and requires the use of high-energy laser. The powder material is selectively melted by scanning the cross section generated by the 3D digital description of the components on the surface of the powder bed. After scanning each section, it is necessary to further reduce the thickness of the powder bed, apply a new material layer to the upper part, and repeat the process until the part is completed [9]. Direct laser sintering technology (DLS) and SLS are examples of the same concept, but the technical details are different. Stereolithography (SLA) is to put the resin material into the resin tank and drop the platform into the material tank during printing. According to the shape of the slice layer, the laser transmitter scans and cures the resin in the gauge through a laser oscillator.

5. RESEARCH ON FURNITURE DESIGN PRACTICE WITH 3D PRINTING TECHNOLOGY

5.1 Design Concept

Specific ideas are as follows:

Through the research on the Ming Dynasty furniture, the researchers selected the armchair for specific analysis, combined with 3D printing technology, and carried out deformation and innovation on the Ming Dynasty armchair, using new technology to reflect the Ming Dynasty armchair, so that Chinese traditional culture can be inherited and continued, and the Ming Dynasty furniture can be presented in a new way. 3D printing is used to present the designed seats, which are full of vitality like vines, indicating that the ancient culture has a long history. It is not only the design of a seat, but also the study of the traditional Ming seat. The seats of the Ming Dynasty can reflect more than this. There are gentle lines, the shape of the round sky and the place. The perfect integration of the square and the round can more represent the Chinese cultural tradition, and the outward tolerance is smooth, and the internal discipline is strict. Methods: The preliminary analysis was carried out at the beginning, and the most distinctive Chinese furniture was identified as the furniture of the Ming Dynasty for further research. The most interesting round-chair was found in the furniture of the Ming Dynasty for further research, and the shape of the round-chair was combined to carry out innovative sketch drawing and modeling. Compared with the traditional furniture production process, the combination of 3D printing technology and parametric design technology has significant technical advantages: 1) High processing accuracy. Parametric models have extremely rich forms. When used in large-scale projects such as architectural design, traditional technology is easier to achieve. However, the shape of furniture products is generally small, and too many details of the connection structure will lead to the inability of traditional technology to meet the sales standards. In the traditional furniture manufacturing industry, when designing furniture, they draw first and then process and make according to the drawings. 2) High processing efficiency. The process of traditional furniture processing is complex, and the processing process will be limited by technology and equipment, with long time and low production efficiency. In the actual production process, if

problems are found in the physical production process and the design scheme needs to be modified, it needs to be modified one by one from the design drawing to the previous process, with a large amount of work. Designers can use parametric modeling and 3D printing technology for furniture design and production can simplify the process from design to production. Parametric modeling software can not only accurately set the relevant dimensions of furniture and transmit them to 3D printing equipment, so that 3D printers can print relatively accurate products, but also make designers more easily modify the design scheme. Parametric design technology and 3D printing technology can realize the one-step completion from design to finished product, effectively improve production efficiency and reduce error rate, and also realize distributed production.

3) Rich materials. 3D printing materials are rich in variety, mainly including polymer materials, metal materials, ceramic materials, composite materials, etc., and are applied in the fields of aerospace components and food. In addition to natural wood, new composite materials such as bamboo plastic, wood plastic and other wood composite materials can also be used as 3D printing materials, and advanced printers can also print a variety of materials.

4) Low carbon and environmental protection. Traditional furniture manufacturing uses cutters to cut and mill plates during production. The utilization rate of raw materials is relatively low, and noise and dust will also be generated. The 3D printing equipment is more flexible than the traditional tool processing. It can stack complex shapes through the substrate, and there is no huge noise in the whole production process.

5) Easy to customize. The unique manufacturing method of 3D printing basically breaks away from the traditional concept of furniture production line [10]. The production is customized according to the user's personalized production needs, rather than according to the traditional furniture production scheduling. The printed furniture surface can also be personalized painted according to needs. The designers make the model through the modeling model, and make the final debugging after the model is made. Printing material: 3D printing material. Support conditions: 1. Data support: Rhino, Keyshort rendering, Photoshop. 2. Design support: parametric technology, 3D printing technology. 3. Model material production: laser sintering powder molding technology, hot melt deposition solidification molding technology.

5.2 Sketch Design Analysis

In the early stage of design printing, the designers can use divergent thinking to envision a large number of model designs, and fully express the early ideas. According to the envisaged hand-drawn sketch of the chair ("Figure 2"), use Rhinoceros 7 software to make a virtual three-dimensional approximate model of the chair.

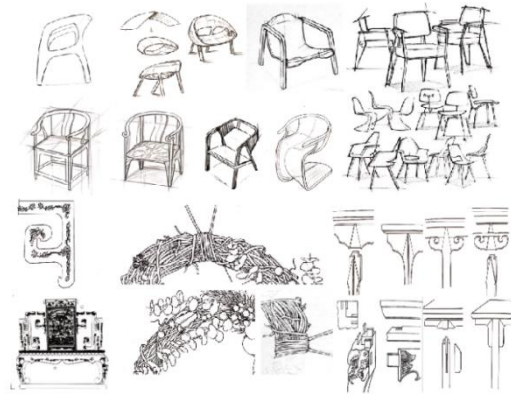


Figure 2 Sketch.

5.3 Modeling Structure Study

The designers use Rhinoceros 7 software to first build a large shape ("Figure 3"), and then use parametric modeling to build the final model ("Figure 4") after several modifications. ("Figure 5")

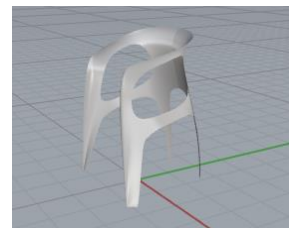


Figure 3 3D model test of product prototype.



Figure 4 Parametric deformation.

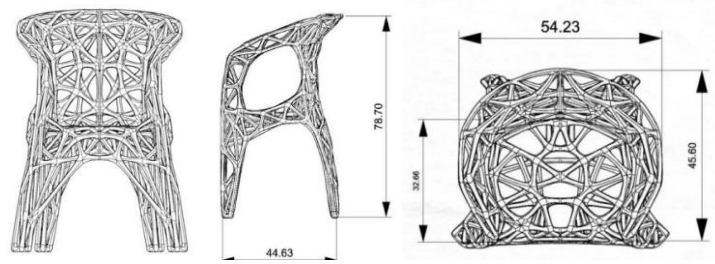


Figure 5 Three views of chair.

5.4 Effect Display

Finally, the designers use KEYSHORT software or other rendering software to render the final rendering of the model (“Figure 6”).



Figure 6 Rendering effect.

5.5 Production of Physical Model

The designers send the finished model file to the factory making the model for 3D printing. The printing of the seat takes a week. Because the model size is too large, it needs to be divided into two parts and printed with PLA material. After printing, the model needs to be polished and glued; Because it is a hollow structure, every hollow part needs to be supported, but the supporting part needs to be cut and polished, which takes a lot of time.



Figure 7 Model making process.

6. CONCLUSION

The organic integration of 3D printing technology and furniture manufacturing industry will push modern furniture to a new stage, and China's furniture manufacturing industry will have more possibilities and creativity in the future

development. The application of 3D printing technology in the furniture manufacturing industry has, to a certain extent, updated the furniture molding method and the furniture product design system, accelerated the development of the furniture industry, and promoted the update and iteration of the furniture design industry.

The use of 3D printing technology makes furniture manufacturing and production more convenient and reduces the production cost of furniture manufacturing. The application of 3D printing technology can shorten the construction period, and can also produce sustainable furniture products with complex structure and diverse materials. In future, society will become intelligent. For the traditional furniture manufacturing industry, the application of 3D printing technology in the furniture manufacturing industry is still at the beginning and is not mature enough. However, the steady development of 3D printing technology in recent years has made the furniture industry also improved accordingly. Therefore, 3D printing technology can not only simplify the design steps of furniture, but also make the design more novel and interesting.

REFERENCES

- [1] Jin Nengmao, The Most Promising New Industry [J]. *Global Market*, 2016, (36): 57. (in Chinese)
- [2] Li You, Zeng Yong, Lv Jun, et al. Application of Computer-aided Design and 3D Printing Model in Operation for Complex Mandibular Fractures [J]. *Chinese Journal of Traumatology*, 2018, 34(04): 299-304. (in Chinese)
- [3] Cellink AB; Patent Application Titled "Preparation And Applications Of 3D Bioprinting Biinks For Repair Of Bone Defects, Based On Cellulose Nanofibrils Hydrogels With Natural Or Synthetic Calcium Phosphate Particles" [J]. *Biotech Business Week*, Published Online (USPTO 20190307923) 2019.
- [4] Lin Shan, Chen Tie, Li Mei, Introduction to 3D Printing Technology [J]. *Rubber & Plastics Resources Utilization*, 2014, (05): 23-7+2. (in Chinese)
- [5] Wang Mofen, The Influence and Challenge of 3D Printing Technology on Traditional Art Design Industry [J]. *Art Science and Technology*, 2018, 31(11): 176+211. (in Chinese)
- [6] Zhu Lin, Liu Jiaying, Innovative Design of Customized Furniture Based on 3D Printing Technology [J]. *Industrial Design*, 2017, (07): 46-7. (in Chinese)
- [7] Chen Linfang, Research of the Application of 3D Printing Technology in Automobile Manufacturing and Maintenance [J]. *Auto Time*, 2020, (13): 186-7. (in Chinese)
- [8] Liu Lina, The research of Visual Merchandising Design in the furniture product [D]. *Central South University of Forestry & Technology*, 2009. (in Chinese)
- [9] Huang Yanli, Xu Lei, The Influence of Modern Science and Technology on Architecture and Product Modeling [J]. *Art Science and Technology*, 2017, 30(09): 429. (in Chinese)
- [10] Song Jie, Chen Qiming, Chen Li, et al. Furniture Design and Manufacturing based on Parametric and Additive Manufacturing Technologies [J]. *China Forest Products Industry*, 2022, 59(06): 52-6. (in Chinese)