Research on Customized Service of 3D Printing Cultural and Creative Product Design Based on FDM Technology

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Abstract

With the advent of the era of personalized and small batch production of cultural and creative products, 3D printing technology is inevitably required to reduce the cost of product development and break through the material restrictions in order to achieve civil popularization. This paper analyzes the advantages of FDM technology and its fit with the future development of cultural and creative customization and small batch; the possibility of using PEEK as a popular material was explained; the basic architecture of personalized design service system is proposed.

Keywords: *FDM, 3D printing, civil popularization, peek, cultural and creative products, customization*

I. Introduction

As a rapid prototyping technology, 3D printing is widely used in medical field, military industry, aerospace industry, architecture, automobile manufacturing and other fields. Because it is suitable for manufacturing parts with complex shape and structure, many varieties and small batch, it makes the structure difficult to realize by traditional manufacturing technology easy to realize, and releases huge space for innovative design. Its convenient and fast modeling realization ability also provides strong support for artists and designers to realize creativity and complete creation. Relying on 3D printing technology, art and design disciplines, such as industrial product design, display model design, art props design, clothing accessories design, ceramic design and many other directions, have opened up a convenient and efficient creative path for design innovation and creative experiment. Under the existing conditions of material, cost and precision, it is combined with the production and production of small cultural and creative products to make personalized cultural and creative products according to personal needs. Through small batch production, it can reduce the cost of product development, and find a new direction for the sales of 3D printing equipment. It not only creates economic benefits in the sales, it also reduces the risk and cost of printing equipment entering the market.

II. Application Status of 3D Printing Technology

Charles Hull invented stereolithography (SLA) 3D printing technology in 1984 and developed the first commercial 3D printing press in 1986. Until 1990, people began to pay attention to this technology. As an additive manufacturing technology, academia and industry showed great interest. Different from the traditional processing technology, 3D printing creates the product model through the computer, and uses the printing method of layered manufacturing and layer by layer superposition, which can realize the rapid three-dimensional forming of objects with arbitrary geometric shape. It does not need the traditional cutting tools, fixtures and multiple processing procedures, and can quickly and accurately print out various parts with complex structure and geometric shape.

3D printing technology is completely different from traditional injection molding, cutting and other processing technologies. Using 3D printing technology, multiple parts made of various materials can be replaced with one

component, which greatly reduces the cost, time and quality problems caused by assembly operation, and improves the effectiveness of manufacturing process. These advantages make 3D printing technology widely used in aerospace, industrial manufacturing and other engineering and industrial fields, such as various parts in aerospace, transplants in medical devices and various devices in industrial manufacturing. With the rapid progress of science and technology, the products in life are developing in the direction of diversification and complexity. 3D printing can not only manufacture complex geometric shapes with high precision, but also save materials to the greatest extent. It also has the advantages of great flexibility and personalized customization in design, so it has a strong competitive advantage in the market.

III. Popularization Prospect of 3D Printing for Civil Use

If 3D printing technology wants to enter ordinary families, it must break through the limitations of printing equipment and materials. The diversity of materials has become a big obstacle to the popularization of 3D printing. 3D printer technology has not yet reached the mature level. High end industrial manufacturing field can realize the printing of plastics, some metals or ceramics and other materials, and can not support the printing of products with all kinds of materials in daily life. With the popularity of equipment production and sales in civil use, 3D printers are used as teaching aids to popularize 3D printing technology and principle knowledge, mostly in universities, primary and secondary schools and research units. In terms of sales, the popularity is poor. With the popularization and application of Internet, big data and 5g, the advantages of 3D printing are becoming more and more obvious. The changes of these conditions also bring new ideas for equipment production and sales. A customized service platform system for users, equipment and personalized products is constructed, and customized manufacturing and production is proposed, which combines printing products with life and work needs, Inject new vitality into the popularization of 3D printing. With the rapid development of technological innovation, once the bottleneck of technological constraints is broken, 3D printing will become an indispensable tool to meet the personalized needs of different people, so as to integrate into people's lives and even change their lifestyles.

IV. 3D printing technology based on FDM

At present, the main types of 3D printing technology in the market are: FDM, 3DP and SLS. Since FDM technology was developed in the early 1990s, it has been the most popular technology in the field of 3D printing because of its low cost and easy to use. Compared with other types of 3D printing such as SLS and 3DP, FDM has the lowest cost, simpler operation, and more convenient use and maintenance. There are many materials suitable for FDM, and most of the thermoplastics can be used as FDM materials. The materials are generally non-toxic, environmentally friendly, and the noise of the equipment is very small during operation. FDM operating environment is very clean and safe, equipment volume is small, generally in the office environment can be operated. FDM process is simple, easy to operate, material utilization rate is very high, will not produce a lot of garbage, no molten wire can be further recycled, product post-treatment is relatively simple, only need to peel the support structure. Polymer materials will melt from solid state and then solidify in the FDM printing process. The whole process is carried out in the printing room and no harmful substances will be discharged. It also has the common advantages of 3D printing, such as rapid prototyping, personalized customization and so on. The forming principle of FDM is similar to other kinds of 3D printing technology, both of which need to use the computer to model first, then transfer the data model to the printer, and print the products layer by layer according to the set path. Different from other 3D printing technologies, polymer materials need to be made into linear materials of about 1.75 mm. The linear materials are transported to the hot end of the nozzle through the wire feeding device to make the materials melt and print.

4.1 The principle of FDM

FDM, invented by Dr. Scott Crump in 1988, is one of the most widely used 3D printing technologies. Its forming principle is to heat and melt various hot-melt filamentous materials (wax, ABS, nylon, etc.). After melting, the filamentous hot-melt material is ejected from the nozzle and deposited on the panel or the previous layer of cured

material. When the temperature is lower than the curing temperature, the filamentous hot-melt material begins to solidify, and the final product is formed by layer by layer stacking of materials (Fig.1) [1]. The thickness, width, direction and air gap of filaments are the main process parameters that affect the mechanical properties of printing parts [2]. Interlaminar deformation is the main reason for weakening mechanical properties [3]. Low cost, high speed and simple operation are the main advantages of FDM, but there are also some disadvantages such as poor mechanical properties, low accuracy, poor surface quality and limited amount of thermoplastic materials. The development of fiber reinforced 3D printing composites can improve the mechanical properties of 3D printing components, which provides a new idea for the development of FDM technology. However, fiber orientation, adhesion between fiber and matrix and the formation of voids are the main challenges for fiber reinforced 3D printing composites.

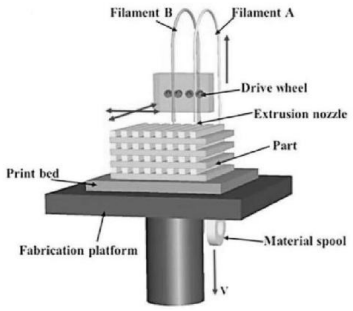

Fig.1: FDM principle.
(Source: Wang X, Jiang M, Zhou Z, et al.3D printing of polymer matrix composites：a review and prospective. Compos B Eng, 2017,110: 442-58.)

4.2 Requirements of materials for fused deposition molding

One of the most important factors in the development of FDM technology is the material of FDM. The performance of the material will affect the printing process and the final product. FDM materials generally need to have the following properties: the wire is transported to the nozzle by the wire feeding structure with a certain pressure for melting. In order to avoid wire breaking and bending of the material driven by the motor, the material needs to have certain mechanical properties such as bending resistance, tensile strength and compressive strength. In order to ensure the smooth extrusion of the nozzle, the viscosity of the material should not be too high. Generally speaking, the wire will swell when extruded from the nozzle after melting. In order to avoid affecting the molding accuracy, the material needs to have a small shrinkage. In addition, printing materials need to have low hygroscopicity to avoid product quality damage caused by moisture evaporation of molten materials under high temperature. Generally, molding materials need to be dried before printing to keep them dry. FDM is a layered manufacturing, layer by layer printing, the adhesion between layers is the key to determine the performance of the product, the adhesion of the material should not be too low, otherwise the product will produce defects due to thermal stress, so that the product can not be used [4].

At present, the main FDM materials on the market are polylactic acid (PLA), acrylonitrile butadiene styrene copolymer. The most commonly used thermoplastic materials are PLA and ABS [5]. As a common consumables, PLA will not produce peculiar smell in the printing process, and it is a very environmentally friendly material with degradability. At the same time, PLA has good fluidity. The disadvantages of PLA are poor toughness, large molding shrinkage and low heat resistance temperature. It generally needs to be used after modification. ABS is easy to print, but the smell of ABS is strong in the printing process. In addition, ABS is easy to contract when it is cold. In the printing process, the product is easy to fall off from the printing platform or warpage, which affects the final performance of the product.

An important factor limiting the development of 3D printing is the lack of advanced polymer materials and

available composites to meet the performance and manufacturing requirements. Therefore, the current research focus is to develop new high-performance materials, improve process efficiency and speed, and expand its performance and application range [6].

4.3 PEEK is a good material for 3D printing

Polyether ether ketone (PEEK) was first synthesized and commercialized by ICI company in 1978. PEEK is a light tea gray aromatic polymer, and its molecular formula is shown in Figure 2[7]. The rigid benzene ring in the molecular chain makes PEEK have good thermal stability. Ether bond and carbonyl group make PEEK have certain flexibility and good processing performance. PEEK is a special engineering plastic with very high modulus, strength and good toughness. It has excellent comprehensive properties such as creep resistance, impact resistance and so on.

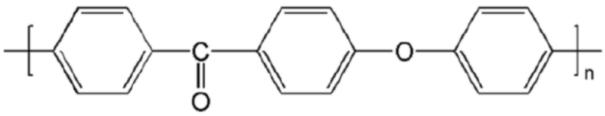

Fig.2: Molecular formula of PEEK.
(Source: Zhai Tong. Study on surface metallization of PEEK and its carbon nanotube composites. Tianjin University, 2016)

4.3.1 Properties of PEEK

PEEK is a semi crystalline polymer with good mechanical and electrical insulation properties, which has the advantages of wear resistance, hydrolysis resistance, high temperature resistance and radiation resistance. In addition, PEEK has good fluidity at high temperature, easy processing and good thermal stability. PEEK has high melting point and glass transition temperature, which are 343 ℃ and 143 ℃ respectively. It can be placed in the environment of 250 ℃ for a long time. It is an extremely excellent material with excellent heat resistance in thermoplastic. At the same time, PEEK has excellent aging resistance, is not easy to expand when heated, and has good dimensional stability [8]. In addition, PEEK has good toughness, excellent fatigue resistance, creep resistance and impact resistance, and its strength and modulus are not affected by high temperature. PEEK has strong chemical stability and can only be dissolved in concentrated sulfuric acid at room temperature. PEEK is resistant to hydrolysis and its water absorption can be kept at a very low state under high humidity conditions. PEEK has excellent wear resistance, which is less affected by temperature, pressure and speed. PEEK is easy to process, molding, injection molding, extrusion and other processing methods are suitable for peek, which can mass produce high-performance products [9]. PEEK has low dielectric loss and permittivity, and has excellent electrical insulation in a wide frequency and temperature range. In addition, PEEK has self extinguishing, low smoke emission and low toxicity during combustion, which will not cause harm to the environment and human body.

4.3.2 Application of PEEK

PEEK was initially used as a material for national defense and military industry in China. With the continuous development, the application field of PEEK has expanded from military industry to various civil high-tech fields [10].

In the field of aerospace, due to its low density, low smoke emission, excellent mechanical properties and flame retardancy, PEEK can replace metal to make various parts of aircraft and rocket, such as engine, transformer shell and fuel pipe bracket frame, wing panel, etc. [11]. PEEK is widely used in automobile manufacturing market, which can meet the requirements of high performance and lightweight materials in automobile industry. It is used to prepare automobile parts such as bearing, gasket, supercharger impeller, etc. Due to the small influence of temperature, pressure and humidity, PEEK can work continuously under harsh conditions. In the field of electronic and electrical appliances, it is used to prepare connectors, printed circuit boards, chip carriers, etc. Due to wear

resistance and corrosion resistance, PEEK can be made into pump body parts, piston rings and valve plates in the industrial field [12]. PEEK has the advantages of non-toxic, good chemical stability, strong radiation resistance, excellent biocompatibility and so on. It is an important material in the field of medical devices. It can be used to prepare adult implants, such as artificial bones, and is the best bone and joint material. Its application fields include orthopedics, prosthodontics, craniomaxillofacial surgery, etc. Due to the high temperature resistance and thermal stability of PEEK, PEEK can be made into food plates and tableware in the food field. In the field of 3D printing, there are few researches on peek, mainly focusing on medical devices and other fields. Compared with the commonly used thermoplastic polymers such as PLA and ABS in 3D printing, PEEK has more excellent properties, such as high temperature resistance and mechanical properties. Using PEEK as 3D printing material can not only enrich the types of printing materials, but also adjust the mechanical properties such as strength and modulus according to the demand, so as to realize the low cost, high precision and high quality of high-performance PEEK products Controllable rapid prototyping.

V. Customized Service of 3D Printing Cultural and Creative Product Design Based on FDM Technology

5.1 The era of personalized customization of cultural and creative products ushers in a new era for 3D printing

Cultural and creative products are derived from cultural themes, transformed by design creativity and have market value. In March 2014, the State Council issued several opinions on promoting the integrated development of cultural creativity and design services and related industries, which indicates that the integrated development of cultural creativity and design services and related industries has become a national strategy.

Beijing "2019 capital culture and tourism integration development high end forum" released "Beijing culture and tourism consumption big data report". Data show that most of Beijing's core tourist areas (spots) are concentrated on high-quality IP (such as the Forbidden City, Summer Palace, etc.), and the corresponding scale of cultural industry has exceeded 1 trillion yuan for the first time. In the context of cultural tourism integration, the scale of "culture + tourism" industry has further expanded.

With an annual sales revenue of 1.5 billion yuan, the cultural creation of the Palace Museum has become one of the most successful cases of cultural creation in China. By the end of 2018, there were more than 10000 kinds of cultural and creative products in the Palace Museum, and 266 kinds of cultural and creative products were sold in Taobao [13]. According to the report on market data of cultural and creative products of museums in 2019, museums around the world are experiencing a wave of "collective Internet surfing". At present, 24 museums have settled in tmall, and the Forbidden City alone has opened six stores on Taobao tmall. In the past year, the cumulative number of visitors to the flagship store of Taobao tmall Museum alone has reached 1.6 billion, 1.5 times the number of visitors to museums nationwide, of which 100 million users are "post-90s". According to the data of Alibaba retail platform, the number of consumers who actually purchased Museum Cultural and creative products in 2019 has reached nearly 9 million, an increase of more than four times compared with 2017. Young urban women with high purchasing power are the main consumers. In addition, according to the classification and statistics of the types of cultural and creative products operated by museums, household and cultural entertainment products are still the core industries of cultural and creative products operated by museums, accounting for more than 80% [14]. The success of the cultural creation of the Palace Museum lies not only in finding creative elements based on tradition, expressing traditional oriental aesthetics and being close to the life of consumers in the development and design of cultural creation products, but also in the embodiment of personalized customization characteristics and the personality of the place where the products are produced, so as to meet the different needs of different consumers and extend the entire industrial chain, Use offline and online multi-channel services to meet the purchase needs of consumers.

5.2 Personalized customized design service system is gradually established

The basic characteristics of 3D printing integrated into lifestyle are personalization and customization. In the construction of user, device and product customization service platform system, it is the key to reflect the

personalized customization service. To meet the personalized needs of users is the premise, to create a multi type and multi type product library is the prerequisite, and to have a good proofing ability of the printing equipment is the prerequisite to achieve customized production.

5.2.1 Design by designer

In the context of the Internet, with the progress of technology, the maturity of business model and the formation of big data, designers make full use of and analyze users' real data to conduct research, and have insight into users' behavior, psychology and needs, so as to better improve the existing service ecology. As a new technology that is constantly evolving and facing the future, designers can create shaped and multi form objects in an unprecedented way, so that new and diverse designs have more possibilities. In the traditional design stage, product designers mainly use 3D printing prototype design, such as industrial design, model mold manufacturing in the field of product design. In the personalized and open design stage, with the progress of technology, 3D printing can be used in a wider range of materials and applications. From prototype design to direct manufacturing of some products, such as industrial products, clothing and jewelry, daily necessities, cultural products, etc.

5.2.2 Consumer participation in design

In the process of product customization, the identity of consumers is changing to that of designers. With the integration and development of cultural industry, finance, Internet and other high-end industries, the Internet provides a platform for 3D printing customized services. Companies that provide 3D sharing and printing services can meet the needs of consumers for personalized products and experience, and can be customized for individual buyers. At the same time, consumers can change from choosing a pattern to choosing a material, designing a function to optimizing a function With this new technology, this personalized program allows consumers to actively participate in product design and manufacturing.

With the improvement of technology and the maturity of business model, many designers have been able to set up their own enterprises on the Internet by using 3D printing, and sell their products by cooperating with third-party companies that produce small quantities of works.

5.2.3 Everyone is a designer

Thirty years ago, the popularity of personal computers at home was unimaginable. Therefore, there is every reason to believe that the popularity of 3D printing machines in the future, for those consumers who do not have the skills and time, can at least modify the products they have purchased and decide how to use them. This is the key to a personalized product. The vision is to see future consumers download what they need from the Internet and print it at home instead of going to the store.

5.2.4 Customized design service system

A good personalized design service system promotes the formation of a community of co construction, CO consultation and co construction and sharing among 3D printing equipment manufacturers, sellers, designers and consumer groups, which reflects the equality, gradual and sustainable relationship among the four. Integrating cloud computing, 3D printing, intelligent manufacturing and other high-tech 3D printing cloud service system in the 5g era, the 3D printing personalized customization service mode of "3D printing + consumer service + transaction portal" is constructed. The design concept of "demand satisfaction, creative personalization, design customization, printing diversification, and product consumption" is adopted to define the demand of cultural and creative products R & D and design (forward and reverse), printing manufacturing and sales are closely linked. Through the mobile Internet platform, customized design services are provided for consumer groups, creative designers, device vendors and system builders to enhance the sense of participation and experience of all parties in the whole process of cultural and creative product design and 3D printing technology, so as to form a cultural and creative product design group The new business model is composed of consumer groups, 3D printing service providers and system platform builders. It provides personalized customization and consumption services for individual cultural and creative products consumer market and cultural and creative industries. The generation of

3D printing personalized customization cloud service system is oriented to cultural and creative products, innovative design education and other fields and industries, to meet the online publishing of personalized creative products, design resource sharing, personalized customization services, online printing manufacturing services, 3D printing cultural and creative product development and sales services.

VI. Conclusion

In the era of Internet and intelligent manufacturing, with the help of 3D printing rapid prototyping technology to support the client-side product self-service printing for the purpose of personalized customized consumption, it provides a new development idea for 3D printing. At the same time, breaking through the technology, materials and other factors that limit the development of 3D printing, especially the use of low-cost, high-precision and controllable materials like peek, provides more possibilities for the civil use of 3D printing. Based on the feasible technology and materials of FDM, the customized service system of 3D printing cultural and creative product design is constructed to produce small batch and personalized cultural and creative products integrated with people's lifestyle, which is of great significance for the future development of 3D printing industry and social and economic growth.

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