

Research on the Application of 3D Printing Technology in Enamel Jewelry Design

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Abstract

With the advancement of globalization, the design style and production skills of enamel jewelry continue to exchange and integrate. Modern enamel jewelry not only retains the essence of traditional craftsmanship, but also integrates modern aesthetic and fashion elements. In addition, the progress of science and technology has also provided new opportunities for the development of enamel jewelry, such as 3D printing, CNC engraving and other modern technologies in the application of enamel jewelry production. Enamel jewelry has always been loved by consumers for its unique texture and color. However, the traditional manufacturing method of enamel jewelry has some limitations, such as long manufacturing cycle, high cost and limited design. The emergence of 3D printing technology has brought new possibilities for enamel jewelry design, making the manufacturing of enamel jewelry more efficient, precise and personalized. With the continuous development of 3D printing technology, its application in the field of jewelry design is increasingly widespread. It is important and necessary to explore the application of 3D printing technology in the jewelry industry. First of all, 3D printing technology can improve the efficiency of design and manufacturing, break through the production restrictions, and promote the popularity of personalized customized services, so that small batch diversified design and production become economical. Secondly, the introduction of 3D printing technology in the jewelry industry can promote multidisciplinary cross-border cooperation and the formation of diversified styles, which is the perfect combination of science and technology and art. Finally, 3D printing technology can speed up prototyping and iteration, effectively improve the success rate of design and production, reduce production costs and error risks, and enhance the comprehensive competitiveness of the market. This paper aims to discuss the application and advantages of 3D printing technology in enamel jewelry design, analyze and compare the production process of 3D printing technology and traditional enamel jewelry, and analyze the limitations of 3D printing technology and the development trend in the future.

Keywords: 3D Printing Technology, Jewelry, Enamel Jewelry

Literature Review

Enamel jewelry with its exquisite skills, rich colors and unique style has won the love of consumers around the world. Enamel jewelry artists continue to explore new materials and production methods, such as wire enamel, inner enamel, transparent enamel, etc., to further enrich the types and styles of enamel jewelry. Combined with the current advanced 3D printing technology, the production efficiency of traditional enamel jewelry has been greatly improved, which is of great significance to the improvement of the production process of traditional enamel jewelry. Many experts and scholars have made different studies on this. Zhou & Zhang (2021) have studied the fusion design of 3D printed metal jewelry and enamel process, and proposed the 3D printing technology with the help of digital modeling. It can effectively avoid the production difficulties of traditional enamel process, and help designers to improve efficiency and develop innovation. Liao (2020) conducted a comparative study on 3D printing technology and traditional jewelry manufacturing process, and analyzed the advantages and disadvantages of the two manufacturing methods in terms of production process, production cost and product yield. Jia & Sun (2023) analyzed the design application of mortise and tenon structure in 3D printing jewelry, analyzed the basic situation of mortise and tenon structure and 3D printing technology, and summarized the design key points of transformation mode, structure, material and size of mortise and tenon structure in jewelry structure Gong (2021) proposed a precision integrated forming method of multi-material flexible structure based on metal powder laser melting technology, which greatly improved the tensile strength of the flexible structure, providing a new solution for the application of modern jewelry design and additive manufacturing technology in jewelry production. Yang (2019) studied the diversity, cultural, social and economic application of 3D printing technology in various fields.

In view of the research on 3D printing materials, Xu (2019) made corresponding research on the casting quality of jewelry 3D printing model based on molten deposition molding wax substrate, formulated the casting process according to the melting characteristics of the material, and formulated the corresponding heating and high-temperature roasting system. The surface quality of castings can be improved by simplifying the steam dewaxing procedure, adopting the open door dewatering method, extending the constant temperature period, high temperature and high temperature holding stage, and strengthening the air circulation. Xin et al (2019) developed a bio-based photosensitive resin that can be used in Stereo Lithography (SLA) for 3D printing with biosafety, and finally used the bio-based photosensitive resin for jewelry printing and obtained different series of jewelry. Teng et al (2020) studied the design and production of creative jewelry with movable structure based on 3D printing, and used silver and resin materials for jewelry creation. Zhang (2018) studied the use of 3D printing technology to reshape the specific links and processes of traditional jewelry personalized customization industry, analyzed the characteristics of changes in each link of personalized customized jewelry development under 3D printing technology, and the impact of 3D printing technology applied in jewelry design on economy and efficiency.

3D Printing Technology Concept Formation and Development

The concept of 3D printing was proposed by American Charles Hull in the 1980s and invented the first SLA(light curing) technology in 1986, the same year that Charles Hull developed the first commercial 3D printing machine. 3D printing technology is a rapid prototyping technology, also known as additive manufacturing technology, is a method to create three-

dimensional objects by adding materials layer by layer, is an important innovation in the field of manufacturing. It is widely used in architecture, industrial design, civil engineering and construction, auto parts, aerospace, dental and medical industries, teaching and research, clothing and footwear, military fields, etc (Wang, 2019). involving multiple directions of industrial manufacturing and consumer goods production, and is known as "an important production tool of the third industrial revolution" with an irreplaceable role (Gu, 2023).

Depending on the technology and materials used, 3D printing technology can be divided into several categories (see Table 1). The main 3D printing methods commonly used in the jewelry industry are Fused Deposition Modeling, light curing technology and powder sintering technology, fused deposition modeling (FDM), is the use of thermoplastic materials through a extrusion outlet layer by layer deposition on the construction platform process. This technology is often used in small desktop 3D printers, and the materials used are usually plastics such as ABS and PLA. Vat Photopolymerization includes Stereolithography (SLA) and Digital Light Processing (DLP), using liquid photosensitive resins. By selectively curing the resin layers with ultraviolet light, the object is constructed layer by layer. The products printed by this method are realistic in detail and have high resolution. Powder Sintering techniques include Selective Laser Melting (SLM), Selective Laser sintering (SLS), and Electron Beam Melting (EBM). These techniques use lasers or electron beams to selectively melt or sinter layers of powder materials, commonly metals, plastics, and ceramics (Xiao, 2023).

The product design is constructed by the commonly used three-dimensional modeling software of jewelry (JewelCAD, Rhino, Zbrush, etc.), combined with 3D printing technology, it can effectively shorten the production cycle, improve the production efficiency of products, and reduce the production cost. After continuous creation and innovation of 3D printing technology, the technology has become more mature. Become an effective tool for enhancing productivity and creativity today (Yuan& Hu, 2022).

Table 1

3D printing principles, printing materials and main application areas

Printing principle	Printing material	Application field
Fused Deposition Molding (FDM)	Plastics, artificial rubber, wax , etc	Low precision models, industrial products, art products
Selective laser Sintering (SLS)	Engineering plastics, ceramic powder, metal powder, nylon powder, etc	High-precision models, industrial products, artwork, medical components, engineering parts
Stereo lithography Apparatus(SLA/DLP)	Photosensitive resin composites	High-precision models, jewelry, fine crafts, engineering parts
Selective Laser Melting of Metal Powder (SLM)	Metal powder	High-precision models, jewelry, fine crafts, engineering parts
Laminated Object Manufacturing (LOM)	Metal coil, plastic film, paper and other composite materials	High precision metal mold, wax mold, etc
ink jet printing (IJP)	Ceramic, metal powder and adhesive liquid	High precision models, jewelry, fine crafts, high temperature resistant parts

Enamel Process Introduction

The development of enamel jewelry in the world has a long history, dating back to ancient Egypt, Greece, Rome and other civilizations. In these civilizations, enamel jewelry was seen as a symbol of power, status, and wealth, and was favored by royalty, nobility, and the elite (Chen, 2022). From the end of the 19th century to the beginning of the 20th century, Europe ushered in the golden age of the development of enamel jewelry. With the passing of time, the production technology of enamel jewelry spread to all parts of the world, and gradually became a popular jewelry type in the world (Abisuga et al., 2022).

Enamel is an ancient molten glass material, mainly composed of quartz, feldspar, borax and other raw materials mixed and sintered to the metal surface, and through multiple firing and filling to achieve rich color and texture effects (Monaldo & Marfia, 2024). Enamel jewelry is a product that applies enamel technology to jewelry design, which is widely used in the production of jewelry, utensils and decorative works of art. In jewelry production, enamel has won the favor of designers with its rich color, unique texture, unique material and artistic value, but because of its complex and unique production process, The product is difficult to mass produce (Xue, 2022).

The enamel process can add beauty to metal products and provide a protective layer to prevent oxidation and corrosion, so that it has not faded for centuries, and enamel process has become a unique and popular decorative process with its durability, rich color, high gloss and artistic characteristics(Li, 2020).

Research Methods

This study uses a mixture of qualitative and quantitative research methods to compare the 3D printing of enamel jewelry and the traditional process of making enamel jewelry(See Table 2), analyze the differences, advantages and disadvantages of the two production methods, and carry out theoretical analysis and summary, providing theoretical reference and case reference for subsequent scholars in the research of 3D printing technology and enamel jewelry design and production.

Qualitative Research

Consult and collect the research methods and theories of existing literature and social science research materials, combine the theory with practice, conduct research and analysis on actual cases, and carry out qualitative research through repeated experimental operations.

Literary Analysis

By referring to a large number of books and materials in related fields, I understand the development status and application fields of 3D printing technology and traditional enamel jewelry products, and study and analyze research materials at home and abroad to provide theoretical support for this project.

Field Visit

Conduct field visits to 3D printing research sites and 3D printing machine manufacturing factories, master the status quo, limitations and development trends of 3D printing development, and visit and study traditional enamel jewelry processing factories, truly feel the production process of traditional technology, in-depth field analysis of the development of traditional technology bottlenecks and difficulties, and form the basic information for research.

Case Analysis

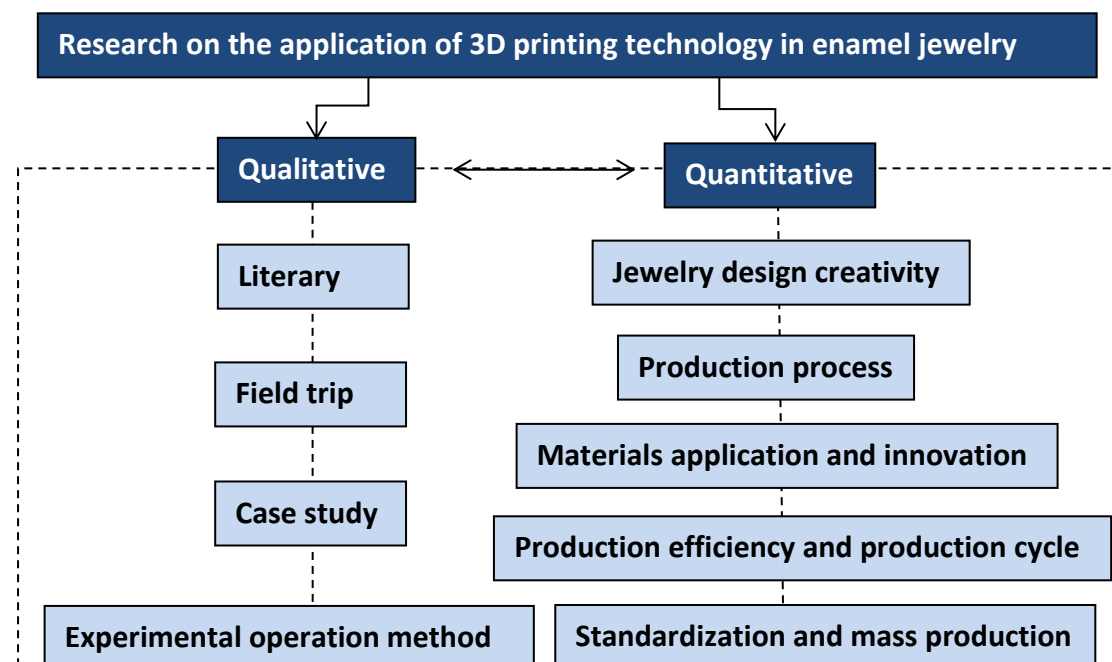
Through the analysis and summary of the works of artists with certain representative significance, on this basis, the 3D printing technology and different process types of enamel jewelry products are deeply integrated and practical analysis, and the possibility of a good combination of 3D printing technology and enamel technology and more innovation is explored.

Experimental Operation Method

After repeated practice in the studio, in the process of creation practice, I used 3D printing technology and different types of enamel technology as the carrier to carry out personal jewelry practice creation, and analyzed and summarized the practice results to form systematic theoretical research materials.

Table 2

Research Framework

*Quantitative Research*

Quantitative research methods can make up for the shortcomings of qualitative research methods, making the research more complete, more comprehensive, more guiding and practical significance, mainly from the jewelry design creativity, production process methods, material application and innovation, product production cycle and standardized production and other aspects of the research:

Jewelry design creativity

In enamel jewelry design, 3D printing technology can quickly generate creative prototypes of designers, so that designers can intuitively see their design effects, so as to adjust and optimize the work. In addition, 3D printing technology can also realize the manufacture of complex structures, providing designers with more creative space.

Production Process Method

Traditional wire enamel, for example, the production process from design to finished product quality inspection requires a variety of processes and a series of processes, and most of the need for manual operation, the production process is complex, designers and producers of high technical requirements, high technical threshold, can not complete the popularization of technology. 3D printing technology can translate the design directly into the physical object, simplifying the manufacturing process. In addition, 3D printing technology can achieve personalized customization to meet the needs of consumers for unique enamel jewelry, which can greatly shorten the processing cycle of jewelry products and improve the production efficiency of products(See Table 3).

Material Application and Innovation

3D printing technology can be manufactured using a variety of materials, such as metals, plastics, ceramics, etc. This provides more choices for enamel jewelry designers, making

enamel products more diverse. At the same time, 3D printing technology can also realize the composite manufacturing of materials and improve the wear resistance and strength of enamel jewelry.

Production Efficiency and Production Cycle

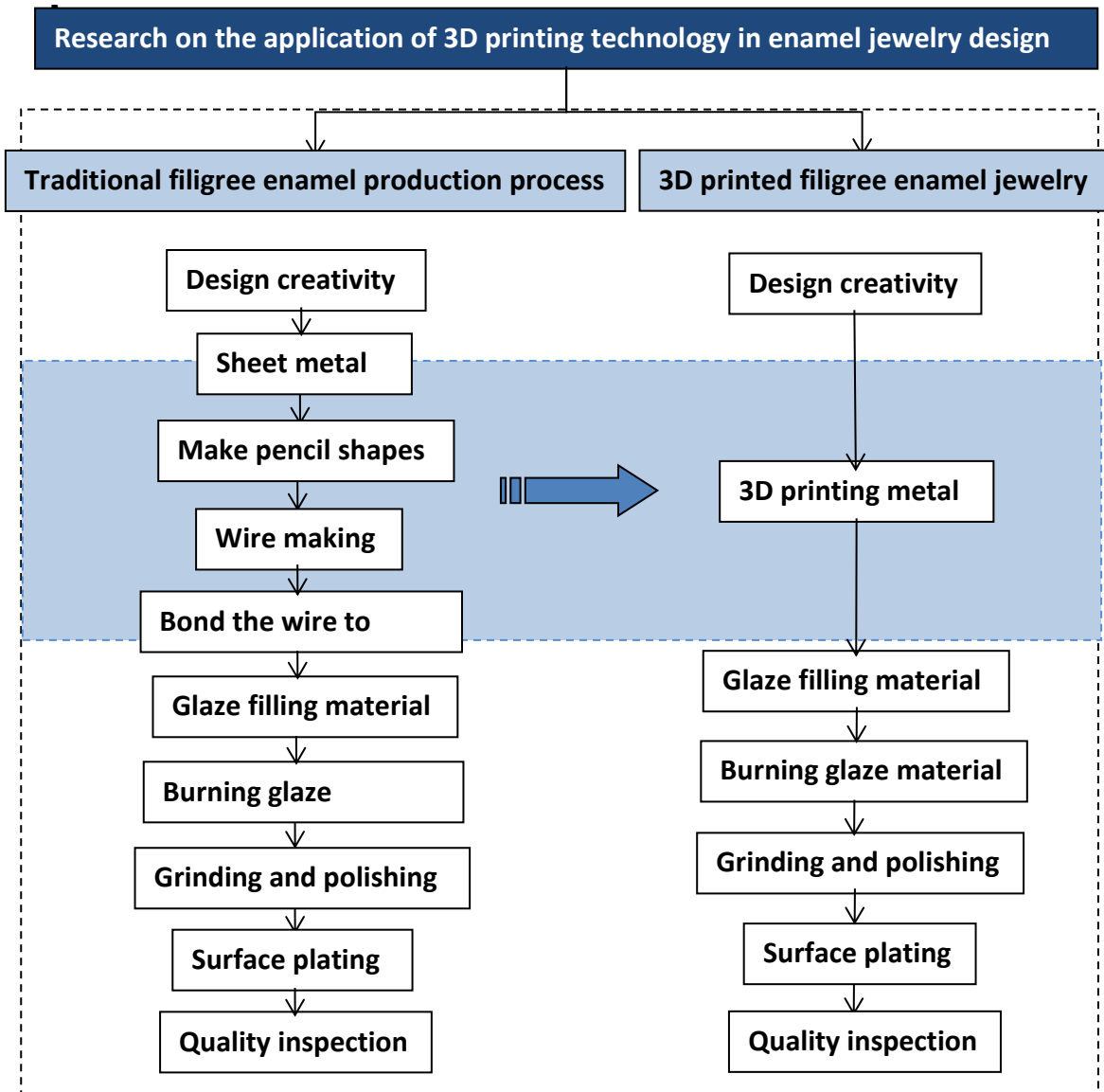
In the process of enamel jewelry production, the manual participation is high, the use of machinery and equipment is rarely auxiliary production, the process steps are complex, the products are mostly ordered and personalized customization, the production cycle is long, can not meet the mass market demand.

Standardization and Mass Production

The production process of enamel jewelry products has a certain degree of chance, the same style of products due to different firing time, firing temperature, glaze dry humidity, material cleanliness, air humidity and the length of opening time will produce different product effects, it is difficult to control the yield, so traditional enamel jewelry products are difficult to standardize and mass production

Table 3

Comparative research framework of 3D printing technology and traditional enamel production process



Research Results

With the development of modern science and technology, the use of 3D digital modeling software directly docking 3D printing equipment to solve the problem of making templates, high printing accuracy, good molding degree, simple and convenient automatic operation, if the modern and efficient 3D printing technology and traditional enamel process can be effectively integrated and innovative, it will shorten the production cycle of the traditional process(See Table 4). It is conducive to the diversified development of enamel craft products, open the market of young groups, enhance the visibility of enamel technology in the international market, better inherit and protect the enamel making process, and inject new vitality into the jewelry market.

Therefore, the use of 3D printing technology can quickly generate design prototypes, simplify the manufacturing process, improve design efficiency, reduce production costs, and can

achieve high precision and complex structure manufacturing, improve the quality and beauty of enamel jewelry products. In addition, 3D printing technology can achieve personalized customization, reduce inventory pressure, and further reduce costs, which is conducive to the mass standardized production of enamel jewelry products.

Table 4

3D printing technology compared with traditional jewelry making projects

Compare the project	Traditional jewelry manufacturing	3D Printing Technology (SLM)
Production cost	incalculability	268 USD/piece
Production cycle	>30 days	7 hours of printing, 3 days of finished products (14 pieces in one edition)
Structure technology	Through the chain can be cast, film unit square side length of about 1 mm, can not be cast assembly	Seamless welding, integrated molding, film can be moved
Precision and accuracy	The movable joint between the grid pieces is 0.1mm, too thin to spot welding	> 98%
Customization complexity	harder	easy
Surface roughness	There is a slight texture in the mold at the chain, and other parts can not be cast	The machine is sandblasted and frosted

3D printing technology in the field of jewelry application limitations

Through the continuous deepening of research, 3D printing technology has significant advantages in many aspects, but at the same time, there are some defects to be optimized and improved, such as:

1. Limited Advantages of Large-Scale Production

Although 3D printing technology has the advantages of distributed production, it does not have the advantages in some areas, such as mass and large-scale production, and its technical maturity is not yet able to meet the needs.

2. Limited Printing Materials

The limitations and bottlenecks of 3D printing technology are mainly reflected in the material. At present, the types of materials that can be used for 3D printing are limited, mainly including plastic, resin, gypsum, ceramics, sand and metal. Developing new materials to meet the needs of different application scenarios remains a challenge.

3. Accuracy and stability need to be improved:

Although 3D printing technology can achieve high accuracy and complex structures, in some cases, its accuracy and stability are still not enough to meet the needs. In addition, problems such as deformation and warping that may occur in the 3D printing process also need to be solved.

4. Environmental impact of manufacturing process:

The 3D printing process may produce harmful substances, such as volatile organic compounds (VOCs), which have an impact on the environment and human health. In addition, the material waste problem of 3D printing also needs attention.

To sum up, there are still many defects in the application and development process of 3D printing technology, which needs continuous research and improvement. However, with the progress of technology, the application of 3D printing in some fields has achieved remarkable results, and its development potential in the future manufacturing industry is still worth looking forward to (Zhang, 2021).

Conclusion

The application of 3D printing technology in enamel jewelry design provides designers with more creative space, improves the design and production efficiency, and reduces the production cost. With the continuous development and progress of 3D printing technology and material science, more 3D printing materials with excellent performance will be applied to the jewelry manufacturing industry, which will greatly improve the printing quality and aesthetics of products. Moreover, according to the continuous upgrading and iteration of design software, designers will be able to use 3D printing technology more easily and conveniently for enamel jewelry design. With the increase of consumers' demand for personalized enamel jewelry, 3D printing technology will play a greater role in the field of personalized customization to meet consumers' pursuit of unique enamel jewelry. The development and application of 3D printing technology in enamel jewelry design will be more extensive, bringing more innovation and change to the enamel jewelry industry, and enamel jewelry will continue to shine, bringing beautiful visual enjoyment and unique wearing experience to people.

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