THE IMPACT OF 3D PRINTING TECHNOLOGY ON TRADITIONAL JUN PORCELAIN SHAPING TECHNIQUES.

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Abstract

The purpose of this study is to investigate 3D printing technology and the traditional forming technique of Jun porcelain, with a view to exploring how 3D printers can be integrated into its original mold system through modernization instead of enhancing production efficiency at the manufacturing level while preserving the essence of authenticity in tradition. This study investigates the synergy of digital modeling and manual production with a novel design methodology balancing both tradition and innovation through literature review, case analysis, as well as experimental validation. An historical overview of Jun porcelain and traditional shaping prescribed by distinctive manual throwing and carving technologies The paper additionally highlights the advantages of 3D printing technology in ceramics: The advantages of 3D printing technology in ceramics include high-accuracy digital modeling, the ability to realize complex shapes, and the use of new materials. The findings indicate that 3D printing technology and traditional craftsmanship can enhance production efficiency without compromising artistic value. Additionally, digital design and rapid prototyping technology offer more efficient processes for the production of Jun porcelain, resulting in significant time and cost savings. This article also explores the preservation of Jun porcelain's cultural characteristics and artistic value through the application of modern technology. These results demonstrated the potential application of 3D printing technology in the molding of Jun porcelain, and they provided

programmatic guidance for its innovation in unconventional expression forms.

Key words: Jun porcelain, product design, 3D printing, traditional crafts

INTRODUCTION

Jun porcelain, a treasure of ancient Chinese ceramic art, dates back to the Song Dynasty and is world-famous for its unique kiln-fired glaze and superb potter's wheel carving techniques. Jun porcelain carries a profound cultural heritage and occupies a pivotal position in Chinese cultural history. Its colorful and unpredictable glaze perfectly blends nature and human ingenuity, and each piece is a unique work of art. (Chen et al., 2019) With the rapid development of modern technology, the traditional Jun porcelain craftsmanship is facing unprecedented challenges. The popularisation of mechanized production has improved production efficiency, but it has also caused some handicrafts to lose their unique charm and warmth. The problem of the lack of skills transfer is becoming increasingly prominent, and the younger generation's interest in ancient skills is gradually waning, putting traditional handicrafts such as Jun porcelain at risk of being lost. (Lai et al., 2024)

Figure 1. 3D printing equipment.

Against this backdrop, the rise of 3D printing technology

has brought new opportunities for the development of Jun porcelain art. 3D printing, as an additive manufacturing technology, can transform a designer's creative ideas into physical models with unprecedented accuracy and speed. (Chen & Almajed, 2022) In the field of ceramic art, 3D printing technology not only simplifies the complex process of traditional handicrafts and reduces production costs but also dramatically broadens the boundaries of design. Designers can use 3D modeling software to create more complex and detailed Jun porcelain shapes while retaining traditional Jun porcelain's artistic charm and cultural connotations. 3D printing technology also allows replicating and preserving Jun porcelain artworks. (Khorsandi et al., 2021) For some precious ancient Jun porcelain works, 3D scanning technology can accurately obtain their three-dimensional data and then use 3D printing technology to achieve high-precision replication, which satisfies people's need to appreciate ancient works of art and effectively protects the integrity of the original.

The historical and cultural value of the traditional Jun porcelain craftsmanship cannot be ignored, while the impact of modern technology has prompted us to find new development paths. The rise of 3D printing technology has provided new possibilities for the inheritance and innovation of Jun porcelain art. It not only makes up for traditional craftsmanship's deficiencies in efficiency and precision but also stimulates designers' creativity and promotes the development of Jun porcelain art in a more diversified and intelligent direction.

RESEARCH QUESTIONS AND OBJECTIVES

This study aims to explore in depth the profound impact of 3D printing technology on the modeling process of Jun porcelain. The specific objectives include three aspects. By carefully analyzing how 3D printing technology reshapes the art of modeling Jun porcelain, this paper hopes to reveal the potential of this modern technological means in enhancing the freedom of Jun porcelain design and achieving innovation in complex forms. With its high-precision digital modeling capabilities, 3D printing technology can accurately capture the designer's creative inspiration and transform complex line and

surface structures that are difficult to achieve in traditional handicrafts into reality, injecting new vitality into the art of Jun porcelain.

This research focuses on effectively preserving and passing on the essence of the traditional handicrafts of Jun porcelain by introducing 3D printing technology. The unique traditional techniques of hand-throwing, fine carving, and glaze color variation are indispensable to the unparalleled Jun porcelain. (Xue et al., 2023) Therefore, this paper needs to explore a balancing strategy that improves production efficiency and design flexibility using 3D printing without losing the cultural heritage and aesthetic value of Jun porcelain. This includes digitally recording and restoring the details of traditional craftsmanship and incorporating traditional elements into the design process to ensure that Jun porcelain works under the new technology can still carry the weight of history and the charm of culture. This study is dedicated to modernizing and efficiently transforming the Jun porcelain process. Faced with an increasingly competitive market environment due to globalization, the Jun porcelain industry urgently needs to enhance its competitiveness through technological innovation.

3D printing technology has brought revolutionary changes to Jun porcelain production thanks to its advantages of rapid prototyping, reduced material waste, and shortened production cycles. This article hopes to inject new vitality into the Jun porcelain industry and promote its development in a more intelligent and greener direction by optimizing the production process and improving production efficiency. This will also promote the widespread dissemination of Jun porcelain culture and enable more people to appreciate the unique charm of this ancient art form.

METHODS

This study adopts a multi-dimensional methodology to systematically explore the impact of 3D printing technology on the traditional modeling process of Jun porcelain. Through an extensive literature review, this paper traces the historical development of Jun porcelain, in particular the inheritance and development status of its unique hand-building and sculpting

techniques, as well as the challenges and opportunities these techniques face in the contemporary era. (Zhu et al., 2024) This paper provides an in-depth analysis of the latest developments in 3D printing technology in ceramic art, including research results in technical principles, materials science, and design innovation, laying a solid theoretical foundation for follow-up research.

This study designs detailed case studies, selecting several representative Jun porcelain creation projects at home and abroad, which all attempt to integrate 3D printing technology into the production of Jun porcelain. By comparing the traditional production methods with the production process assisted by 3D printing, this paper evaluates the advantages and disadvantages of the new technology in terms of modeling complexity, production efficiency, cost control, etc.

The case study not only focuses on the application results at the technical level but also explores in depth the impact of these changes on the artistic style and cultural heritage of Jun porcelain. In terms of experimental design, this paper designs a series of experiments to verify the feasibility and practicality of 3D printing technology in producing Jun porcelain. The experiments include constructing and optimizing digital models, producing 3D printed prototypes, subsequent processing, and final firing.

By comparing the experimental data, this paper quantifies how much the new technology has improved the modeling accuracy, material utilization, and production cycle of Jun porcelain. This paper also pays special attention to problems that may arise while applying new technologies, such as material compatibility and print accuracy control, and proposes corresponding solutions.

The innovation of this research lies not only in the discussion of technical aspects but also in the close integration of technology, art, and culture. It proposes a design methodology that modernizes and streamlines the process while retaining the essence of traditional Jun porcelain craftsmanship. (Zhang et al., 2023)

Through interdisciplinary collaborative research, this paper breaks down the boundaries between tradition and

modernity, providing new ideas and directions for the innovative development of Jun porcelain and ceramic art. This research also provides a valuable reference for the digital protection and inheritance of traditional craftsmanship. This study comprehensively and thoroughly explores the impact of 3D printing technology on the traditional modeling process of Jun porcelain through a combination of literature review, case analysis, and experimental design, providing strong theoretical and practical support for the modern transformation of traditional craftsmanship.

JUN PORCELAIN TRADITIONAL MODELING TECHNIQUES

Characteristics of the traditional modeling process of Jun porcelain

The traditional modeling process of Jun porcelain is deeply rooted in the essence of ancient Chinese ceramic art. Its uniqueness is first reflected in the hand-building and carving processes. As the primary technique for shaping Jun porcelain, hand-building requires the craftsman to rely on their rich experience and feel to place the wet clay on a rotating wheel. The basic shape of the vessel is then formed by squeezing and pulling with both hands. This process not only tests the craftsmanship level of the craftsman but also contains the pursuit and expression of beauty. Jun porcelain formed by throwing on a wheel has smooth and natural lines and a complete and rounded shape, demonstrating the craftsman's deep understanding and use of the material's characteristics. (Yu, 2018)

Carving is an integral part of the decorative art of Jun porcelain. They use techniques such as engraving, scoring, and picking; the craftsman carves various patterns and decorations into the formed body. These patterns include traditional themes such as dragons and phoenixes bringing good luck, peonies symbolizing wealth and prosperity, and landscapes, figures, flowers, birds, fish, and insects, which show the beauty of nature. Carving not only enhances the artistic expression of Jun porcelain but also enriches and diversifies its cultural connotations.

The charm of Jun porcelain lies in the variation of glaze

colors and firing techniques. Jun porcelain is known for its 'one color entering the kiln, a million colors emerging' effect, where the glaze colors change during the firing process due to the redox reaction and the subtle changes in temperature and atmosphere in the kiln, resulting in a kaleidoscope of colors. This unpredictability makes every piece of Jun porcelain a unique work of art. Jun porcelain is fired using traditional wood or coal-firing methods, and control of the fire is crucial – the slightest mistake could damage the piece. Therefore, the skill of the firing technique is directly related to the quality and value of the finished Jun porcelain. Jun porcelain also follows a series of aesthetic principles in the traditional process.

The first is the philosophical idea of 'unity of man and nature,' reflected in the pursuit of natural harmony in the shape and decoration of Jun porcelain, reflecting the intimate relationship between man and nature. The second is the artistic pursuit of 'expressing the spirit through form.' Through precise modeling and vivid decoration, the craftsman conveys the inner charm and emotion of the work. Jun porcelain also emphasizes 'exquisite craftsmanship and fine materials,' that is, the perfect combination of superb craftsmanship and high-quality materials, ensuring that the work has artistic beauty and practical function. (Chen, 2018) These aesthetic principles together constitute the unique charm of the traditional modeling process of Jun porcelain, giving it a pivotal position in the history of ceramic art in China and even the world.

The technical challenges of traditional craftsmanship

Although the traditional Jun porcelain modeling process carries a profound cultural heritage and artistic value, it inevitably faces technical challenges during hand-making. The limitations of hand-making lie in the difficulty of controlling production efficiency and consistency. Each piece of Jun porcelain is hand-thrown, carved, and fired by a craftsman. In this process, the skill level, emotional state, and even the day's environmental conditions can all subtly affect the final shape and quality of the work. According to statistics, an experienced artisan can only complete a few to a dozen pieces a day, and each piece is unique, making it challenging to meet the

standardization requirements of mass production. The inheritance and protection of the craft are facing a severe predicament. (Bose et al., 2024)

The Jun porcelain process is complex and delicate, and it takes years of learning and practice to master its essence. However, with the acceleration of the modernization process, the younger generation's interest in traditional handicrafts has gradually waned, and there are fewer and fewer people willing to devote themselves to the production of Jun porcelain. The transmission of traditional skills often relies on oral transmission from master to apprentice, and there is a lack of systematic written or video recordings, which poses a risk of a gap in the transmission of skills. As the older generation of craftsmen gradually ages, many unique skills and secret recipes may be in danger of being lost.

In order to address these challenges, in recent years, some Jun porcelain production areas have begun to try to introduce modern scientific and technological methods to the protection and inheritance of traditional craftsmanship. For example, by establishing digital archives, classic works can be scanned and modeled in three dimensions, and their forms and details can be preserved in digital form to provide intuitive information for future generations to learn and study. Education and training related to traditional craftsmanship have been strengthened. By establishing professional colleges and organizing skills training courses, more young people are attracted to Jun porcelain production, injecting fresh blood into the inheritance of the craft. (Li, 2023)

The government and all sectors of society have also increased their support for traditional craftsmanship. By setting up special funds, holding exhibitions and competitions, etc., the popularity and influence of Jun porcelain have been enhanced, and the public's interest and attention to traditional handicrafts have been stimulated.

APPLICATION OF 3D PRINTING TECHNOLOGY IN CERAMIC CRAFTSMANSHIP

Principles and characteristics of 3D printing technology

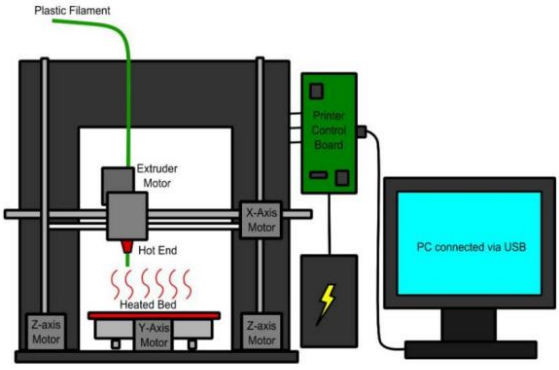

Figure 1. FDM technology, the principle of 3D printing technology

The core concept of 3D printing technology, or three-dimensional stereoscopic printing technology, lies in additive manufacturing, a very different manufacturing method from traditional subtractive or isometric processing. In additive manufacturing, an object is built up by accumulating material layer by layer, starting from the bottom and building up layer by layer until a complete three-dimensional solid is formed. This technology completely subverts traditional manufacturing thinking patterns and provides unprecedented flexibility and freedom for product design, manufacturing, and innovation. (Zhang et al., 2021)

In ceramic technology, introducing 3D printing technology has brought significant technological advantages. 3D printing can achieve precise manufacturing of complex structures. In traditional ceramic production, the shaping of complex forms often relies on the high skill of the craftsman, and there is a high failure rate. 3D printing technology, however, can directly print complex internal structures and delicate surface textures based on accurate 3D models generated by a computer, significantly broadening the boundaries of ceramic design.

3D printing technology has significantly improved the production efficiency of ceramic products. The traditional ceramic production process is cumbersome, involving multiple steps such as molding, grouting, trimming, and glazing, and is mainly done manually, which is time-consuming and labor-intensive. 3D printing, on the other hand, enables rapid

prototyping, significantly shortening the time from design to finished product. It is especially suitable for the production needs of small batches and multiple varieties. 3D printing also reduces material waste and efficiently uses resources by precisely controlling the material used in each layer.

3D printing technology also shows great promise in the application of ceramic materials. With the progress of material science, more and more ceramic materials have been developed, such as ceramic powders and pastes. These materials have good forming properties and meet different performance requirements. 3D printing technology can flexibly respond to the processing needs of these new materials, achieve diversified materials applications, and further promote the innovative development of ceramic technology.

3D printing technology, with its unique additive manufacturing principle, has demonstrated significant technological advantages in ceramic technology. It not only improves product design freedom and production efficiency but also promotes the diversified application of ceramic materials and injects new vitality into the innovation and development of ceramic art. (Lei & Mi, 2023) With the continuous maturity of the technology and the further reduction of costs, 3D printing technology is expected to play an even more critical role in ceramic technology.

The application of 3D printing technology in Jun porcelain

In the art of Jun porcelain, 3D printing technology has dramatically broadened the creative boundaries, especially in digital modeling, precision manufacturing, the realization of complex forms, and the exploration of new materials. Digital modeling technology provides unprecedented freedom for Jun porcelain design. With advanced CAD (computer-aided design) software, designers can construct any complex geometric shape or delicate artistic line precisely.

Everything can be precisely shaped in virtual space, from traditional bottles, cans, and dishes to highly modern abstract sculptures. (Lee et al., 2017) This process reduces the cost of trial and error in the design process and speeds up design

iteration, allowing Jun porcelain works to match the designer's creative vision more closely.

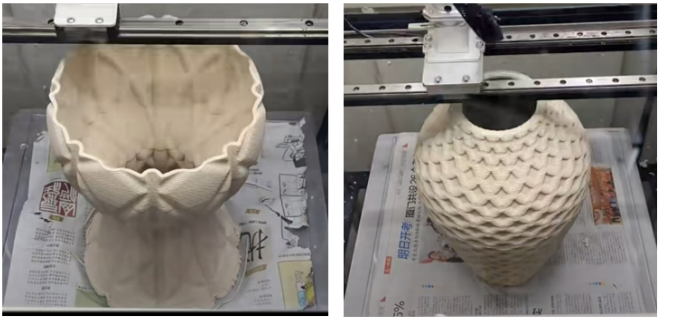

Figure 2. The application of 3D printing technology in Jun porcelain.

The precision manufacturing capabilities of 3D printing technology have enabled Jun porcelain to achieve new heights of precision in its shaping. Traditional hand-building is limited by the experience and skills of the craftsman, making it difficult to ensure complete consistency in each piece. 3D printing technology, on the other hand, directly replicates the design form precisely according to the digital model by layering materials and can achieve micron-level precision control of both the internal structure and external contours, ensuring the fineness and consistency of the work. 3D printing technology has also facilitated the creation of complex forms and structures in Jun porcelain.

Traditional techniques often face many challenges when creating complex shapes, such as constructing supporting structures and carving details. (Zhang & Liu, 2024) 3D printing technology can easily handle these challenges. It can directly print hollow, openwork, and multi-layered complex structures. It can even incorporate multiple materials and textures into the same work, greatly enriching the artistic expressiveness of Jun porcelain.

In terms of exploring and applying new materials, 3D printing technology has also injected new vitality into the art of Jun porcelain. With the advancement of science in ceramic materials, more and more new ceramic materials have been

developed. These materials have excellent physical properties and unique visual effects. (Li et al., 2023) 3D printing technology can flexibly use these new materials, and by precisely controlling the printing parameters, it can maximize the utilization of the material properties, bringing more possibilities to the creation of Jun porcelain. For example, some high-strength, low-shrinkage ceramic materials, with the support of 3D printing technology, can create more durable and versatile Jun porcelain works, further enhancing the artistic value and practicality of Jun porcelain.

The fusion of 3D printing and traditional craftsmanship

When exploring the fusion of 3D printing technology and the traditional modeling process of Jun porcelain, it is not difficult to discover that this is a profound and fruitful dialogue between modern technology and traditional craftsmanship. 3D printing technology, with its unique additive manufacturing method, has breathed new life and possibilities into the ancient art form of Jun porcelain. (Lin et al., n.d.) It is a technological innovation and a respect and extension of traditional craftsmanship.

Figure 4. The fusion of 3D printing and traditional handicrafts.

Modern technology, particularly the introduction of 3D printing technology, has opened up unprecedented flexibility and precision in the design and production of Jun porcelain. Designers can use 3D modeling software to convert complex creative ideas into digital models, which can be accurately reproduced using a 3D printer. This process dramatically

shortens the distance from design to reality and no longer restricts Jun porcelain modeling to traditional hand-building techniques. Digital technology also provides strong support for traditional handicrafts. In producing Jun porcelain, changing the color of the glaze and the firing process are highly critical. Traditional glaze color matching and firing experience often requires years of accumulation and exploration by artisans. (Maurath & Willenbacher, 2017)

Nowadays, with the help of modern scientific methods such as spectral analysis and thermal imaging, the laws of glaze color changes and firing conditions can be more scientifically understood, providing a scientific basis for innovation in Jun porcelain glaze colors. 3D printing technology can also be used to create precise molds, helping artisans better control the shape and size during the firing process and improve the yield of finished products. 3D printing technology has not replaced traditional handicrafts but has formed an excellent complementary relationship with them.

In the creation of Jun porcelain, many artists still insist on the steps of hand-carving and decoration to show its unique artistic charm and cultural connotations. 3D printing technology is more commonly used in areas such as prototype making and the construction of complex structures, providing traditional handicrafts with a broader creative space and technical support. (Wang et al., 2023) The integration of 3D printing technology and the traditional modeling process of Jun porcelain has not only improved the efficiency and precision of Jun porcelain production but also injected new creativity and vitality into it. This integration is a form of inheritance and development of traditional handicrafts and an active exploration and practice of combining modern technology with traditional culture.

THE IMPACT OF 3D PRINTING ON THE TRADITIONAL MODELING PROCESS OF JUN PORCELAIN

The freedom and innovation of modeling design

When discussing the impact of 3D printing technology on the traditional modeling process of Jun porcelain, one significant change is the significant increase in modeling complexity brought about by digital modeling. In traditional Jun

porcelain production, the shape relies heavily on the craftsmanship and experience of the artisan. Limited by physical manipulation and the characteristics of the material, complex and detailed designs are often difficult to achieve.

In contrast, 3D printing technology can easily create highly complex and precise 3D models through high-precision digital modeling software. These models can be repeatedly modified and optimized on a computer to ensure a high degree of restoration of the final product. (Xu, 2024) This seamless conversion from 2D design to 3D entity has dramatically broadened the boundaries of Jun porcelain modeling design, allowing designers to break through the limitations of traditional craftsmanship and realize more complex and ever-changing artistic concepts.

Figure 5. The freedom and creativity of 3D printing in design

Digital modeling technology allows Jun porcelain works to incorporate modern and geometric aesthetics to create unprecedented forms and structures. For example, using 3D modeling software, it is possible to design complex structures such as multi-layer nesting and hollow engraving, which are difficult to achieve in traditional hand-building. These designs not only enhance the work's visual impact but also enrich the artistic expression of Jun porcelain. Digital modeling has also promoted the cross-border integration of Jun porcelain with other art forms, such as architectural design and sculpture, to create Jun porcelain artworks with unique styles.

The application of new technologies in innovative design is also evident. 3D printing technology has brought unprecedented flexibility to Jun's porcelain design. Designers can freely explore various design possibilities in virtual space without worrying about technical difficulties in actual production. This increased freedom of design has stimulated the creativity of designers and promoted the development of Jun porcelain art in a more diversified and personalized direction. (Huang & Chen, 2024) Combining virtual reality (VR) and augmented reality (AR) technologies, designers and consumers can also preview and experience design results in a virtual environment, further enhancing the interactivity and sense of participation in the design.

3D printing technology has revolutionized the traditional modeling process of Jun porcelain by improving modeling complexity through digital modeling and applying new technologies in innovative design. It not only broadens the boundaries of design but also stimulates the creativity of designers and promotes the innovative development of Jun porcelain art. In the future, with the continuous advancement of technology and in-depth application, there is reason to believe that Jun porcelain art will shine even brighter at the intersection of tradition and modernity.

Process optimization and efficiency improvement

The introduction of 3D printing technology has significantly optimized the process of making Jun porcelain, enabling rapid prototyping from design to finished product and significantly promoting the diversification and flexibility of production. In traditional Jun porcelain production, from hand-building and sculpting to firing, each process consumes a lot of time and workforce, and the yield is affected by many uncontrollable factors. (Zhang & Zhang, 2024) In contrast, 3D printing technology directly converts designs into three-dimensional physical models through high-precision digital modeling, eliminating cumbersome manual production steps and significantly shortening the cycle from design conception to physical verification. 3D printing technology allows designers to create prototypes of multiple design options quickly. These

prototypes accurately reflect the design intent and can be quickly adjusted and optimized in subsequent stages, reducing material waste and production costs caused by improper design. According to industry reports, after adopting 3D printing technology, the iteration cycle of Jun porcelain design can be shortened to one-fifth of the traditional method, significantly improving design efficiency and market response speed. 3D printing technology has also promoted the diversification of Jun porcelain production. (Owen et al., 2018)

Traditional handicrafts are limited by the skill level and experience of the craftsman, making it difficult to achieve complex and ever-changing shapes and pattern designs. 3D printing technology, on the other hand, can easily handle the challenges of various complex forms and perfectly reproduce fine textures, unique shapes, and precise dimensional control. This ability allows Jun porcelain works to break through traditional boundaries and develop in a more personalized and artistic direction.

3D printing technology also shows excellent advantages in terms of production costs. Although the initial equipment investment is high, its long-term cost-effectiveness gradually becomes apparent as the technology becomes more widespread and economies of scale are achieved. In small-batch, customized production, in particular, 3D printing technology effectively reduces production costs by reducing the need for mold making and lowering the rate of rejects.

Due to the shortened production cycle, companies can recover funds more quickly and invest in the next round of production, further improving capital utilization efficiency. (Wang et al., 2024) The application of 3D printing technology in the production of Jun porcelain optimizes the process flow, improves production efficiency, and promotes the diversification of designs and personalization of production. These advantages have jointly promoted the transformation and upgrading of the Jun porcelain industry and opened up new paths for the modern development of traditional handicrafts.

Preserving and passing on the essence of traditional craftsmanship

When discussing the impact of 3D printing technology on the traditional modeling process of Jun porcelain, the central position of traditional craftsmanship should be considered. Jun porcelain is a treasure of Chinese ceramic art; its unique hand-throwing and sculpting techniques carry thousands of years of cultural accumulation and the spirit of craftsmanship. Under the impact of the modern technological wave, although 3D printing technology is known for its high precision, high efficiency, and design freedom, the cultural value, artistic charm, and irreplaceable manual warmth inherent in traditional handicrafts are still difficult to completely replace by any modern technology. (Jing, Cheng, Xu, & Zhu, 2023)

In order to effectively preserve and pass on the essence of the traditional Jun porcelain craftsmanship, the key lies in strategic integration and innovation. On the one hand, traditional craftsmanship's aesthetic principles and essence should be explored in depth, such as the natural kiln changes of glaze colors and the feel and strength control when throwing on the potter's wheel. These unique artistic languages must be passed down through master-apprentice teaching and on-site demonstrations to ensure the continuity and purity of the craftsmanship. (Buj-Corral & Tejo-Otero, 2022)

On the other hand, digital recording and replication using 3D printing technology can accurately capture and preserve every detail of traditional shapes, providing valuable information for future generations to learn and study. While retaining traditional elements, the harmonious coexistence of tradition and modernity can be achieved by integrating 3D printing technology into the creation of Jun porcelain through innovative design techniques. For example, 3D printing technology can be used to create complex and detailed molds to assist in the manual completion of difficult-to-achieve modeling parts in the throwing or carving process, which not only retains the warm and tactile feel of handicrafts but also expands the boundaries of design. Through 3D modeling technology, traditional patterns can be combined with modern design concepts to create new works that conform to modern aesthetics and are rich in cultural heritage. In preservation and inheritance, we also need to pay attention to intellectual

property protection and the establishment of cultural confidence. (Chi, 2023)

Strengthening the intellectual property protection of traditional Jun porcelain craftsmanship and preventing the loss of skills and commercial abuse is an important guarantee to ensure the sustainable development of traditional craftsmanship. Through cultural exchanges and exhibitions at home and abroad, the unique charm of Jun porcelain art is showcased, enhancing confidence and pride in national culture and allowing more people to understand and value this valuable cultural heritage. (Yang, Li, & Mu, 2024) The preservation and inheritance of the essence of traditional handicrafts requires us to make flexible use of modern scientific and technological methods based on respect and inheritance, to achieve an organic integration of tradition and modernity, and to enable Jun porcelain, an ancient art form, to shine even brighter in the new era.

Experimental verification and case analysis

This paper conducts a series of experiments to explore in depth the specific impact of 3D printing technology on the traditional modeling process of Jun porcelain. It analyzes the Jun porcelain 3D-printed works produced during the experiments. These experiments cover the entire process from design, modeling, and printing to post-processing but also focus on comparing the differences and integration of traditional craftsmanship and modern technology.

Figure 6. 3D printing experimental process.

In the experimental stage (Figure 6), this paper selected a representative Jun porcelain shape as a prototype, used 3D scanning technology to obtain its precise 3D data, and optimized and innovatively designed it in professional 3D design software. By adjusting design parameters such as curvature, thickness, and internal structure, complex forms that are difficult to achieve using traditional techniques, such as fine openwork carving and variable surface structures, were successfully realized. These designs retain Jun porcelain's charm and add a modern and artistic feel. (Peng et al., 2024)

In the printing process, this paper selects 3D printing technologies suitable for ceramic materials, such as ceramic slurry injection (CIP) or sintering of ceramic powders (SLS), to ensure the accuracy and strength of the printed work. This paper obtains Jun porcelain blanks with smooth surfaces and dense structures by precisely controlling printing parameters such as layer thickness, sintering temperature, and speed. Compared with traditional hand-throwing, 3D printing technology significantly improves production efficiency and the body's uniformity and reduces the reject rate. (Yan, 2024)

In terms of successful cases, this paper designs and prints a series of innovative Jun porcelain works, such as a tea set with modern geometric elements and a vase with complex pattern decorations. These works have won wide acclaim in the industry for their unprecedented beauty of form and structure while maintaining the unique glaze color changes of Jun porcelain. In particular, the delicate carvings and complex structures achieved using 3D printing technology have become a highlight of the works. However, there were also challenges and failures in the experimental process.

For example, when trying to print Jun porcelain shapes with extremely high curvature changes, some works cracked or deformed due to problems with material fluidity and shrinkage problems. The even distribution and adhesion of the glaze layer on the printed blank body have also become one of the technical difficulties. (Li & Cheng, 2024) In response to these problems, this paper has repeated experiments and adjustments, gradually optimizing the printing process and post-processing

procedures, providing valuable experience for future applications.

Through this experimental verification and case analysis, this paper has gained a deep understanding of the great potential and challenges of 3D printing technology in the traditional Jun porcelain modeling process. In the future, we will continue to explore more possibilities, promote the deep integration of traditional craftsmanship and modern technology, and inject new vitality into the development of Jun porcelain art.

CONCLUSION

This study explores in depth the profound impact of 3D printing technology on the traditional modeling process of Jun porcelain. Specifically, 3D printing technology, with its unique additive manufacturing approach, significantly enhances the freedom and precision of Jun porcelain modeling and design. Through high-precision digital modeling, designers can create more complex and detailed Jun porcelain forms, broadening the artistic expression of Jun porcelain and satisfying the modern aesthetic pursuit of personalization and differentiation. For example, some complex geometric patterns and streamlined designs are challenging in traditional hand-building, but 3D printing technology can easily handle them, injecting new vitality into Jun porcelain art.

The introduction of 3D printing technology has dramatically improved production efficiency in terms of the production process. The rapid prototyping capability allows designers' ideas to be quickly transformed into physical objects, significantly shortening the cycle from product design to market. By reducing manual operations, production costs are also effectively controlled. 3D printing technology shows excellent advantages, especially in small-batch, customized production. 3D printing technology also enables precise use of materials and reduces waste, aligning with sustainable development.

The study also emphasizes the importance of maintaining respect for the essence of traditional craftsmanship in modernizing the Jun porcelain process using 3D printing

technology. The unique charm of Jun porcelain lies not only in its exquisite appearance but also in its profound cultural heritage and the emotional investment of the artisans. Therefore, when introducing new technology, attention should be paid to integrating traditional techniques. Through interdisciplinary cooperation, a design methodology can be explored that not only gives full play to the advantages of 3D printing technology but also retains the essence of traditional craftsmanship. For example, 3D printing technology can be used to create the complex structural parts of Jun porcelain, while critical processes such as color variation and firing can still be completed manually by experienced craftsmen.

This not only ensures the artistic and unique nature of the product but also improves production efficiency. 3D printing technology has brought unprecedented opportunities for change to the traditional modeling process of Jun porcelain, but it has also presented new challenges. In future development, the concept of 'technology empowerment and culture as the soul' should be upheld, and the path of integration of new technologies and traditional craftsmanship should be continuously explored to achieve innovative development of Jun porcelain art.

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