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The 3D Printing Equipment Based on Photovoltaic Energy Has Improved the Innovation of Patchwork Products

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Abstract. As an emerging energy source, photovoltaic power generation has the characteristics of strong stability and low energy consumption and is widely used in modern equipment. At present, 3D printing is a new field of photovoltaic energy application. However, the degree of its integration with 3D printing has always been a point of controversy. In this study, photovoltaic energy equipment was used to analyze the characteristics of 3D printing, and the combination effect of photovoltaic energy and 3D printing was discussed, especially the role of patchwork product innovation. The research results show that photovoltaic can extend the use time of 3D printing equipment, play a key role in the innovation of patchwork products, improve the accuracy of splicing, make it reach more than 90%, shorten the production time of patchwork, and play the role of ventilation and warmth of patchwork products, with an improvement rate of more than 10%. It can be seen that this study can deeply explore and utilize the powerful role of 3D printing equipment, to promote the role of new energy in 3D printing and patchwork product innovation and contribute to the innovation of patchwork design.

Key words. Photovoltaic Energy, 3D Printing Equipment, Quilting Products, Innovative Improvement.

1. Introduction

As a new type of energy, photovoltaic energy has the characteristics of low energy consumption and low power generation cost and can realize the continuous conversion of sunlight, which is not limited by factors such as geography and technology so photovoltaic energy has the characteristics of stability and sustainability, 3D printing technology is the main direction of current research, through the 3D printing of materials, it can reduce the pollution of the environment and energy, and reduce the production cost of parts, so 3D printing technology meets the needs of the actual economic development, but 3D printing technology has problems such as long time and continuous energy loss [1], [2]. Some scholars believe that traditional energy sources cannot meet their development requirements, and the integration between photovoltaic energy and 3D printing technology can give full play to the advantages of the two and achieve complementary advantages [3]. Some scholars believe that with the support of 3D printing equipment, textiles, patchwork and other fields have made leaps and bounds, but energy consumption has also increased significantly [4], [5]. Patchwork products are an important medium in the modern cultural industry and play a vital role in clothing, decoration, aviation, and aerospace decoration. Some scholars believe that 3D printing equipment is an efficient molding equipment. The primary operational process includes reverse 3D scanning and computer-aided design to create a 3D digital model [6], [7]. These created models are then divided into ordered two-dimensional elements by specific cutting software. Typically, the Z-axis of the 3D digital model is divided according to the thickness and accuracy requirements, resulting in a series of 2D slices [8]. Then, based on the shape data of each layer, the required machining parameters are entered, the machining process code is created, and finally, through efficient manufacturing equipment [9], [10]. Therefore, how to combine 3D printing technology, photovoltaic energy technology and patchwork product design concepts to meet the needs of modern aesthetics has become the core issue of photovoltaic energy research. Due to the continuous development of new materials, technologies and processes, 3D printing methods have promoted patchwork depth. Combined with the relevant research status at home and abroad, this paper makes an in-depth analysis of 3D printing technology and photovoltaic energy utilization technology. It proposes a fusion strategy: firstly, the innovative data of patchwork products are collected, and the data are analyzed, especially the artistic content of decorative corners and patterns, and then the design of different patterns and the time and effect of 3D printing technology are compared, and the role of positive photovoltaic power generation for 3D printing equipment is proposed, especially the printing time and printing energy consumption. Finally, the effect of 3D printing equipment and photovoltaic energy applications is compared, and the printing accuracy of patchwork products is compared to provide support for the innovation of 3D printing and patchwork products.

2. Model Analysis of Patchwork Product Innovation

A. Integration of Photovoltaic Energy and 3D Printing

3D printing consists of two distinct phases: the material selection phase and the patchwork error adjustment phase. There is a N set of patchwork data, the printing process of the patchwork is as follows.

$$J(t)=\frac{1}{2}\sum_{p=1}^{N}\|dp-yp\|^{2}=\frac{1}{2}\sum_{p=1}^{N}\sum_{k=1}^{O}\left(d_{kp}-y_{kp}\right)^{2} \quad (1)$$

Where, O is the preliminary design of the patchwork product, d_p is the transformation of the design concept, and $J \le \varepsilon$ is the critical path to make when the inspection and optimization design to achieve the goal, the patchwork product will be predicted. In this study, the computer-aided process parameters x_p are x_1, x_2, x_3, the 3D printing time, printing temperature and photovoltaic power supply time, and the patchwork product is d_p, the cost of the patchwork is d_1. According to the number of 3D printing process parameters and the output result, set the number of printing shops of the printer, the photovoltaic power supply is 220V, which corresponds to the input printing process parameters, and the output product is 1, corresponding to the volume of the patchwork. The integration of 3D printers is not only the integration of commercial products but also the choice of printing strategy, reducing the consumption of photovoltaic energy and saving power supply costs. Many computer-aided designs are used to bring convenience, more efficiency, and richer tools for patchwork design and 3D printing, as well as to draw a variety of three-dimensional digital models of patchwork. Photovoltaic energy can provide a continuous power supply for 3D printing equipment and realize the effects of automatic printing, continuous printing, and strategy selection.

B. Photovoltaic Energy Conversion and Printing Effect

The 3D printer uses the optimal and unbiased linear prediction interpolation method to analyze the spatial autocorrelation characteristics of the patchwork, especially the prediction of air permeability, thermal insulation and other indicators.

The results of 3D printing include breathability and heat preservation, and the specific results are as follows.

$$y(x)=f^{\mathrm{T}}(x)\beta+Z(x) \quad (2)$$

For any prediction point x, the air permeability $\mu(x)$ and thermal insulation analysis $\sigma^{2}(x)$ are carried out, which are respectively the air permeability function.

$$\mu(x)=f^{T}(x)\cdot\beta+r^{T}\cdot(x)\rightarrow R^{-1}(y-x) \quad (3)$$

Thermal insulation analysis was performed at the same time as ventilation, and the results are as follows.

$$\sigma^{2}(x)=R\cdot\sigma^{2}\left[1-\left(F^{T}RF\right)^{-1}\pm u(x)\right] \quad (4)$$

Where R is the correlation matrix for air permeability and thermal insulation; The error function is $u(x)=F^{T}$.

Photovoltaic energy supply $f(x)$ is 3D printing; β is the coefficient of accuracy, material and so on; Functions $Z(x)$ is selected for randomness. x is the printing process parameters, x_1, x_2, and x_3 are the printing speed, strength and material, and $y(x)$ is the area of printing.

C. Innovativeness of Photovoltaic Printing Equipment

Innovation can be divided into theory and modeling in printed parts, and the accuracy is mainly manifested as a step effect. After the light energy is reduced, the speed of the printer is reduced to a certain extent, and the innovation mainly depends on the design concept and materials. Theoretically, the lower the light intensity, the slower the print speed, the less significant the layering effect, and the lower the innovation. In the production process, achieving high molding accuracy while maintaining printing speed is a key equipment challenge. In printing, it is difficult to control the cross-sectional shape of the nozzle during filament molding, resulting in the overlapping effect of the wire on the adjacent path, which will not guarantee the forming accuracy of the entire print in the horizontal direction. To ensure excellent moulding accuracy in both concept and shape, this study needs to explore the relationship between movement speed, print layer thickness and material. Assuming that the innovation function is in the interval $\left[y_{\min},y_{\max}\right]$, its calculation formula is:

$$y=\frac{\left(y_{\max}-y_{\min}\right)\leftrightarrow\left(x-x_{\min}\right)}{x_{\max}-\Delta x_{\min}}+\Delta y_{\min} \quad (5)$$

Where, x_{min} is the minimum hardness of the material, the x_{max} is the maximum hardness of the material, x is the innovative concept, y_{min} is the innovative design, and y_{max} is the maximum realization of the concept.

In practice, the innovation needs to be narrowed down so that it is in $[-1,1]$, so the normalization formula can become:

$$y = \frac{n \div \left(x - \Delta x_{min}\right)}{x_{max} - x_{min}} - k \tag{6}$$

Where x_{min} is the minimum value of innovation; x_{max} is for the maximum value of innovation; x represents the optimization results of photovoltaic cells.

3. A Practical Case Study of 3D Printing

A. Case Elaboration

Taking the patchwork material of clothing as the research object, the photovoltaic power supply is a 5nm polycrystalline silicon panel, the storage battery is a nickel-cadmium battery, the printer power is 10KW, air cooling and heat dissipation, 3D modelling in CAD, DOC, OBJ and other formats, and printing materials such as polyethene and silk. The main controller is a PC, the scanning device is a laser scanner, the scanning form is 3D, and the density is 10*10cm.

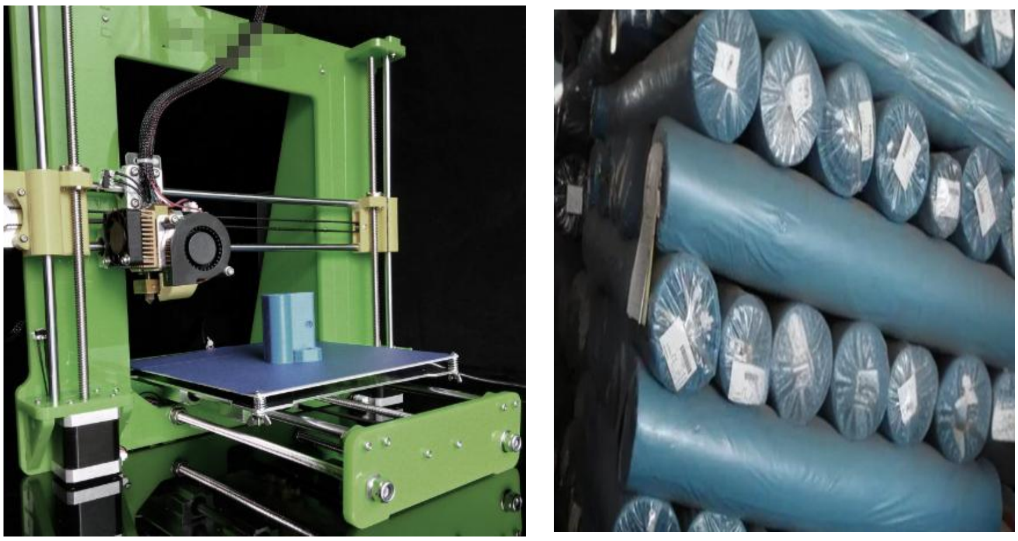


Figure 1. Printer Equipment and Materials

As can be seen from Figure 1, the photovoltaic 3D printer can work continuously for material printing, so its working intensity is closely related to photovoltaic power generation. The overall design process is shown in the figure below.

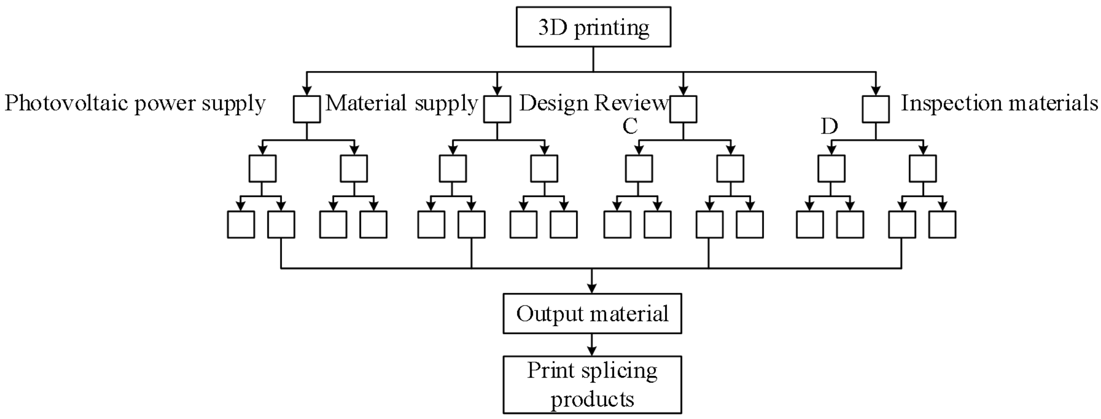


Figure 2. The Process of 3D Printing

As can be seen from Figure 2, the actual effect of 3D printing is related to the working intensity of the material and the workpiece of photovoltaic energy, so in the whole process of material design, the product is most affected by photovoltaic energy, and several other indicators belong to the attributes of the 3D printer itself, which cannot be changed.

B. Accuracy of 3D Printing

When 3D printing patchwork, the average volume rate of the silk material and the average volume rate of the filament at the nozzle hole is the same as the printed piece, and the theoretical value is the same as the ratio of the volume of the printed piece to the printing time, so it is ignored, mainly to test its pattern, colour and silk gap, as follows.

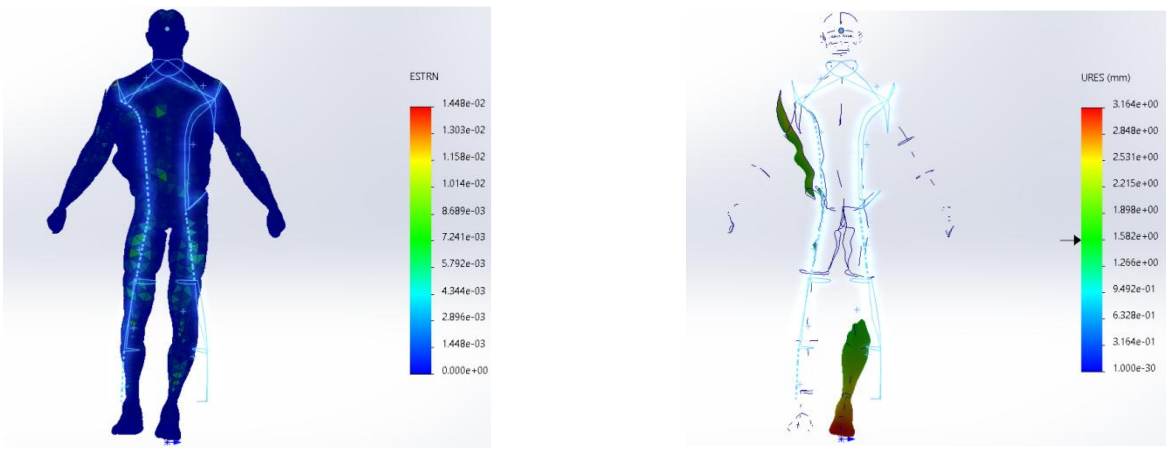
Table 1. Environmental Impact Assessment of Solar Panels in Heritage Sites

Type	Temperature	Speed Class (g/s)	Clearance (m)	Expansion Volume Rate (%)	Chromatic Aberration
Photovoltaic 3D Printers	180~190	3(31.84)	3(12.09)	3.22	Exist
	190~210	3(31.85)	3(12.98)	3.17	Exist
	220~230	3(31.59)	3(13.53)	3.60	Exist
	240~250	3(22.56)	3(12.75)	3.65	Exist
Industry-standard Printing	190~210	2(12.61)	1(8.45)	1.23	Not
	220~240	2(12.41)	1(8.186)	1.06	Not
	250~260	2(11.87)	1(8.29)	1.82	Not
	270~280	2(31.91)	1(8.72)	1.62	Not

It can be seen from Table 1 that the patchwork material printed in this paper is better as a whole, although there is a particular gap with the industry ' s standard printing, the gap is small, and the 3D printer can be adjusted later through continuous printing, and its final printing accuracy meets the industry standard, and the production of patchwork products can be carried out. In addition, the accuracy in the horizontal and vertical directions under different printing speeds and layer thicknesses was found to be 0.1, 0.2, 0.3, and 0.4mm.

C. *Breathable and Warm Results of 3D Printing*

Under the condition of various printing rates, the interaction between the lamination thickness and the diameter of the extruded filament shows a significant difference in its shape and warmth, which is a requirement index for 3D product innovation, as shown in Figure 2.



Warm Breathable

Figure 3. Breathability and Warmth Retention Results After 3D printing

As shown in Figure 3, when the lamellar thickness reaches 0.1 mm, the filament width changes significantly under different rate conditions, and the heat dissipation gradually decreases with the rate increase. At the printing rate of 50 mm/s, the filament width reaches 0.46mm, which coincides with the diameter of the nozzle hole of about 0.4mm, and there is a small difference in the angle and poor form of printing, and its air permeability is better. At a print rate of 30 mm/s, the wire width may increase to 0.74mm, exceeding 0.4mm of the nozzle aperture, indicating that the ratio of layer thickness to print rate is not appropriate, indicating that the relationship between the 3D printing process and photovoltaic energy is negligible. In addition, when the filament's width increases, the filament's ejection rate will be faster, and the moulding accuracy of the filament will be higher. It can be seen that the warmth and air permeability of photovoltaic energy 3D printing are better, mainly because the nickel-cadmium battery in photovoltaic energy can reduce the disturbance of the power supply. When the thickness of the layer exceeds 0.3mm, the filament width of the three printing rates is almost the same, and the filament width drops to less than 0.4mm, which is close to the maximum value at this time, which means that the printing speed at the moment is too fast, and the manufacturing accuracy of the printing equipment in the load state is difficult to guarantee both horizontally and vertically. However, the photovoltaic energy 3D printer improves the printing effect by slowly heating the form and adjusting the width of the extrusion line, as shown in the figure below.

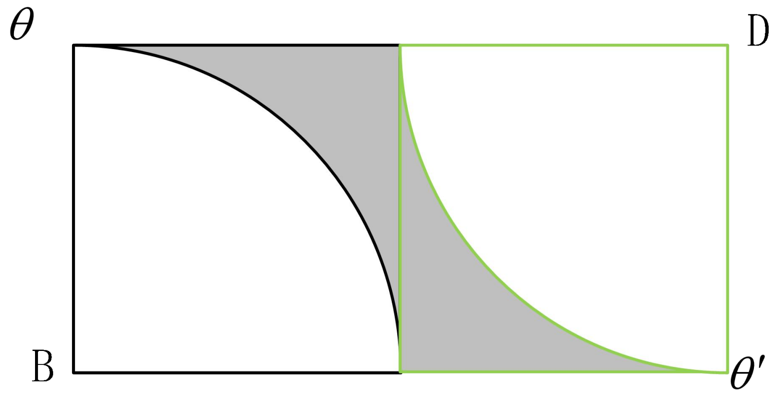


Figure 4. Adjustment of the Amount of Injection by Photovoltaic Energy During the Printing Process

As shown in Figure 4, the photovoltaic energy supply is temperature-adjusted in the form of injection volume to increase its adhesion, and when the adhesion ratio is too high, a large number of adjacent filaments will accumulate. When the meshing is insufficient or zero, the meshing between adjacent extruded filaments will be insufficient, resulting in gaps between adjacent sedimentary trajectories. When the lapping rate reaches the right level, the extruded wire can be formed evenly and smoothly. By adjusting the thickness of the filler, various lap ratios can be achieved, thus guaranteeing the accuracy of the mold in the vertical position.

D. Stability of 3D Printing and Photovoltaic Energy Supply

At different times, when the 3D printer is sprayed, the different spraying will cause the increase of the material and will affect the heating uniformity of the material, so the direct relationship between the printer and the photovoltaic cell can be studied to judge its stability better. When the 0.3 mm delamination thickness curve and the 0.4 mm delamination thickness curve matched well, the 0.4 mm delamination thickness value was excluded from the experiment. In order to study the influence of filament connection methods on manufacturing accuracy, this study determined a suitable filament connection ratio to improve the horizontal displacement accuracy of the manufactured parts and adjusted its fill rate to 90%. Finally, three sets of experiments were developed in this study, as detailed in Table 1. During the experiment, the temperature of the printhead was adjusted to 220 °C to avoid interfering with the printing, as shown in Table 1.

Table 2. Test Process Parameters

	Content	Output Rate（mm/s)	Power Supply Rate /（mm)	Stability /（%)
Photovoltaic Energy	Thickness	30	80.1	90
	Heating	30	90.2	90
	Velocity	30	90.3	90
3D Printers	Thickness	40	90.2	90
	Heating	40	90.3	90
	Velocity	50	90.1	90
DC Power Supply	Thickness	50	90.2	93
	Heating	50	90.3	93
	Velocity	50	90.2	93

From the data in Table 2, this study can compare the data of photovoltaic power supply, 3D printer output and DC power supply and find that when the diameter of the silk wire is 0.3 mm, the horizontal and vertical accuracy of sizes 3, 6 and 9, the printing effect of photovoltaic power supply is inferior to that of DC point. Still, the output power of photovoltaic cells is consistent with the input power of the printer, indicating that there is no verified power supply contradiction, which can ensure the stable impression of the printer. During the experiment, the number of filaments was insufficient because the layer thickness was set too high, the printing speed was too fast, and the wire width was set too small. Extrusion section of the nozzle at this time: When the layer thickness is 0.3 mm, a print speed of 30 mm/s or higher may cause the printer to be overloaded, mainly because the printing speed is too fast, resulting in the extruded filament not being able to print at a speed that is sufficient for printing. In addition, there is no effective extrusion between the material layers, and the low bond strength requires a large amount of photovoltaic energy, reducing the overall printing efficiency. Analyze the different power supplies to verify the fusion of printing materials, as shown in Figure 5.

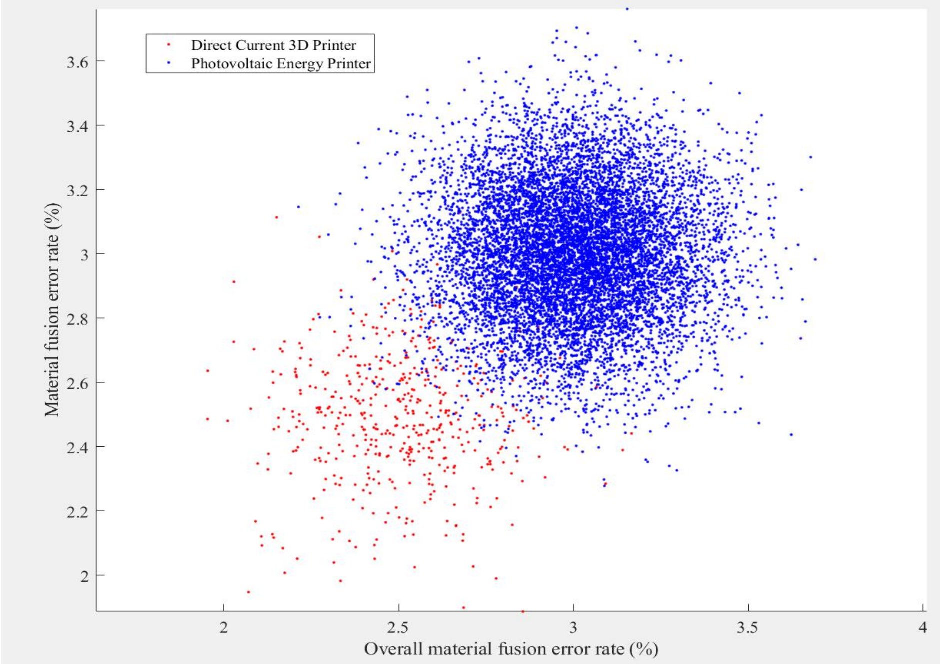


Figure 5. Comparison of Fusion Rates of Different Materials

E. Suggestions for the Integration of Photovoltaic Energy and 3D Printing

In the preliminary design stage of the patchwork, as mentioned earlier products, the designer uses computers to build a model using 3D printing equipment based on photovoltaic energy and conducts design verification and implementation evaluation. Several key points need special attention to be paid to during this design process.

First, select the appropriate 3D wall thickness and size. When making 3D patchwork products, this study must focus on their wall thickness and specifications. In general, the wall thickness increases the hardness and stability of the parts of the patchwork product, and with the expansion of materials and product specifications, the requirements for minimum wall thickness also increase. If the strength is expressly specified or specific to the structure of the pressure zone, additional reinforcing materials may be added to this study to increase the strength of the component. The study does not recommend making the most significant models at a time, as FDM 3D printing can bend when making too large or too small parts. Secondly, the 3D digital model of the patchwork was appropriately combined and segmented. When a study begins the ideation process of a 3D digital model, various designers often use various design tools, so the study must focus on all aspects of the ideation process. The most common problems typically occur in free-interleaved surfaces, internally overlapping surfaces, and free-form interleaved surfaces of 3D digital models. If the scale is not configured correctly or the overlap area is too large, it may lead to broken faces, which can negatively affect the print quality and even cause the G-code to fail to cut. For complex product design, this study should be carefully divided in the model construction process, and pay attention to its tolerance. In general, the clearance range required for assembling components of 3D printed devices based on photovoltaic energy is 0.2 mm~0.3 mm, and the requirements increase as the model increases. Finally, the matching of photovoltaic cells with the power flow and current of the 3D printer is strengthened to improve the accuracy of printing details. During the modeling process, some minor details or decorative elements of the object, such as relief or lettering, must have a large enough scale that cannot be recovered on the 3D-printed object. Therefore, designers must have a deep understanding of the manufacturing precision of 3D printers and the minimum standards that can be achieved. By adjusting the subtleties of the design to follow the 45-degree principle and reducing the need for a mould support frame during the FDM production process, this study helps improve the mould's surface texture. In addition, if the contact area between the bottom of the model and the printing platform is small, the 3D printing may trigger the tilt of the mold, so the study suggested that a support frame needs to be built to ensure that the components can be produced smoothly.

4. Conclusion

As a new type of technology, 3D printing technology has the advantages of simple production, higher moulding rate, fast printing speed, etc.. Still, there is a problem of high energy consumption, so some scholars integrate photovoltaic energy with the information system of 3D printers and analyze it theoretically. However, there is a deviation when printing at high speeds. Regarding the stability research of photovoltaic printers, its stability is greater than 90%, and the reaction speed can meet the requirements of 90% of the printer, which is different from the 220-volt DC printer. Therefore, the photovoltaic printer still needs patchwork product design, and the future development potential is enormous, in the process of instinct research, the data collection time in the analysis process of the photovoltaic energy printer is relatively short, and the future will focus on real-time information collection of data for the first time to discover the advantages and disadvantages of kung fu printers

References

[1] J. M. Chen, Y. J. Jiang, and Y. S. Li, "The application of digital medical 3D printing technology on tumor operation," in *SPIE Proceedings*, Apr. 2016, doi: 10.1117/12.2209252.

[2] H. Y. Jeong, S. C. An, Y. Lim, M. J. Jeong, N. Kim, and Y. C. Jun, "3D and 4D printing of multistable structures," *Applied Sciences-Basel*, vol. 10, no. 20, Oct. 2020, doi: 10.3390/app10207254.

[3] A. Y. Lee, A. W. Zhou, J. An, C. K. Chua, and Y. Zhang, "Contactless reversible 4D-printing for 3D-to-3D shape morphing," *Virtual and Physical Prototyping*, vol. 15, no. 4, pp. 481-495, Oct. 2020, doi: 10.1080/17452759.2020.1822189.

[4] J. Y. Lee, J. An, and C. K. Chua, "Fundamentals and applications of 3D printing for novel materials," *Applied Materials Today*, vol. 7, Jun. 2017, pp. 120-133, doi: 10.1016/j.apmt.2017.02.004.

[5] C. M. Li, "Structure design of braille puzzles based on 3D printing technology," in *Innovative Technologies for Printing and Packaging*, M. Xu, L. Yang, L. Zhang and S. Yan, Eds. 2023, vol. 991, pp. 146-152.

[6] J. H. Lim, Y. W. Weng, and Q. C. Pham, "3D printing of curved concrete surfaces using Adaptable Membrane Formwork," *Construction and Building Materials*, vol. 232, Jan. 2020, doi: 10.1016/j.conbuildmat.2019.117075.

[7] J. Son and S. Choi, "Orientation selection for printing 3d models," in *2015 International Conference on 3D Imaging (IC3D)*, Liege, Belgium, Dec. 2015, pp. 1-6.

[8] Y. W. D. Tay, M. Y. Li, and M. J. Tan, "Effect of printing parameters in 3D concrete printing: Printing region and support structures," *Journal of Materials Processing Technology*, vol. 271, pp. 261-270, Sep. 2019, doi: 10.1016/j.jmatprotec.2019.04.007.

[9] G. M. Zhang, H. B. Lan, L. Qian, J. W. Zhao, and F. Wang, "A microscale 3D printing based on the electric-field-driven jet," *3D Printing and Additive Manufacturing*, vol. 7, no. 1, pp. 37-44, Feb. 2020, doi: 10.1089/3dp.2018.0154.

[10] X. Zhang *et al.*, "Large-scale 3D printing by a team of mobile robots," *Automation in Construction*, vol. 95, pp. 98-106, Nov. 2018, doi: 10.1016/j.autcon.2018.08.004.