USE OF THREE DIMENSIONAL PRINTING IN THE PRODUCTION OF TEXTILE PRINT FORMS

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Abstract: *Since the invention of woven fabric, various types of artistic printing on fabric have been used. One of the most ancient and widespread methods is letterpress and gravure printing. Besides printing, it is also widely used in industrial textile production. The creation of industrial printing plates is a very expensive process today. For this reason, for small editions more economical technologies are used, such as silk-screen printing. However, gravure and letterpress methods have several advantages over screen printing. Reducing the cost of production of printing plates of this type will be an undoubted progress. The relief on the surface of the printing plate is a three-dimensional construction. Therefore, it can be formed in the form of a digital three-dimensional model. Modern methods of three-dimensional printing make it possible to form a printed form based on such a digital model, suitable for use in the textile and printing industries. The introduction of this technology will definitely reduce the cost of manufacturing forms for textile printing. The article describes an experiment that confirms this assumption.*

Keywords: *3D printing, printing plate, photopolymer, letterpress, intaglio printing.*

1 INTRODUCTION

Since the invention of the woven fabric, various types of artistic printing on fabric have been used. Some of the most ancient and widespread methods are letterpress and gravure printing (Figure 1). Besides printing, it is also widely used in industrial textile production. The creation of industrial printing plates is a very expensive process today. However, this is entirely justified due to the mass production. Over time, such costs in the presence of large circulations pay off and generate income. This technique is not available for small-scale production. For this reason, for small editions, more economical technologies are used, such as silk-screen printing. However, gravure and letterpress methods have several advantages over screen printing. Reducing the cost of production of printing plates of this type will be an undoubted progress. There is no consensus regarding the place and time of the appearance of this technique. Most likely it was Egypt, India or China. There are still workshops in India and China that use ancient methods of printing on fabric. The material used for the forms are wood and ceramics.

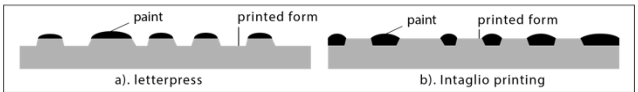

Figure 1 Diagram of letterpress and gravure (intaglio) printing

Similar plaques have been found in Egyptian burials dating back to around 1400 BC. [1, 2]. The ancient historian Pliny the Elder also describes similar printing methods in his writings [3]. The printing form is a plate with a relief on one of the sides. Thick paint is applied to the relief side of the plate. The canvas was then pressed against the painted embossed surface of the printing plate. Thus, the paint was transferred to the canvas. The production of printing plates from polymers and metals is an expensive process, which causes certain difficulties in the textile industry, especially for small enterprises. Despite this, letterpress and gravure printing have a number of advantages over screen printing. The first is the simplicity of the printing process. Secondly, the clarity of the edge and the saturation of the tone. And thirdly, a longer life of the printing plate. The introduction of such methods will reduce the cost of manufacturing unique printing plates for the textile industry and improve quality. The subject of the research is the production of printing plates for letterpress and gravure printing using innovative technologies. The purpose of the study is to study the possibility of creating a printing form with sufficient detail for use in textile production by 3D printing. The study, according to the author, can help expand the possibilities of manufacturing printing plates from traditional materials for printing on fabric. In the modern scientific literature, the author did not find studies on this topic.

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Modern methods of production of printing forms

We will deal exclusively with the main areas of production methods relating to letterpress and gravure printing plates. Basically, there are two types of forms: flexographic and typographic. Flexographic forms are photopolymer forms that can be classified according to a number of features: solid and liquid PPC - photopolymer printing composition;

• chemical composition of the layer, depending on the composition of the PPC;

• design (geometric shape) - they can be lamellar and cylindrical (including seamless and sleeve).

Flexographic photopolymer forms also differ in structure (they can be single-layer and multilayer, the type of substrate (polymer or metal), as well as thickness, format, resistance of forms to solvents and other parameters [4, 5]. Printing forms, depending on the nature of the material, are divided into metal and photopolymer. Currently, photopolymer printing plates are mainly used. They are made of solid PPC on polymer or metal substrates, varying in thickness and format. Printing photopolymer plates can have a different structure, which depends on the structure of the used for the manufacturing of the plate material. Most often, the printing elements of the forms consist of a photopolymer, and the space elements are either the substrate, or the base of the form, or the carrier layer with a stabilizing film. The printing elements are made of metal, and a copy layer is located on the surface of the printing elements. The main parameters characterizing the forms of letterpress are the steepness of the profile of the printing element, and the depth of the space elements. The maximum depth of whitespace characterizes the depth of the relief, which in practice is often called the height of the relief. Depending on the size of the printing elements and the distance between them, the blank elements of letterpress forms have different depths [6]. Without going into technical details, modern letterpress and gravure printing plate production methods can be divided into three main groups:

1. Laser engraving
2. Photoelectric method
3. Photochemical method

The author does not set the task of comparing the cost of classical methods of making printing plates. It is known that the cost of each of these methods is significant. This is due to the complexity of the process and the use of highly specialized equipment. The use of the 3D printing method will definitely reduce the cost of production of printing plates through the use of general-purpose technology. This is especially true for forms with a complex structure.

2 3D PRINTING TYPES ANALYSIS

Currently, 3D printing technology is one of the fastest growing industries. This is primarily due to the prospects that these technologies promise us in the future. At this stage of development, unfortunately, technology is in its infancy. Their own technological shortcomings hold back their global spread:

1. Additive FDM - fused deposition modeling printing technology with polymers. At this stage, the following plastics are used: ABS - acrylonitrile butadiene styrene, PLA - polylactic acid and others. The printing method consists in the successive application of layers of molten plastic by an extruder. Of the advantages should be noted the availability of technology. In all other aspects, it requires serious improvement. The disadvantages are the quality of the print itself, the slow speed of model formation, and geometric limitations. Application so far is only in prototyping and prototyping [7, 8, 9].
2. Additive technology SLS – selective laser sintering, SLA – stereolithography photopolymer printing. In this case, the quality of the product is much higher. With professional devices, it reaches the industrial level. The disadvantages are the speed of printing, the relatively high cost of consumables, and geometric limitations. Technology is rapidly evolving and improving. Application: medicine, small-scale production, and particular, jewelry [10].
3. Additive technology for 3D printing with plaster has. Good print quality but the application is very limited and the disadvantages are similar. Application so far is only in prototyping and souvenirs.
4. Additive technology SLM - selective laser melting powder metal printing allows you to get a professional quality product and is already quite widely used for small-scale production in the automotive, aviation and rocket industries. Among the shortcomings, it should be noted the cost and speed of printing, as well as some limitations [11, 12].
5. Additive building technology. This technology is at the very beginning of the journey. A lot of experiments are being carried out in different directions [13, 14].

It should be noted that not all existing 3D printing technologies are listed here, however, they are not related to our subject. For example: printing with biomaterials or food formulations. To solve our problem, two of the listed technologies are suitable for us: photopolymer 3D printing and 3D metal printing. In terms of materials, these two methods are very well combined with traditional printing plate materials.

3 EXPERIMENTAL AND METHODS

The relief on the surface of the printing plate is a three-dimensional construction. Therefore, it can be formed as a digital three-dimensional model. Such a model is necessary for subsequent conversion into a G-code or a sequence of sections, which in turn is an instruction for building a model on a 3D printer. Let's consider the main stages of creating a printed form using 3D printing.

Creation of a vector drawing of a textile décor is shown in Fig. 2.

After the artistic side of the textile decor is solved, the vectorization of the picture is necessary. To generate a 3D model based on a vector image, any general-purpose 3D editor is suitable. You can use for example: Rhinoceros, Autocad, SolidWorks, etc. To obtain a relief, we use the extrusion method. In the case of creating a cylindrical printed block, we use the method of evenly distributing the pattern on the curved Emboss surface. The resulting model is saved in STL. format. To determine the depth of gap areas, we use the following calculations. For industrial typographic forms:

$$h_{min} > A_{k\,r} + \sum \left(\triangle i_{1} \right) \quad (1)$$

h_{min} - minimum depth of whitespace elements [nm].

$A_{k\,r}$ - deformation of the knurling rollers [nm].

$\sum \Delta i_{1}$ - the sum of metric inaccuracies of the printing apparatus [nm]. In this case, the inequality [15].

The minimum depth of the gap elements is related to the amount of elastic deformation of the deckle:

$$h_{min} > A_{dec} + \sum \left(\triangle i_{2} \right) \quad (2)$$

A_{dec} - deckel deformation value [nm].

$\sum \Delta i_{2}$ - the sum of inaccuracies, including changes in the size of the plate cylinder [nm]. Must be respected.

When transferring the ink layer from the letterpress form to the fabric, the latter should not come into contact with the blank elements of the form. In the case of the artistic application of the printing plate, as in our case, the depth of the relief comes from the experience of the master and varies between 1 - 3 mm according to the type of printing and the distance between white space elements. The greater the distance, the deeper the relief (Fig. 1, 2).

The digital form model in STL format is imported into the editor for printing preparation. The choice of slicer depends on the brand of 3D printer. For most models, proprietary applications are supplied. To successfully convert to a G-code or section sequence, the mesh of the model must meet certain requirements. Polygons should not overlap, etc.

Figure 2 Vector image from a drawing

Today there are printers that work with different materials. Most often it is plastic, photopolymer resin, gypsum, metal.

Metal, plastic and photopolymer resin are suitable for our task. The FDM additive printing method for ABS plastic is not suitable due to its resolution. Usually it is 0.5 - 0.2 mm This is a low resolution for such a task. But the method of powder printing with metal SLM (20 micrometers) and professional photopolymer technologies SLS, SLA are quite suitable for us. Metal printing is expensive. However, compared to the cost of making a prototype, the traditional method may be preferable. For this reason, it may well replace traditional industrial printing plate production methods in the future. For small volumes, the photopolymer method would seem the obvious choice. Since the resolution of this method ranges from 0.15 - 0.01 mm. which fully meet the requirements of studio printing. Prices for materials and devices become affordable for personal use (Fig. If the size of the printer's desktop is smaller than necessary, we divide the model into several parts so that each of the parts fits in the printer's workspace. We calculate in such a way that the joint falls on the edge of the gap.

Formation of a printing plate on a 3D printer is shown in Fig. 3.

4 RESULTS AND DISCUSSION

For our experiment, the selected model fits completely into the working area of the printer, which greatly simplifies the task (Fig. 2). After obtaining a vector image by vectorization in the graphics editor, it became possible to create a three-dimensional model of a printing plate from the original drawing (Fig. 3). A variant of letterpress imitating the technique of linocut was chosen. In the Fusion 360 system, when trying to project a vector drawing onto the surface of a future 3D model, the system generated an error. Most likely, during the vectorization of the pattern, one or more self-intersections in the form of loops were formed. Breaks in closed areas of the resulting contours can also lead to a similar problem. When trying to project such a line onto the surface of a 3D model, the system may generate an error. This was expected, due to the complexity of the drawing. The search for the cause in such cases can be very time consuming due to the very large number of elements. The complex drawing was not chosen by chance. The task is to check the possibility of printing delicate parts. It is in such places that the shortcomings of the quality of the form appear. It was decided to use an alternative method of building a three dimensional model. The method of extruding a surface through a mask. A digital sculpting system (Fig. 4) was used.

A three-dimensional model of the printing plate was created (Fig. 4). The image was projected in the form of a raster mask onto the high-poly surface of the model in high resolution. After creating the mask, a high relief of 2.5 mm was formed by extrusion method. This method is quite suitable for printing an artistic image. With this method of building a model, the process of image vectorization is not necessary.

After performing the optimization process for the number of polygons, the model was successfully generated and converted to the STL file format. Furthermore, the model was successfully uploaded to the Lychee Slicer system, where the scene for printing was formed and successfully converted into a sequence of sections in pwmx format. This format is designed to be read and executed on Anycubic brand printers. The calculation was made deliberately in the lowest resolution (0.15mm.) to speed up the printing process. Printing was done on an Anycubic mono x photopolymer printer and took 26 hours (Fig. 3). This amount of time is due to the peculiarities of the formation of the model by the photopolymer method.

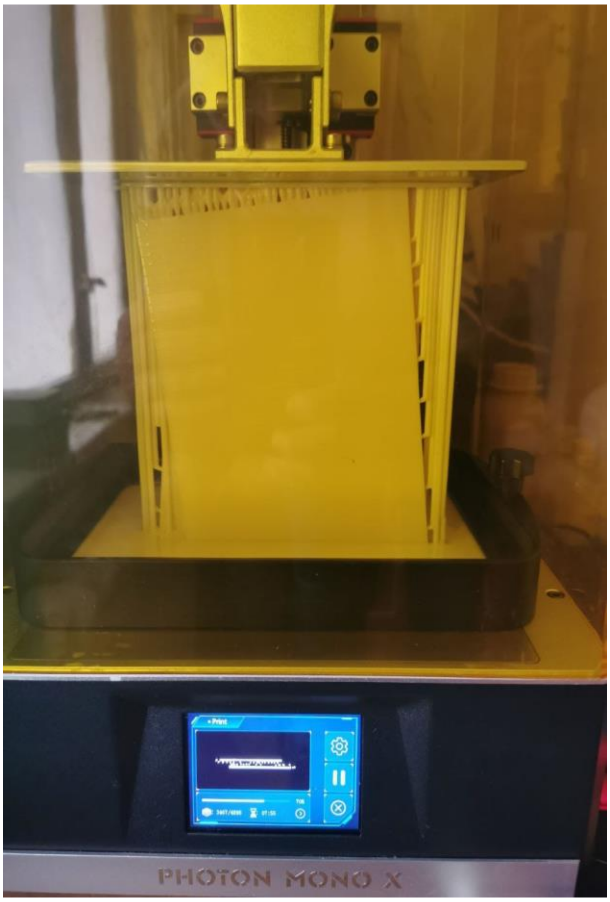

Figure 3 Plate 3D printing process

Figure 4 Three-dimensional model of the plate obtained by extrusion through the mask

Figure 5 The resulting printed plate by 3D printing

Figure 6 Printed plate with applied typographic composition

The model should have the smallest possible contact area with the substrate and, therefore, should be printed vertically along the z-axis. Such an arrangement of the model is due not only to printing features, but also to the dimensions of the plate itself. Only in this position it was possible to place our model in the dimensions of the working area of the printer. The plate material was Wanhao (water washable) brand photopolymer resin in white color. The result was a printing plate measuring 113 x 230 mm with a maximum height of the working area ofthe printing table of 250 mm. Of course, there are professional printer models on the market with a much larger working area. To keep the plate vertical while printing, supports were used in the form of additional reinforcing cylindrical rods supporting the structure a thus giving it additional rigidity. An attempt to print without support failed. In theory, this shouldn't be a problem. The printer only works in one z-axis. But in practice, with a long print time and a large length of the model, the material hardens unevenly and receives minor deviations from the main axis. Due to this process, an undesirable texture is formed on the printed surface of the plate, which will cause artifacts when printed. In a horizontal position, printing is not possible due to the large adhesion area. The first layer will simply not adhere to the print bed and will remain in the material bath. In addition, the distance along the z-axis is always greater.

The resulting surface is suitable for applying paint without prior preparation (Fig 5). Obtain an impression, we used standard printing ink of the CoMax brand of black color, applied to the printed surface using a rubber roller (Fig. 6).The printing method is implemented according to the stamp principle. The printed substrate, in our case a white cotton fabric with a density of 120 g/m², was pressed against the printed surface with black printing ink (korean brand CoMax) under pressure. For the best result, a soft layer is laid between the plate and the printed base. The resulting prints can be considered satisfactory even without the use of a printing press in our case. Despite some unevenness of the colorful printed surface, due to the lack of industrial equipment, all the small details on the fabric were printed perfectly evenly (Fig. 7a). Visually, there is no "liasing" (jagged edge) at all, despite the not the highest resolution of the printing plate. The edges are clearly defined. The fact is the most important thing in this experiment is that it proves the suitability of 3D printing for the production of textile printing plates. In terms of quality, the resulting form is in no way inferior to the traditional one. To prove this, a rather complex pattern was chosen. Thus, the final impression was successfully obtained (Fig. 8). On the final print, you can see several artifacts formed at the attachment points of the supports. For this reason, it is better to place the supports on the back of the slab.

(a) (b)

Figure 7 Detail of the printed form and impression

5 CONCLUSION

1. The experiment proves the effectiveness of the 3D printing method for the production of letterpress and gravure printing plates. On the basis of a specially created high-poly three-dimensional model, a good experimental sample of the printing plate was printed. As a result, a successful impression was obtained, proving the success of the experiment. In the zoomed image, we see well-printed details and the absence of artefacts characteristic of low resolution at the edges of the image. (Fig. 7b, 8). The advantage of this technology is the flexibility of the process and the ability to implement any types and shapes of printed substrates using 3D printing. There is also a simplification and, as a result, an expected reduction in the cost of production of forms for textile printing, which is important for small businesses. Good results can be achieved even with a semi-professional 3D printer, the cost of which is currently affordable for a specific application.
2. A direct relationship has been found between the quality of the print and the quality of the original 3D model of the printing plate, as well as the method of building a sequence of layers and the 3D printing device used. Based on the foregoing, the final quality of the product depends solely on the quality of the 3D model and the quality of the 3D printer itself. The article did not study the economic feasibility of using 3D printing for the production of textile printing plates, however, the constant decrease in the cost of materials and equipment of this technology gives reason for optimism.
3. Based on the accuracy of printing plate reproduction, it seems realistic to use the 3D printing method to produce printing plates.

The method of digital modeling and 3D printing is the best way to create multi-color textile printing plates. Since a separate plate is created for each color and printed separately, registration accuracy is critical to avoid color shifts. For digital technologies, this is not difficult. A properly designed 3D scene will always produce a perfectly predictable result when implemented. The purpose of this study is an attempt to prove the possibility of using 3D printing technology for the manufacture of plates for letterpress and gravure textile printing.

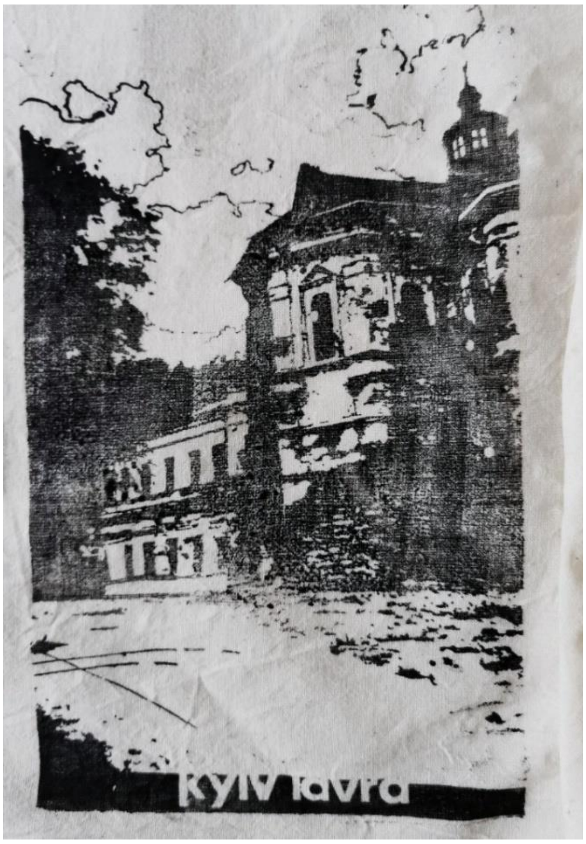

Figure 8 The impression obtained as a result of the experiment

Aspects such as the technical feasibility of introducing this technique into the textile production process and economic opportunity require additional research.

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