INVESTIGATION OF THE RESISTANCE OF DIFFERENT TEXTILE PRINTS TO WASHING AND ABRASION

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ABSTRACT

The article presents the next stage of experimental studies applying images to textile materials. The method of calculating the cost of manufacturing thermal transfer according to the proposed technologies, which were obtained as a result of the practical activity of the authors of the article in production conditions, was tested. The operational, and functional properties of thermal transfers have been studied. Durability of printed fabrics to rubbing and washing has been established. The images were applied to synthetic and natural fabrics. The methods of printing were as follows: DTF printing, offset and screen printing. The application of the results of this study will allow to carry out a qualitative and effective assessment of methods of printing images on textile materials depending on the production conditions for each type of product. A practical test of the proposed method of printing images on the products of the author's collection of women's clothing was carried out.

KEYWORDS

Images; Textile materials; Innovative technologies; Decoration; Printing methods; Screen printing; Digital printing; sublimation printing; Thermal transfer printing; Printing cost; Print; Author's collection.

INTRODUCTION

Fashion is one of the most profitable areas of business that is constantly developing a high level of competition in the fashion industry market becomes an impetus for designers to search for more and more effective methods of designing clothes and apply innovative approaches to solving a number of artistic and deseveral [1,2,3]. Therefore, innovative technologies are actively introduced into the fashion industry, influencing the formation of fashion trends [4,5].

This market is currently one of the most dynamic, which means it is one of the most promising. Thus, one of the main tasks facing fashion industry specialists is the application of the achievements of science, technology, and art in creating ordinary, aesthetically, and ergonomically perfect clothes and the decoration itself provides an opportunity to increase competitiveness and expand the range of sewing products. Therefore, the search for the concept of future collections, it's rethinking, and the use of means of artistic expressiveness and novelty in the form of innovative decoration become the key to the success of an author's clothing collection among a wide range of consumers.

For the garment industry, the possibility of decorating the models of the collection by applying a print to the clothes is familiar [6, 7]. Products decorated with a pattern look impressive and can give exclusivity to even the simplest models. The main types of image application on textiles are known, in particular, transfer printing; silk screen printing; sublimation; author's artistic painting of textile products, etc. [3,7]. Over the past few years, brands have been created worldwide that work exclusively with their own designed print.

That is why the direction of design is a priority given to designing sewing products with the optimal and high-quality method of printing author's prints.

In previous studies, the authors proved that textile printing is an increasingly important area of the contemporary graphic industry, and screen printing represents a dominant technique in this field [6]. The quality of the print depends on many parameters, such as the type of substrate material or the type of printing ink. The usual way to evaluate print quality consists of an objective assessment of the color and tone of the printed image. Quality parameters, such as contrast, sharpness, and macro non-uniformity, are not associated with color reproduction but certainly, affect print quality. These parameters are

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Received December 2, 2022; accepted May 31, 2023

directly related to the quality of the lines and raster dots, which is an integral part of any image.

In particular, the research of the authors [9, 11] is aimed at the development by artists of new color palettes for inkjet printing and the study of the appearance of a color image from the point of view of the psychophysical perception of images. The psychophysical relationship between image quality and its component attributes was investigated. The authors found a high correlation between four points that form image quality: between sharpness and contrast and between naturalness and visual information.

In the study [10], the effect of whiteness, roughness, and paper gloss on the optical density of color digital printing is substantiated.

In studies [11,12], the methodology of color printing in digital inkjet textile printing was developed, and an algorithm for the application of knowledge about color in the methods of creating a project and new color palettes for inkjet printing was proposed.

The analysis of literary sources [13-15] made it possible to establish that the main studied characteristic affecting the quality parameters of t-screen printing is the structure of the fabric and the type of printing ink.

Also, researchers [2,3,5,16] develop prints using modern computer methods of clothing modeling and 3D virtual clothing prototyping. The author [16] offers examples of the development of smart textile prints with an interactive capability.

The desire for innovation becomes an impetus for designers to choose a great, complex source of inspiration and search for new ideas for its rethinking and interpretation in the material, form-forming elements of the collection, and rhythmic organization of the composition series [2-5, 16-18].

All of the above studies form a powerful direction of innovative author's decoration of clothing models.

At the same time, this direction is relevant from an economic point of view because today, in Ukraine, there are no approaches to the mass design and production of sewing products with high-quality author's prints obtained by the screen printing technique.

This paper aims to continue experimental research on applying images to textile materials. To achieve the goal, the following tasks were solved:

1) The method of calculating the cost of manufacturing thermal transfer according to the proposed technologies, which was obtained as a result of the practical activity of the authors of the article in production conditions, was tested.

2) The degree of resistance of images printed by DTF print, Screen printing, and Offset printing to friction and during washing has been established using two different transferring techniques (hot press, iron) and two different textile substrates (polyester, cotton). .

3) A practical test of the proposed method of printing images on the author's collection of women's clothing products was carried out.

METHODOLOGY

One of the critical factors influencing the choice of the method of applying the image to textile materials is the cost of making the print.

To determine the total cost, it is necessary to consider the cost of each stage of the technological sequence, the cost of electricity, and the cost of preparing the print.

To determine the cost of one print calculation was made for a batch of 100 units. Execution of a set of 100 units made it possible to decide on the ink cost for different printing methods.

The above method of calculating the cost of a batch of products is simplified and corresponds to each way of applying the image to textiles. However, each of the preprinting method’s technical operations affects the final result of the cost calculation.

Data for calculating the costs of manufacturing images on textile materials by different printing methods were obtained as a result of the practical activities of the authors of the article in terms of production in enterprises FOP Zozulyuk and Dprint Studio, Khmelnytskyi, Ukraine.

The results of calculations according to the above method are presented in Table 1. When an operation is absent in the technological sequence, the sign «–» is put into Table 1.

The calculation is given for the national currency of Ukraine; at the time of analysis, the exchange rate of UAH to the EURO was 36: 1 at the rate of the National Bank of Ukraine. The calculation for European countries will differ in absolute value, but in relative terms, i.e., in percentage terms, it will be fair. This will give a general idea of the economic feasibility of using a particular method of printing images.

Based on the cost calculation results summarized in Table 1, it is possible to draw conclusions about the economic feasibility of each method under consideration.

For a batch of 1000 units, the cost of printing for all three methods differs for both light and dark fabrics. It is more expensive to make one sample than to make one unit in a batch of 1000 units. Since prepress is expensive and is done both for a single sample and for a batch of 1000 units. For example, for light fabrics, the difference between sublimation and screen printing is 60%, while for dark fabrics, the difference between direct printing using DTF technology and screen printing is 300%.

Table 1. The cost of applying the image to textile materials.

№	Cost item	The method of making a transfer of A4 format (210x297 mm)		
		DTF (digital CMYK/ CMYK+White)	**screen printing for white/colored fabrics**	**Offset + substrate (base) by screen printing**
1	C_D Image design preparation for batches of 1000 units of products, UAH	100	100	100
2	The cost of technological tools C_E for batches of 1000 units of products, UAH	-	300/350	1500
3	The cost of ink C_p, UAH	4.5	2.5/3	1.5
4	The cost of the intermediate carrier, C_1,UAH	7	3	3
5	Worker's labor costs C_w, UAH:			
	– applying the image to the intermediate medium;	10	6	6
	– applying an adhesive layer;	-	1	1
	– transfer the image to the product	5	5	5
6	Electricity costs C_{El} for, UAH:			
	– applying the image to the intermediate medium;	0.55	- (in the case of non-automated printing)	- (included in the price of offset printing)
	– transfer from the intermediate carrier to the product;			
	– intermediate drying operation;	0.2	0.2	0.2
	– finishing drying operation or glue drying	-	0.33/0.42	-
		-	0.16	0.16
∑	The cost of making C , UAH:			
	batches of 1000 units of products;	27.25	18.59/19.23	18.46
	product units	127.25	418.19/468.78	1616.86

CMYK – subtractive color model (Cyan, Magenta, Yellow, Key/BlacK)

If we consider the manufacture of a single sample, the cost of the product increases significantly in contrast to mass production. This is because the cost of technological tools is fully transferred to the product's price. In this case, the cost of printing on light fabrics for the first two methods is almost equal, and for screen printing is 240% higher.

Therefore, in the case of a single production, screen printing is considered inexpedient in terms of economic effect; however, for serial production, it is the cheapest way to apply the image, and given the results in Table 1, it is the moseffectiveve and versatile in terms of raw material composition and fabric color.

RESULTS AND DISCUSSION

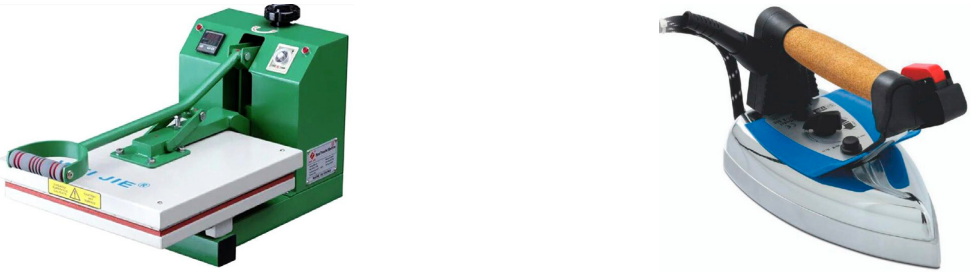
To assess the performance of the applied image

DTF printing. First, the image is printed on a special transfer film, in our production this happens in a roll. Then, in automatic mode, a special thermal transfer glue is applied to the still raw image, and it is immediately baked in the oven. Next, the image is cut out and transferred from the film to the product using a heat press. At the same time, the product does not need to be pre-processed, and the image should be cut out with a contour. Any fabric, cotton, synthetic, etc., is suitable for carrying. To the touch, the application is similar to silk screen printing, elastic and resistant to washing, and also does not burn out, does not crack, and does not wear out.

Screen printing. The essence of this method of printing is to push by a special tool (squeegee) ink through the open holes of the flexible mesh stencil on the printing surface. Printing can be done on paper, tin, glass, fabric, polyethylene, plastic, leather and other sheet or roll materials and products from them.

The technological process of applying the image to the transfer surface by screen printing contains some differences from the direct screen printing method:

- design preparation - mirror image;
- drying transfer (used for paper media, to remove excess moisture and prevent further deposition, the film, unlike paper, is non-hygroscopic, so it does not require this operation);
- applying colors of multicolor images in the opposite direction;
- application of a layer of paint - an adhesive base that covers the entire image to create a unique adhesive surface (usually performed with white paint or anti-migration paint, which then acts as a barrier when applied to colored and black fabrics).



(a) (b)

Figure 1. Equipment for transferring a picture to fabric: (a) Thermal printing press Weijie WJ-38, the size of the compression plate: 380×380 mm, power: 3200 W, temperature range: 50-300 °C, timer: 60 s; (b) Steam iron Silter STB-200, weight: 2 kg, power: 800 W.

Offset printing. Printing technology, in which the ink is transferred from the printing form to the receptive surface (the material to be printed) not directly, but with the help of an intermediate transfer and, in fact, through an intermediate, offset cylinder. Accordingly, unlike other printing methods, the image on the printing form is not a mirror, but a direct one.

The image are made by three printing methods and applied to a transparent transfer base. The next step was to transfer the picture on the fabric. The transfer of the picture is done with an iron and a press to show the possibility of decorating clothes at home. The consumer can buy a picture and apply it to clothes with an iron.

Transfer temperature modes depend on the type of media, paint, and material on which the drawing is applied, and range from 170 to 190 °C, exposure from 10 to 15 s, under pressure in the range from 35 to 40 psi (from 0.24 to 0.31 N / mm^2). Specific modes of temperature 180 °C, exposure 15 s, pressure were selected for the experiment 0.31 N/mm^2. The appearance and characteristics of the press and iron is shown in Fig. 1.

Research was conducted on two types of material, detailed information about which is shown in Table 2.

By analogy with the previous study [7], the performance indicators of images printed using DTF print, Screen printing, and Offset printing were evaluated for resistance to friction and washing. The first stage of experimental research was the evaluation of the preservation of image quality on textile materials in the friction process according to GOST 9733.27–83, DSTU ISO 12947-2:2005, Table 3.

Sample 1-4 made by DTF (direct to films) technology. Cotton and polyester fabrics were chosen for the research.

After 50 cycles, there are no saws, and color loss is insignificant in samples 1 and 2. There is a more significant loss of color in samples 3 and 4, due to the transfer of the image with iron, creating uneven pressure during transfer. After 100 cycles: visible to the naked eye, discoloration and mechanical damage to the tissue. The trend was maintained for samples 3 and 4.

Sample 1-4 made by screen printing similar to the previous technology, more wear occurs when transferring the image with an iron. Screen printing is more resistant to friction than DTF. At 50 and 100 cycles, the loss of color along the abrasion trajectory is barely noticeable. More significant color loss is observed at 150 cycles of abrasion in the samples obtained by transferring the image with an iron.

Offset printing is the least durable. In all samples already at 50 cycles of processing, loss of color of the image is observed. After 100 cycles of processes, there is a significant loss of color along the abrasion trajectory, the fabric structure is broken. The study of this sample is stopped.

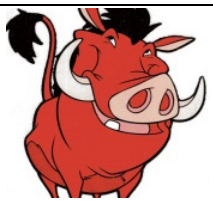
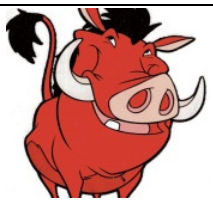
So, according to the results of the research, screen printing is the best way to make a picture. The best result is achieved when the image is transferred to fabric 1 using a press.

Table 2. Characteristics of materials.

Material	Color	Thickness [mm]	Weave	Yarn linear density [tex]	Density [treads/10cm]	Weigh (GSM), [g/m^2]
Fabric 1 (80% cotton; 20% polyester)	White	0.36	Plain	warp:24.1 weft: 22.5	warp:329 weft: 248	206
Fabric 2 (100% polyester)	White	0.42	Plain	warp:34.8 weft: 34.4	warp:256 weft: 188	254

Table 3. The results of the study of image stability during friction.

Sample №	Type of material	Photographs of the sample after friction			
		Reference images	50 cycles	100 cycles	150 cycles
DTF print					
Sample 1 press	Fabric 1				-
Sample 2 press	Fabric 2				-
Sample 3 iron	Fabric 1				-
Sample 4 iron	Fabric 2				-
Screen printing					
Sample 1 press	Fabric 1				
Sample 2 press	Fabric 2				
Sample 3 iron	Fabric 1				

Sample 4 iron	Fabric 2				
Offset printing					
Sample 1 press	Fabric 1				-
Sample 2 press	Fabric 2				-
Sample 3 iron	Fabric 1				-
Sample 4 iron	Fabric 2				-

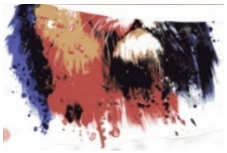
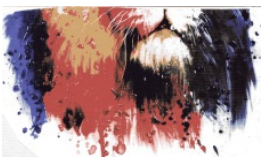
The next step in studying the performance characteristics of images on textiles was to determine the stability of the image during washing according to DSTU ISO 105-C06:2009 on a household washing machine using detergents, in accordance with the composition of the textile. The temperature mode is 40 °C; washing time 30 minutes; spin 800 min-1. Drying took place in a vertical position until completely dry, after which the ironing of the sample was performed at a temperature of 100-110 °C. [7]. The results of studies on the loss of image quality on textiles during washing are presented in Table 4.

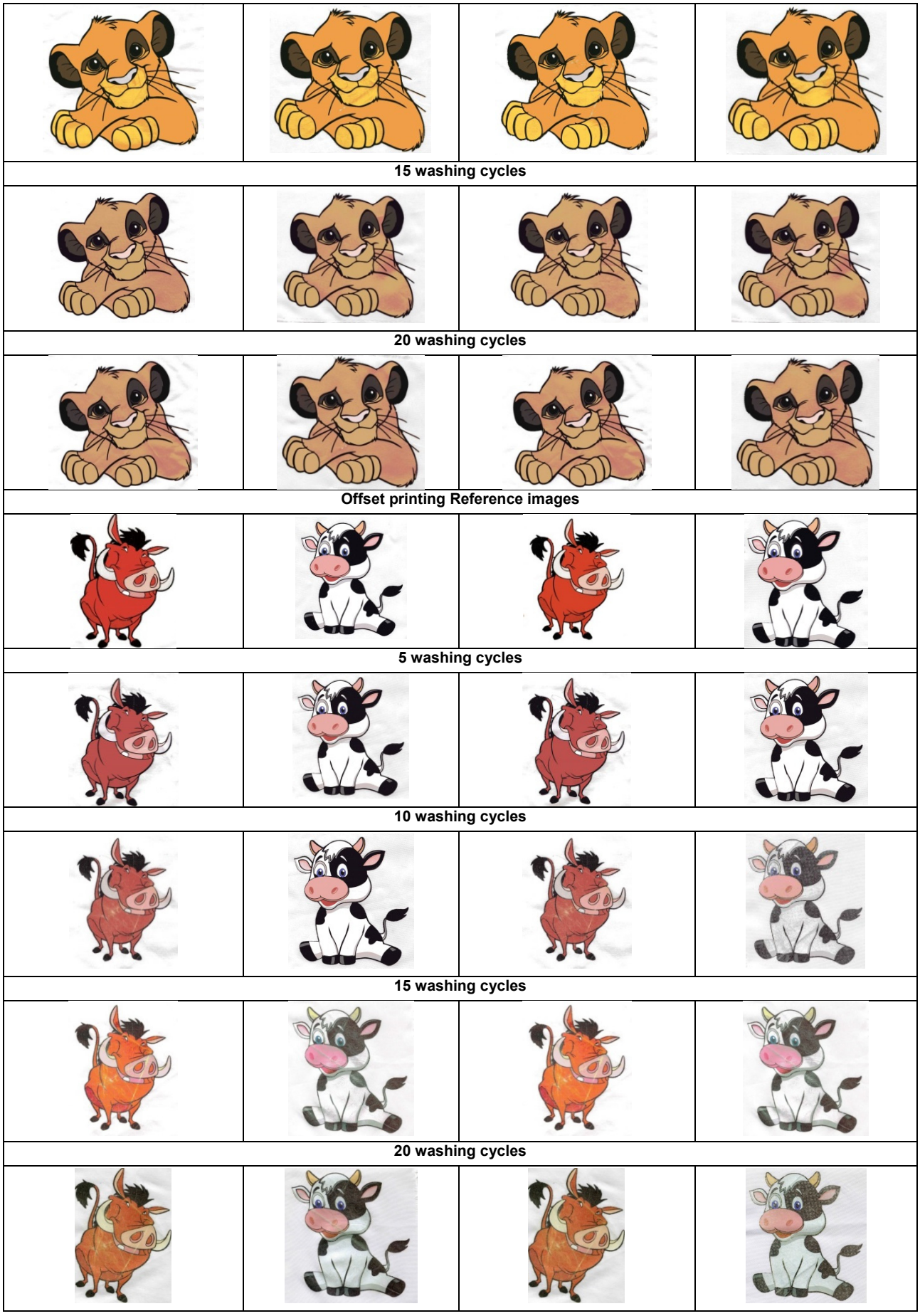
As a result of organoleptic evaluation of images on textiles made by different printing methods, a gradual loss of color in the samples was established. The most resistant to washing were the samples of pictures created by screen printing 20 cycles of washing and DTF 20 cycles of washing. The image obtained by offset printing of only 15 wash cycles turned out to be less stable.

In table 3, the patterns have changed color because the washing cycles have passed. And after the 15th washing cycle, a change in color is observed in all types of printing. A visual comparison of the images shows that the most resistant to washing without a significant loss of color were the samples created by DTF after 15 washing cycles and the samples created by screen printing after 10 washing cycles. The loss of color during a longer cycle of washing and drying significantly disrupts the aesthetic appearance of the product and this would be unacceptable to the consumer.

Analyzing the effect of washing, we can conclude that the composition of the fabric did not affect the durability of the picture. Because the washing and ironing regimes according to the fabric were maintained.

Table 4. The results of research on the loss of image quality on textiles during washing.

Printing method			
Cotton, press	**Polyester, press**	**Cotton, iron**	**Polyester, iron**
DTF, Reference images			
			
5 washing cycles			
			
10 washing cycles			
			
15 washing cycles			
			
20 washing cycles			
			
Screen printing, Reference images			
			
5 washing cycles			
			
10 washing cycles			


15 washing cycles
20 washing cycles
Offset printing Reference images
5 washing cycles
10 washing cycles
15 washing cycles
20 washing cycles

Analyzing the effect of washing, we can conclude that the composition of the fabric did not affect the durability of the picture. Because the washing and ironing regimes according to the fabric were maintained.

So, the study of the effect of washing and resistance to friction of three methods of applying the picture showed the following: All three techniques were in combination with iron and press. There are no significant differences in the quality of the picture when using an iron and a press to transfer the picture. Therefore, it is possible to decorate clothes at home in this way. The best result will be achieved using pictures made by the screen printing and DTF method, as they are the most resistant to washing and wiping.

Designing an author's collection of women's clothing using screen printing

Thus, it can be concluded that screen printing on textile materials is one of the most popular, economically expedient, and sustainable operations among the types of decoration of light industry products today. It has been proven that the decoration of products with different designs, which are oriented towards a specific brand, different age categories, gender, and youth movements, significantly improves the appearance of products [1-3, 16].

It is known that the style of clothing, the basis of which is the author's prints, is the style of Arty Fashion and its variety of Pop art [3, 17]. This sophisticated fashion style draws attention with bold, bright colors and prints. Features of these styles are that they do not depend on fashion trends and modern style. They are chosen by creative, self-confident individuals - experimenters. Among the most famous brands that presented their collections in the Pop Art style, fashion houses Maison Margiela, Marni, Prada, Burberry, and Alexander McQueen are worth noting.

At the preliminary stage of research [18], the authors defined and thought out the main images, forms, and constituent elements of the developed products of the author's collection sets. The collection was created open in the Pop Art style format using fashion trends. The products in the collection are made of different materials, which, when combined into sets, give the image of unusualness and sophistication.

When creating clothing models, special attention was paid to the originality and multifunctionality of the collection's products and their parts, Figure 2.

When designing an author's clothing collection using their prints, the drawings are female portraits. It is planned to place the picture on each product of the group differently, but in general, these will be large portraits placed on the central parts of the products.

To achieve the research goal, thermal transfer or flux printing of authority prints in the style of Pop Art was chosen to create a harmonious image for the consumer.

The design and development of an author's print and ready-made thermal transfer films with the author's prints are presented in a previous study.

In the first stage, the print is developed in color in the Gimp 2.10 bitmap graphic editor. In the second stage, its vector step-by-step development was performed in the Xara Designer Pro X 19 Free Trial vector graphics editor. The CMYK color scheme was chosen as the image's color scheme, as it is the most widespread in the printing industry and in full-color direct screen printing [8, 18]. Examples of prints for decorating clothing models of the author's collection are shown in Figure 3.

Figure 2. The author's collection women's clothing in the style of Pop art.

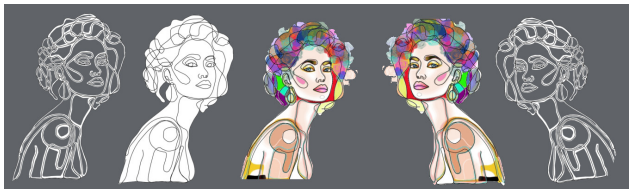


Figure 3. Examples of author's print options in the Xara PRO X 19 graphic editor.

Technological progress, market oversaturation with goods, and the speed of changes in society force manufacturers to reconsider their development strategy, in which they should develop.

The essence and content of automated design systems, such as Marvelous designer, CLO 3D, and other approaches involving digital technologies, today partially raise and resolve the issue of overproduction and excessive consumption of objects in the fashion industry.

Modern technologies of 3D design of clothes at the stage of artistic development of models provide for the following functions: 1) visualization of the appearance of clothing models before the creation of patterns and sewing of the product itself; 2) the possibility of selecting materials, color solutions and simulating the physical properties of a large number of materials for the future model; 3) forming a presentation of sketches of a complete collection of models.

The practical implementation of the described approach is presented by the study's authors in the form of visual transformations of images of sketch forms of project images of digital products of the author's collection using the computer graphics program PaintTool SAI [19]. PaintTool SAI is a lightweight raster graphics editor, and painting software for Microsoft Windows developed and published by Systemax Software. The Digital - presentation of the clothing collection is shown in Figure 4.

Visualization allows you to work out options for the color solution of clothing models and to offer the optimal placement of prints. As a result of the completed work, the models of the author's collection were approved and manufactured, Figure 5.

CONCLUSION

According to the simplified calculation method, the cost of a 100-unit batch of products is determined for each image printing method. The influence of the features of each printing method's individual technological operations on the calculation's final result is taken into account.

The obtained results make it possible to perform an economic assessment of each method and decide on the appropriateness of their use in each case.

The following result of this study is the evaluation of the performance of the image on textile materials applied by different printing methods. In the course of experimental research, the degree of resistance of the images made by various ways of printing to friction and in the course of washing was established.

It was found that the most resistant to abrasion and washing were samples of images applied by screen printing and DTF printing.

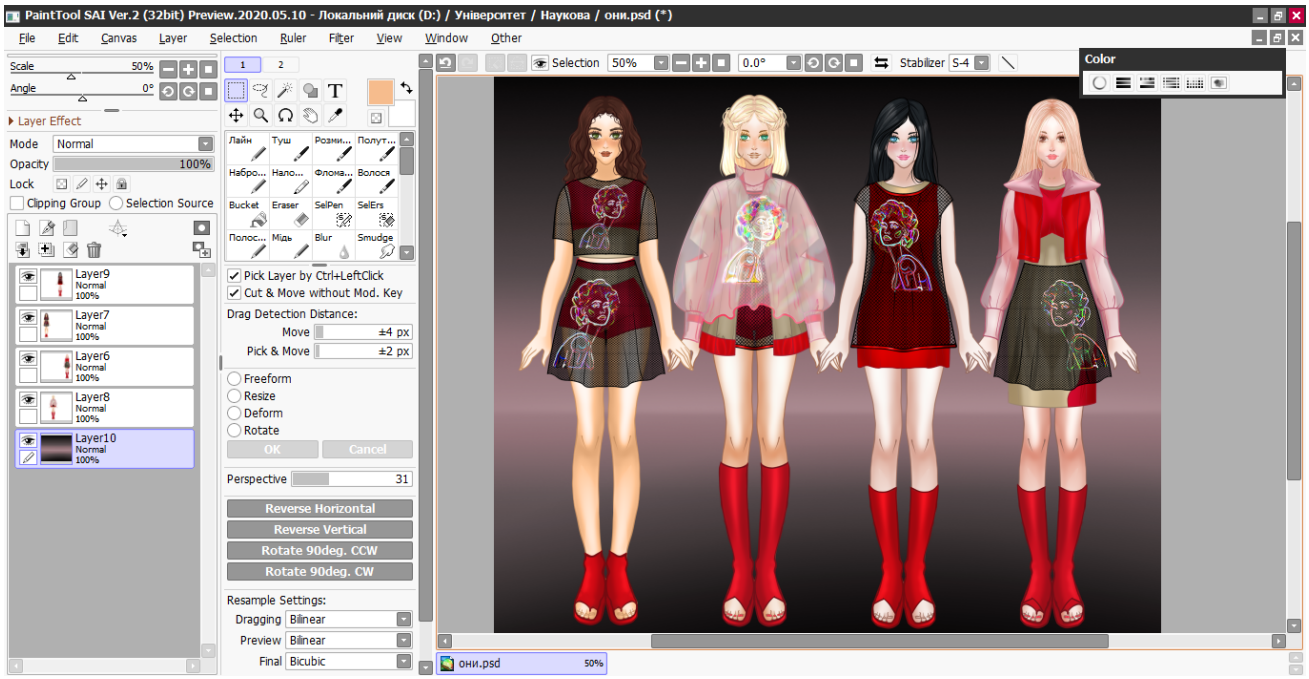


Figure 4. Sketches of the author's collection of women's clothing in Paint Tool SAI.

Figure 5. The author's collection women's clothing in the style of Pop art decorated with the author's prints.

So, the study of the effect of washing and resistance to friction of three methods of applying the picture showed the following: All three techniques were in combination with iron and press. There are no significant differences in the quality of the picture when using an iron and a press to transfer the picture. Therefore, it is possible to decorate clothes at home in this way. The best result will be achieved using pictures made by the screen printing and DTF method, as they are the most resistant to washing and wiping.

The scientific novelty of the study consists of the analysis and systematization of creative and innovative decoration technologies with the aim of further integration into the fashion design of clothing.

The practical significance lies in the experimental study of the functional properties of thermal transfers as elements of clothing decoration. It has been proven that screen printing on textile materials, currently among the types of decoration of light industry products, is economically expedient and sustainable in the operation process. This is confirmed by calcalculatinge the cost of transfer production methods for various types of printing.

The presented Digital technology - presentation of the clothing collection gives space for implementing engineering and design ideas. It can also be an effective tool for product promotion on the market. In particular, the obtained images of the product on figures in different projections can become the basis for creating an electronic catalog of products available for viewing in online stores and the simulation of a mannequin walking on a catwalk - for various video advertisements.

As part of this study, we obtained results reflecting the psychophysiological reactions of consumers, as well as their dynamics for choosing a prototype of a projected image of a clothing model and author's prints for the development of a new clothing model that meets the wishes of the consumer [20]. The image evaluation results on textile products can be used as a data set to populate the database with knowledge of pre-developed expert systems to support designing clothes that correspond to predetermined consumer impressions [21, 22].

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