

## RESEARCH OF SUBLIMATION THERMAL TRANSFER PRINTING IN THE PRODUCTION OF GIFT PRODUCTS ON FABRIC AND CERAMICS

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*The work conducted a comprehensive study of the technology of thermal sublimation printing in the manufacture of gift products from ceramic and fabric materials, in particular T-shirts and cups. The features of the sublimation printing process were analyzed, the key technological modes and their impact on image quality were determined. A system of criteria for assessing the quality of prints on ceramic and fabric products was developed, which allows objectively assessing the compliance of products with established standards and forming practical recommendations for optimizing technological printing modes. The practical application of the research results was implemented through the development of a technological process for manufacturing T-shirts and cups using the sublimation method, which ensures improved print quality, their durability and attractive appearance. The proposed evaluation system allows integrating quality control at all stages of production, increasing the efficiency of the technological process and the competitiveness of gift products. Cups should be pre-treated with a polymer coating, and it is best to use white fabrics with a polyester percentage of at least 60%. The shape of the surface of T-shirts is flat and requires a flat type of heat press, and for cups a cylindrical heat press is required for each individual cup shape. Also, the pressure and time of image transfer for cups are significantly higher (5–7 bar; 150–210 s), for T-shirts – 3–5 bar, 40–60 s.*

**Keywords:** *Special types of printing, souvenir gift products, sublimation thermal transfer method, fabric and ceramic materials, image printing quality.*

**Problem Statement.** In the current context of the packaging industry's development, not only the functionality of packaging materials but also their aesthetic and quality characteristics are gaining increasing importance. The growing demand for environmentally friendly, customized, and visually attractive packaging necessitates improvements in printing technologies. In the production of packaging made from wood-fiber materials, one of the most promising technologies is dye-sublimation printing, which is characterized by accessibility, cost-effectiveness, and high image quality. However, despite the widespread use of this technology, the influence of dye-sublimation printing parameters on the quality of the final image on different types of materials remains insufficiently studied. This complicates the optimization of technological regimes and the assurance of stable quality of finished products.

Therefore, the following research objectives are relevant:

1. Analysis of the specific features of dye-sublimation printing technology in the manufacture of gift products made of ceramic and textile materials.
2. Identification of the main factors affecting image quality in dye-sublimation printing.
3. Development of criteria for evaluating the quality of prints on ceramics and textiles, as well as recommendations for optimizing dye-sublimation printing regimes to improve the quality of gift products.

**Analysis of Recent Research and Publications.** In study [1], factors influencing image quality during offset printing on uncoated and coated paper were investigated. Color measurements were carried out to identify color differences between standard color values and those of the printed sample. The main objective of study [2] was to analyze the effect of ink film thickness on the optimal optical density of cyan prints, obtained using densitometric measurements of samples printed by the IGT method on coated and uncoated paper. In [3], the authors presented a procedure for using a scanner as a densitometer for color correction and colorimetric measurements. The optical density of printed fragments was calculated using pixel intensity values obtained during scanning of a test target. Optical density was measured simultaneously using a densitometer and calculated based on  $L^*$  measurements for the same areas.

The electrophotographic printing method was analyzed by the authors of [4] using three types of electrophotographic printing machines and eight types of uncoated paper with different properties, including weight, surface roughness, whiteness, brightness, and opacity, using cyan, magenta, yellow, and black toners under standard identical conditions. The results showed that reproducibility significantly depends on the type of printing machine rather than on the optical and mechanical properties of the paper.

The purpose of study [5] was to analyze the influence of ink viscosity, printing plate, and printing substrate on the optical density of solid tone areas and tonal value increase (TVI) of flexographically printed samples. The results revealed a significant influence of the characteristics of the printing plate and the substrate, and a lesser influence of ink viscosity for coverage areas of 40–100%. The optical density of solid areas is mainly affected by the properties of the printing plate and the printing substrate.

Domestic researchers [6] studied methods for controlling the main indicators that determine the quality of color reproduction at different stages of graphic information processing in the overall color image reproduction process. The main parameters of image reproduction quality using various printing methods were investigated, including offset [7], screen printing [8], and digital printing in the production of advertising and souvenir products, souvenir and banknote products, and other types of publishing and printing products [9–11].

**Purpose of the Article.** The aim of this study is to investigate the features of dye-sublimation printing technology in the manufacture of gift products made of ceramic and textile materials, to identify the main factors influencing image quality in dye-sublimation printing, and to develop criteria for evaluating the quality of prints on ceramic and textile products.

**Presentation of the Main Research Material.** The technological process of manufacturing T-shirts and mugs using the dye-sublimation method differs slightly (Fig. 1).

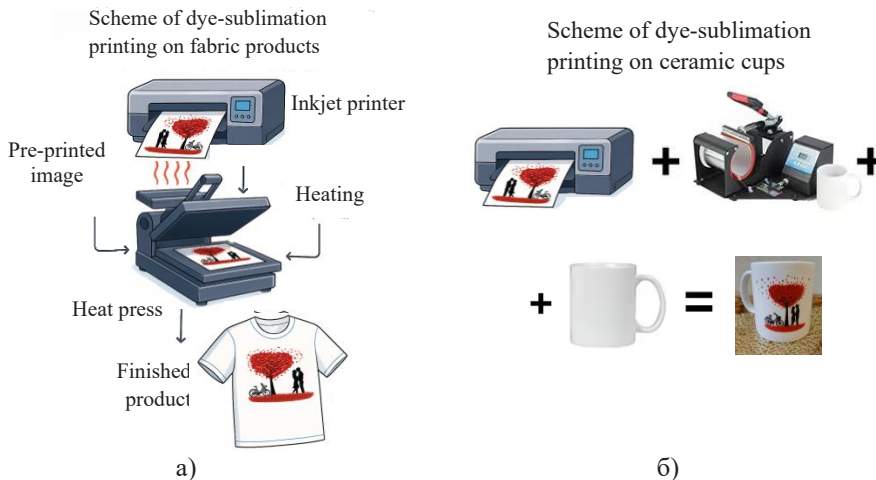


Fig. 1. Technological process of manufacturing T-shirts (a) and cups (b) by sublimation thermal transfer method

Preparing the image layout using Photoshop or CorelDRAW graphics programs and converting it to mirror image, followed by printing on sublimation paper using an inkjet printer and special sublimation inks (water-dispersion based), are common for T-shirts and cups. Further preparation of materials differs for textile and ceramic products. The requirements for fabrics are: composition – 100% polyester or fabrics with a polyester content of at least 60%; the surface must be clean, dry, lint-free. Requirements for ceramic materials – ceramics with a polymer coating (sublimation surface); the surface is degreased with alcohol or isopropanol.

The process of transferring the image is also different: the paper with the image is applied to the T-shirt with the image to the fabric, fixed with heat-resistant tape to avoid shifting, and pressed in a flat heat press (Fig. 1a). When making cups, the printed paper is tightly wrapped around the cup and fixed with heat-resistant tape. The transfer is performed in a thermopress for cups (usually 20×9 cm format) (Fig. 1b). The main technological modes and differences in the processes are given in Table 1.

Table 1

**Main technological modes and differences in the processes of manufacturing T-shirts and cups**

Base parameters	T-shirt	Cup
Material	Fabric (mostly polyester) and white color	Ceramic with polymer coating
Type of heat press	Flat	Cylindrical
Temperature	~190 °C	~190 °C
Pressing time	40–60 s	150–210 s
Pressure	3–5 bar (medium)	5–7 bar
Surface shape	Flat	Cylindrical
Durability	Up to washing	Up to washing
Base parameters	T-shirt	Cup
Image fixation result	In the fabric fibers	In the polymer layer

Taking into account the differences between the processes and having identified the key technological regimes, the main indicators influencing image quality in dye-sublimation printing were determined. On this basis, a system for evaluating the quality of prints on ceramic and textile substrates was developed, which made it possible to formulate recommendations for optimizing dye-sublimation printing regimes in order to improve the quality of gift products.

The image quality evaluation system for these types of products includes three levels:

**1. Color accuracy and uniformity** (objective color metrics:  $\Delta E_{2000}$ , saturation, gamut—the range (area) of colors that a particular device or technology can reproduce, display, or capture, such as a monitor, printer, camera, or color model (RGB or CMYK)).

**2. Mechanical / retention durability of the image** (rubbing / crocking resistance, adhesion, resistance to washing / cleaning, lightfastness).

**3. Visual and functional indicators** (edge sharpness, cracks or deformations during bending, changes in material “hand,” and subjective visual satisfaction under standard lighting conditions).

#### **Indicators (metrics) and measurement methods**

##### **1. Color and color accuracy**

- $\Delta E$  (CIEDE2000) – measured by spectrophotometry between the reference (target file) and the printed sample. Target values:  $\Delta E_{00} \leq 2$  for brand-critical colors;  $\leq 3$  for most commercial applications;  $\leq 5$  acceptable for low-critical printing. Instrument: spectrophotometer with  $\Delta E_{00}$  calculation.

- Color coverage / gamut – comparison of the printed color space area with a reference RGB/PANTONE color space; evaluation of percentage coverage.

##### **2. Uniformity and density**

- Optical density / Lab\* – spot measurements in control areas (solid color patches). Deviations greater than  $\pm 0.05$  in L\* or noticeable non-uniformity require further evaluation. Instrument: densitometer or spectrophotometer.

##### **3. Sharpness / resolution**

- Edge acuity / line width – microscopic or magnified measurements of image edges; threshold values are defined by technical specifications (e.g., minimum line sharpness of 0.2 mm). Instrument: digital microscope.

##### **4. Adhesion / abrasion resistance (rub / crock)**

- Rub test / crocking – laboratory abrasion tests (ISO / ASTM / AATCC methods). Evaluation on a scale from 1 (severe transfer) to 5 (excellent). Recommended value:  $\geq 4E$ .

- Resistance to thermal treatment (sublimation).

##### **5. Lightfastness**

- Lightfastness (ISO / AATCC methods) — exposure to a standardized light source and comparison with the blue wool scale; for products subjected to long-term light exposure, the value should be  $\geq 4$ .

##### **6. Mechanical properties of the printed substrates (HDF and textile materials)**

- Changes in strength / deformation behavior (burst, tensile) – assessment of whether the mechanical parameters of wood-fiber and textile materials deteriorate after printing.

### 7. Visual evaluation under standard lighting

- Visual inspection under D50 (5000 K) to detect color casts, banding, and defects.

This assessment should complement instrumental measurements.

#### Standards and methods

- **ISO 12647** – color management in printing processes; application of core principles for process setup.
- **ISO 18947-1** (rub/abrasion) – methods for evaluating the resistance of printed images to rubbing.
- **AATCC 117 / 133** – tests for the effects of dry heat and pressing, which are critical for thermal transfer and dye-sublimation processes.

The evaluation scale and threshold values are presented in Table 2.

Table 2

#### Rating scale and threshold values according to core standards

Indicator	Index/scale	Acceptable	Comment
$\Delta E_{00}$ (critical colors)	quantitative	$\leq 2$ — excellent; $\leq 3$ — good; $> 5$ — failure	for branded areas $\leq 2$
Rubber test (crook)	1–5	$\geq 4$ — acceptable	ISO/AATCC methods
Lightfastness	1–8 (blue wool)	$\geq 4$ — satisfactory	depends on application
Uniformity $L^*$	$\Delta L^*$	$\pm 0.5$ — excellent; $\pm 1$ — acceptable	for spot areas
Edge acuity	mm	according to the technical specifications ( $\geq 0.2$ mm)	graphic elements

In addition to optical density, the quality of thermotransfer dye-sublimation printing on textile and ceramic substrates is characterized by the main indicators listed in Table 3.

Table 3

#### Main parameters for evaluating the quality of printing by thermal transfer sublimation printing

Indicator	Essence	What characterizes
Print contrast	The difference between the optical densities of light and dark areas of the image	How “alive” and expressive the image looks
Tone rendition (gradation characteristic)	The relationship between optical density and nominal tone (raster area)	How accurately the print transmits halftones (0–100%)
Dot gain	Comparison of actual optical density with theoretical	The degree of ink blurring, which affects the clarity and accuracy of reproduction
Color saturation (colorimetric effect)	Comparison of the densities of different inks (C, M, Y, K)	Color balance, correct reproduction of shades
Color uniformity (field uniformity)	Measurement of density in different areas of the print	Stability of the printing process, uniformity of ink application
Gloss / surface reflection	Derived from the behavior of light during	Visual quality (matte, shine, depth colors)

**Conclusions.** As a result of the experimental studies, the key indicators influencing image quality in dye-sublimation printing on ceramic and textile substrates were identified, and a comprehensive system for evaluating print quality was developed. The proposed system comprises three levels of assessment: color accuracy and uniformity, mechanical and retention durability, and visual and functional indicators. The application of this system enables objective evaluation of print quality and supports the formulation of recommendations for optimizing the technological regimes of dye-sublimation printing. This, in turn, contributes to improving the quality of gift products and ensures effective control of the printing process across different materials.

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## ДОСЛІДЖЕННЯ СУБЛІМАЦІЙНОГО ТЕРМОТРАНСФЕРНОГО ДРУКУ ПРИ ВИГОТОВЛЕННІ ПОДАРУНКОВОЇ ПРОДУКЦІЇ НА ТКАНИНІ ТА КЕРАМІЦІ

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У роботі проведено комплексне дослідження технології термосублімаційного друку при виготовленні подарункової продукції з керамічних та тканинних матеріалів, зокрема футболок та чашок. Проаналізовано особливості процесу сублімаційно-го друку, визначено ключові технологічні режими та їхній вплив на якість зображення. Встановлено основні показники, що визначають рівень якості відбитків, зокрема колірну точність і однорідність, механічну стійкість, а також візуальні й функціональні характеристики, які впливають на естетичну та експлуатаційну придатність продукції.

Розроблено систему критеріїв оцінювання якості відбитків на керамічних та тканинних виробках, що дозволяє об'єктивно оцінювати відповідність продукції встановленим стандартам і формувати практичні рекомендації щодо оптимізації технологічних режимів друку. Практичне застосування результатів дослідження реалізовано через розробку технологічного процесу виготовлення футболок і чашок сублімаційним способом, що забезпечує підвищення якості відбитків, їх довговічно-сті та привабливого зовнішнього вигляду.

Запропонована система оцінювання дозволяє інтегрувати контроль якості на всіх етапах виробництва, підвищуючи ефективність технологічного процесу та конкурентоспроможність подарункової продукції. Результати роботи можуть бути використані для удосконалення технологій термосублімаційного друку, розробки нових продуктів та стандартизації процесів виготовлення декоративної продукції з кераміки та тканини, а також для оптимізації виробничих витрат і підвищення стабільності якості готових виробів.

**Ключові слова:** спеціальні види друку, сувенірна подарункова продукція, сублімаційний метод термоперенесення, тканинні та керамічні матеріали, якість друку зображення.

Стаття надійшла до редакції 17.03.2026

Received 17.03.2026

Стаття прийнята 22.05.2026

Accepted 22.05.2026

Опубліковано 30.06.2026

Published 30.06.2026



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