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THE STUDY OF THE MECHANISM OF IMAGE FORMATION DURING THERMAL TRANSFER PRINTING ON FABRIC PACKAGING

BADANIE MECHANIZMU POWSTAWANIA OBRAZÓW PODCZAS DRUKOWANIA TERMOTRANSFEROWEGO NA OPAKOWANIACH Z TKANIN

ABSTRACT: In the present paper, the peculiarities of the mechanism of image formation during thermal transfer printing on polyester fabric packages made of polyester fiber have been investigated. Physico-mechanical properties of fabric packaging, and, in particular, tensile load, elongation at maximum force and change of linear dimensions after wet treatment have been determined. On the grounds of the conducted thermogravimetric analysis it was found that active thermooxidative processes and the product combustion processes of fabric samples' destruction with the printed thermal transfer image were less intense as compared to the samples of unprinted tissue. This was evidenced by the gradual and less intense weight loss, and the emergence of less rapid exogenous effects, reflected on the DTA curves. Electron microscopic studies of the fabric structure confirmed that plastisol inks did not penetrate deeply into the fabric fibers, did not stain them, but enveloped them, forming mainly a mechanical connection. It has been found that the mechanism of printing image formation on polyester fabric packaging using thermal transfer presses depends on the technological printing modes, fabric structure, processes of ink polymerization and adhesion on the fiber surface, and requires further research.
Key words: fabric packaging, thermal transfer printing

STRESZCZENIE: W artykule zbadano cechy mechanizmu powstawania obrazu podczas druku termotransferowego na opakowaniach z tkaniny z włókien poliestrowych. Określono właściwości fizyko-mechaniczne opakowań z tkanin, w szczególności obciążenie rozciągające, wydłużenie przy maksymalnej sile oraz zmianę wymiarów liniowych po obróbce na mokro, porównywalne z próbkami tkanin niezadrukowanych. Na podstawie analizę termograwimetrycznej stwierdzono, że aktywne procesy termooksydacyjne oraz procesy spalania produktów niszczenia próbek tkanek z nadrukowanym obrazem termotransferowym były mniej intensywne w porównaniu z próbkami tkanki niezadrukowanej. Świadczyło o tym stopniowa i mniej intensywna utrata masy ciała oraz pojawienie się mniej szybkich efektów zewnętrznych na krzywych DTA. Badania struktury tkaniny pod mikroskopem elektronowym potwierdziły, że farby plastizolowe nie wnikają głęboko we włókna tkanek, nie plamią ich, lecz otaczają, tworząc głównie mechaniczne połączenie. Stwierdzono, że mechanizm powstawania obrazu drukarskiego na opakowaniach tkanin poliestrowych z wykorzystaniem pras termotransferowych zależy od technologicznych trybów drukowania, struktury tkaniny, procesów polimeryzacji tuszu i adhezji do powierzchni włókna i wymaga dalszych badań.
Słowa kluczowe: tkaninowe torby opakowaniowe, drukowanie termotransferowe

INTRODUCTION

The humanity is nowadays faced with the important task of preserving the natural environment. It refers especially to the urgent need to replace the plastic packaging that constitutes ca. 10% of all waste. Bags, foil bags and other plastic packaging are intensively employed in all domains of human activities. Plastics may be stored for many decades, accumulating more and more at landfills. Besides it, during the combustion of plastics, the harmful dioxins and other products of organic degradation are generated in the air. One of the methods for reduction of plastics quantity includes the application of reusable packaging, produced from

PIC. 1. THE SAMPLES OF FABRIC FOR PACKAGING:

A) COTTON, B) SERGE, C) TARPAULIN, D) LINEN FABRIC (CANVAS – RAW LINEN).

SOURCE: [OWN DOCUMENTATION]

natural materials or polymers which are subjected to biodegradation [1, 2].

Fabric packaging, such as bags as alternative to plastic bags, is a popular product. Such packaging is made of durable material and serves for a longer period of time, considerably longer than the traditional plastic bags. Fabric-made packaging is environment friendly product and is suitable for its reuse. [3].

Fabric packaging has a certain international history, for example in the USA and in Europe. Such packaging was produced and used at the end of the 20th century. In many countries, the application of packaging made of natural materials has been promoted for a long time. For example, in Taiwan in 2003, plastic was removed from the trade centres; in Japan, the authorities run a campaign in favour of fabric bags' use and in certain states of America, the penalties have been introduced for the employment of plastic bags. In many developed countries, goods in the supermarkets are wrapped in paper and placed in common linen bags. The average Ukraine inhabitant spends ca 70 hryvnias annually for plastic bags. Reusable bag may be bought at 10 – 15 hryvnias or may be sewn and decorated by hand. Owing to a deep interest in the environmental problems, eco-bags are more and more searched by the inhabitants of big cities. The main property of high-quality environmental bag consists in resistance to use, durability, resistance to washing cycle many times and differing in naturalness and a low cost [4].

Therefore, it is important to select the appropriate fabric for production of packaging. It refers, in particular, to sewing of packaging such as eco-bags. In the opinion of scientists, the following products are especially popular: double-thread cotton fabric, serge, tarpaulin and canvas (Pic.1). The double-thread fabric is characterized by a high strength.

As a rule, double-thread fabric is made of cotton fibres; therefore, it is environment-friendly natural material. Its values are evident: strength, resistance to wearing, resistance to high temperature, good ventilation, capable of keeping a given shape of the product. It is worthy to know the important fact: the discussed fabric is characterized by unravelling at the edge when cut.
Serge fabric is also interesting material for production of bags (Pic.1 b). The mentioned fabric is multi-dimensional because, in case of this material, we may use natural fibres (silk, wool,

A

B

PIC. 2. THE SAMPLES OF TEXTILE PACKAGING:

A) PACKAGING OF SOUVENIRS, MADE FROM FABRIC BY HAND

[SOURCE: WIKIPEDIA – DIY.RUHTTP.//WWW.DIY.RU];

B) BAGS MADE OF FABRIC

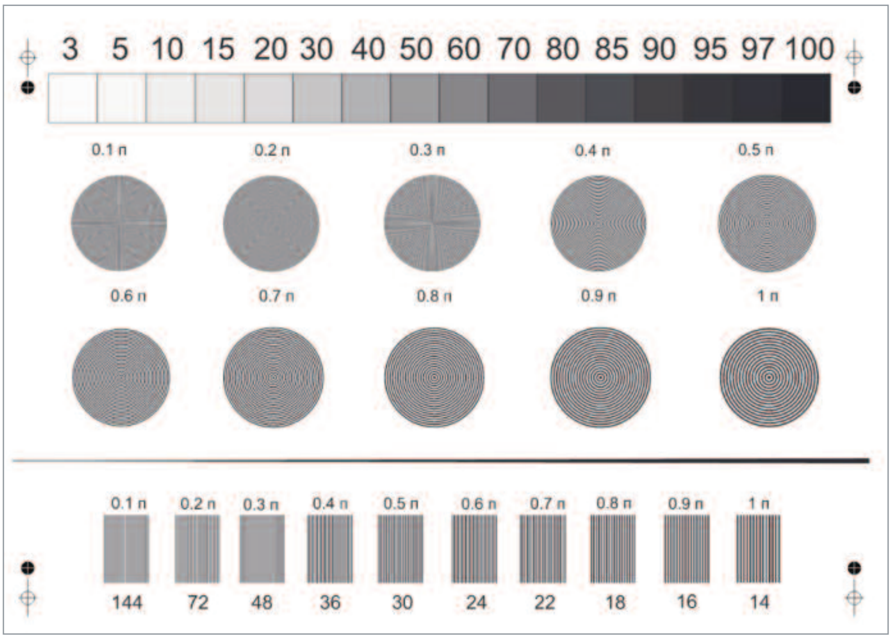
[OWN SOURCE].

cotton) as well as the synthetic ones (polyester, viscose, spandex). But the way of their weaving is unchanged – diagonally. Therefore, serge is easy to be recognized by texture: it is a relief fabric with the inclination. The mentioned fabric is multi-dimensional because, we may, on its basis, employ natural fibres (silk, wool, cotton) as well as the synthetic ones (polyester, viscose, spandex). Packaging made of serge has a high density, absorbs humidity well, is non-electrified, hygroscopic, and resistant to contamination and cheap [3].

The producers offer also a dense tarpaulin for production of fabric bags (Pic.1 c). The tarpaulin many be called one of the strongest types of natural textiles. Contrary to common tilt, the discussed material does not possess a synthetic waterproof impregnation and refraction. Depending on the composition, the tight tarpaulin may consist of the mixture of cotton and linen fibres, in a form of cotton yarn. Another high-quality and durable option includes jure tarpaulin in combination with cotton. The first component makes that the discussed material is reliable and resistant to deformations and cotton fibres allow bending of the material; it is also possible to make application or matrix on its surface. When choosing the tight tarpaulin for sewing of bags, we should take their destination into account. The compact eco-bags with wide straps require fabric with density of 300 g/m^2. If the big shoppers for voluminous packaging from supermarket are to be produced, we should choose density of 500 – 600 g/m^2 [4].

Canvas – i.e. raw linen (Pic.1 d) is a popular fabric for packaging. Canvas has an original texture. The history of linen was commenced at the middle ages when a strong sailing fabric was produced from hemp fibres for the sailing ships. The modern textile linen has preserved homage for traditions – a characteristic pattern in a form of weaving. The scientists distinguish 5 advantages of packaging (bags) made of linen fabric: long-lasting, with a high resistance, pleasant and rather soft in touch, having the effect of breathing material, and practically dirt-resistant. It may be easily decorated with thermal printing [5]. The samples of the textile packaging are given in Pic.2.

The aim of the present study was to examine the mechanism of adhesion of paint to the fabric on packaging during thermal



PIC. 3. TEST SCALE PRINTED ON A TEXTILE BAG

transfer printing, with the consideration of their physical and mechanical properties and modes of technological printing.

OBJECTS AND METHODS OF TESTING

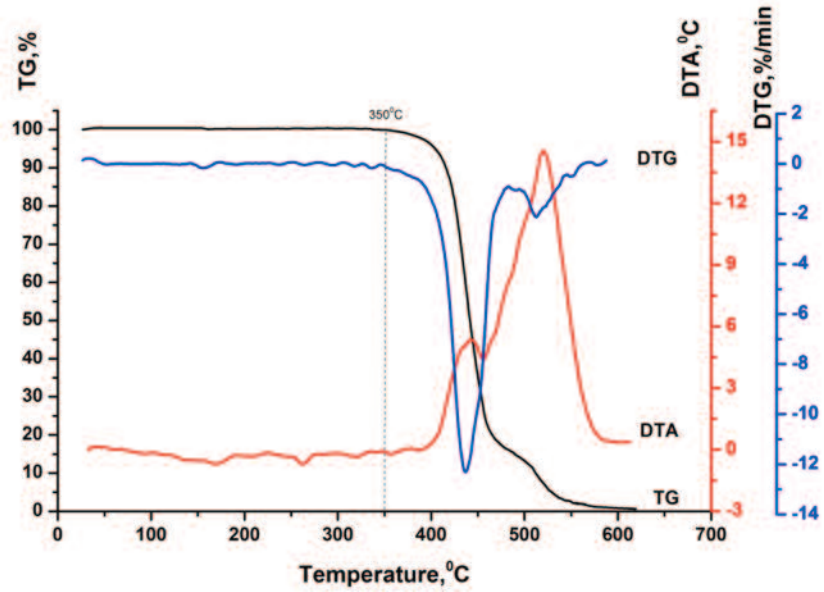
One type of fabric from which the packaging (bags) was produced, i.e. polyester fabric made of polyester fabric with polyethylene terephthalate was chosen for the tests [6].

Printing of the test scale on the fabric (Pic.3) was carried out in thermo transfer press EB 380 FN by EVER BRIGHT MACHINERY CO. LTD in the manufacturing conditions of LLC “Eney” company in Lvov. The printed image was transferred to the textiles in the following conditions: work temperature: 140°C, transfer time – 5 seconds, pressure – 3-4 bars. For printing, the plastic inks of the series Antex, NF, including NF 82 (purple), NF 83 (yellow), NF 84 (blue) and NF (black) were used. To increase the adhesion of the ink to the fabric, the coarse transfer adhesive TM 200 was employed. The mentioned transfer was carried out from paper 90/m^2. The physical and mechanical properties of packaging made of textile material were determined according to the following indicators: breaking strength, stretching of material at maximum effort which was tested in breaking machine RT-250 M-2 in conformity with DSTU EN ISO 13934-1:2008. As the packaging made of textile materials is reusable type of packaging, the test of changes in the dimensions of the discussed fabric after washing were carried out (DSTU GOST 30157.0:2003). The electronic microscope tests were performed in scanning electronic microscope JEOL JSM-T220A by a standard method [7]. To carry out the mentioned test, the surface of the fabric was metalized by a thermal sprinkling of a thin copper layer (up to 10 nm). The sprinkling was carried out with the use of sprinkler VUP-5.

Thermal tests of the samples of the printed images (Fig.3) on the textile materials were carried out on a derivate of system Q-1500D “Paulik – Paulik – Erdej” with the computerised registration of analytical signal of the weight loss and thermal effects. The samples were analysed by a dynamic method, with the rate of heating equal to 5°C/min at the air environment. The weight of the samples amounted to 100mg; aluminium oxide Al203 was the reference substance.

THE RESULTS OF THE TESTS

In the case of textile packaging, the resistance of the fabric is an important issue, especially its breaking strength. The physicochemical tests of polyester fabric, used in the tests, were carried out in accordance with the respective standards. The obtained results confirmed the consistence of the values with the required standards.



PIC. 4. THERMOGRAMS OF THE POLYESTER FABRIC SAMPLES

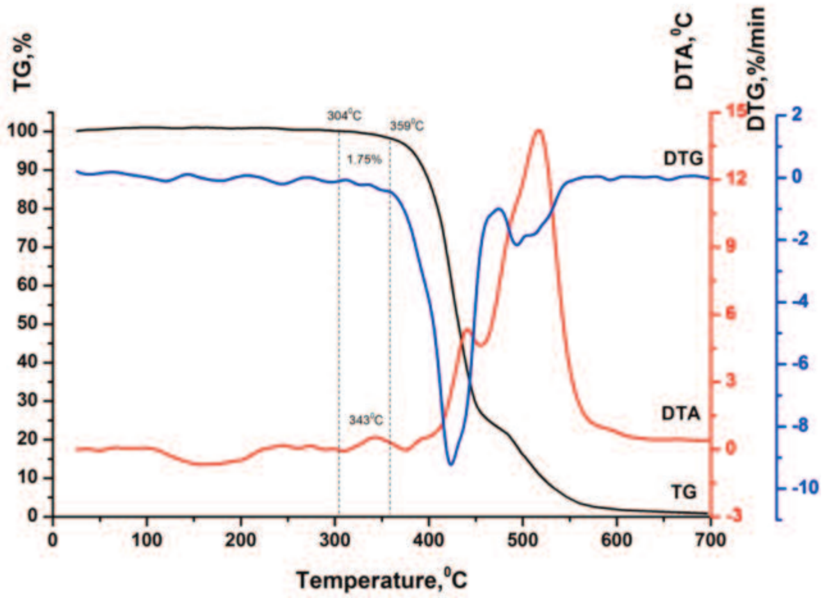
During the thermal transfer printing, the textile packaging is subjected to the impact of high temperatures. The method of thermal transfer printing consists in the application of image on intermediate paper (ribbon) with its later transfer on the printed material. The transfer and fixation is resulting from the effect of a high temperature. The transfer of the printed image is implemented with the use of "ordinary" thermal transfer paints (plastic or those on the water basis). In the discussed case, the image is printed in a mirror-like way, the colours are printed in a reverse sequence and finally, the layer of adhesive is placed, using a template (alternatively the adhesive in a dry form is placed on a wet layer of paint).

The composition of the thermal transfer ink includes not only pigment but also polymer. After heating up, it is melted and transferred onto a paper and then, solidified again. The advantage of thermal transporter consists in a good resistance of the paint fixation on the printed material.

DTA curve of the fabric (polyester) sample (Pic. 4) in the range of temperature of 20 – 270°C shows small endothermic effects which are not accompanied by the loss of the sample's weight and they correspond to processes of vitrification, softening and melting of polyester (PE) [8]. At the temperatures higher than 350°C, the active destructive and thermostatic processes occur in the samples of the polyester fabric; their culminating point is combustion of the destructive products. It is evidenced by intensive loss of the weight of the sample and occurrence of meaningful exothermal effects on DTA curves.

The samples of polyester fabric with the printed image are characterized by a lower heat resistance as compared to the samples without paint. It may be explained by the increased capability of paint elements to heat evaporation. The thermogram of the packaging sample with the printing on the polyester fabric (Pic. 5) shows that in the range of 304 – 359°C, the loss of the sample weight is found (1.75%) what is accompanied by exothermic effect on DTA curve. It is caused by a leakage in the sample during the initial process of thermal transfer. Contrary to the sample without printing in a given packaging, the thermal coupling processes run at temperatures higher than 350°C.

We should notice that in all cases, the active processes of thermal transfer and the processes of combustion of the products, destructing the fabric samples and printed thermo-transferred images proceeded less intensively as compared to the samples of pure non-printed fabric. It was reflected in phasic and less intensive weight loss of the sample at temperature above 248°C and occurrence of slower exogenous effects on



PIC. 5. THE THERMOGRAMS OF THE PACKAGING SAMPLE WITH THE PRINTING ON POLYESTER FABRIC

DTA curves. The lower capacity of combusting the printed samples of fabric results, probably, from the presence of the paint components which might slow down the combustion processes.

The tests of the samples with the thermal transfer printing, as made under the electronic microscope, allowed identification of mechanism of paint fixation. Polyester belongs to the class of polymers, containing a series of repeating significant groups in the polymer chain. The fibrous fabric has a curved pipe-like or cylindrical shape with microscopic pores and breakings. On the surface of the fibre, there are stains with irregular shape. The micrographs show that polyester materials are twisted mutually in a form of microfiber intertwining (Pic. 6). The threads twisted from the fibres have a great number of capillary channels which are able to attract paint during colouring of the fabric. As it was shown in the electronic microscope, the cross-section of the fiber tissue resembles a shape similar to circle. Printing on the textile material is performed with the use of plastisol paints. Plastic paints do not penetrate deeply the

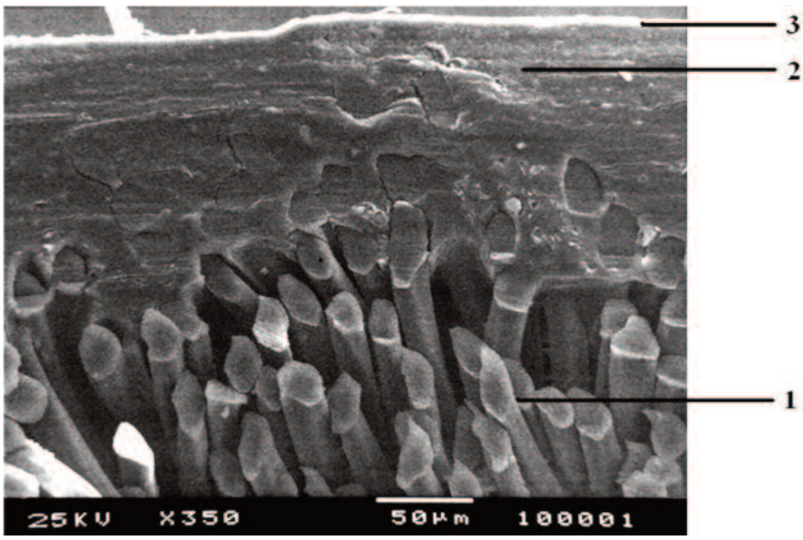
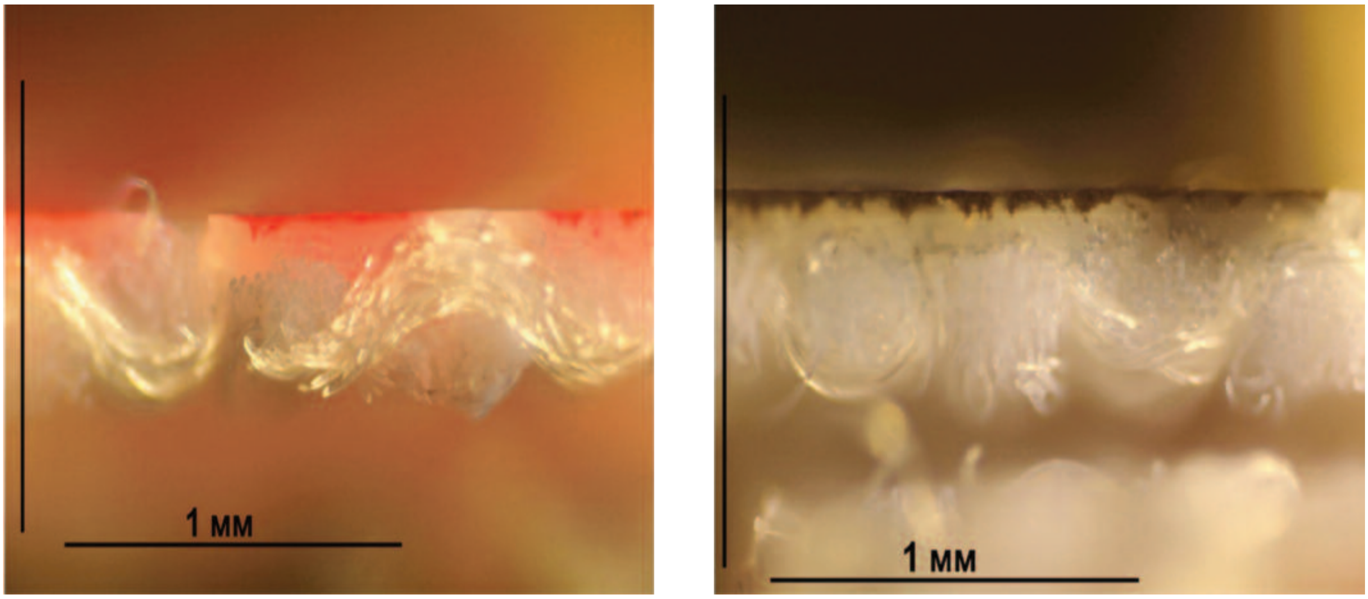


FIG.6. MICROPHOTOGRAPHY OF POLYESTER FABRIC WITH THE PRINTED IMAGE: 1- NON-PRINTED FIBRE; 2- TRANSFER ADHESIVE; 3 –PAINT



A

B

PIC. 7. MICROPHOTOGRAPHY OF THE CROSS-SECTION OF PACKAGING FABRIC WITH THE PRINTED IMAGE

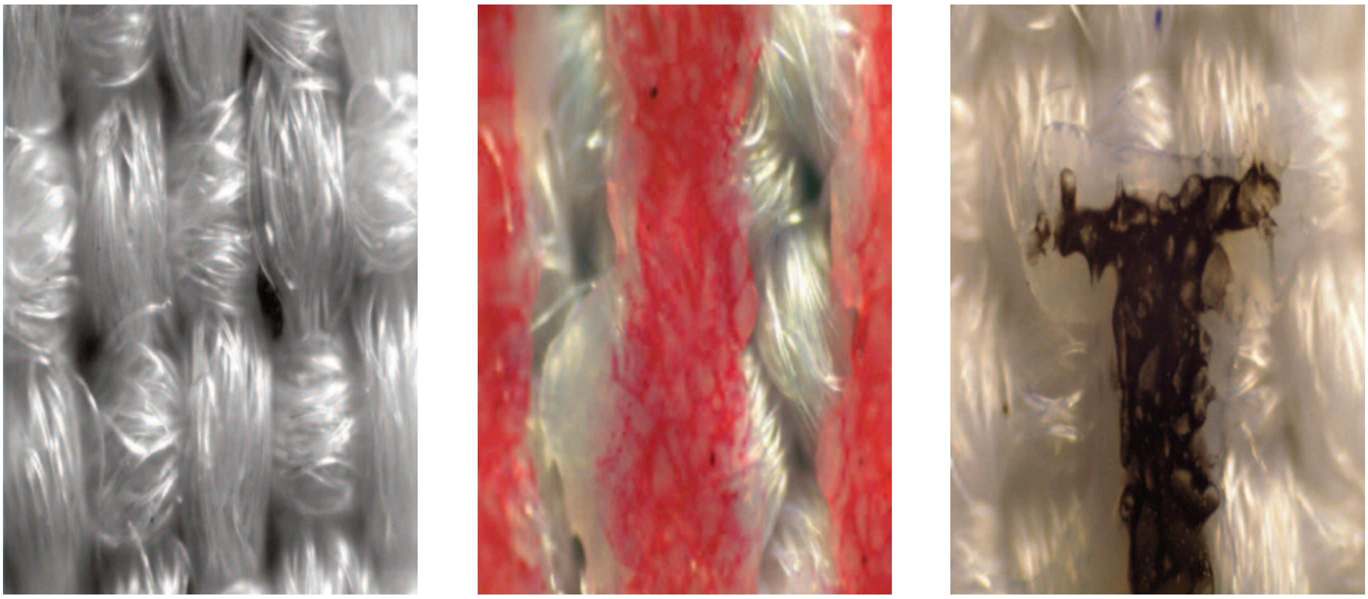
A – RED PAINT, B – BLACK PAINT

textile fibres, do not colour them but expose (distinguish) them, generating mainly mechanical coupling. It is distinctly visible in fragments of the cross-section of the images, printed on the bags, and made with the use of purple and black paints (Pic. 7).

As the paint is produced on the basis of polymers, the main components of which include PVC and plasticiser, the preservation of the image, transferred onto the fabric after heating up in the heat press occurs after the complete polymerisation (Pic. 8).

The analysis of the studies of the earlier authors [9] suggests that during thermal transfer printing on the fabric packaging, a physical heat sorption or chemical sorption of paint colours has place on the external (outer) surface of fibre. Fibres are two-phase, non-uniform in respect of their physical structure; the ratio between phases is dependent on the technological nature of their generation. According to scientists ( ), three-dimensional (3D) properties of fibres play the important role in preservation of the printed image. The exchange of weight occurs due to the diffusion flows in outer and inner environment. The fibre of the fabric, i.e. constant porous polymer is usually the mentioned medium. Transfer of the paint, as affected by the pressure and temperature is performed in few stages: firstly, in macropores, that is, in the empty spaces between the fibres and then, on the surface of the fibres where the catalyst of polymerisation is released due to the effect of temperature. The interfacial mask of the colour transfer is ended by the image preservation on the fabric in the process of the complete polymerization of the paint. The rate of the preservation of the image may theoretically depend on the kinetics of the polymerisation process and on the diffusion of colour in the outer phase on the surface of the fiber, paint heat sorption on the surface of the fabric and adhesion of the paint to microspores of the surface layer of the fibres.

Technological factors of heat transfer (temperature, pressure, time of contact with the textile, thickness of paint layer in the repeatable image) have a meaningful effect. Volume of fibre has an influence on the processes of partial paint sorption on its surface. Properties of 3D fibres are determined by a thin ultra-molecular structure and play the important role in preservation of the printed image on a textile packaging. To produce a high-quality printed image, fibre must possess active centres on which a given colour may be absorbed. The presence of the examined tissue fibres and system of pores, creating a developed internal surface (volume) as examined under a microscope, allows obtaining the printed images of high-quality.



A B C

PIC. 8. MICROPHOTOGRAPHY OF TISSUE FRAGMENT:

A – WITHOUT PRINTING; B – WITH PURPLE PRINTING; C – WITH BLACK PRINTING

CONCLUSIONS

The conducted analysis has confirmed the perspectives for utilization of heat transfer printing in decoration of fabric packaging. To ensure the quality of print, we should consider the structure of textile material and technological methods of transferring the image.

Mechanism of generating the thermo-transfer image on the fabric packaging, using the heat press is dependent on technological methods of printing, structure of fabric, paint polymerisation on the surface of fiber, adhesion of the paint to the surface of the textile, in particular, the adhesion to the surface of the fiber.

The discussed complicated process requires deeper further tests, in particular concerning the effect of the percentage of synthetic fibres in the fabric and the thickness of paint payer on the quality of the printed image. <<

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