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Research of the relief images forming process on the imprints by means of screen UV-varnishes

ABSTRACT

This article describes the process of relief image forming by UV-varnishes on self-adhesive labels done by means of screen printing plates with different screen mesh - 36 and 90 lines per cm. The influence of substrates' surface energy on the process of UV-varnish transfer has been investigated. It was defined a disproportional distribution of surface energy on nonprinted self-adhesive paper and it was determined the influence of screen ruling on the varnishing relief's height as well as the value of substrate's surface energy and viscosity of UV- varnish.

KEY WORDS
Screen printing, UV-varnish, viscosity, mesh thickness, surface energy

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Introduction

According to the forecasts made by Smithers Pira Company the world's label market is going to reach $ 43, 4 billion by the year 2017, and, including the production output obtained in 2012, an average annual growth will be about 4% (Smithers Pira, 2014). It is worth to point out that self-adhesive label is dominating in Europe: its share on the European market is 42%; at the same time it involves 40% of the world's market (Llewellyn, 2011). Growth of the label market can be explained by a considerable increase of social and economic factors, as well by the development of new technologies and materials and new trends in consuming. These trends make the printing industry to develop, especially in the fields of flexographic and digital printing as it was analyzed and predicted by the above-mentioned company. In order to give the imprints new properties, such as the ability to create relief texture images, tactile fonts and warning signs, a combination of traditional printing and rotary or flat-bed screen printing has been used lately. This tendency allowed stabilizing the reduction of screen printing use.

Application of UV-varnishes is done by rotary or flat-bed screen printing; the advantage of the rotary process is its simple integrity in the narrow-web UV-flexographic printing presses and possibility of in-line finishing of imprints, as some producers of narrow-web printing presses offer the possibility of changing a flexographic printing unit to a screen printing unit (Rumyantsev, 1999; Natur, 2004). One more factor enhancing the development of screen printing is the development of UV-inks and varnishes; it ensures the stability of technological printing process, as they do not dry out on the printing plate and produce the imprints with high optical and exploitation properties. When creating the UV-varnished imprints of relief structures on the surface, it is necessary to ensure their correlation with preset parameters. This article is aimed to reveal influencing properties of the printing plate and imprint on the forming of reliefs by UV-varnishes.

Methodology

To create a screen printing plate we have used the screens PET 1500 produced by SEFAR. These screens have two types of ruling, as it is shown in the Table 1. A Plus 8000 (MacDermid Autotype) was used as a copying emulsion to create a screen printing plate. Exposure of UV-sensitive emulsions performed on screen copy unit Variocop (TECHNIGRAF). The tension force of printing screen was equal to 19 N/cm. In both cases double sides were covered with emulsion (number of layers 2+5) to ensure a thicker layer of UV-varnish.

Table 1

Characteristics of screens (Sefar, 2014)

Mesh	Mesh count (l/cm)	Weave	Mesh opening (μm)	Open area (%)	Mesh thickness (μm)	Teoretical ink volume (cm^3/m^2)
1	36	1:1	174	39	162	63
2	90	1:1	55	25	78	19

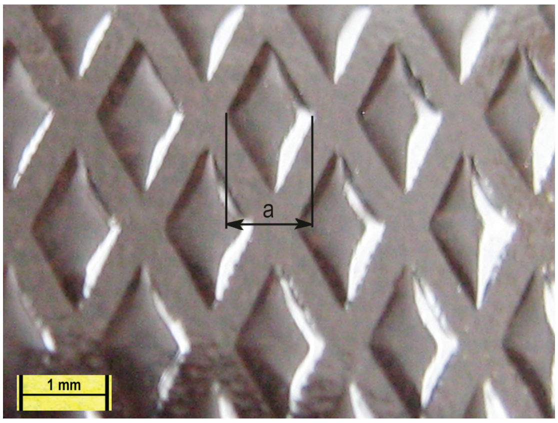
Two types of UV-varnishes UVivid Screen RN 622 (Fujifilm-Sericol) and UV 947 (N.V. UNICO) were used in the experimental test. Application of UV-varnishes onto the labels was done by means of SMAG Galaxie 2005 screen printing press with speed 20 m/min. "Doctor Blade's" slope was equal to 22^0. Both the nonprinted self-adhesive paper Herma White Super and paper printed by flexographic UVivid Flexo JD UV-inks separately were varnished. Spot color (Pantone, brown) is applied on the paper by rubber roller (hardness 60 Shore A units) and anilox roller 315 lines/cm on Narrow web printing press Gallus EM 280. The drops images of UV-varnish and test-liquids on surface were captured by using a CCD camera (1280x720 px) attached to the microscope, and then recorded by a computer. Using a micropipette, a small test liquids and varnish droplet 7,5±0,5 μl is placed on the substrate. Spreading of the test liquids and UV-varnish were evaluated in 30 sec. after application on the substrate out at temperature 20±0,5 ^{0}C and 80 % relative humidity.

The polar and dispersion components of the surface energy are determined by Owens-Wendt method (Owens & Wendt, 1969) for wetting angle of test liquids (distilled water and pure ethylene glycol):

$$0{,}5\gamma(1+\cos\theta)/(\gamma_d)^{0,5} = (\gamma_d^{\,s})^{0,5} + (\gamma_p^{\,s})^{0,5}(\gamma_p/\gamma_d)^{0,5} \quad (1)$$

where: γ – surface tension of the liquid, γ_d and γ_p – dispersion and polar components of the surface energy, that characterize solid body S or liquid (index missing). For the calculation of this connection, which lies in coordinates $0{,}5\gamma(1+\cos\theta)/(\gamma_d)0{,}5$ — $(\gamma_p/\gamma_d)^{0,5}$ is a straight line with a slope of $(\gamma_p^{\,s})^{0,5}$, and the point of intersection of this line with the axis of ordinates — $(\gamma_d^{\,s})^{0,5}$, was used the developed program.

Throughout the printing process the imprints were randomly varnished to form a relief surface as it is shown on the Figure 1.



» **Figure 1:** *Random application of UV-varnishes to create a relief surface structure*

When determining the height and width a (see Figure 1) of the varnished areas the samples sized 60×60 mm were conditionally divided into 25 squares, the same procedure was performed with the samples sized 100×100 mm to find out surface energy of the substrates. In the studied surface was applied to 25 drops of each test liquids, recorded their images and determine the cosine of the contact angle. By definition the width and height of UV-varnished elements were analyzed two elements in each of the 25 squares.

UV-varnish elements on imprints were recorded by camera Nikon D40, which was mounted on microscope. The width of printing elements and applied UV-varnished elements on the imprint was measured in the course of pictures analysis by means of Measure Tool in Adobe Photoshop 8.0. The thickness of screen printing plate, paper and the height of relief varnished elements were controlled by a thickness gauge model TH (scale division = 0,001mm). Viscosity of UV-varnishes was measured by the viscometer Brookfield RVT at the temperature 18 ^{0}C, rotor #5.

Results and discussion

It is well-known that the amount of UV-varnish applied on the substrate will be determined by the thickness of screen printing plate and open area, which in the case of screen #1 will be equal 235 microns and open area 39 %, in the case of screen #2 will be equal to 110 and 25 %, correspondingly. Figure 2 demonstrates the difference between the cells of printing plates having different screen ruling.

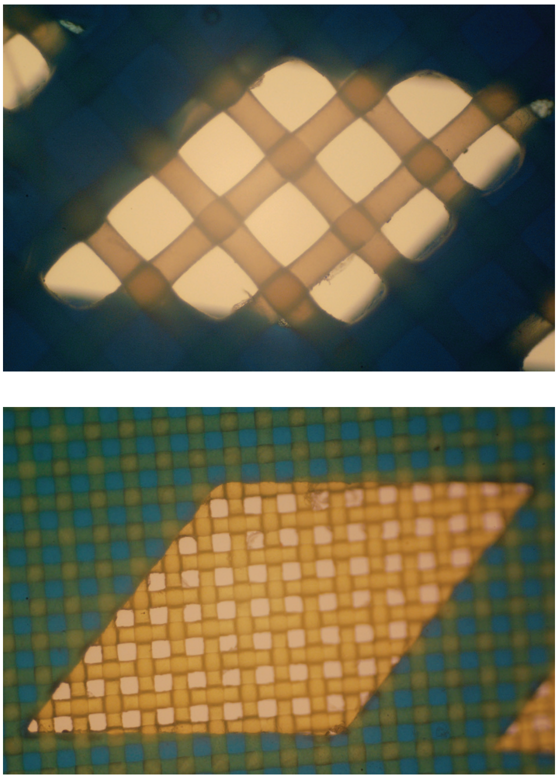


Figure 2: *Printing elements of screen printing plate: pic. above –mesh count 36 l/cm; pic. below – mesh count 90 l/cm*

When determining the viscosity of UV-varnishes it was fixed that the viscosity of varnish UV 947 is two times less than those of the varnish RN 622 and it is equal to 6,4 and 14,0 Pa·s, correspondingly. It is necessary to point out that the varnish RN 622 has a gel consistence, it is capable of creating the structures and consecutively it has a minimal ability to spread out; this made impossible to fix a real wetting angle.

The results represented in the Table 2 show that the relief obtained in the case of the UV-varnish RN 622 application is higher when comparing it to the UV-varnish UV 947. This fact can be explained by a higher rate of its viscosity, although a lower relief is formed when both types of UV-varnishes are applied. In screen printing as well as in other types of printing techniques the process of printing is the result of adhesive and cohesive interaction between the substrate and ink (varnish), in this case a determinant factor is a surface energy of printed surface. To find out the reasons of a low relief on the surface of nonprinted paper a surface energy has been determined using the Owens-Wendt method.

Table 2
Height of relief and width of applied UV-varnished elements

UV-varnish	Mesh count - 36 l/cm		Mesh count - 90 l/cm	
	Paper	Ink layer	Paper	Ink layer
Relief height, мкм				
RN 622	104,1	107,2	38,7	41,4
UV 947	99,2	102,3	37,1	38,5
Enlargement of varnished elements, in %*				
RN 622	2,1	2,5	1,5	1,9
UV 947	3,2	4,5	2,1	2,6

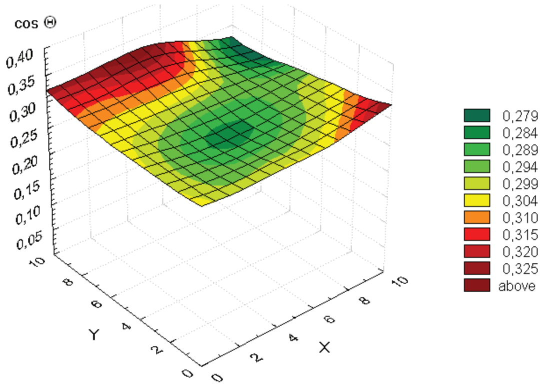
** increasing the width of the elements in the varnish imprints were calculated relative to the width of the printing elements on screen plate.*

As you may see on the Table 3 printed and non-printed areas of the imprints have quite different properties. Despite the fact that the surface energy of substrates is almost the same, the area printed by flexographic UV-ink has a surface energy with a higher polar component. It causes spreading out of UV-varnish and the enlargement of varnished element. Correspondingly the cosine of contact angle is equal to 0,866 for varnish UV 947 on the ink layer, and 0,829 on a nonprinted paper.

Table 3
Energetic characteristics of surfaces and spreading out the UV-varnishes

Substrates	Surface energy (OW method)			Cosinus contact angle of UV coating	
	Polar component γ_p, (mJ/m²)	Dispersion component γ_d, (mJ/m²)	Surface energy γ_s, (mJ/m²)	RN 622	UV 947
Herma White Super	9,25	28,20	37,45	n/d	0,829
UVivid Flexo JD	14,96	23,51	38,47	n/d	0,866

UV-varnishes create a higher relief of varnished elements on the surface of paper printed by UV inks than the relief of varnish on the unprinted surface. The reason is that in the course of varnish screen printing when transferring varnish from the printing plate a stronger adhesive connection is formed due to a high viscosity of UV-varnish related partially to a cohesive intermolecular interaction and liquid's resistance a bigger amount of varnish is transferred to the substrate. A smaller relief of vanish 947 and wider areas of varnished elements on the imprint can be explained by its better ability to spread out before the UV-polymerization process when passing through the UV-drying unit. It is necessary to point out that the UV-varnish UV 947 has a lower viscosity in comparison with the varnish RN 622 and its application through a finer screen onto a nonprinted paper gives a noticeable fluctuation of height and width of formed elements and distortion of relief elements' geometry.



» **Figure 3:** *Inhomogenity of Herma White Super paper's surface tested by distillated water*

The reason for this fact is a raise of temperature of self-adhesive paper during its transportation or storing and subsequent diffusion of silicon layer on the surface of coated layer of paper which results to a inhomogeneous distribution of surface energy (Figure 3); The main difference of self-adhesive label papers is the presence in their multilayer structure of adhesive and silicon layers which make possible an easy separation of printed paper from the base during an automated process of production labeling. As a result of an inhomogeneous distribution of surface energy on particular areas of the imprint we can see the difference in the UV-varnish distribution.

Conclusion

The investigations showed that the plate thickness, open area of mesh and substrates' surface energy, especially its polar component, exercise a considerable influence on the varnish transfer from screen printing plate to the imprints. Due to them formed adhesive cohesion between the surface and UV-varnish from the cells which causes a greater relief of optionally varnished elements. Printed and non-printed surfaces of the imprints have quite different properties, that affect relief of UV-varnished elements. Is it can be seen in the case of 947 UV-varnish, when applying to a surface printed with UV-inks having a polar component of surface energy equal to 14,96 mJ/m^2 and cosine of dampening angle equal to 0,866. One more factor is the viscosity of UV-varnish which allows increasing the transfer of varnish when printing and reduces its rumbling on the surface; it results to a minimal distortion of geometry of varnished elements. In the course of investigation it was determined a disproportional distribution of surface energy on the surface of self-adhesive paper which can be explained by the diffusion of silicon layer on the surface of coated layer of paper which can be removed by preliminary application of primer varnishes on the imprints.

One of next directions of research will reveal the influence of the surface properties of polymer films on the formation UV-varnished elements by means of screen printing, including Braille symbols.

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