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INFLUENCE OF INK SOLVENT CONCENTRATION ON WETTING OF FLEXO PRINTING PLATE AND PE FOIL

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Abstract:

The imprints quality is highly influenced by the ink transfer from the printing plate to the printing substrate. Ink transfer depends on the surface characteristics of the printing plate and substrate and the printing ink composition as well.
The aim of this research was to determine wetting characteristics of the printing plate and printing substrate depending on printing ink composition in the flexographic printing.
For this purpose samples of printing ink were made with varying solvent concentration. Evaluation of the printing ink was made by measuring viscosity and the characterisation of surface topography of printing plate and PE foil was made by measuring roughness parameters. To determine wetting characteristics of the prepared samples of printing inks on the printing plate and PE foil measurements of contact angle were performed. Obtained results showed that the ink composition has significant influence on the printing ink viscosity and on the wetting of the printing plate but on the printing substrate as well. The contact angle between printing ink and both investigated surfaces (printing plate and PE foil) is increasing by reducing the solvent concentration (higher viscosity) thereby resulting in worse wetting.
The conducted research showed the importance of the printing ink composition on the wetting of the printing plate and printing substrate, consequently on the ink transfer from the ink tray to the imprint.
Furthermore, one must monitor all observed parameters (surface topography, ink viscosity, wetting characteristics) in order to achieve best printing results.

Keywords: *flexography, printing ink, polyethylene, contact angle, surface topography*

1 INTRODUCTION

Flexography has a large scale growing rate in the graphic industry turnaround as it has ability to produce relatively high quality imprints on a various substrates. Flexible printing plate and usage of various printing inks provide ability to print on coated and uncoated paper and board, non-porous substrates including metallised and paper foils and polymer films, used especially in the packaging industry. In order to achieve imprint with satisfactory quality demands one must ensure defined ink transfer from ink tank to the printing substrate. Many parameters could influence ink transfer, among others printing pressure, the surface characteristic of the printing plate and the printing substrate but also the ink composition.
Previous research showed that surface roughness and chemical heterogeneities have critical influence on contact angle values. Numerous authors have proposed models to describe the relationship between wettability and roughness, especially on structured surfaces with low surface energy as are polymers [1].
Aim of this paper was to determine the wetting characteristic of the flexographic printing plate and printing substrate (PE - polyethylene) depending on ink composition by measuring static contact angle. Characterisation of surface topography materials was made by measuring significant amplitude surface roughness parameters (R_a, R_p, R_v, R_q and R_z). Printing inks used in this research were determined by measuring viscosity.

2 THEORY

Wetting. Wettability (or wetting) is physical phenomenon described as the tendency for a liquid to spread on a solid substrate depending on the solid surface properties (surface chemistry and surface roughness) and the type of used liquid [2-7].

Wetting is conditioned by surface tension decrease in solid - liquid system (reduction of surface free energy value occurs when a liquid is wetting a solid surface) [5-7]. The liquid on the solid surface is spreading until the balance between cohesion (internal forces) of liquid, capillary (surface tension) forces and gravity is reached [5-7]. The achieved state of equilibrium corresponds to the minimal energy state among the three phases and thus equilibrium (static) contact angle or Young angle [2,5,8]. The determination of the Young angle is important for the characterization of solid–liquid interfacial systems [5,9]. Relation between Young angle and interfacial energies of materials is given by the Young equation [1, 9-13] (Fig. 1):

$$\gamma_{sg} = \gamma_{sl} + \gamma_{lg} \cos \theta, \quad (1)$$

where γ are the surface tension coefficients of solid–gas (sg), solid–liquid (sl) and liquid–gas (lg) interfaces.

The equation (1) stands only for ideally smooth and homogeneous solid surfaces. The Wenzel and Cassie–Baxter models of wetting are more appropriate for rough and homogenous surfaces, since they get into account the effect of surface roughness on the static contact angle [1,5,10-13].

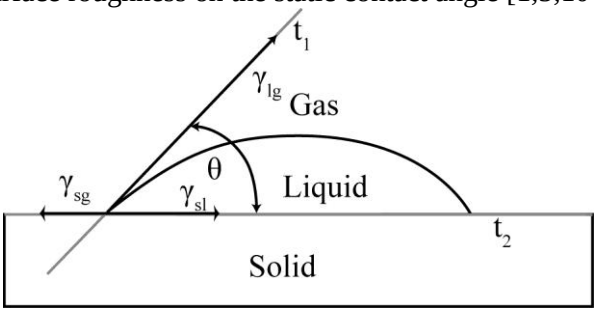


Figure 1: Contact angle between liquid and solid surface

Contact angle (CA) is defined as the angle between tangent on the liquid drop (t_1) and the tangent on the solid surface (t_2) in the point where all three phases (solid, liquid and gas) meet (Figure 1) [6,7]. It can be said that a liquid will spread on the surface with high surface free energy and would not on the surface with low surface free energy [8].

As mentioned before, spreading of the liquid on the solid surface is dynamic process influenced by gravity and surface tension of solid and liquid (Figure 2) and therefore one must take into account time from liquid-solid contact in which measurement of the CA will be conducted [6,7].

a)  b) 

Figure 2: Contact angle between liquid and solid surface a) 0.3 seconds after solid-liquid initial contact and b) 1.3 seconds after solid-liquid initial contact

On the other hand, if measuring a liquid which evaporates at measuring temperature, measurements of CA should be made at short time (before reaching equilibrium state).

Roughness analysis. Determination of surface roughness parameters of a material is used in many engineering industries as surface texture of the material often defines its functionality. Substrate and printing plate properties in relation to the pressure and printing speed have a major role in the ink transfer. Surface roughness of the printing plate is more significant than the surface energy when considering print quality [14].
Surface roughness parameters are depending on instrument settings, instrument characteristics, the post processing of obtained data and the nature of the surface texture [12,15]. Taking into account roughness, Young's contact angle and the Wetzel's equation it can be seen that differences in roughness significantly influence on measured values of Young's contact angle or solid–vapour interfacial energy (up to 20%) [12].
Surface roughness could be estimated by usage of various imaging methods such as SEM-scanning electron microscopy or AFM-atomic force microscopy, as well as profilometric methods, like MSP-mechanical stylus profilometry or non – contact laser profilometry [15].
Profilometric analysis is used in material science to quantify the morphology of material surfaces. In contact profilometry peaks and valleys are directly measured. The measuring unit is equipped with sharp diamond tip which is moving along line of the investigated surface and measures displacements induced by surface irregularities. In this way method provides two dimensional data of the surface. Several test lines need to be recorded to get precise determination of surface texture [15,16].
There are many roughness parameters which can be used for the surface characterization, but most commonly used are amplitude ISO roughness parameters (ISO 4287:1997 and ISO 12218:1997): R_a, R_q, R_{zDIN}, R_p and R_v [15,17-20].
R_a is average surface roughness - the arithmetic mean of the absolute values of profile deviation of mean within sampling length [15,19,20]:

$$R_a = \frac{1}{l}\int_0^l |y(x)|dx \qquad (2)$$

R_q (R_{ms}) is root-mean-square deviation – the square root of the arithmetic mean of the squares of profile deviation from mean within sampling length [15,19,20]:

$$R_q = \sqrt{\frac{1}{l}\int_0^l y^2(x)dx} \qquad (3)$$

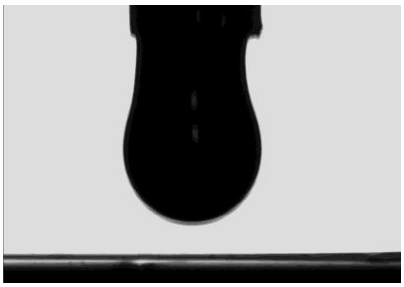
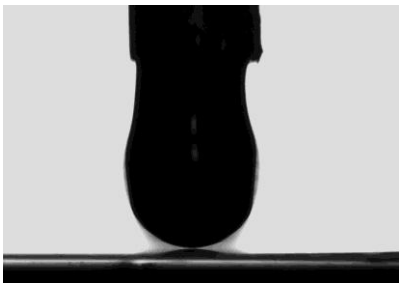
R_{zDIN} is average maximum height of the profile (average of all vertical distances between the highest and the lowest point for a sampling length) [15,19,20]:

$$R_{zDIN} = \frac{1}{n}(Z_1 + Z_2 + ... + Z_n) \qquad (4)$$

R_p is the height from the highest profile peak line to mean line within the sampling length [15,19,20].
R_v is the height from the lowest profile peak line to mean line within the sampling length [15,19,20].

3 MATERIALS AND METHODS

In this study 1.14 mm thick digital flexographic printing plate with thermal processing and polyethylene corona treated foil 0.045 mm thick were used.
The ink samples were made of commercial ink in which different amount of solvent was added. Six samples of the printing ink were prepared, V1 – V6, V6 meaning smallest amount of the solvent and V1 largest amount. Viscosity of the ink samples was determined using Brookfild DV/II+ Pro programmable viscometer at temperature of 23°C.
Contact angle (CA) analysis was performed to evaluate the wettability characteristics of the polymer printing plate and PE foil on which inks of different solvent concentration were applied.
Measurements of static contact angle were performed by Dataphysics' OCA30 computer controlled measuring unit using Sessile drop method. Measurements were conducted at 24°C with drop volume of 1.5 µl. CA computations were made by using Laplace-Young fitting method. Figure 3 shows three steps in contact angle measurement, drop forming, induced contact between liquid and solid and contact angle computation at precisely defined time.

a)  b) 

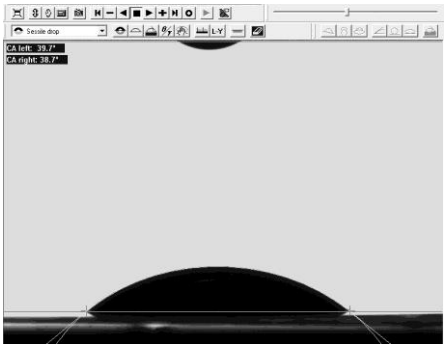
c) 

Figure 3. Measurement of the contact angle: a) drop forming b) contact between liquid and solid phase c) measurement of contact angle

Profilometric roughness parameters - R_a, R_p, R_v, R_q and R_z were measured by the Portable Surface Roughness Tester TR 200. The unit is compatible with ISO 4287, DIN 4768, ANSI B 46.1 and JIS B601

standards. The measurement's parameters were: sampling length: 0.80 mm, traversing speed: V_t = 0.135 mms^{-1}, measuring range: ± 20 μm and resolution: 0.01 μm.

4 RESULTS AND DISCUSSION

Measurements of the roughness parameters of the investigated solids were repeated ten times longitudinal and ten times across to avoid possible variations in the corona processing of the PE foil or surface texture of the developing fabric in printing plate processing. In Table 1 are shown average values of the roughness parameters results.

Table 1: Surface roughness factors

Material		Surface roughness factors			
	R_a (μm)	R_p (μm)	R_v (μm)	R_q (μm)	R_z (μm)
Printing plate	0.46	1.19	1.23	0.56	2.42
PE foil	0.39	1.10	0.84	0.48	1.95

One can see that printing plate has higher values of the roughness parameters than PE foil. Surface roughness of the thermal developing in which surface of the printing plate comes in contact with relatively rough fabric used to remove unexposed parts of photopolymer. On the other hand rather rough surface of the PE foil is made by corona treatment which is made to improve printing ink adsorption in the printing process.

Table 2 presents results of the viscosity measurement of investigated ink compositions. Results show that increasing concentration of the solvent causes decrease of the printing ink's viscosity.

Table 2: Ink viscosity values

Ink	V1	V2	V3	V4	V5	V6
Viscosity value (mPas)	15.7	20.8	24.2	26.6	29.2	39.2

CA measurements were repeated 12 times and results presented in Figure 4 show average values. Lines in the graphic presented in Figure 4 are trend lines of the measured results.

Results show that CA value measured on printing plate as well as on the PE foil decreases by increasing solvent concentration in printing ink. The differences between minimal and maximal value of CA are on both solids round 12^o. Trends of the measured CA values are for both investigated solids polynomial (2^{nd} order) but are opposite behaviour. The CA on PE foil trend curve show constant increase achieving maximal value at the last investigated printing ink sample. CA on the printing plate is increasing to reach maximum at V4 and further decrease of the solvent concentration causes decrease of CA value.

These results indicate smaller influence of the roughness on the wetting of investigated solids with printing ink sample as printing plate has rougher surface then PE foil but in the same time higher CA value with all printing ink samples. Although, one must keep in mind that diamond tip of the contact profilometer has diameter of 2 μm which makes it unable of detecting smaller peaks or valleys.

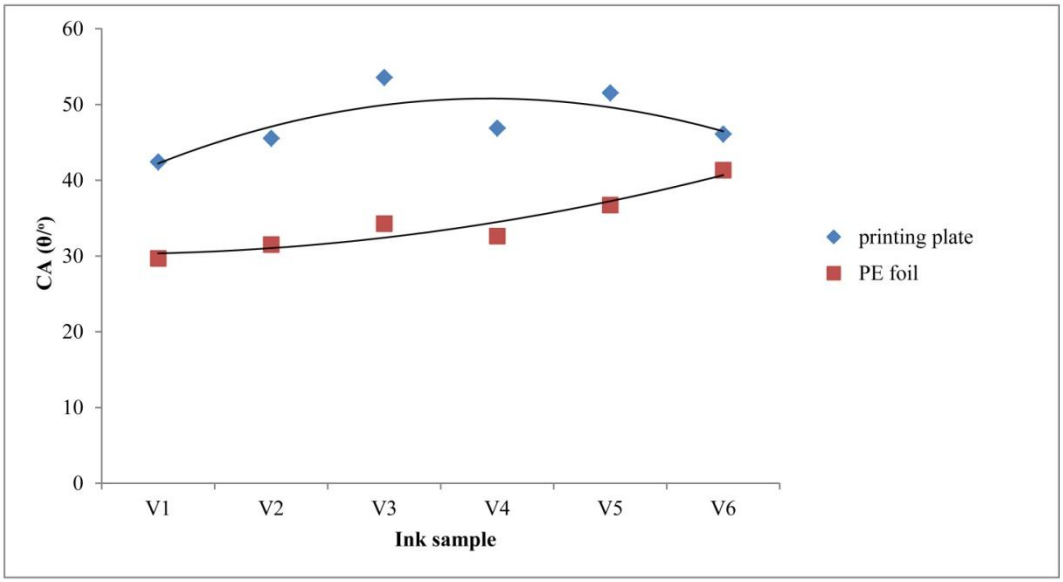


Figure 4. Contact angle values of ink samples on printing plate and PE foil

5 CONCLUSION

The aim of this paper was to define wetting characteristic of two different polymer surfaces: the flexographic printing plate and printing substrate PE – polyethylene foil depending on ink composition. Determination of the wetting properties was made by measuring static contact angle between prepared printing inks and investigated solids. In addition, characterisation of surface topography of solid surfaces used in the research was made by measuring of roughness parameters (R_a, R_p, R_v, R_q and R_z) by contact profilometry. Used inks were characterised by viscosity measurement.

The investigation was made assuming that ink transfer is highly influenced by the surface characteristic of the printing plate and printing substrate as well as the ink composition.

Results of the investigation showed that concentration of the solvent has high impact on the viscosity of the investigated ink samples meaning possible problems in the ink transfer from the ink tray to the printing plate.

Contact angle values on the PE foil were smaller than on printing plate for all investigated printing inks. This fact implies better adsorption of printing ink on the PE foil, i.e. good transfer of the printing ink from printing plate to the printing substrate. As there is different influence of the solvent concentration on wetting of printing plate and PE foil, it can be seen that lowest solvent concentration causes smallest difference in contact angle value, consequently smaller ink transfer from printing plate on the printing substrate. On the other hand, pressure in the printing press and higher viscosity of the printing ink with lower solvent concentration could positively influence ink transfer.

In addition, flexography is influenced by many parameters which all must be optimised to achieve desired level of the imprint quality. Obtained results have showed the influence of the ink composition on its viscosity and wetting of printing plate and PE foil. One should keep these results in mind and include them in future research of other parameters in order to optimize printing process to gain needed level of imprint quality.

6 ACKNOWLEDGEMENT

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