less legible than the transitional or the old-style one. The design of the "old" newspaper somehow followed the common European newspaper design, especially in the 19th and at the beginning of the 20th century, while in the "new", modern newspaper, the design could not be detected; it seems as if the newspaper wanted to show its historical connection with the "old" newspaper. Therefore, the respect and cultural heritage of the "old" newspaper was lost.

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Flexographic ink composition and its wetting influence on flexo printing plate and printed substrate (PE FOIL)

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Abstract

Surface topography of the printing plate and substrate and the printing ink composition are factors which highly influence ink transfer during flexographic printing process. Consequently, their influence on final imprint quality is certainly not in question.The research presented in this paper was aimed on determination of wetting characteristics of the printing plate and printing substrate, depending on printing ink composition, as well as their surface topology. Samples of printing ink were made with varying solvent and varnish 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 ink samples on the used solids 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 is decreasing by increasing the solvent and varnish concentration thereby resulting in worse wetting.
The conducted research showed the importance of printing ink composition on the wetting of printing plate and printing substrate, consequently on the ink transfer from ink tray to 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 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. The inks used can be overlaid to achieve brilliant colours and special effects. Among the fluid inks used in flexography are aniline inks (aniline dyes dissolved in alcohol or some other volatile solvent), polyamide inks, acrylic inks and water-based inks. These are superior to oil-based printing inks because they adhere to the surface of the material, while oil-based inks must be absorbed into the material. Many parameters could influence ink transfer, among others printing pressure, surface characteristic of printing plate and printing substrate but also the ink composition. Surface roughness and chemical heterogeneities showed their importance as well as 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. The detailed survay of these methods can be found in [1].
Characterisation of surface topography materials was made by measuring significant amplitude surface roughness parameters (Ra, Rp, Rv, Rq and Rz). Printing inks used in this research were determined by measuring viscosity. This study is aimed to determine the wetting characteristic of the flexographic printing plate and printing substrate (PE - polyethylene) depending on ink composition by measuring static contact angle.

2. Theory

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 is wetting [2-7]. It 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] (*Figure 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].

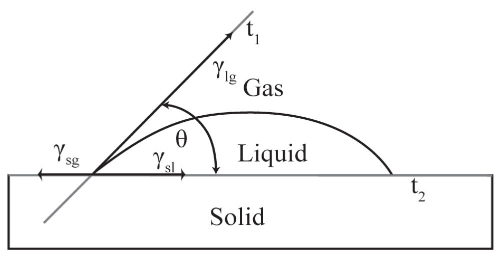


Figure 1: Contact angle between liquid and solid surface

Contact angle (CA) is defined as the angle between tangent on the liquid drop (t1) and the tangent on the solid surface (t2) 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 and therefore one must take into account time from liquid-solid contact in which measurement of the CA will be conducted [6,7]. In *Figure 2a* and b one can observe the significant phases of contact angle measurement.

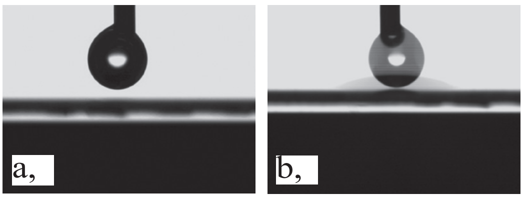


Figure 2: a) Drop forming and b) first contact between liquid and solid phase

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).
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): Ra, Rq, Rz-DIN, Rp and Rv [15,17-20].
The measured surface roughness parameters used in this study are compliant to the geometric product specification standards [15,19,20] and listed below:

– Ra is average surface roughness - the arithmetic mean of the absolute values of profile deviation of mean within sampling length, defined as:

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

– Rq (Rms) - root-mean-square deviation – the square root of the arithmetic mean of the squares of profile deviation from mean within sampling length, mathematically described as:

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

– RzDIN - average maximum height of the profile (average of all vertical distances between the highest and the lowest point for a sampling length), defined by:

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

– Rp – levelling depth, distance between highest peak and the reference line, and
– Rv – maximum depth of profile valley (see *Figure 3*).

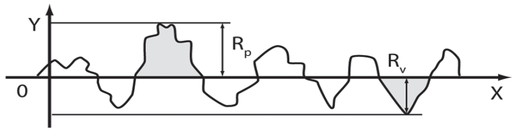


Figure 3: Levelling depth and maximum depth of profile valley

4. Materials and methods

The flexographic printing plate used in this study was a 1.14 mm thick thermal processing digital printing plate. As a printing substrate, a 0.045 mm thick polyethylene corona treated foil was used.

The ink samples were made of commercial black ink with different amount of containing components. The ink components were: base black slow, base technology varnish, base varnish and solvent.

The base black slow is a concentrated liquid black inorganic pigment dissolved in polyurethane binder and organic solvent (chemical mixture of nitrocellulose, ethyl acetate, ethyl alcohol, 1 – methoxy – 2 propanol).

The base technology varnish is a technology varnish based on nitrocellulose / polyurethane binder and organic solvents (chemical mixture of nitrocellulose, ethyl acetate, ethyl alcohol, 1 – methoxy – 2 propanol, 1 – propoxy – 2 propanol , 3 – methoxy – 1 – butanol).

Base varnish is a varnish made of nitrocellulose binder dissolved in organic solvents (chemical mixture of nitrocellulose, ethyl acetate, ethyl alcohol, 1 – methoxy – 2 propanol, n – propanol).

Solvent used is organic solvent used for nitrocellulose based dies.

Six samples of the printing ink were prepared, where amount of added base varnish and solvent was varied. They are named as Specimen 1 up to Specimen 6. Their composition is listed in *Table 1*. Viscosity of the ink samples was determined using Brookfild DV/II+ Pro programmable viscometer at temperature of 23^{0}C.

Table 1: Ink specimen composition specification

Ink specimen	Base black slow (g)	Base technology varnish (g)	Base varnish (g)	Solvent (g)
Specimen 1	500	300	100	100
Specimen 2	500	300	120	110
Specimen 3	500	300	110	110
Specimen 4	500	300	105	110
Specimen 5	500	300	100	110
Specimen 6	500	300	100	120

The contact angle (CA) analysis was performed in order to evaluate the wetting characteristics of used solids (flexo printing plate and PE foil) applying inks with different composition.

Measurements of static contact angle were performed by Dataphysics' OCA30 computer controlled measuring unit using Sessile drop method. Measurements were conducted at 24^{0}C with drop volume of 1.5 µl. CA computations were made by using Laplace-Young fitting method. *Figure 4* shows formation of drop and point of the measurement.

Figure 4. Measurement of the contact angle in OCA software

Profilometric roughness parameters - Ra, Rp, Rv, Rq and Rz were measured by the Portable Surface Roughness Tester TR 200 provided with a diamond tip with 2 µm radius. The unit is compatible with ISO 4287, DIN 4768, ANSI B 46.1 and JIS B601 standards. The relevant parameters of the device used in measurements are presented in *Table 2*.

Table 2. The measurement parameters of the TR200

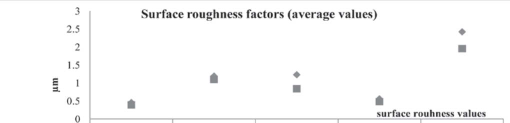
Sampling length	Traversing speed	Measuring range	Resolution
0.80 mm	0.5 mm/s	+/- 20 µm	0.01 µm

5. 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.

On the graph presented in *Figure 5* the average values of the measured roughness factors are given.

It can be seen that printing plate has higher values of the roughness parameters than PE foil.



	Ra	Rp	Rv	Rq	Rz
◆ Printing plate	0.46	1.19	1.23	0.56	2.42
St.dev.	0.059	0.19	0.19	0.07	0.37
■ PE foil	0.39	1.1	0.84	0.48	1.95
St.dev.	0.07	0.29	0.17	0.08	0.42

Figure 5. Surface roughness factors (average values)

Surface roughness of the printing plate is certainly influenced by thermal developing where the surface of the printing plate comes in contact with relatively rough fabric used in order to remove unexposed parts of photopolymer. Rather rough surface of the PE foil is made by corona treatment used to improve printing ink adsorption during the printing process.

Table 3 presents results of the viscosity measurement of investigated ink compositions. Results show that increasing concentration of the solvent and base varnish causes decrease of the printing ink's viscosity. Knowing the variations in amount of added base varnish and solvent (*Table 1*), it can be seen that solvent has a greater influence on ink viscosity meaning that the same amount of solvent added, causes lower ink viscosity than the same amount of added base varnish.

Table 3: Ink viscosity values

Ink specimen	Specimen 1	Specimen 2	Specimen 3	Specimen 4	Specimen 5	Specimen 6
Viscosity value (mPas)	39.2	29.2	26.6	24.2	20.8	15.7

CA measurements were repeated 12 times and results presented in *Figure 6* show the average values. Lines in the graphic presented in *Figure 5* are trend lines of the measured results.

Results show that the CA value measured on printing plate, as well as on the PE foil, decreases by increasing solvent and varnish concentration in printing ink. The differences between minimal and maximal value of CA are on both solids round 12o. The CA for PE foil shows constant decrease achieving minimal value at the last investigated printing ink sample. On the other hand, CA on the printing plate is increasing to reach maximum for specimen 4 after which it decreases.

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.

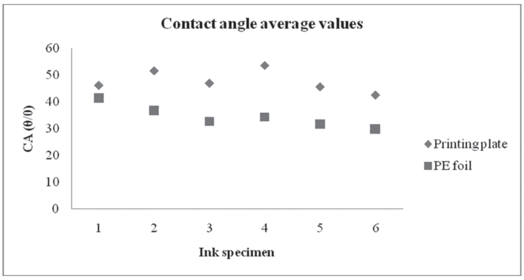


Figure 6. Contact angle average values of ink specimens on printing plate and PE foil

6. Conclusion

The objective of this paper was to define wetting characteristic, in dependence of ink composition and surface topology, of two different polymer solid materials: the flexographic printing plate and printing substrate PE – polyethylene foil. Wetting properties were determined by measuring static contact angle between prepared printing compositions and investigated solids. Characterisation of surface topography was made by measuring five amplitude roughness parameters - Ra, Rp, Rv, Rq and Rz using contact profilometry method. 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.

Gained results showed that concentration of the solvent and varnish in printing ink has high impact on the ink viscosity 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 regardless of printing ink composition implying better adsorption of printing ink on the PE foil, i.e. good transfer of the printing ink from printing plate to the printing substrate. The lowest solvent and varnish concentration (the highest ink viscosity) 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.

7. Acknowledement

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Containerboard paper types and their properties

Péter Borcsek
Hamburger Hungaria Ltd.

Containerboard paper is produced in Hungary in the paper mill operated by Hamburger Hungaria Ltd. On the two paper machines located there, about 670.000 tonnes of paper are produced a year, exclusively utilising waste paper, accounting for 85% of the total paper production in Hungary.
The portfolio matches the recommendations by CEPI Containerboard.
Without proper professional experience, choosing from the containerboard grades available on the European market can be quite a headache for anyone wanting to use them for making corrugated products.
Contrary to several other industrial products, there are no official standards for paper grades in the paper industry; whereas, in case of a connector element, for example, an international standard regulates the minimum requirements concerning the element in question.

Paper type	Commercial name	Grammage range
Testliner	Austroliner 2	120 – 150 g/m^2
	Austroliner 3	120 – 175 g/m^2
Brown light weight recycled liner	Austroliner 2 Light	100 – 115 g/m^2
	Austroliner 3 Light	80 – 115 g/m^2
Other brown recycled liner	Austroliner 4	100 – 150 g/m^2
	Austroschrenz	100 – 140 g/m^2
	Austroschrenz Light	70 – 95 g/m^2
Recycled medium	Austrofluting-R	112 – 175 g/m^2
	Austrowelle	100 – 150 g/m^2
	Austrowelle 2	110 – 175 g/m^2
Light weight recycled medium	Austrowelle Light	70 – 95 g/m^2

Purchasing such an element would also give us exact information regarding what load it can withstand; however, in the paper industry, there may be significant differences between the same products made by different paper-makers.