A Comparative Study of Offset Plate Quality Parameters using Image Processing and Analytical Methods

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Abstract: Printing plate performance is one of the crucial factors affecting the printed product quality. In particular, when producing printing plates for larger print runs, a rigorous quality control has to be performed, since any bulk and surface imperfection can have a large detrimental effect on print sharpness, contrast, non-uniformity, colour gamut, and other print properties. In our research two characteristics of an aluminium-based offset printing plate after 0, 123,000, 177,000 and 300,000 runs were studied: surface topography and contact angle. Each was determined using two assessment methods. For the surface roughness determination, the conventional mechanical profilometry and scanning electron microscope (SEM) imaging followed by an implementation of a texture analysis method Gray level co-occurrence matrix (GLCM) were applied. The contact angle of a printing plate with water was acquired by the sessile drop method using a DataPhysics OCA30 instrument and, alternatively, by implementing image analysis routines on a sequence of images captured by a simple image acquisition system. Image analysis for both surface topography and contact angle assessment was accomplished using ImageJ, a public domain Java image processing program. Both image analysis-based evaluation methods proved to be a viable alternative to the two established ones, providing a reliable tool for the monitoring of the wearing and other surface changes of a printing plate during the print run.

Keywords: surface roughness; contact angle; scanning electron microscopy; gray level co-occurrence matrix

1   Introduction

The surface quality of materials includes many engineering performance factors, such as mechanical function, wear, lubrication, and appearance. Several surface topography assessment techniques are currently used, and it is desirable that the characteristics of the material under investigation be studied comparatively in view of the practical applications [1]. The surface properties of a particular material are generally described in terms of its chemical composition, morphology and topography. Although all three surface aspects are important for the quality and functionality of materials and products, the influence of topography is frequently underestimated [2]. Surfaces with a non-periodic roughness pattern, such as aluminium printing plates used for lithographic applications, require accurate topography characterization, since this is one of the most important engineering factors that determine product characteristics.

The production of aluminium plates for offset printing involves roughening of the aluminium substrate in order to increase its surface area, which is necessary to improve the adhesion of the photosensitive coating and to enhance the water repellent properties of the aluminium surface [3]. Stability and surface definition are crucial parameters during the production and processing of printing forms. During the printing process, these properties of an aluminium offset plate play a key role in adsorption – wetting process as a function of contact angle between a solid surface (aluminium oxide) and a liquid (fountain solution with water as the basic component). Wetting is a physical phenomenon conditioned by a decrease in the surface tension of a solid – liquid system. A liquid will wet a solid surface only if it has lower surface energy than the solid surface [4]. One can determine the degree of wetting by monitoring a liquid drop shape. Contact angle is an angle between two tangents, one touching the solid surface and second touching a drop of liquid at the intersection point of three phases (solid, liquid and vapour). By measuring contact angle, one can determine the wetting degree of the investigated system [5]. The aim of our study was to compare the performance of the conventional surface topography and contact angle assessment methods with those using image analysis routines implemented through ImageJ, a public domain Java image processing program. The comparison was made in order to evaluate the possibility of utilizing the latter two methods for characterization of surface topography and wettability of printing plates and to determine their usefulness in quality control in the graphic arts technology. The applied methodology is presented in Figure 1.
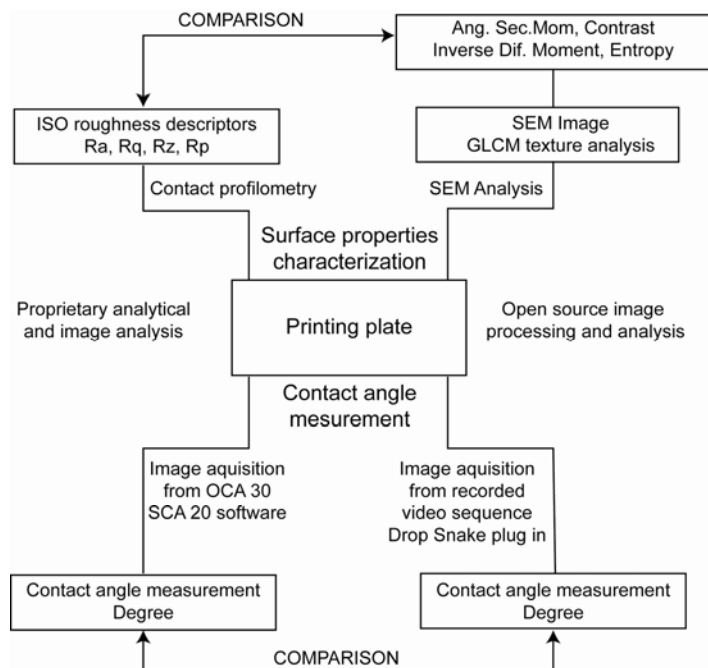
Figure 1

Applied methodology for surface roughness and contact angle characterization

2   Materials and Methods

In this research, we used one particular type of lithographic printing plate with a rather uniform surface structure and roughness of the non-image (aluminium oxide) areas. This selection was made for the following two reasons: first, the printing plates are manufactured in accordance with stringent, standardized procedures [6] assuring that the quality and the size of the grained surface microstructure will influence the printing performance and durability of the printing plate in a suitable way [7]; and second, the printing plate surface characterization during the production stage is of major technological importance [8, 9]. In addition, such a choice was also motivated by the fact that the surface characterization methods examined in this study and the results obtained could be of interest for the whole nanotechnology community, as the aluminium oxide nano-templates play a significant role in the template-based approach to nanotechnology [10-12].

Material used in this study was the thermal positive Kodak Sword Ultra T98 printing plate with a 0.3 mm thick AA1050 aluminium foil electrochemically roughened and anodized. The imaging was made on circular sample areas, of the

radius $R = 1.5$ cm, from the same non-image (non-printing) region of the printing plate sample, positioned along the line of printing pressure in the printing sets (Figure 2).

Figure 2

Locations of the samples on the printing plate

2.1 Surface Roughness Measurements

Profilometric measurements were made on the samples from an unused (reference) printing plate and on the samples taken after print runs of 123,000, 177,000 and 300,000 impressions. The printing process was performed on the four colour web offset printing press Komori 38 D, which has the ability to print with heat-set printing inks, a maximal printing area of 1250×960 mm, and a top speed 36,000 prints per hour. For each colour, a single printing plate was used and the measurements were done on each printing plate. For this investigation we utilized the data obtained from measurements on the samples from the plates used in the second printing unit, assuming that this printing unit has contact with the paper which has a small amount of dust and other substances left after the first printing unit: ink, fountain solution, etc. It should be emphasized that the printing ink, i.e. the colour, itself had no influence on the measurement results, as the measurements were accomplished on the samples from the non-imaging (non-printing) area of the printing plate.

To make aluminum suitable for producing printing forms, the plate is processed by a rolling procedure, which results in the characteristic structure of the surface in the direction of rolling. Lines that occur on the surface are not desirable in the further preparation of aluminum and require special treatment to reduce their negative impact on the surface roughness. The processing of aluminum includes the processes of electrochemical surface roughening and anodic oxidation, as was mentioned earlier, which produces aluminum surface microstructure of porous aluminum oxide [13]. Therefore, the measurements of surface roughness of the printing forms are carried in x and y direction, i.e. in the direction of aluminum rolling and perpendicularly to it.

Since previous investigations [14] showed that a high depth of focus SEM can provide detailed topographical information about the surface but cannot yield quantitative topographical information, we analysed the printing plates before and after print runs by a roughness meter (Time Group TR200) and by a SEM, and we

thus combined the quantitative topographical information with that contained in the SEM micrographs.

The profilometric measurements were performed with the Portable Surface Roughness Tester TR200 from Micro Photonics, Inc. using a diamond tip with 2 μm radius. The TR200 generates a number of roughness parameters: Ra, Rz, Ry, Rq, Rt, Rp, Rmax, Rm, R3z, S, Sm, Sk, tp, and hybrid parameters: primary profile (P), roughness profile (R), and tp curve (material ratio Mr), all defined according to the pertinent ISO standards [15, 16]. The relevant setting sof the device are presented in Table 1.

Table 1
Portable Surface Roughness Tester TR200measurement settings

Sampling length	Traversing speed	Measuring range	Resolution
0.25 mm	0.135 mm/s	± 20 μm	0.01 μm

The measured surface roughness parameters are compliant to the geometric product specification standards [6, 15, 16] and listed below:

- Ra - average surface roughness:
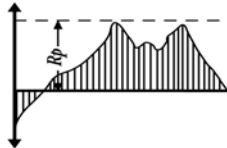
$$\mathrm{Ra} = \frac{1}{l}\int_0^1 |y(x)| dx \tag{1}$$

- Rq – root-mean-square roughness(R_{rms}):

$$Rq = \sqrt{\frac{1}{l}\int_0^1 y^2(x) dx} \tag{2}$$

$RzDIN$ – mean value of the single roughness depth Z_i:

$$RzDIN = \frac{1}{n}(Z_1 + Z_2 + ... + Z_n) \tag{3}$$

- Rp – levelling depth, distance between the highest peak and the reference line

The micrographs of the samples used for gathering topography information via image analysis procedures were made by a JEOL JSM 6460 LV scanning electron microscope (SEM). To assure the uniform electrical properties and to avoid the charging/discharging of the aluminium oxide surfaces, the printing plate samples were gold coated by ion sputtering (thickness 15.0 nm, density 19.32 g/cm^3). SEM recording parameters are presented in Table 2.

Table 2

SEM recording parameters

Working distance	Voltage	Tilt angles	Magnification	Image size
15 mm	20kV	0 ±5 deg.	500x	128 μm x 96μm

After acquiring the SEM images of the printing plates, ImageJ 1.44 software was used to analyze the images and to calculate the relevant profilometric parameters by texture analysis as explained below. These parameters were subsequently compared with the ones obtained from TR 200 contact profilometer.

2.1.1   Texture Analysis with GLCM

The roughness of a substrate can also be investigated using different texture analysis tools [17]. In this study we focused on the parameters derived from the grey level co-occurrence matrices (GLCM) that were computed from the corresponding images using ImageJ *GLCM Texture* plugin. Image texture is a substrate's appearance related term which can be regarded as a descriptor of local brightness variation from pixel to pixel in a small neighbourhood through an image [18]. Digital images can represent various texture attributes, such as graininess, periodicity, directionality and also smoothness/roughness. As for the latter, topography measurements are usually performed with an either mechanical or laser profilometric device generating range images – 2D images whose pixel values correspond to the distance to points in a scene from a specific point [19]. Our idea was to use SEM images of printing plates to see whether image intensity variations correspond to the expected smoothening of the plates due to the friction/wearing. One of the most frequently used texture analysis methods is based on the computation of GLCM. GLCM is a matrix that keeps track of how often different combinations – pairs – of pixel intensity (gray level) values in a specific spatial relationship and distance occur in an image. From this matrix it is possible to compute various first and second order statistical parameters or texture measures. Details of this procedure can be found in [20]. Each measure describes one aspect of the image texture and does not necessarily correlate to the other measures.

From each of the four SEM images (1280 x 960 pixels) of the cyan printing plate surface – the reference and plates after 123,000, 177,000 and 300,000 impressions, respectively – three smaller 500 x 500 pxl 8-bit grayscale images were obtained. They were after performing Gaussian filtering (r = 1 pxl) subject to image processing in ImageJ. Its plugin GLCM Texture can generate four different texture measures: angular second moment, contrast, inverse difference moment and entropy. Their values depend on the way the GLCM is calculated. In our case, these settings were as follows: step size: 1 pxl, step direction: 0 deg, meaning that the calculations were based on the horizontally adjacent image pixels.

2.2 Contact Angle Measurements

The contact angle measurements of the applied fountain solution (H_2O) on the non-printing areas of lithographic printing plate were performed by a Dataphysics SCA 20 instrument. The computer-controlled unit can operate in several modes: Spinning drop, Needle in, and Sessile drop method. The latter one was used in our investigations [21]. Accurate drop position and volume – precision up to 0.1 μl – are possible. Recording measurement with CCD camera makes it possible to determine static or dynamic contact angles [22]. In our study the liquid drop volume was 1.5 μl. In Fig. 3 one can see two significant phases of the contact angle measurement.
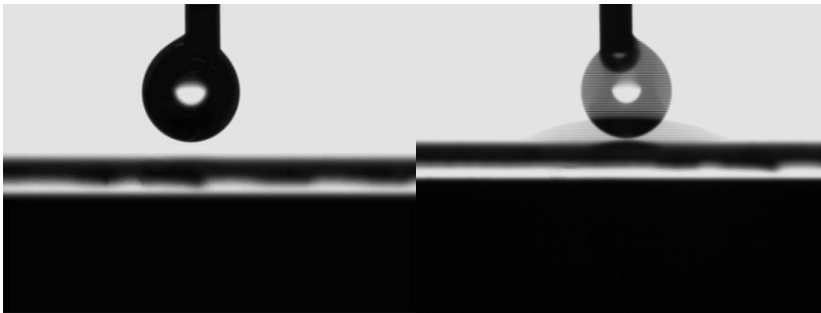

Figure 3
a) Drop formation; b) First contact between a liquid and a solid surface

The unit is controlled thorough a computer program, OCA SCA20, which in addition to measuring contact angle enables calculation of surface free energy of a substrate providing dispersive and polar components. The program also provides the possibility to use various fitting curves (circle, ellipse, tangent and Laplace-Young fitting) depending on the shape of the drop. Fig. 4 shows a software screenshot during the measurement.

Figure 4
Measurement of contact angle by means ofSCA 20 software

The contact angle was also determined on the basis of images captured by a video-based optical angle measurement device followed by an ImageJ implementation of the DropSnake plugin developed by the Biomedical Imaging Group, École polytechnique fédérale de Lausanne – EPFL [23]. The plugin uses a general method to measure contact angle and is suited for non-asymmetric or general drops. The contact angle is obtained by a piecewise polynomial fit on B-spline snakes (active contours). The drop reflection may be used to detect the interface and a small tilt in the image [24, 25]. The images of the three drops were assessed for each plate. All images (768x574 pixels) were first transformed to8-bit ones and saved as uncompressed TIFF files. On each drop 10 to 12 knots were manually added, starting at the left interface point and following the drop contour until the right interface point (Figure 5). When the last knot was placed, the spline was closed and the contact angles separately for the left and right drop side were calculated. Finally the average value for all three drops for both left and right contact angle was calculated.
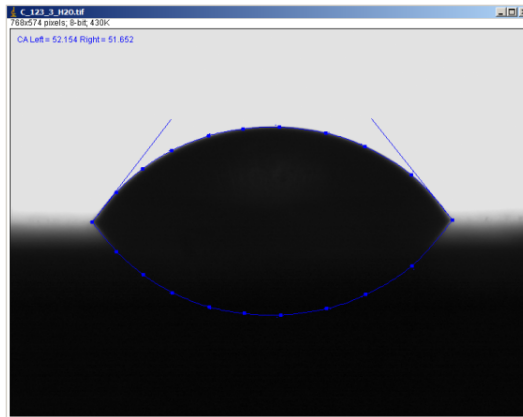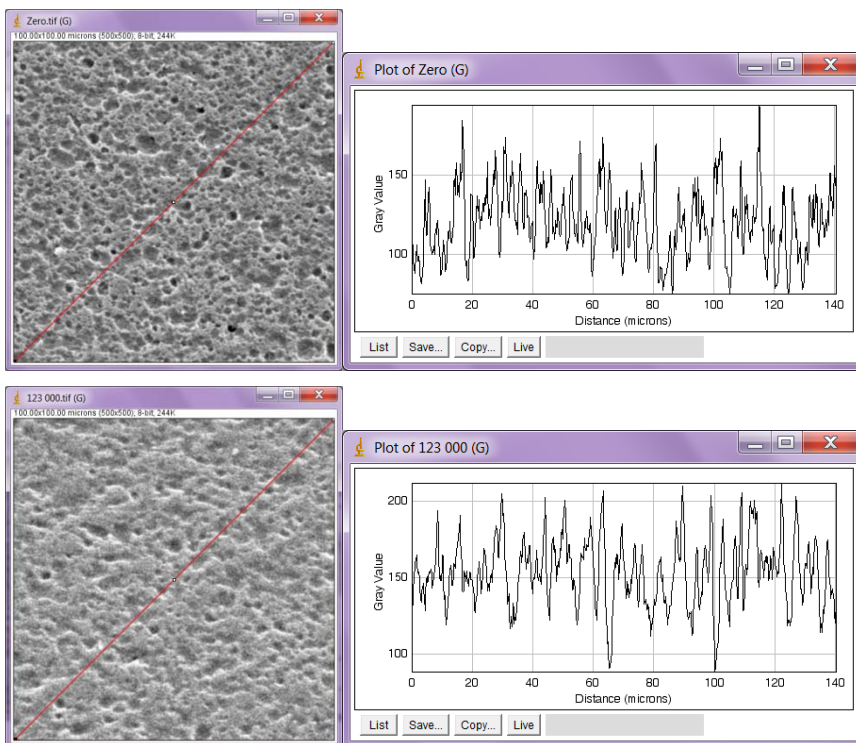

Figure 5
DropSnake measurement

3   Results and Discussion

The values of standard roughness descriptors obtained by the TR 200 measuring instrument together with GLCM derived texture measures for the investigated samples/images are displayed in Table 3. Fig. 6 shows their 1D intensity profiles along the depicted diagonal lines.

Table 3

Roughness descriptors and GLCM based texture measures for investigated sample images

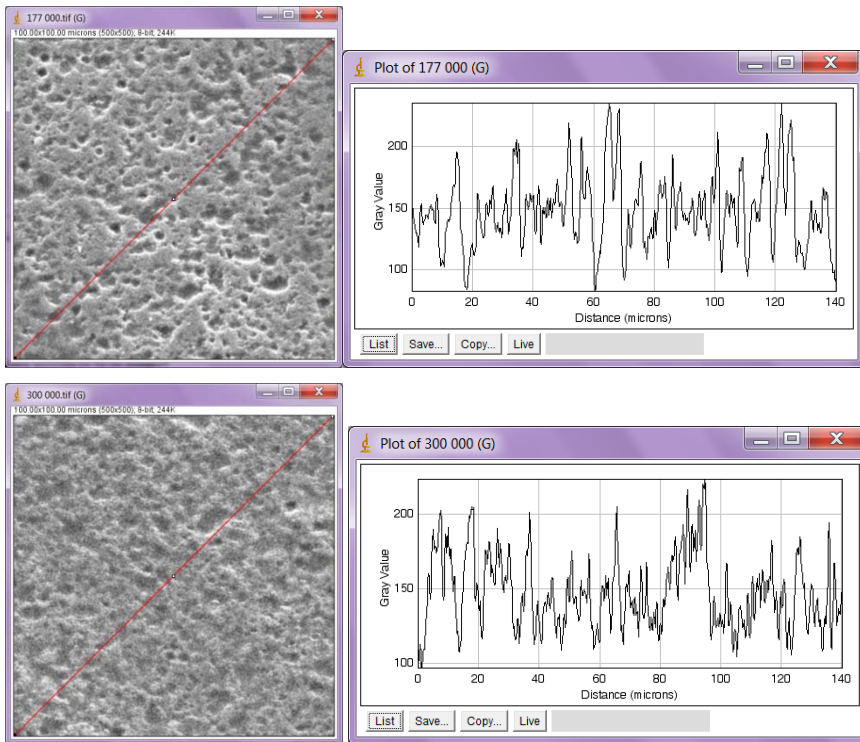| No. of print runs	Standard topography descriptors (µm)				GLCM-based texture measures			
	Ra	Rq	Rp	Rz	Angular Second Moment	Contrast	Inverse Difference Moment	Entropy
0	0.39	0.52	1.17	3.23	3.79E-04	93.848	0.165	8.196
123000	0.38	0.48	1.04	2.87	4.51E-04	96.778	0.171	8.014
177000	0.33	0.42	0.90	2.40	5.51E-04	86.812	0.198	7.897
300000	0.30	0.39	0.81	2.28	5.49E-04	88.006	0.18	7.821

Figure 6
Linear intensity profiles of SEM images

Of the four GLCM-based texture measures, the angular second moment, inverse difference moment and entropy show good correlation with the values obtained by the stylus-based topography assessment method: with an increasing number of impressions, the values of the first two parameters monotonically increase – with a single exception of the 300,000 impressions' plate – while the value of the third parameter decreases. As angular second moment corresponds to the uniformity of pixel values in the grayscale image and inverse difference moment to their similarity and since entropy is a measure of disorder or randomness, these findings are in agreement with an increasing smoothness of the plate surface. The contact angle was determined with a DataPhysics OCA30 instrument and, alternatively, using digital images processed by ImageJ plugin DropSnake. The results of both methods are displayed in Table 4.

Table 4

Results of contact angle measurements obtained by OCA 30 and ImageJ plugin DropSnake

No. of print runs	Optical angle measurement DataPhysics OCA30	ImageJ - DropSnake
	Contact angle [°]	Contact angle [°]
0	48.85 ± 0.86	49.67 ± 1.94
123000	61.87 ± 0.64	61.79 ± 0.30
177000	64.55 ± 0.55	62.98 ± 3.21
300000	67.32 ± 0.30	68.88 ± 2.74

From the results presented in Table 4, we can see that with a growing number of impressions, the contact angle increases, thus influencing the wettability of the investigated offset aluminium plates. This trend of increasing contact angle is most probably due to the applied printing pressure. With larger print runs the non-printing areas of the plate are exposed to a stronger continuous pressure and the pre-roughed surfaces are smoothed, leading to higher contact angles. This change of the surface properties from rougher to smoother surfaces can be observed through the ISO surface roughness parameters and through some of the investigated image analysis parameters. With a decrease in the surface roughness there is a decrease in the surface free energy, which directly influences the amount and angle of the fountain solution. This effect can have negative results on the print quality due to paper stretching or lower ink saturation, and therefore should be controlled during the print run. A comparison of the average contact angle values shows that the two methods produce very similar results. The difference lies in the precision of the methods, which is evidently higher for the OCA 30 instrument.

Conclusions

By comparing different methods – analytical instrumental and image processing based – to characterize surface roughness and wettability of offset printing plates, we have demonstrated the possibilities of quality parameters quantification. The wearing of the aluminium plate surfaces caused by paper dust, pressure and other factors lead to the degradation of several parameters, mostly surface roughness and contact angle, thus reducing the quality of the printed product. Of the four surface descriptors derived from the image analysis-based surface assessment method (GLCM), three of them – angular second moment, inverse difference moment and entropy – were found to correlate well with the values obtained with the stylus profilometer. The fourth descriptor – contrast – did not exhibit linear relationships, possibly because the SEM technique – unlike e.g. confocal laser scanning microscopy (CLSM) – does not generate actual surface images. Both methods for contact angle determination yielded very similar results.

The presented findings indicate that ImageJ can be used as a convenient tool for the inspection of the surface roughness and contact angle assessment. Further investigations will be conducted to test a larger number of important quality

parameters. This can lead to an easier quality control via machine vision and image processing systems that have a potential to replace conventional analytical methods which are sometimes time consuming and cannot be as easily automated.

Acknowledgement

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