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The influence of pH/conductivity of fountain solution on dot circularity, line and text raggedness

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Abstract:
The influence of pH and conductivity of fountain solutions on the quality of dot, line and text raggedness was investigated. Physico-chemical parameters of fountain solutions were analyzed by standard methods. Image quality assessment (IQA) was carried out using the ISO methodology and ImageJ software. There is a great influence of pH and conductivity of fountain solutions on the final quality of magenta prints. Magenta dot circularity on the printed sheets showed the mutual nonlinear dependence, second-order polynomial, followed by equation: y = 0.00514x2 - 0.07524x + 0.78238. Line analysis pointed out the least raggedly edges of 1pt horizontal and vertical lines. Times printed text had the most raggedly edges in comparison with Arial. The results indicated that the dot circularity, line and text raggedness could be useful attributes in the quality control of offset prints.

Keywords: pH, conductivity, fountain solution, sheet-fed offset, print quality

Introduction

Offset printing is a commonly used printing technique which requires the application of printing ink, fountain solution, printing plate and blanket. Fountain solution, as one of the major offset printing component, has seven key functions:

- keep ink off the background with a film of water;
- maintain the hydrophilic nature of the background;
- quickly clean ink off the background during press starts;
- promote fast spreading of water over the plate surface;
- help the water flow evenly through the dampening rollers;
- lubricate the plate and blanket;
- control emulsification of ink and water (Dynodan, 2012; Fuchs, 1996; Froberg et al., 2000). This control is important to ensure the consistent and recommended composition and maintenance of all components, water, wetting agent (isopropyl alcohol), buffer, desensitizing agent (gum-arabic), corrosion inhibitor, biocide and additives, in order to achieve the fountain solution effectiveness.

Accurately-measured pH and conductivity of fountain solution are both essential for quality printing. While these two parameters are basically independent, each one provides vital information about the water quality and composition of fountain solution during the press. Fountain solutions are normally buffered at specific pH levels of 4-5.5.

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Conductivity, as another important parameter of fountain solution, complements the pH in two ways: (i) by accurately identifying initial fountain solution strength and (ii) by gauging the contamination fountain solution picks up during production. The ink and paper, as primarily alkaline-based materials, contaminate the fountain solution and weakening the buffer capacity. As consequence the fountain solution than affects the final print quality and leads to scrumming, toning, tinting, etc. (PIA/GATF, 2007; Deshpande, 2011; Mahajan, 2006; Sappi Europe SA, 2004). Therefore, in order to prevent the negative effects of pH and conductivity on print quality the monitoring of these parameters is necessary.

A common way to analyze the print quality is quantitatively assess the image tone and colour with light-reflection measuring. The image tone and colour are easily perceptible but they are not sufficient to determine print quality. Therefore, several standards of graphic images quality, developed by the International Standards Organization, have defines various parameters such as tone, colour, resolution, contrast etc. (Dhopade, 2011). Standard ISO 13660 (ISO, 2001) in accordance with standard ISO 19751 (ISO, 2004) provides definitions of 14 different printed image's attributes, categorized in two groups by their domain of appearance that help analyze the printing defects:

1. Area attributes: darkness, background haze, graininess, mottle, extraneous marks, and background voids.
2. Character and line attributes: blurriness, raggedness, line width, darkness, character contrast, fill, extraneous marks, character field, and background haze.

The objective of this investigation was to establish the press quality due to the influence of pH and conductivity of fountain solution on dot circularity, line and text raggedness.

Materials and methods

Offset printing process. A four-colour offset printing press Heidelberg SM HD102VP, which prints in the sequences MCYK, was used as the investigated printing machine. Printing was done by CAPRICORN VT thermal positive offset plate (KODAK, Germany) which contained the CMYK colour strips, horizontal and vertical lines and serif and sans-serif text.

Thirteen printed sheets (samples 1-13) were collected from the delivery unit during the printing of 24,000 prints. Samples 1 and 13 were taken at the beginning and at the end of a print run, respectively. All other samples were collected once after every 2,000 prints. Sample 7 was taken at the half of a print run.

Fountain solution. The fresh fountain solution was prepared by mixing of 2% buffer (P56 Alkopufer, Cinkarna Celje, Slovenia), 12% isopropyl alcohol (P43 ISO fount, Cinkarna Celja, Slovenia) and 86% tap (untreated) water. The tap water, as the highest proportion ingredient in fresh fountain solution, was taken for the analysis.
Each fountain solution sample (1 to 13) was followed by the printed sheet and analyzed *in-situ*.

Fountain solution dosing system. The Baldwin circulating device equipped with a refrigerating unit and storage tank with an alcohol control (Balcontrol) have been installed on Heidelberg SM HD102VP offset printing press.

Before the printing, the mixture of buffer and tap water (fountain solution) flows through the feed line via the preliminary filter into the storage tank where alcohol is added from alcohol storage bottle (Balcontrol). Such prepared fountain solution is cooled by the cooling coils and its level in storage tank is controlled by the float valve. During the printing, the fountain solution circulates from the storage tank to the aggregates of printing press and the surplus of fountain solution flows back to the storage tank through an overflow pipe. The recirculated fountain solution which contains ink residue, oil, paper dust and spray powder is cleaned by the filter, which also serves to reduce the formation of foam.

Ink. During the printing two magenta ink samples (Inkredible RAPIDA F 10 RP, Huber group, Germany) were taken from magenta ink unit. Sample 1 was the reference magenta ink, whereas sample 2 was magenta ink at the half of a print run (sampled with sample 7 of fountain solution). The chemical composition of Inkredible RAPIDA sheet-fed offset ink specified by Huber group is presented in Table 1.

Table 1. Chemical composition of sheet-fed offset ink (Huber group, 2009)

Component	mass %
Pigment (organic and inorganic)	10 - 35
Carbon black	0 - 20
Resin	20 - 35
Vegetable oil	15 - 20
Mineral oil	15 - 20
Additives	>10

Paper. A glossy coated paper (BIOGLOSS, B&B Papirnica, Vevče) defined as Type I in ISO 12647-2 (ISO, 2004) was used for the printing process.

Elements for image quality assessment (IQA). CMYK colour strips with patches of 0, 2, 4, 6, 8, 10, 20 30, 40, 50, 60, 70, 80, 90, 92, 94, 96, 98 and 100% tone value, horizontal and vertical lines (1, 1.5 and 2 pt) and Times and Arial text (4, 5, 6, 7, 8, 9, 10, 11 and 12 pt font size) were used for the IQA test.

Methods

Measuring of pH and conductivity. During the printing process pH value and conductivity of fountain solution were monitored *in-situ* by HANNA handheld combo tester HI 98129 (USA). Also, the same instrument was used for pH, conductivity and total dissolved solids (TDS) measurement of tap water.

Measuring of hardness. The measurement of water hardness was conducted in the laboratory by using the standard analytical method.

Measuring of Ca^{2+} ion concentration. The Ca^{2+} ion concentration in tap water was determined by Inductively Coupled Plasma with Mass Spectrometry (ICP-MS), using a PerkinElmer Elan 5000 mass spectrometer (USA).

Elemental analysis of magenta ink. Scanning electron microscopy (SEM), SEM JEOL JSM-6460 LV with Oxford INCA Energy EDS system operating at 20 kV was used in order to determine the elemental analysis of magenta ink.

Image quality. Spectrophotometer SpectroPlate (TECHKON GmbH, Germany), flat-bed scanner CanoScan 5600F (Canon Inc., Canada), Adobe Photoshop CS3 and ImageJ (version IJ 1.45m) were used for IQA test. The IQA was carried out using the ISO 12647, ISO 13660 and ISO 19751 methodology in order to analyze the quality of dot, horizontal and vertical line, serif and sans-serif text style on thirteen printed sheets (samples) during the changes in fountain solutions quality.

Analysis of dot, line and text

Parameters, such as line and text raggedness and dot circularity were of interest in this study, since these parameters have an obvious and major influence on the quality of any print. The analysis required the usage of 'visual rulers' or 'ideal prints' (in our case it was original print layout) which were compared to the actual samples to check the significance of the generated data. As the actual samples it was used:
(i) the microscopic images of 30% CMYK tone value for the analysis of dot circularity and (ii) the scanned samples with 1200 dpi resolution for the analysis of line and text raggedness. After this procedure, the print defects are detected and quantified by the ImageJ software. It must be noted that 'paper' is neglected as an influencing parameter, because the same paper was used during the printing.

Results and discussion

Work experience has shown that the most common press problems in offset printing are pH/conductivity related. Therefore, in order to obtain the consistent, high-quality results in offset printing process it was essential to accurate control the physico-chemical parameters of tap water and fountain solutions during the printing. The values of conductivity and total dissolved solids (TDS) (Table 2) indicated that used tap water contains the significant amounts of dissolved ions, which is confirmed by hardness of 11°dH. Although the used water is hard, it is suitable for the offset printing process.

Table 2. Physico-chemical parameters of tap water

Parameter	Value	Unit
pH	7.49	-
Conductivity	497	μS/cm
Hardness	11	°dH
	196.9	mg/l $CaCO_3$
TDS	249	ppm
Ca^{2+} ion concentration	155.2	mg/l

The study showed that the values of pH and conductivity of fountain solution samples significantly varied during the printing (Figure 1) with the increasing tendency of both parameters in sample 7. The explanation for those phenomena is the fact that conductivity rises as the press runs due to increased contamination from inks, paper dust, metals particles of press/dampening system and atmospheric gases. Whereas, increasing of fountain pH value is caused by buffer capacity weakening during the interaction of fountain solution with paper, ink, plate coatings or metal offset plate. Higher print speed and interaction between the used materials during the reproduction process gradually increasing the fountain solution contamination in Baldwin system causing weakening of buffer capacity which was reflected through the slightly increasing of pH and conductivity in samples 1 to 6. Dramatically increasing of both parameters are observed at the half of a print run, sample 7, when buffer totally disappear from fountain solution. After that, the decreasing trend of pH and conductivity is observed in samples 8 to 13 due to the new quantities of buffer and tap water was dosed in Baldwin system, which significantly diluted the contaminated fountain solution and allowed its further usage in the printing process.

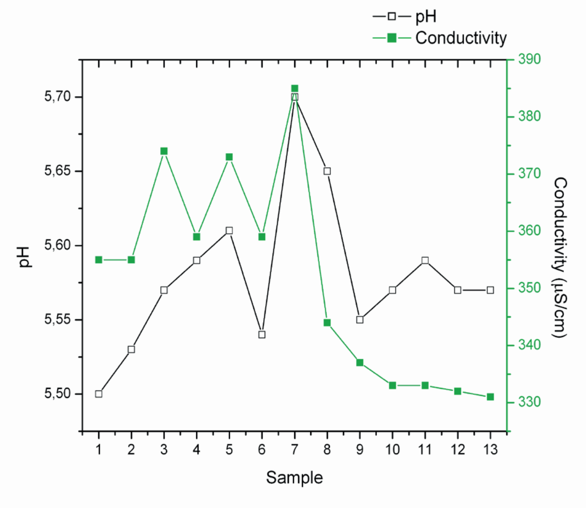


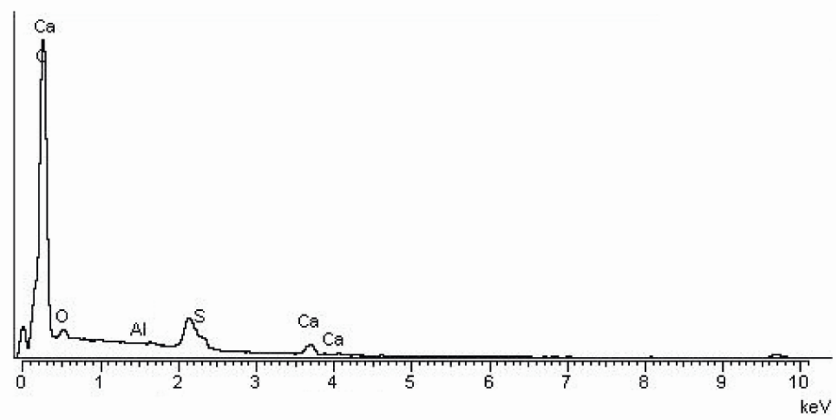
Figure 1. A correlations between pH and conductivity of fountain solutions (samples 1-13)

However, the most common reason for pH and conductivity changes is calcium carbonate. Therefore, in order to investigate a reason for the pH/conductivity changes in fountain solutions two magenta ink samples were analyzed by Energy Dispersive Spectroscopy (EDS). The obtained EDS spectra of the magenta samples, Figs. 2 and 3, showed that the dominant element in magenta ink formulation is calcium.

The EDS elemental analysis of the magenta samples indicated that the amount of calcium decreased in magenta sample 2 due to the higher interaction between magenta ink and fountain solution on the press, which caused calcium ions to be absorbed into the fountain solution. Exactly this phenomena, so called saponification of magenta ink, slightly increases pH (up to 5.61) and conductivity (up to 374 µS/cm) of fountain solutions (samples 1 to 6), and dramatically increased in sample 7. In samples 8 to 13 pH and conductivity have decreasing trend. Based on obtained experimental data it can be concluded that calcium ions from magenta ink affect the quality of fountain solution by causing a change in fountain solution quality parameters during the printing.

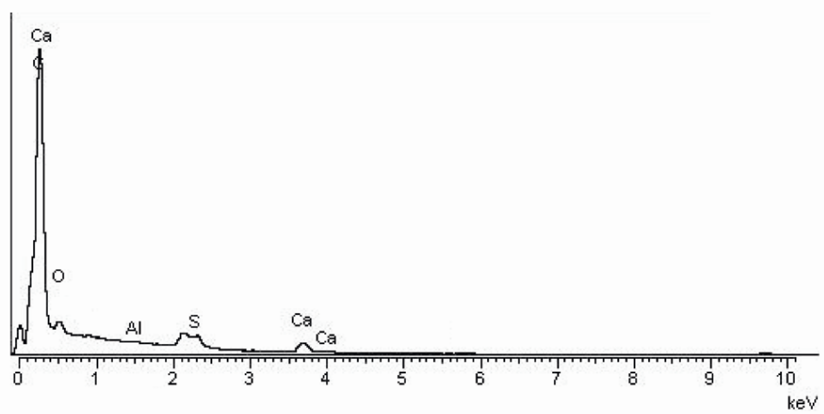
Dot quality

One important factor for print quality is the sharpness and contrast of halftone dots that are used to print continuous-tone images. The sizes of the dots on the prints must not be significantly modified, i.e. they must not



Element	mass %
C	88.66
O	9.49
Al	0.09
S	0.84
Ca	0.92

Figure 2. EDS elemental spectrum of reference magenta ink (sample 1)



Element	mass %
C	85.68
O	12.35
Al	0.09
S	0.80
Ca	0.87

Figure 3. EDS elemental spectrum of magenta ink at the half of a print run (sample 2)

change either the size or their ideal geometrical shape (circularity). The results of dot circularity in this investigation showed the deviations from circularity (ideal value 1) for all colours (CMYK) during a print run (Figure 4). Yellow dots were the most ragged and had irregular, distort shape with circularity less than 0.44 and standard deviation (SD) up to 0.08. The best circularity was observed for black and cyan dots, whereas the magenta dots showed the significant decreasing and increasing of circularity during a print run.

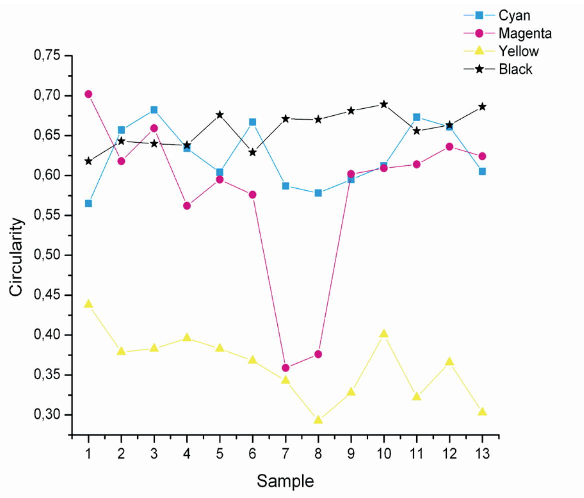


Figure 4. Dot circularity changes during a print run

Although, there was observed the changes between the cyan, yellow and black dot circularity and printed sheets (1 to 13), but theirs mutual dependences could not be described by any of the function. While the non-linear dependence, described by second-order polynomial, was existed between the magenta dot circularity and printed sheets (1 to 13). The dependence of magenta dot circularity on samples of printed sheets with the equation curve: $y = 0.00514x^2 - 0.07524x + 0.78238$ is presented in Fig. 5. This correlation is weak: correlation coefficient, $R^2 = 0.4527$; standard deviation SD = 0.08.

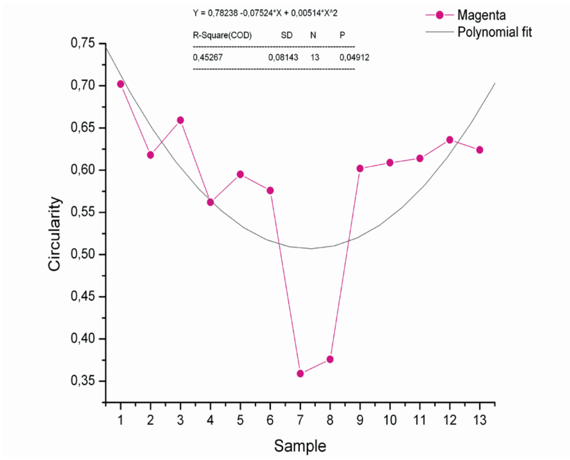


Figure 5. Magenta dot circularity dependence on samples of printed sheets

The comparison of the curves from Figs. 1 and 5 indicated that magenta dot circularity could be in the correlation with pH and conductivity during a print run, i.e. increasing of pH and conductivity caused decreasing of magenta dot circularity, and vice versa. The reason for these correlations was calcium ion and its concentration changes (amount of salt) in magenta ink during the printing.

Experimental data indicated that dot reproduction was not consistent during a print run due to the high standard deviation (up to 0.08) and the dissimilarity of dot shape.

Line and text quality

As an image quality must not be judged based on a single entity such as dot circularity, the reproduced line and text must be considered. Line and text analysis is easier since they primarily depended on the value of 'raggedness' (the geometric distortion of the edges of the line and text). Since ISO 13660 standards (ISO,

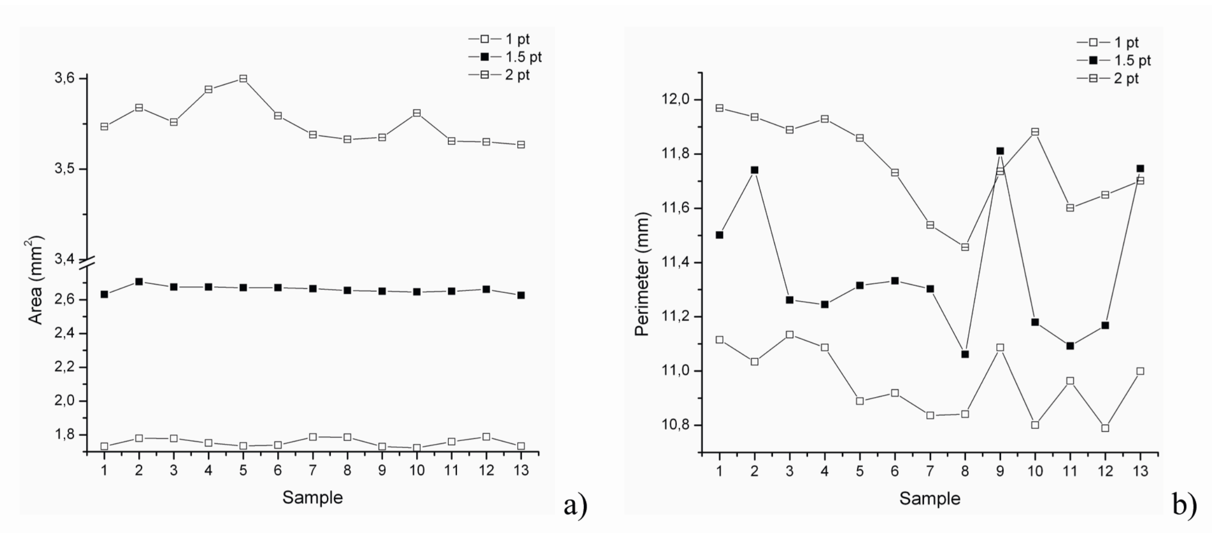


Figure 6. Vertical line raggedness as a function of: a) line area and b) line perimeter (black colour)

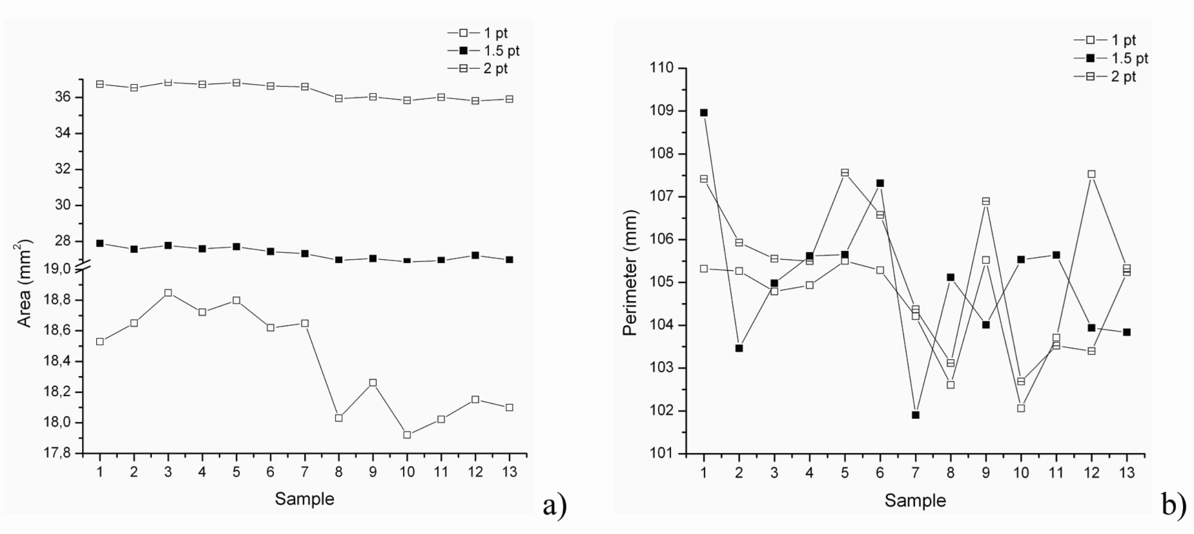


Figure 7. Horizontal line raggedness as a function of: a) line area and b) line perimeter (black colour)

2001) defines only the minimum length of line (1.25 mm) in this study the analyzed horizontal lines were longer than vertical. A good quality line and text is described as the one having the least raggedness and sharp edges.

Considering the results it was showed that the area and perimeter of analyzed lines increased during the printing due to the ink smearing on the line edges (Figs. 6 and 7). The results of line area (Figs. 6 a and 7 a) for black color indicated that vertical 1.5pt line (with 2.2 to 5.3% area increase) and horizontal 1.5pt line (with 6.4 to 10.5% area increase) had the most raggedly edges.

Line raggedness as a function of line perimeter, Figs. 6 b and 7 b, showed also that vertical 1.5pt line (with 2 to 8.9% perimeter increase) and horizontal 1.5pt line (with 2.4 to 7.8% perimeter increase) had the most raggedly edges. The possible reason why line of 1.5pt had the most raggedly edges (regard to lines of 1 and 2pt) is the damaged blanket in the region of printed 1.5pt line, which caused addition ink smearing on line edges. In the both cases, the least raggedly edges are obtained on the tiny horizontal and vertical lines (1pt).

The text analysis also showed that the text area increased during the printing due to the ink smearing on the text edges (Figure 8 a, b). If visually checked, all the prints with a text value up to 12 units showed no eye visible difference, but when magnified they look raggedness. For the serif font, Figure 8 a, the least raggedness is observed with 10pt font size (up to 7.6% area increase); whereas 5pt font size had the most raggedly edges (up to 41% area increase). The sans-serif font (Figure 8 b) showed significantly better results in comparison with the serif font. The least raggedness is observed with 9pt font size (up to 5.3% area increase); whereas 4pt font size had the most raggedly edges (up to 12.4%).

The similar curves are obtained for cyan, magenta and yellow printed lines and text, and therefore it was irrelevant whether the results of magenta or black, yellow and cyan are shown. Experimental data indicated that between line and text on printed sheets and pH and conductivity of fountain solutions did not exist the mutual dependences.

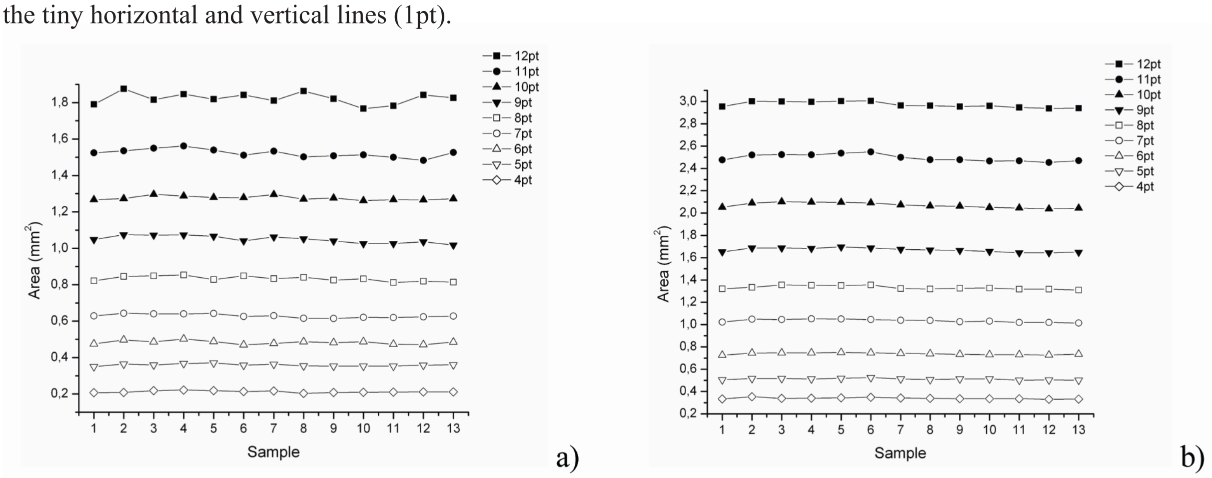


Figure 8. Text raggedness: a) Times and b) Arial font

Conclusion

The experimental data indicated that the values of pH and conductivity of fountain solution significantly varied during the printing with the increasing tendency of both parameters in sample 7 due to the higher interaction of fountain solution with ink and absorption of calcium ions into the fountain solution. The changes of calcium mass share in used magenta inks were confirmed by EDS characterization.

Although the measurements in ImageJ software showed the considerable deviation of yellow and magenta dot circularity, only between magenta dot circularity and the samples was existed the mutual dependence, second-order polynomial, described by equation: $y = 0.00514x^2 - 0.07524x + 0.78238$.

The optimal prints were obtained with black and cyan, i.e. these prints showed the lowest tone value increase and the higher value of dot circularity. The geometric distortion of the printed line and text was also identified. The line analysis showed that 1.5pt horizontal and vertical lines had the most raggedly edges, whereas the least raggedness was obtained with 1pt horizontal and vertical lines. The sans-serif font, Arial, showed the least raggedly edges in all range of font size (4-12pt), in comparison with Times.

The results showed that pH and conductivity changes in fountain solutions only influenced on magenta dot circularity, whereas they have not influenced on line and text raggedness.

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