STUDY OF WETTING ON THE NON-IMAGE AREA OF OFFSET PRINTING PLATES BY AN ALTERNATIVE ISO-PROPYL ALCOHOL-FREE FOUNTAIN SOLUTION

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Abstract

In this study, an alternative aqueous isopropyl alcohol-free fountain solution for sheet-fed offset printing is prepared comprising 5 w/w% McIlvaine's buffer system for pH control, 0.3 w/w% Polysorbate 80 as a surfactant, 1 w/w% magnesium nitrate hexahydrate as a conductivity agent and 10 w/w% ethylene glycol mono-butyl ether as an additional wetting agent. The percentages of each composition are w/w% of active and then adjusted to 100 w/w% by adding distilled water. The contact angles of the obtained fountain solution on non-image areas of three common offset printing plates: CTP plate of Kodak, CTP plate of Huaguang Graphic Co. Ltd (China), and CTP plate of Mylan Printing Media Co. Ltd (Vietnam), range from 10° to 20°.The surface tension, conductivity, pH and viscosity were found to be 30.5 mN/m, 1.45 mS/cm, 4.8, and 1.05 x 10^{-2} g/cm.s, respectively. In comparison to the commercial fountain solution (KF – Trade Mark (China) containing isopropyl alcohol (IPA), the obtained fountain solution shows similar wettability on the non-image area of the offset printing plate whilst having similar physico-chemical parameters. The results indicate that ethylene glycol mono-butyl ether could be a potential substitute for IPA in fountain solution in offset printing, and the obtained fountain solution displays suitable properties for the offset printing process.

Keywords: Contact angle, Fountain solution, IPA, Offset printing, Wettability

Introduction

Offset printing is an indirect printing technique in which the inked image is transferred (set off) from the printing plate via a blanket onto a printing substrate [1-3]. Offset printing is a lithographic process in which the image and non-image areas are defined based on the difference of wettability between ink and aqueous fountain solution on the printing plate. The offset printing plate is basically formed from a micro-roughened aluminum substrate having a photosensitive coating [4]. After image setting exposure and a subsequent developing process, image areas and non-image areas are created on the surface of offset printing plate. The image area is hydrophobic (lipophilic) and readily receives oil-based inks. In contrast, the non-image area is hydrophilic and readily wetted by the water based fountain solution [5, 6].

A fountain solution generally contains the following major ingredients: a water solute gum, a pH buffer system, wetting agents, emulsion control agents, including solvent in the form of water. Actually, fountain solution that has only these compounds proves difficult to create a uniform fountain film on the non-image areas of a printing plate. To overcome these problems, fountain solution is combined with about 8 w/w% to 25 w/w% of isopropyl alcohol (IPA). Using IPA delivers advantages such as providing a good wettability of the printing plate surface, while increasing a viscosity of the water phase, lowering dynamic surface tension and stabilizing the ink/water balance [7]. However, using IPA also has many negative effects on the offset printing process. IPA reduces the solubility of Ca^{2+} ion, for example, causing starvation (ghosting) and breaks down the adhesion of printing ink when using too much IPA [8]. Moreover, IPA is characterized in the category of volatile organic compounds with both health and environmental risks [9].

One of the possibilities is to adopt substitutes such as one or more surfactants, including, for example, ethoxylated linear alcohol [6], or a specific polymer synthesized by ethylene monomer in the presence of a multifunctional thiol group. Uchida *et at.* indicated that a water soluble organic solvent can be used as IPA substitute in fountain solution of offset printing technology [10]. Another possibility is the use of a ceramic filter system to prevent rapid contamination and so keep the fountain solution clean over long print runs [9]. However, these alternative formulations still suffer from drawbacks, such as the high cost and poor wettability of fountain solution, especially in the case of printing on coated papers.

A lot of research about wetting phenomena of fountain solution on surfaces having controlled roughness such as coated papers and various printing plates has been published over many years. Tag *et al*. has interpreted the influence of the physico-chemical properties of coated papers on the wetting kinetic of a fountain solution on-press [11, 12]. The effects of a fountain solution on surface chemical properties and the surface energy of coated paper has also been reported [13, 14]. Pavlovic *et al*. studied the effect of the roughness on printing quality and the stability of the printing plate [4, 15]. Arif Ozcan indicated that printing tests using IPA-free fountain solution gave a better and wider color gamut than those of IPA-based fountain solution [16].

In this study, a fountain solution with ethylene glycol mono-butyl ether (EGME) as the IPA substitute was prepared. The main contents of fountain solution, such as buffers, surfactant, conductivity agent and wetting agent were investigated. The physico-chemical parameters of the solution obtained were measured and compared with those of a commercial fountain solution with IPA. The wettability of the proposed alternative fountain solution on some available types of offset printing plates is also investigated.

Material and Methods

A fountain solution was prepared by physically mixing the constituents until homogeneous. The surfactant used in this study was non-ionic Tween 80. Magnesium nitrate hexahydrate was used as a conductivity agent. Ethylene glycol mono-butyl ether (EGME) was used as the IPA substitute. All chemicals were purchased from Sigma Aldrich.

Preparation of Buffer Solutions

pH was controlled by using McIlvaine's Buffer System (made from 1.4 g of disodium phosphate and 1.94 g of citric acid in 200 g of distilled water). The pH value was measured by an HI-8314 (Hanna Instruments) pH meter. The buffer solution was fixed at the pH level of 4.80. Results of the buffer capacity are shown in Figure 1.

Effects of Surfactant

The surfaces become saturated by increasing the surfactant concentration. Then the surfactant molecules in solution start associating to form micelles. This concentration is referred as the critical micelle concentration. Polysorbate 80 was investigated for its effect on surface tension ranging from 0.01 to 0.3 w/w% concentration. Meanwhile, EGME was investigated similarly over a range from 0.5 to 13.0 w/w% concentration. The surface tension was determined using the DST 30 Digital tensiometer (SEO-Korea) based on the du Noüy ring method. Results of critical micelle concentration are showed in Table 1.

Wettability on Offset Plates

In this study, the wetted materials are offset printing plates and the wetting behavior of a liquid on the plates could be determined by contact angles. Offset plates from computer-to-plate (CTP) systems were used as commercially available from a number of producers, namely Kodak, Huaguang Graphic Co. Ltd. (China) and Mylan Printing Media Co. Ltd. (Vietnam), respectively. All plates are thermal positive printing plates of 0.3 mm thickness, with outputted images by Screen PlateRite 8800 CTP Imagesetter. This system uses an IR laser with 830 nm wavelength and 140 mJ/cm^2 energy as exposure irradiation. Exposed areas of the photosensitive layer were removed from the plate by chemical processing in alkaline developer - in this case GSP 100 of Mylan Group. The developing process was taken in an offset processor HD 85 of Glunz & Jensen at a temperature of 22.5 $^{\circ}$C with the processing speed of 0.9 m/min, before studying the wettability of the obtained solution. Then, a contact angle was determined by capturing a liquid droplet shape on the solid surface and referred to the standard sessile drop shape analysis method [17]. A droplet of the studied fountain solution (~ 2 μL) was pumped by micro syringe onto both non-image area and the image area of the offset printing plates was captured by high quality imaging camera. The captured images were processed by ImageJ software. The contact angles of the test fountain solutions and the commercial fountain solution on three different offset printing plates were measured at five different positions and average values reported. Examples of the obtained droplet behavior on the non-image areas of the Kodak offset printing plates are shown in Figure 2, and results from all the measured samples are shown in Figure 3 and Figure 4.

Finally, the commercial fountain solution (KF – Trade Mark (China)) was used to compare with the studied fountain solution via physico-chemical properties. The conductivity and viscosity of commercial fountain solutions were measured, respectively, by a Meterlab CDM210 conductivity meter and a glass capillary viscometer from Cannon Instrument Company (USA).
* All experiments were carried out at 25 $^{\circ}$C.

Results and Discussions

Buffer Solution System

In the offset printing process, the fountain solution is contaminated by paper coating, inks, wash-up solution, and other extraneous contaminants. Therefore, pH of fountain solution generally increases [8, 18]. The chosen buffer system is intended to keep the pH value of the fountain solution at the ideal balance of 4.5 to 5.5. The buffer solution capacity was measured using additional volumes of 0.1 M NaOH. The results show that in 100 ml buffer solution, pH value changes from 4.8 to 5.63 when adding 35 ml of NaOH (see in Figure 1). The buffer capacity of the solution is around 30%, is therefore lightly good and sufficient for the process.

Determination of Critical Micelle Concentration of Polysorbate 80 and Ethylene Glycol Mono-butyl Ether

Surfactants play an important role of decreasing surface tension, emulsifying printing ink, and improving wettability of fountain solution. These properties of surfactant link directly to their critical micelle concentration (CMC). CMC values of Polysorbate 80 and Ethylene glycol mono-butyl ether follow the order of 0.3 w/w% and 10 w/w%, respectively (see in Table 1). Simultaneously, at these critical micelle concentrations, the surface tensions of Polysorbate 80 solution and ethylene glycol mono-butyl ether were 34.4 mN/m and 27.5 mN/m, respectively. The obtained solution has surface tension close to that of the ideal fountain solution, typically 30 mN/m. Therefore, the fountain solution readily wets out non-image areas on the offset printing plate.

In offset lithography, an ink, from the ink supply fountain, is transferred from roller to roller, until the ink reaches the plate and finally the blanket from which it was printed to the substrate. When ink arrives from the form roller, it comes under pressure along with the non-image area fountain solution in the nip. At the backside of the nip, the layer of ink and the fountain solution split at the weakest point in the film, i.e. within the fountain solution. This process, therefore, tends to form a residual thin film of fountain solution on the non-image area and also a similar layer on the ink form roller. When the ink film splits from the plate, the fountain solution left on the ink form roller forms reticulate beads, which then come into the ink, emulsifying it [1].

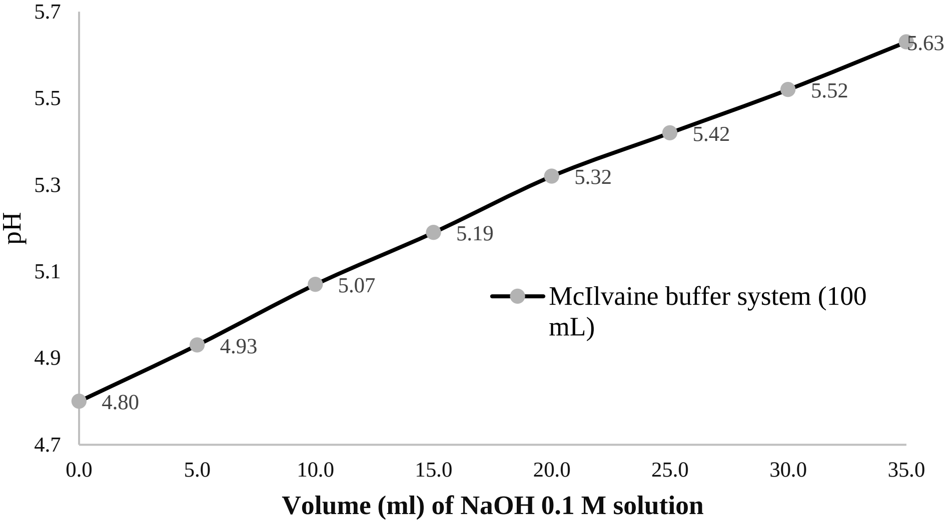

Figure 1. Buffer capacity of the obtained solution

Determination of the Contact Angel of the Obtain Solution When Using Ethylene Glycol Mono-butyl Ether

The investigations results show that the contact angle of fountain solution on the non-image area of the offset printing plate decreases linearly with increasing ethylene glycol mono-butyl ether concentration (see in Figure 2). The contact angle is 10.4° when ethylene glycol mono-butyl ether concentration is 10 w/w%. Consequently, ethylene glycol mono-butyl ether helps to increase the wettability of the fountain solution. This can be explained as follows: ethylene glycol mono-butyl ether is an organic solvent that contains both an ether function group and an alcohol function group in its molecular structure. When it is dissolved in aqueous medium, these function groups connect with H_2O via hydrogen bonds. This causes ethylene glycol mono-butyl ether to have hydrophilic properties. However, with the long structure of the hydrocarbon chain, it is also capable of solubilizing oil (see in Figure 3).

Aluminum foils were used as the based layer in the structure of lithographic printing plates. This layer was roughened by electrochemical graining and anodic oxidation to form a thin aluminum oxide film. This helps the surface of the lithographic printing plate to adsorb better the fountain solution as well as the photosensitive coating [15].

Table 1. Critical Concentration of the Surfactants

Surfactant	Surface Tension, (mN/m)	Hydrophilic-Lipophilic Balance, (HLB)	CMC (w/w%)
Polysorbate 80	34.4	15	0.3
EGME	27.5	9	10

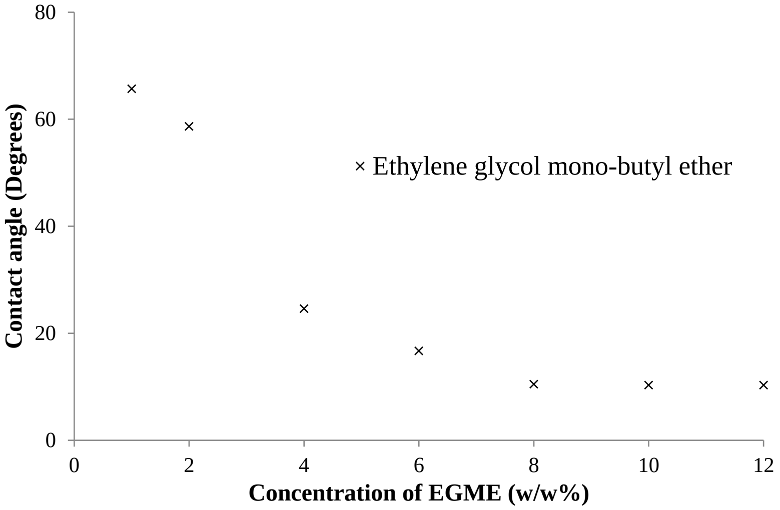

Figure 2. Contact angles of the fountain solution with the offset printing plate for different concentrations of EGME

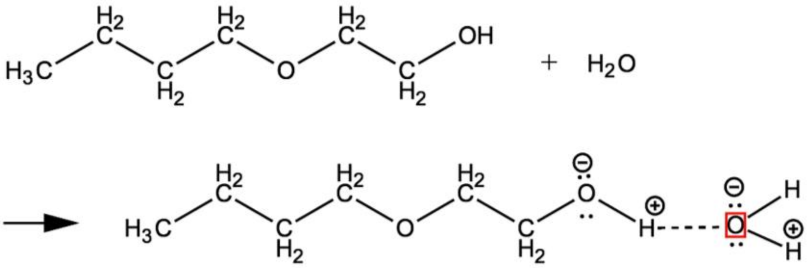

Figure 3. Ethylene glycol mono-butyl ether dissolves in water

With the low contact angle (~ 10.4°) the alternative fountain solution rapidly lay down a thin and uniform film of water across the plate surface (see in Figure 4). The results of contact angle measurements of the obtained solution on the non-image areas of the three different CTP plates show that it is capable of good wetting (contact angle below 20°). The CTP Kodak offset plate displays a lower wetting contact angle than those of both the Huaguang CTP plate and the Mylan CTP plate. The measured results of the commercial fountain solution using IPA show the similar wettability of CTP Kodak offset plate (see in Figure 5). This behavior of the CTP Kodak offset plate for wettability indicates the role of the average roughness parameter value as well as surface energy of the printing plate, in that the CTP Kodak plate has both higher the average roughness parameter value and surface energy than those of the Huaguang CTP plate and the Mylan CTP plate [15].

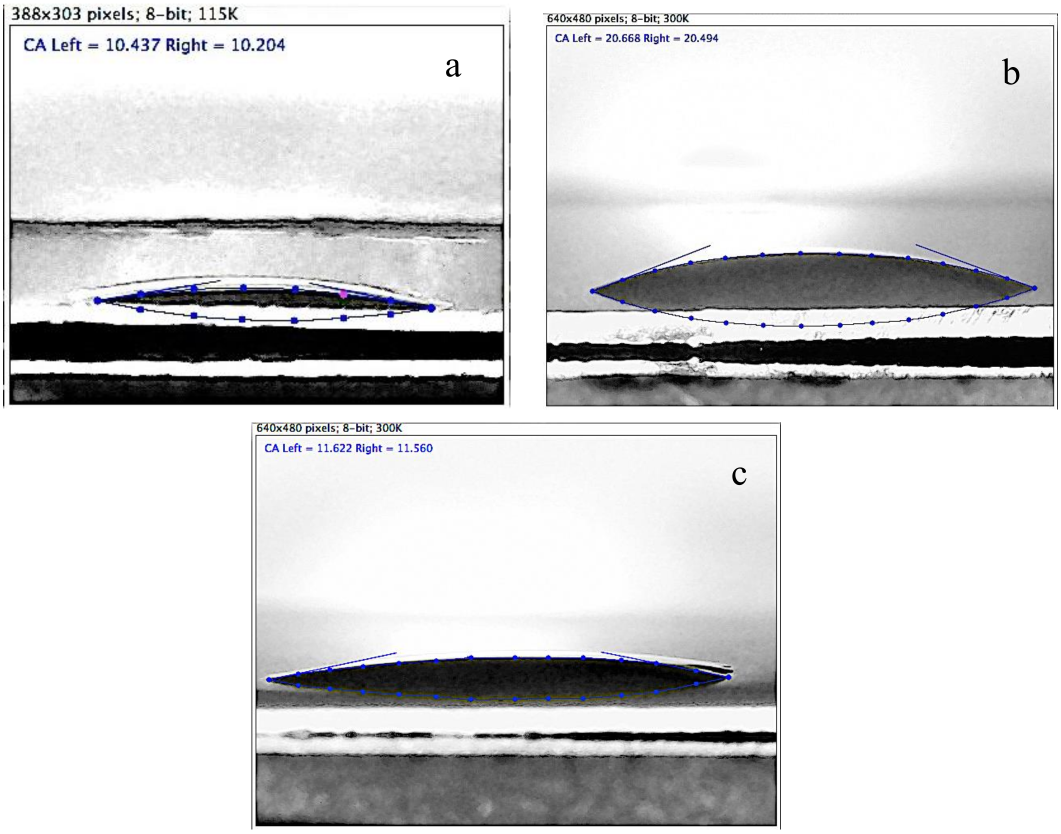

Figure 4. Images of the contact angle of the obtained solution on non-image area of the CTP offset plates; a) Kodak CTP offset plate, b) Huaguang CTP offset plate, c) Mylan CTP offset plate

Table 2. The Physico-chemical Parameters of The Alternative Solution Compared With The Commercial One Adding IPA at 10 w/w%

Parameters	Types of Investigated Offset Plate	The Alternative Fountain Solution	The Commercial Fountain Solution Adding IPA 10 w/w%
Conductivity, mS/cm	-	1.45	1.65
pH	-	4.8	5.2
Surface Tension, mN/m	-	30.5	32.5
Contact Angle (°)	Kodak CTP plate	10.4	7.5
	Huaguang CTP plate	20.6	15.5
	Mylan CTP Plate	11.7	12.3
Viscosity, ($\mathrm{x}10^{-2}$g/cm.s)	-	1.05	1.03

Comparing with commercial fountain solution containing IPA the alternative solution with ethylene glycol mono-butyl ether shows the similar wettability on the plate surface (see in Figure 5). Moreover, the physic-chemical parameters of the obtained fountain solution are equivalent to those of the commercial one (see in Table 2).

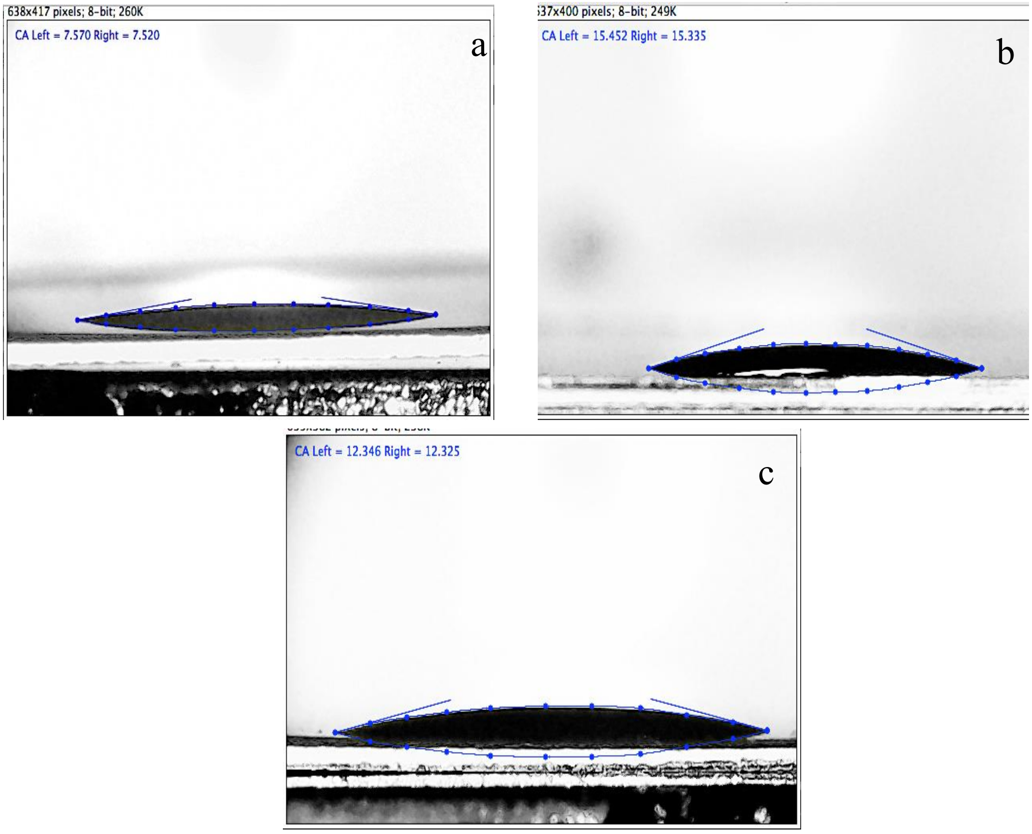

Figure 5. Images of the contact angle of the commercial fountain solution on non-image area of the CTP offset plates; a) Kodak CTP offset plate, b) Huaguang CTP offset plate, c) Mylan CTP offset plate

In the offset printing process, forming a uniform film of water on the plate surface is an important function of the fountain solution. Practically, the thickness of fountain solution film on the non-image area is 0.5 - 1.0 µm. When an offset printing press is running, the fountain solution is evaporated from the plate surface or absorbed, mostly by permeating under pressure into substrate materials (printing papers). Therefore, the fountain solution is applied continuously to compensate for these lost amounts. In an ideal condition, the fountain solution being added exactly equals that which is being removed by the plate.

In fact, fountain solution has to be under the good stability of the ink-fountain solution emulsification besides being good wetting on the non-image areas of offset plates. The ink-fountain solution emulsion properties are characterized by many factors such as the water pick-up ability of sheet-fed offset ink, and ink's response due to addition of fountain solution in tack value and rheology properties. These factors are important subject works before applying to a printing press.

Conclusions

Concluding, the results of this study show that the obtained alternative proposed fountain solution using ethylene glycol mono-butyl ether as the IPA substitute has increased the wettability compared with a commercial fountain solution with IPA. This substitution substance for IPA has a low evaporation rate and good solubility. Moreover, the alternative proposed fountain solution delivers similar physico-chemical properties to those of the example commercial one, whilst potentially enhancing a safe working environment in the vicinity of an offset printing.

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