Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 45 No. 3 (2024)

Investigation of the influence of different Isopropyl Alcohol (IPA) percentages in offset lithography and its impact on print parameters

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Abstract

Isopropyl alcohol, or IPA, is extensively used in the fountain solution for offset printing in India. However, printers use varying amounts of alcohol in the fountain solution. This work aims to analyze the influence of different IPA proportions on print quality, providing practical insights for the industry. The research involved the meticulous preparation and testing of three fountain solutions containing 5%, 8%, and 12% IPA samples. The lab tested these solutions to measure their pH, conductivity, surface tension, water pick-up by emulsified ink, wet pick, wet repellence, and dynamic penetration. The lab tests recorded the values, which were later correlated with the results of press trials conducted on a 4-color Mitsubishi press using a specially designed 4-color sheet-fed test form. The press trials were performed using the three samples of fountain solutions, and ink and dampening duct rotations were recorded to note the amount of ink and fountain solution used as the percentage of IPA was increased. This was followed by densitometrical and visual analysis of the print samples to study the effect of changes in IPA proportion on print quality. The primary aspect of printing influenced by IPA was the ink-water balance and, consequently, water-interference mottling. Graphs were plotted for density, dot gain, contrast, and trapping, directly comparing 5%, 8%, and 12% IPA and establishing specific, consistent trends with the increasing IPA proportion. The final print results for the mottling index were checked with the PapEye Mottling Analysis tool. The samples showed a lower water supply and less IPA could prevent water-interference mottling, offering practical solutions for print quality improvement.

Introduction

A distinctive feature of the offset lithography process is the fact that the printing and non-printing areas on the printing plate are on the same level. A very thin film (approximately 2 microns) of fountain solution is applied to the entire plate by the dampening unit to separate these areas [1]. The fountain solution contains a wetting agent, Isopropyl alcohol (IPA), having a chemical formula of (C_3H_8O). It is a colorless liquid that is fully miscible in water. [2] It helps reduce surface tension and promotes film formation in the dampening unit. [3] Lowering the surface tension helps to spread the fountain solution evenly on the plate's surface. However, it is important to control the amount of IPA in the fountain solution, as too much of it can lead to poor ink transfer onto the paper substrate, resulting in an uneven print ink film.

Acidic fountain solutions are typically designed to operate within a pH range of 4 to 5.5. During printing, the fountain solution absorbs impurities from the paper and ink, many of which are alkaline and can increase its pH. However, modern acidic fountain solutions have a buffer system to counteract these impurities and maintain a stable pH. This buffering action helps prevent the paper and ink from affecting the pH balance. Conductivity measured in micro siemens, is important while preparing a fountain solution because it helps to measure the amount of fountain concentrate in millilitres/litres mixed with water. It is recommended that the conductivity of the fountain solution be measured. Water has a surface tension of 72 mN/m. Water is the main component of the fountain solution. Using plain water with higher surface tension does not allow for good wettability. Lowering the surface tension of the fountain solution improves its wettability. Adding fount concentrate and IPA to water helps to lower the surface tension, thus improving wettability.

When a liquid droplet is applied to a solid material, an angle is formed at the point of contact between the droplet and the solid, known as the wettability angle or contact angle. This contact angle indicates the wetting performance of liquids applied to solids [4]. However, adding excessive IPA does not further reduce the surface tension. Dynamic Absorption Tester (plate_number_1, Fibro System AB) helps to measure the surface tension and contact angle. The surface free energy can be increased (corona treatment), or a combination can be used. The wetting process starts when the lowest part of the liquid drop first contacts the paper. The liquid spreads over the surface and penetrates the porous paper [5]. The fountain solution is transferred to the paper from a blanket in offset printing. This fountain solution must disappear from the surface before the paper enters the next printing nip. Hence, initial penetration is very important in this printing process. Penetration is controlled by the fountain solution's surface energy, paper roughness, and surface tension. Contact angles of fountain solution droplets on paper depend not only on the surface free energy. Still, they are also influenced by the paper's porosity and the pores' size.

The surface of the paper is the main carrier of the print. Paper smoothness and absorbency are key parameters in print quality [6]. An ideal paper surface for printing should be able to accept, retain, and present the ink to the observer in the best possible way. The porous structure of paper is complex due to the irregular shapes of pores and the interconnection between them. The paper is wetted not only by the emulsified ink but also by the fountain solution. The film of the fountain solution remaining on the paper can cause issues such as ink repellence and water interference mottling in multicolour printing. When the fountain solution is transferred onto the paper, it is pushed into the voids on the paper's surface. Some of it penetrates the porous structure of the paper, while the rest remains on the paper [2]. Mottling is a printing defect caused by uneven ink distribution on the paper's surface, resulting in an uneven appearance. It can be influenced by factors such as ink colors, fountain solutions, and printing press construction. Mottling is caused by paper and ink quality or the printing process and can result in uneven coverage of the paper surface by ink [7]. Proper selection of ink with the surface characteristics of the paper and appropriate adjustments in the press, such as pressure between the cylinders, ink sequence, and viscosity, need to be considered to manage print mottle. The fountain solution and its contents also play a crucial role in print mottle [8]. Our work aimed to investigate the performance of different IPA % added to fountain solutions and measure its impact on various physical parameters and print parameters such as density, dot gain, print contrast, and trapping.

Materials And Methods

Lab tests

Ph, conductivity, water uptake, and surface tension are a few parameters that help control acidic level, contamination and flow, emulsification, and the wettability of the fountain solution during printing. With the addition of IPA to the fountain solution, the behavior of these parameters, such as pH, conductivity, and surface tension, may change. Hence, it is important to measure their performance. pH meter, conductivity meter, Duke’s Emulsification Tester, and Dynamic Absorption Tester were used to calculate the pH, conductivity, and surface tension of the fountain solutions prepared.

Offset Lithography Press and Prepress Specifications

The printings were carried out in three series of tests in order on four colors Mitsubishi. The first Series of Tests was performed with Fountain Solution with 5% IPA. The fountain reservoir was filled with a fountain solution - Tap water + Fount concentrate + IPA in the proportion 100: 2: 5. This was continued by a second series of tests, which was performed with Fountain Solution with 8% IPA. Three liters of IPA were now added to the Fountain Reservoir to contain the fountain solution - Tap water + Fount + IPA in the proportion 100: 2: 8. The continuous third series of tests was carried out with fountain solution with 12% IPA by further adding 4 liters of IPA to follow the proportion of Tap water + Fount + IPA- 100: 2: 12. For each series of tests, after achieving the target ink densities, ink and dampening duct rotations of each color unit were recorded to take into account the amount of ink and fountain solution taken up during the trial.

Press and Prepress details	Specifications
Machine used	Mitsubishi Diamond 1000 LS – 4 Color Sheetfed
Machine Specifications	Machine Size: 600mm × 730mm, Plate Size: 600 mm × 730 mm, Gripper: 48mm
Screen frequency and dot shape	175 lines per inch and circular dot
Substrate Used	Sappi Matt (130 GSM)
Ink and Fountain Solution Used	Huber group

Design and Layout of Test Chart

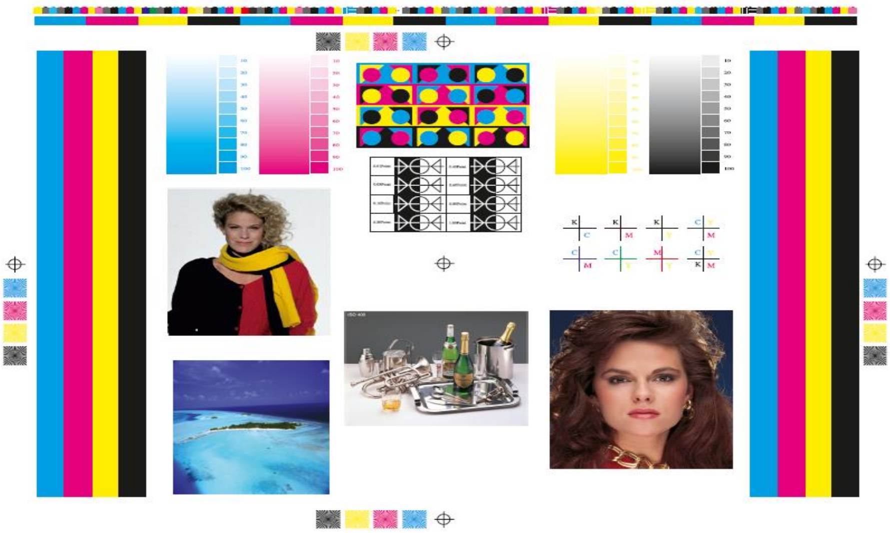


Figure 1: Test chart comprising of different elements to test print parameters

A test chart (Figure 1) was designed to analyze the print parameters during printing, such as solid ink film density and dot gain. The test chart comprised various test elements such as images with skin tone, a step wedge starting from 10% with an increment of 10 up to 100% solid patches, and images.

Results And Discussion

Effect of IPA percentage on pH

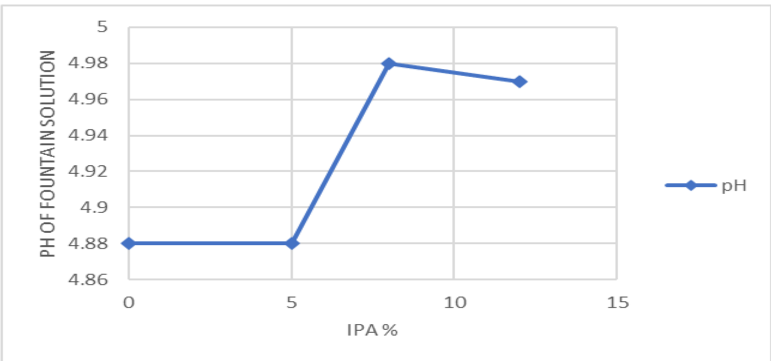


Figure 2: Relation of IPA% and pH of fountain solution

Figure 2 shows that since fountain solutions are buffered, there is not much change in pH even after increasing the IPA proportion.

Effect of IPA percentage on conductivity

Figure 3: Relation of IPA % and Conductivity of fountain solution

The conductivity of tap water is low, which increases with the increasing additive but declines with the increasing IPA. Note that after a certain limit, conductivity does not decline even with increasing IPA (Figure 3).

Effect of IPA Percentage on Surface Tension

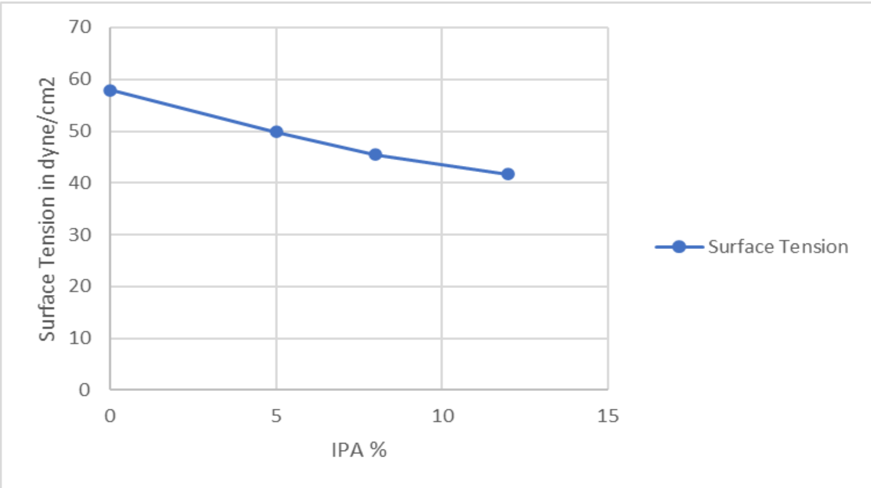


Figure 4: Relation of IPA% and Surface Tension of fountain solution

Surface tension falls as the fount concentrate increases (Figure 4), but it can be lowered further by increasing IPA proportion beyond a specific limit.

Water pick-up by the ink on a Duke Emulsification Tester

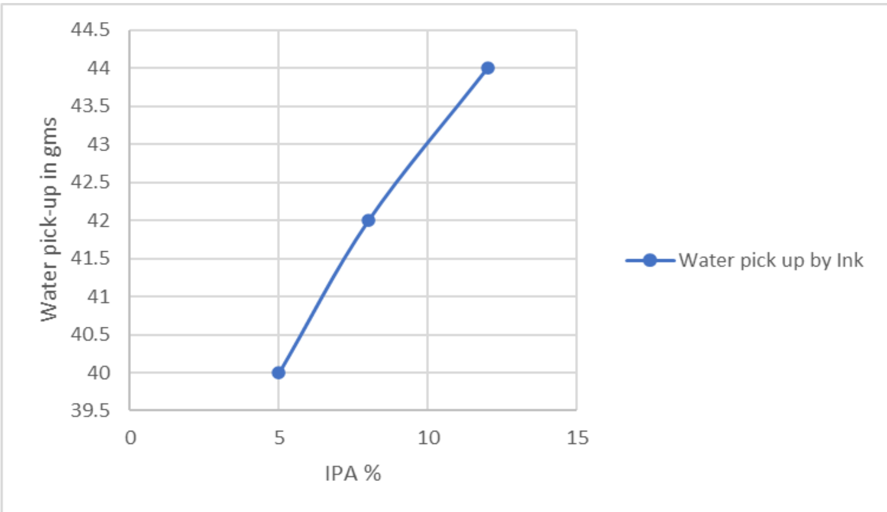
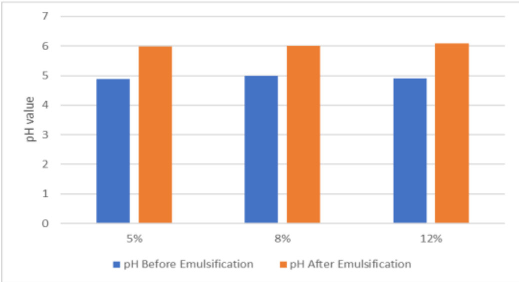
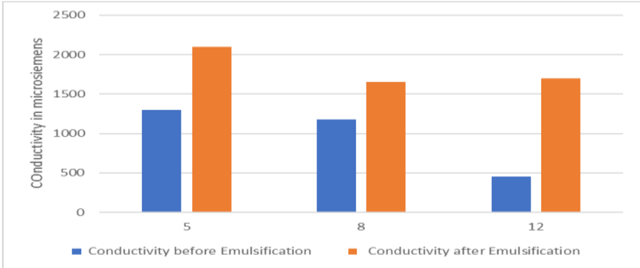


Figure 5: Relation of IPA% and water pickup

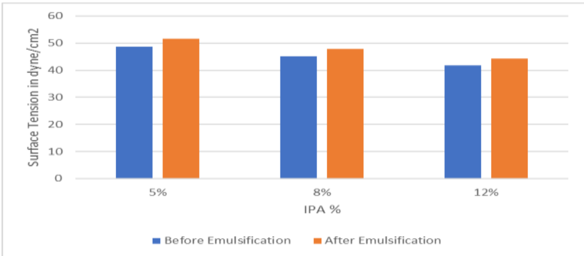
The above graph in Figure 5 shows the water-pick-up values of Cyan ink. Higher IPA% has higher water pickup.

Comparison of pH, conductivity & surface tension -Before and after emulsification





a) b)



c)

Figure 6 Relation of IPA% and Fountain solution's (a) pH, (b)conductivity, and (c) surface tension before and after emulsification at 5%, 8%, and 12 %

Normally, we measure the fountain solution's pH, conductivity, and surface tension before it is used on the press, and we consider it the final one. But its chemistry changes on press when it comes in contact with ink. Due to the shear action of rollers and plate cylinders, some ink components get mixed with the fountain solution. So, the product we get from this action can be called an emulsified fountain solution [9]. Consider the properties of this emulsified fountain solution as important as an emulsified ink because the emulsified fountain solution will be transferred to the blanket cylinder and then onto the paper [10]. After emulsification, the actual change in surface tension of the fountain solution will decide its transfer from plate to blanket and then to paper. The test we conducted (Figure 6) shows that pH, conductivity, and surface tension all increase after interacting with the ink, i.e., after emulsification.

Effect of the addition of IPA on the ink and fountain solution required during printing

The printing was carried out in three tests on a four-color Mitsubishi press. The first test was performed with

- Fountain Solution with 5% IPA. The Fountain Reservoir was filled with a fountain solution of tap water + Fountain Concentrate + IPA in the proportion 100: 2: 5.
- Followed by a second series of tests performed with Fountain Solution with 8% IPA. Three liters of IPA were added to the Fountain Reservoir to contain the fountain solution - Tap water + Fount Concentrate + IPA in the proportion 100: 2: 8.
- The third series of tests was carried out with a fountain solution containing 12% IPA, adding 4 liters of IPA to follow the proportion of Tap water + fountain concentrate + IPA proportion 100: 2: 12.

After achieving the target ink densities for each series of tests, ink and dampening duct rotations of each color unit were recorded to account for the ink and fountain solution used during the trial, as given in Table 3.

Table 3: Ink and Dampening duct roller rotations of each color unit during each series of test series on the addition of IPA % to the fountain solution

Test Series	IPA Percentage in	Ink Duct Rotation	Dampening Duct Rotation Rotation

	Fountain Solution	C M Y K	C M Y K
1	5 %	14 16 14 13	38 34 34 35
2	8 %	13 13 12 11	34 30 30 33
3	12 %	12 10 09 10	27 27 30

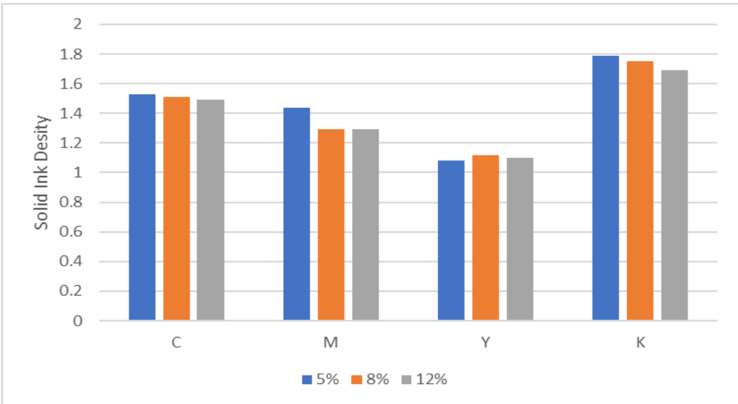
Effect of IPA % on Print Trials

Densitometrical Analysis

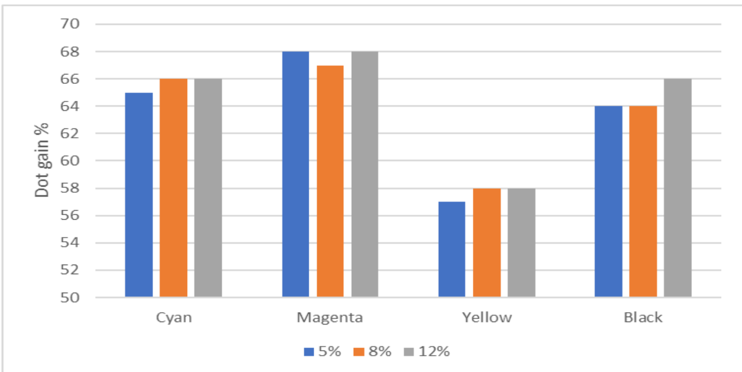
This includes analyzing and evaluating print attributes measured from the Test Form using a Densitometer. The attributes include:

- Solid ink density
- Dot gain
- Print contrast
- Ink trapping

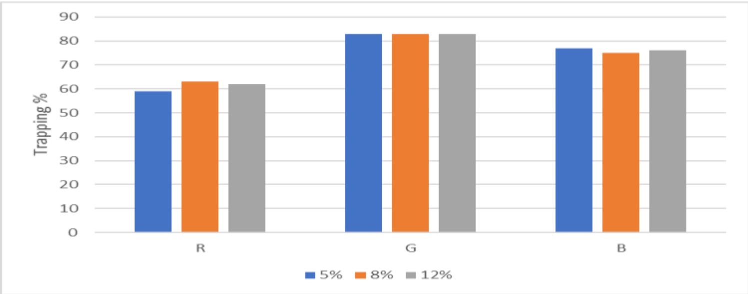
To study the effect of a change in IPA proportion, we plotted their graphs showing a direct comparison of 5 percent, 8 percent, and 12 percent IPA for each color: cyan, magenta, yellow, and black. Graphs were plotted showing Density, Dot gain, Trapping, and Contrast for 5%, 8%, and 12 % IPA



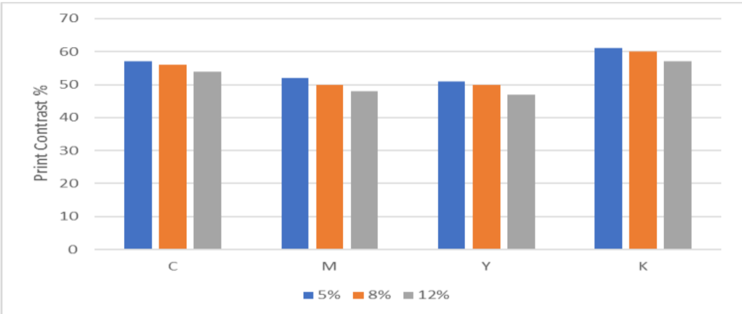
(a)



(b)



c)



(d)

Figure 7 Influence of Fountain solution and its components on a) solid ink density b) dot gain c) trapping d) print contrast

The fountain solution's amount and components influence the solid ink density [11]. As seen in Figure 7 (a-d), density decreased as the percentage of IPA increased, while the dot gain increased with the increasing IPA %. Trapping showed very inconsistent values. Print contrast steadily fell, with IPA% rising from 5 to 12%.

Results obtained from the Print trial

As IPA % increases,

- Density decreases
- Dot gain increases
- Contrast decreases

Trapping showed inconsistent results. Hence, the effect of change in IPA % on trapping could not be established.

Mottle performance through PapEye Results:

The mottle test was conducted using a PapEye Mottle tester. The results are given in table 4.

Table 4 Mottle tester results through PapEye

Mottle Index (for 100% Cyan) PapEye	
5% IPA	3.04
8% IPA	3.34
12% IPA	3.52
A lower number indicates less mottle.	

Co-relation of Print Results with Lab Tests

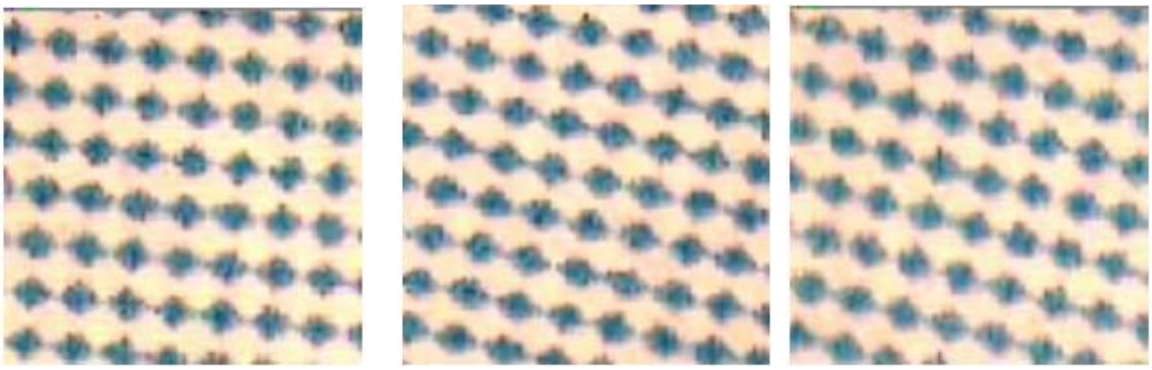
Table 5 Summary of the effect of varying IPA% on different parameters

IPA %	Effect on various parameters of fountain solution, printability, and ink		
As IPA % increases	*Contact angle* Decreases	*Surface Tension* Decreases	*Wettability* Increases
As IPA % increases	*Ink Repellence* Increases	*Mottling* Increases	
As IPA % increases	*Water-pick up* Increases	*Emulsification* Increases	*Tack* Decreases
As IPA % increases	*Density* Decreases	*Dot gain* Increases	*Contrast* Decreases

As IPA % increases, surface tension reduces, which decreases the contact angle. The smaller the contact angle, the better the wettability. However, the problem of ink repellence improves at a higher contact angle. The higher the contact angle, the lower the sensitivity for ink repellence. Thus, as the IPA % increases, ink repellence increases as shown in Table 5. It is now known from the test printings that a higher water flow is necessary when printing with little alcohol. Thus, as IPA % increases, the flow of water is reduced. However, water on the plate remains the same under all these conditions; the water uptake by the ink varies. The printing plate always requires the same quantity of water. Water uptake of ink demonstrates different behavior each time. In spite of the increased flow of water with 5% IPA, the amount of water transported with the ink is much smaller than with 12 % IPA. Therefore, it gives a better printing result about water-related mottling. Also, the lab tests show that water pick-up of the ink increases with the increasing IPA %. This increases emulsification, i.e., the water emulsified in the ink, and this explains increased mottling with an increase in IPA %. Thus, the water emulsified in the ink plays a decisive role in the differences in water interference mottling observed with the same paper.

The samples showed that a low water supply and less Isopropanol could largely prevent water interference mottling. As the water pickup of the ink increases with an increase in IPA %, emulsification or the water emulsified in ink increases, and the density decreases. Also, tack reduces; hence, dot gain increases while contrast decreases.

Comparison of dot structure from microphotography of print samples



a) b) c)

Figure 8 Halftone dots captured by the camera at 40% for different IPA% a) 5% b) 8 % c) 12%

As seen in Figure 8, these photographs show a detailed view of all three conditions of 5%, 8%, and 12% IPA for a 40% dot for one of the colors (Cyan). These pictures clearly show the effect of increased emulsification (more water in ink) with an increase in IPA %.

Conclusion

Our printing and laboratory tests confirmed fountain solutions' influence on print quality. Surface tension, emulsification, pH, and conductivity of the fountain solution and the ink tack are key parameters determining print quality. The sharpness in the printed dots is affected due to the above parameters. Optimal adjustment of the constitution and supply of the fountain solution enables the printer to minimize inconsistency and unevenness in the print results. It also helps to fulfill the customer's increasing quality requirements. The most favorable printing condition for reduced mottle and better print quality was 5 % IPA.

Acknowledgment

Two reputed companies in India sponsored this research project: Ballarpur Industries Ltd. (BILT) and Huber Group. We conducted the BILT & Huber group laboratory tests and press trials at K. Joshi & Co., Pune. We thank these companies for their contribution to this project.

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