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Analysis of the Fountain Solution in the Offset Printing in Terms of Printability

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Fountain solutions have been used in the offset lithographic printing for decades. They are water-based solutions applied immediately before or after the ink is applied to the printing plates. Today, fountain solutions are used all around the world and the experienced printers constantly struggle with the issues of the compatibility of the fountain solution with the ink and the alcohol or acid replacement. The most ideal way is to have a fountain that is neutral, effective and completely compatible with all inks.

Key Words: Fountain solution, Offset printing and printability.

INTRODUCTION

When Senefelder discovered the lithographic process in 1798, he found that the way of keeping ink in the image area of the printing plate or, in his days, of the lithographic stone was to have a thin film of water in those areas where ink was not required[1].

Offset lithography is used for image and non-image areas that are coplanar and are differentiated through variations in surface energy. The method thus uses the variation in surface energy along the plate to produce an image. During the process a water-based fountain solution is deposited through roll coating onto a heterogeneous surface, composed of hydrophilic non-image areas and hydrophobic image areas. Oil-based ink is then deposited in the same manner onto the same surface and the properties of the liquids and the solid plate dictate the quality of the print. This transfer of the two fluids to the plate and then to the substrate lies at the heart of the successful printing. The basic flow regimes of roll-coating or nip flow have been studied and analyzed[2-5] (Fig. 1). The dampening of the offset plate is one of the most critical factors in the production of quality offset printing. A working fountain solution that performs several essential functions on press is formed only through the use of a fountain concentrate mixed with water. The most important of these is wetting and desensitizing the non-image area of the plate. Fountain solution also lubricates the plate and blanket. This reduces image wear and prolongs plate life. Fountain solution also cools the plate, helps to maintain the working properties of the ink and aids in proper blanket release, which, in turn, reduces piling on the blanket. The surface coverage of fountain solutions in lithographic ink emulsions can only be understood by resolving complex interaction effects between surface hydrophobicity and fountain solution formulation at the level of droplet size and number density[6]. Since the surface chemistry plays an important role in offset printing, many studies have been conducted on the surface chemical properties of substrates used in offset have been made[7-9]. Forced wetting of a solid by a liquid is one

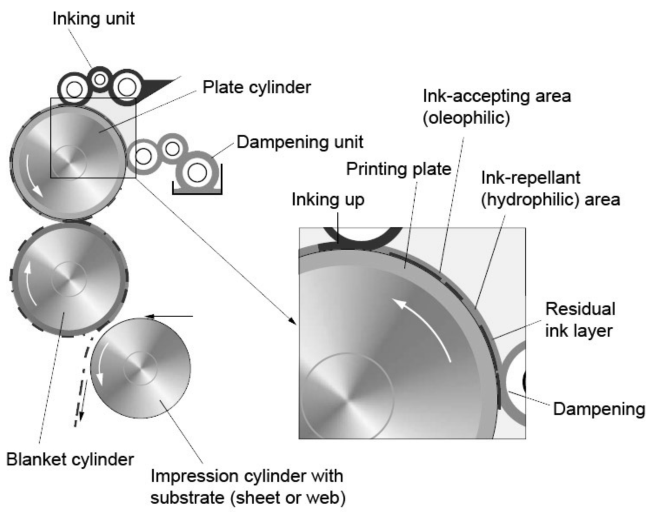

Fig. 1. Offset Printing Schematic Diagram[17].

of the most commonly encountered situations in many engineering applications[10] such as the ink transfer mechanism study of lithographic offset printing[11]. Wetting and dewetting of a solid surface by a liquid is essential in several industrial applications, *e.g.*, coating, printing, paints, adhesion, lubrication and cleaning[12-14]. It is important to understand the interactions between ink, paper and fountain solution in offset printing in order to be able to control the quality of the printed product. The transfer of the fountain solution to the paper causes, among the other results, dimensional changes, surface picking and a reduction in the surface strength. The fountain solution may also interfere in the transfer of ink to the paper[15]. Practitioners of lithographic printing thus tend to focus on maintaining the appropriate balance of ink and water to ensure a successful product[16].

An excessive amount of water causes disturbances in ink transfer (water marking)[18]. The wettability of a solid surface with a liquid, which is determined by its chemical properties and microstructure, is an important property of the surface[19]. The damping solution is one of the many important parameters of the offset printing process. The main tasks of the damping solution are to wet the non-image areas of the plate, to emulsify in the ink, to maintain the ink viscosity at acceptable values by a cooling effect and to act as an antifriction material to reduce heat production during printing. The composition of the damping solution has to be adapted to the local conditions at each printing plant[20].

Minimal changes in dampening feed, which on a running press can easily be caused by a build-up of deposits on the rollers or changes in temperature *etc.*, led almost immediately to dramatic deviations in colour reproduction within the image. Thus, during the use of this combination of ink and fountain solution, the press operator must monitor the process constantly and make any adjustments necessary to produce saleable prints. Offset lithography relies on the different surface chemistry and rheology of ink and fountain solution (mostly water) and their respective preferential interaction with a plate made up of a lipophilic (ink accepting) image carrying area and a hydrophilic (water accepting) non-image area. Ink and water are delivered through separate roller trains and meet on the plate by the forme rollers. Under normal circumstances, the inks will, caused by turbulent jet and shear action[21], partly emulsify some of the water during nip film splitting and leave some of the water as surface water[22].

Printability features of the fountain solutions: Fountain solutions have been used in the offset printing for 30 years. Nowadays, isopropyl alcohol is still being used widely in the under developed and developing countries but in Europe and America, its use is largely restricted or completely abolished due to the fact that it is a source producing volatile organic compound. In an ideal world one would have a fountain solution that was neutral, effective and completely compatible with all inks.

Basically, fountain solution is a formulation consisting of the following raw materials.

(a) Wetting agents; (b) Desensitizing agents; (c) Evaporation inhibitors; (d) Non-piling additives; (e) Corrosion inhibitors; (f) Biocides; (g) Water-soluble gums; (h) A pH buffer system; (i) Desensitizing agents; The non-image areas of the plate (such as gum arabic); (j) Acids or their salts, (depending upon the desired pH of the fountain solution); (k) Wetting agents (also called surfactants). Commonly an alcohol such as isopropanol, or an alcohol substitute), which reduces the surface tension of the solution and enables it to flow more easily; (l) Solvents; (m) Non-piling or lubricating additives; (n) Emulsion control agents; (o) Viscosity builders; (p) Biocides (fungus, bacteria and mold control agents), which help skill any organic growth in the fountain or elsewhere in the dampening system; (q) Defoamers, as its name indicates, reduces the tendency of the solution to foam or bubble, which can cause distribution problems on press; (r) A corrosion (such as magnesium nitrate), which prevents oxidation or other chemical reactions that may damage the plate[23-26].

The ability to obtain and maintain the proper balance of ink and fountain solution on an offset lithographic printing press is a function which includes many factors as the press, dampening system, rollers, ink, paper, water quality and operator's training and skill[27].

Viscosity: Tack and viscosity are not always related. The viscosity of the ink should be at a level that ensures ink/water balance. When the ink and fountain solution viscosity become similar, ink/fountain balance problems will occur. Heat builds up while a press is running. This heat may decrease the viscosity of the ink, bringing it closer to that of the fountain solution. Ink and fountain solution balance may be affected.

Surface tension: Wetting agents, typically surfactants, aid in the cleaning of ink from the non-image area of the plate, reducing scumming and toning. A quality surfactant will lower surface tension. This lower surface tension will allow the plate to wet out faster, thus allowing the pressmen to print with the least amount of ink and water required to stay clean. Surfactants also help control the emulsification[23].

When a liquid is dripped on a solid surface, the drop spreads on the surface. The physical and chemical features of the solid material on which it is dripped determine shape of the water drop. Surface tension total of 3 phases is zero until the water drop moves. Formula indicating the relation between the surface tension and contact angle is as follows:

$$\cos\theta_c = \frac{\gamma_{GS} - \gamma_{LS}}{\gamma_{GL}} \quad (1)$$

where θ_c is contact angle; γ_{GS} is vapour-liquid surface tension; γ_{LS} is liquid-solid surface tension and γ_{GL} is vapour-liquid surface tension[28].

The extent of wetting can be derived from the balance of surface tension forces, acting on the three-phase contact line in the plane of the solid. This balance is accounted for by the Young-Dupre equation, which states that the equilibrium contact angle (θ_c) is a function of the three interfacial tensions according to (Formula 1, Fig. 2) where γ_{GS}, γ_{LS} and γ_{GL} are the interfacial tensions at the liquid-vapour, solid-vapour and solid-liquid interface, respectively[29].

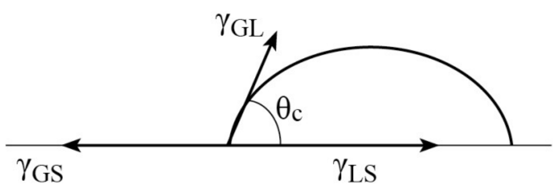

Fig. 2. Side-view of a drop of liquid in contact with a solid surface. Illustrating the contact angle and the tension forces acting on the three-phase contact line

Surface tension is a rapid formation of thin wetting water film plates and the ability to offset printing fountain solution on the two key demands, mainly by the surface tension of fountain solution decision. People generally believe that the low surface tension of fountain solution can be well used in high-speed printing, but in Europe there are reports contradicting this argument. It is understood that the current alternatives to alcohol can achieve printing operators are accustomed to IPA the Low Surface Tension.

Surface tension of pure water is 72 $N m^{-1}$ and in the fountain solution, the alcohol concentration of 10 to 25 % reduce surface tension to a level (35-45) 10^{-3} N/m, which makes fountain solution quickly to form a continuous film covering the entire plate. Alcohol fountain solution without the use of surfactants and solvents reduce the surface tension.

Surfactants or surface-active additives are organic chemicals, because of their polar molecular structure; they tend to concentrate at the interface. Under normal circumstances, the fountain solution and ink and air to air between the interfaces. In the high-speed printing, these interfaces change rapidly, so the surface-active agent to be dispersed quickly to re-add the new interface. Fountain solution including a large number of surfactants is very important in the printing process, but adding more will increase ink emulsification[30].

A vector diagram from the field of physics makes this easy to understand. When a water drop is sitting on a surface, there are two important forces (represented by the arrows) (Fig. 3) acting on the water.

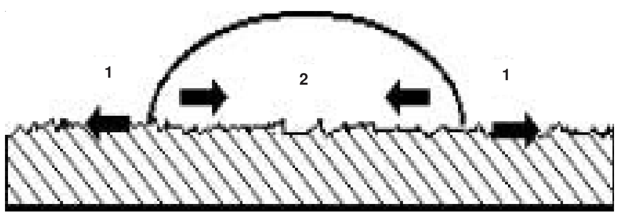

Fig. 3. Force 1 -Surface Energy of the Plate Pulls Out Force 2 -Surface Tension of the Water Pulls In

The balance of these two forces determines how easily the drop spreads. Fountain solution has a dual role affecting both forces. The surfactants (wetting agents) reduce the surface tension thus making the inward forces smaller. The desensitizers maintain the hydrophilic surface, thus increasing the outward forces. The net result is that fountain solution; when it's working well, help the drop spread by increasing the outward forces and minimizing the inward forces[24].

Printing brightness and gloss: Alcohol is an active invasion of ink thinner, which allows ink to lose luster and affects the colour. The colour is acceptable to require a thicker coating on the impression cylinder of the ink film. When used in proper concentration, alcohol substitutes no dilution of the ink, the colour is acceptable only for a small amount of ink and water, this network will become more precise, dot gain trend is also decreased.

Conductivity and pH: Water is regarded to be a rather strong electrical conductor. However, it is not such a strong conductor. It displays a ionic structure due to the dissolved carbon dioxide and mineral salts that it contains and conducts electricity even if its amount is too little. Tank water mixture contains useful mineral salts dissolving within the water and a great amount of chemical compounds that conduct electricity. It is necessary to keep the pH value of the fountain solution as well as its conductivity value under control (Fig. 4). This is because contamination caused by paper, ink and solvent wastes during printing changes the conductivity value.

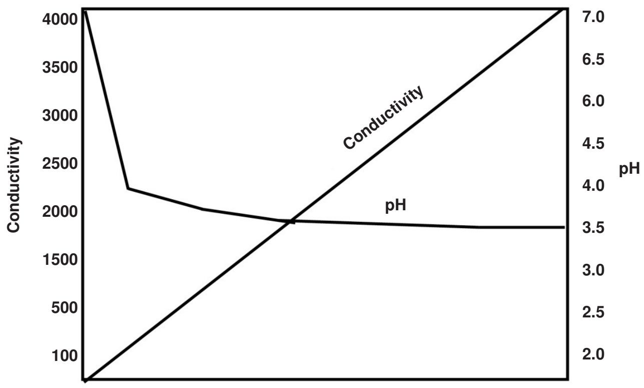

Fig. 4. Relation between pH value and conductivity

Most dampening systems use acid compounds to enable the gum arabic to stay in solution so that it can adhere to the non-image areas of the plate. Ideal pH for most acid dampening solutions is between 4.0-5.0. When the solution becomes more alkaline, the gumming agent loses its ability to desensitize the non-image areas, resulting in scumming, in which the ink replaces the gum on the plate. Scumming may also occur if the solution becomes too acidic because it can affect the protective layer of the plate. The latter type of scumming generally appears darker and is not as evenly distributed as scumming resulting from excessive alkalinity.

Increased acidity also slows or inhibits ink drying and can cause plate blinding, where the image area becomes less receptive to ink, thereby causing a ghost-like image. Decreased acidity can prevent the ink from adhering to the inking rollers, resulting in stripping. If stripping occurs at the beginning of the press run, it is generally a result of glazed roller surfaces; stripping during the press run is often the result of declining pH[31].

Alcohol-based isopropyl alcohol (IPA) and alcohol-free printing: Alcohol is identified as a volatile organic compound (VOC). As a volatile organic compound, alcohol pollutes our pressrooms and our environment.

Isopropyl alcohol (IPA), the additive of choice in certain dampening systems, is the target of increasingly stringent environmental regulations because it is a volatile organic compound. The EPA is currently working on standards that may set national limits on the permissible amount of isopropyl alcohol in dampening solutions. In addition, there are safety and health concerns. Isopropyl alcohol can be an irritant when present in the form of vapours in the air. The Occupational Safety and Health Administration (OSHA) has set maximum exposure limits of 400 parts per million (ppm) over an 8 h time-weighted average. Isopropyl alcohol also has a low flash point of 53 F and therefore must be handled with extreme caution.

(a) Isopropyl alcohol is often more expensive than most alcohol substitutes on a total use basis; (b) Isopropyl alcohol use may trigger regulatory obligations, since the amount of volatile organic compound emissions from a printing facility will dictate air pollution control permit and other regulatory requirements; (c) Isopropyl alcohol is flammable and must be stored and dispensed in accordance with OSHA requirements, which include the use of approved fireproof containers; (d) Isopropyl alcohol is a volatile organic compound that contributes to the formation of ozone by reacting with nitrogen oxides in sunlight; (e) The fumes from isopropyl alcohol can be irritating without proper ventilation[32].

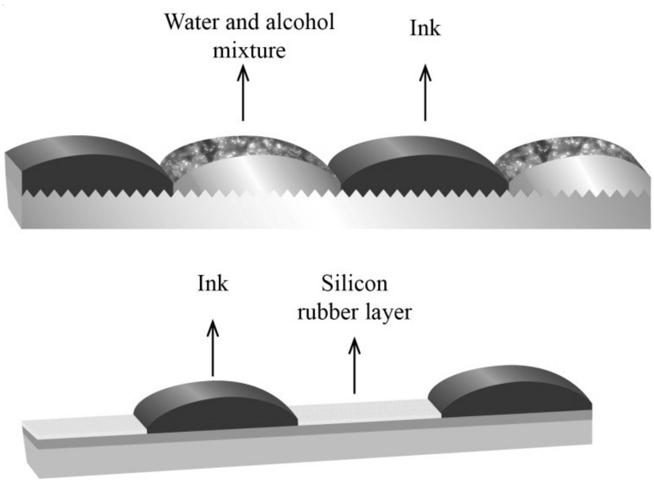

Fig. 5. Surface structure of exposed conventional and waterless offset printing plate

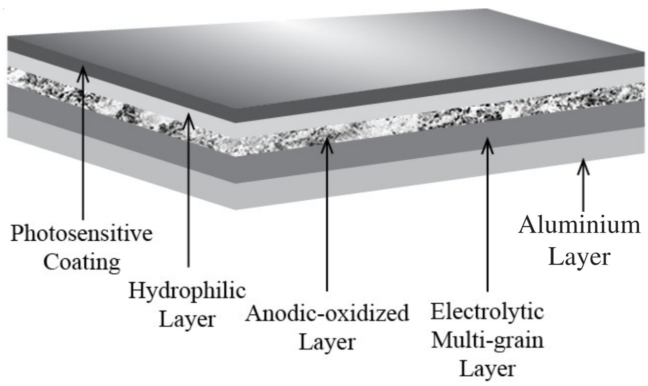

Fig. 6. Profile of waterless offset printing plate

Conclusion

The dampening of the offset plate is one of the most critical factors in quality offset printing. The main tasks of the damping solution are to wet the non-image areas of the plate, to emulsify in the ink, to maintain the ink viscosity at acceptable values by a cooling effect and to act as an anti-friction material to reduce heat production during printing[33].

This hardness used for offset printing must be at specific values in terms of pH and conductivity.

Solution can contain calcium, sodium, hydrogen carbonate, chloride, sulphate, nitrate, iron, oxygen, carbon dioxide, hydrogen (ion), bacteria, algae and the other natant substances. Certain ions that normal water contains can react with the pigments of paper or ink during printing in the offset printing. Calcium ions interact with the printing ink and tank water and it reflects on the paper. For offset printing, the water hardness should not be higher than 100 dH. If the hard water is used, calcium and magnesium salts may settle on printing plates, blankets and rollers and disturb the ink respectively. To avoid this disturbance, ion exchange process is performed in order to reduce the Ca^{2+} and Mg^{2+} within the solution to the minimum level. Sodium ions form instead of the Ca^{2+} and Mg^{2+} within the deionized solution. This solution is immediately filtered to be cleared of salt-forming components. Only salt components that do not cause hardness or carbonate are left within the solution. This process is the first step of preparing the damping solution. Then, tap water can be added to adjust the water to the appropriate total hardness degree. In general, deionization or reverse osmosis process is applied in order for the solution to be cleared of salts. Moreover, the chemical reaction of calcium salts with fatty acids in the printing ink may cause lime soaps to develop. These then act as wetting agent and can also disturb the printing process by making ink-receptive areas water-receptive and *vice versa*. These difficulties can be avoided by installing a water softener. If such deposits are already present on the surfaces, they can be removed by treating the surfaces with a solution of 50 g tartaric acid in 1 L water. This method, however, is time consuming and can by no means replace water softening.

The importance of pH control in lithographic printing is critical for plate performance. It is important to monitor pH and conductivity throughout the press run (see fountain solution guidelines for additional information on this subject). Any changes in pH may lead to picking, sensitivity of the anodized layer, ink drying and scumming problems[34].

pH value of the untreated water that will be used to prepare the damping solution of the offset printing must be 7. pH value of the tank water mixture must be between 4.8 and 5.3. A low pH value causes water to acquire a feature of rusting. Acids lead to corrosion by affecting the metal surfaces. Moreover, it can cause drying difficulties in the printing ink, oxidation of metallic inks and a shorter operating life of the printing plate. As for a high pH value, it can cause calcification. As a result of the reduction of surface tension between printing ink and dampening medium, the ink emulsifies. Furthermore, it can cause the plate tend to scumming.

The pH value is usually measured by means of specially treated paper, so-called indicator paper, which changes its colour upon contact with the liquid. This decolouration is compared with a given colour scale and thus permits to determine the pH value. Unsuitable pH values of the dampening medium can be very detrimental to the printing result.

Conductivity of the solution is its degree to be able to conduct electricity charged particles. Damping solution is composed of dissolved useful mineral salts and large amounts of chemical compounds that can conduct electricity. Conductivity value of the damping solution must be kept under control as well as its pH degree. It should be kept in mind that the materials such as paper can contaminate the damping solution, ink and solvent and this contamination will increase the conductivity. Surface coverage of the paper used in the printing can also increase the conductivity degree of the damping solution by 5-10 %.

Isopropyl alcohol application to the damping water has been reduced or completely abolished in Europe and America. Isopropyl alcohol is used to reduce the surface tension of the damping water on the aluminumoffset printing plate and to form a thinner and more homogeneous water film. It also contributes to the cooling of the damping solution as it evapourates quickly. It is bactericide. It helps to maintain the ink-water balance stable. Surface tension of a conventional damping solution or a solution to which 8 % isopropyl alcohol is added must be about 40 mN/m.

The ink/water balance is more critical when printing non-porous stocks than when printing regular paper. Non-porous stocks do not absorb water, therefore very little is needed. Use only enough to keep the surface of the plate wet. Water settings are critical, as emulsified ink will also increase drying time[35].

To standardize the offset printing process, composition of the tank water mixture must also be standardized. All effective compounds must be used in the recommended ratios. It is not recommended to use the components either below or above the recommended values because they can cause printing and corrosion problems in the long run. What recommended here is to use the automatic dosing systems for the additives of the tank water solution.

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