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Investigation of Different Solvents in Flexographic Printing Ink's Effects to Print Quality on Coated and Uncoated Paper

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There are different solvents used in flexographic inks. There are also different properties of solvents which affect the printing quality in different ways. In this study, seven different flexographic ink with seven different solvents has been prepared. Prepared ink has been printed with IGT F1 Flexo test machine on uncoated and coated papers. The viscosity changes according to the usage of different solvents. This change also affects the printing quality. As a result, the fact that which solvent constitutes the best printing quality for flexographic print on a coated and uncoated paper has been understood.

Key Words: Flexography, Solvent, Flexo ink, Paper, Print quality.

INTRODUCTION

Flexographic printing is a known method of reproduction in which the master or printing plate is in the form of a relatively flexible impression of the original that will be reproduced. As raised areas, such flexible relief plates contain the image portions which are to retain ink, subsequently transferred to a desired surface. Such surface is commonly a paper or a continuous plastic or other synthetic film. Flexographic printing also used for the reproduction of information on relatively rough surfaces such as corrugated cardboard and so forth[1]. Two types of papers are generally used in print production. The first one is uncoated paper and the second one is coated paper. Coated paper has surface sizing. Surface sizing is more important for printing papers, as it improves printability characteristics of a paper. Ink penetration is more homogeneous on the coated paper. The surface of uncoated paper is not stable of printing ink[2].

The most different property of the flexographic printing system is its plate prepared by polymerization which is a type of relief printing. Flexographic printing system's plate has printing areas that are higher than non-printing areas. The plate of flexographic printing system is reverse imaged[3] (Fig. 1).

A paper or other substrate to be printed, is passed around a cylinder which is known as an impression cylinder that is in relation to the plate cylinder is adjusted to allow the raised areas of a flexible relief printing plate to contact the surface while the depressed areas of such flexible relief plate do not contact the surface of the substrate.

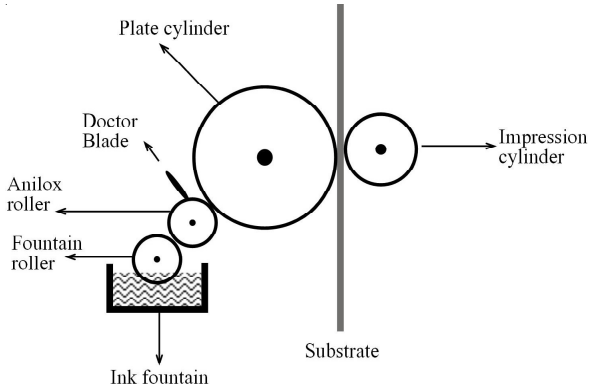

Fig. 1. Flexographic printing system

An inking system is provided *via* ink which is transferred to the surface of the flexible relief plate. Such inking system consisting of an anilox roller that may be etched or engraved on its outer surface by which the quantity of ink transported is controlled and anilox roller is positioned in the way that it contacts to the surface of a fountain roller and the fountain roller of which is at least partially immersed in a bath of liquid ink.

When the printing station is energized to enable the rotation of the various rollers and cylinders, a clockwise rotation of fountain roller lifts a layer of ink which is transferred to the anilox roller rotating in an anticlockwise direction. The plate cylinder rotates in the clockwise direction and the film of ink on the surface of the anilox roller is transferred onto the surface of the flexible relief plate on which it forms ink film. The ink

film is formed in the raised printing areas and in the depressed non-printing areas of the flexible relief plate.

As the anilox roller rotates in the clockwise direction, the inked portions of the plate are brought progressively into the printing zone where the substrate contacts to the raised portion of the flexible relief plate. When the prior art methods are used; the ink transfers from the depressed portions of the plate to the substrate as well as transferring from the raised printing areas[1].

A flexographic printing ink comprises a solvent, a colorant, a binder and additives. Wherein the solvent is water and organic solvents the colorant is a water-soluble dye or a mixture of such dyes dissolved in the solvent. The binder is selected from different resins dispersed in the solvent that is above 7 pH (preferably at about pH 8-9) and the additives include a wax selected from the group consisting of polyolefin waxes, paraffin waxes and mixed polyolefin and paraffin waxes dispersed in the solvent[4]. A flexographic printing ink is concentrated in order to prepare this printing ink comprising the components mentioned above in which the amount of solvent is reduced by about 1-20 % when it is compared with the amount of solvent in a flexographic printing ink ready for use[5]. Flexographic ink is normally described as thin ink or as relatively low viscosity ink, by this way it is understood that the ink is sufficiently fluid in character to flow in a bath and assume a comparatively level surface. This allows the use of an ink distributing system which usually consists of two roller and one of which is known as the fountain roller, is partially immersed in the bath of ink and it rotates in contact with another roller known as the form roller. This form roller is arranged to touch to the surface of the flexible printing plate and transfer ink thereto[1].

EXPERIMENTAL

Varnish, paper adhesive and wax were added to 100 g blue ink paste of Seigwerk NC process colour series. Various solvents were added to obtain several ink solutions which has a viscosity of 14 (Table-1). Different amounts of solvents alter the pigment concentration in the unit volume. The concentration was supported by density and L*, a*, b* measurements. All test prints were applied on coated and uncoated paper with IGT F1. The anilox roll has 60 = 150 lpi cell frequency and 16 mL/m^2 ink volume. Test prints were performed under room conditions. Viscosity measurements were done by using dyn 4 cup. Density, L*, a*, b*, tone value measurements were carried out by using X-Rite SpectroEye Spectrophotometer. Spectrophotometer's measurement conditions are observer angle 2º, illumination D50 (5000 K), geometry 0/45. Polarize filter was used in density measurements but not in spectrophotometric measurements. Visual print quality was observed with Olympus SZ61 Stereo Microscope by 50X magnification. Test print conditions are anilox force 150 N/m, printing force 250 N/m and printing speed 0.30 m/s. 80 g/m^2 uncoated paper and 110 g/m^2 coated paper were used in test prints.

For coated paper: Fig. 2 shows different solvents' ink order of densities. Different solvents' viscosity in the same ink paste and correspondingly the amount of the solvent used to obtain a solution of viscosity of 14, is different for each solvent.

TABLE-1
PREPARED INKS CODES AND SOLVENTS

Ink code	Solvent
OE 3	Ethyl alcohol
OE 5	Ethyl acetate
OE 6	Ethoxy propanol
OE 7	Water
OE 8	Methoxy propanol
OE 9	Ethyl alcohol-ethyl acetate (50:50)
OE 13	Methoxy propyl acetate

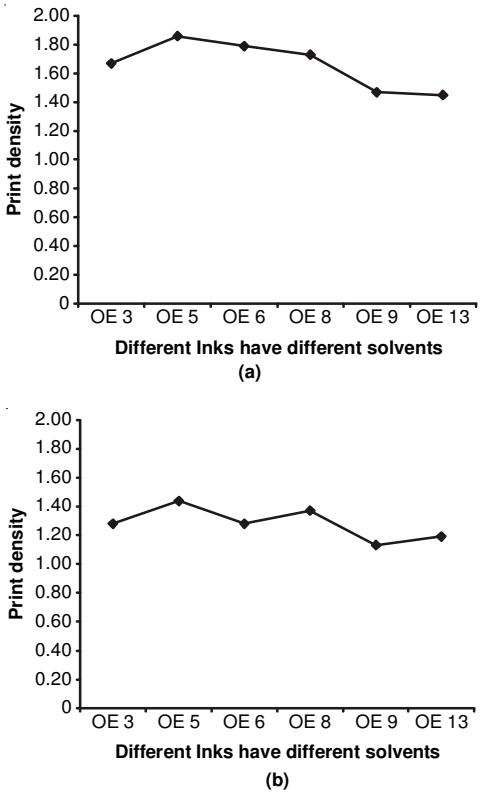

Fig. 2. Print density of inks prepared with different solvents (a) coated (b) uncoated

With less solvent, the ink that reaches the viscosity of 14 has higher densitiy value than the ink that reaches the viscosity of 14 with more solvent. The more the amount of solvent decreases, the more the pigment concentration of ink increases. Low pigment consantration causes low print density.

For uncoated paper: When substrate is changed, due to the adhesion of the substrate; slight changes have occurred in the order above and in the viscosity changes of the ink solution with different solvents. The explanation made for the coated paper is also applicable to uncoated paper.

ΔE values of cyan standard for flexo are calculated according to ISO 12647-6:2006 (CIE L*, a*, b* values for the solids of the process colours)[6].

$$\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2}$$

The usage of prepared methoxypropanol has been understood to meet the standard in the best way as the result of calculations for coated paper (Table-2). ΔE values of 4-5 are considered acceptable according to the ISO 12647-6:2006 stan- dard. All ink solutions are in the acceptable range except methoxy propyl acetate.

TABLE-2
ΔE VALUES CALCULATED WITH STANDARD AND INKS ON COATED PAPER

Inks	L*	a*	b*	ΔE
Standard	54	-36	-50	–
OE 3	52	-32	-55	5
OE 5	52	-35	-55	5
OE 6	55	-36	-54	4
OE 8	56	-36	-52	2
OE 9	59	-39	-51	5
OE 13	60	-39	-49	6

Most of the solvents which are in compliance with ΔE values for flexo printing standards ISO 12647-6:2006 are ethyl alcohol-ethyl acetate (50:50), methoxy propyl acetate and ethoxy propanol for uncoated paper. The ones which are not in compliance are ethyl alcohol and ethyl acetate. (Table-3).

TABLE-3
ΔE VALUES CALCULATED WITH STANDARD AND INKS ON UNCOATED PAPER

Inks	L*	a*	b*	ΔE
Standard	58	-25	-43	–
OE 3	54	-19	-48	8
OE 5	53	-19	-47	8
OE 6	57	-22	-45	3
OE 8	55	-22	-46	5
OE 9	61	-25	-44	3
OE 13	58	-22	-44	3

The reason of this is the porous structure of uncoated paper on the adhesion of ink. Furthermore, the gloss of the coated paper is the reason of a higher ΔE value. Even though ethyl alcohol and ethyl acetate are not separate adequately, a 50:50 mixture of these meets the standard. This is because of the increase in the L value of ethyl alcohol based ink and the decrease in b value of ethyl acetate based ink that minimizes the adverse effects of the solvents.

Test print plate's tone values are between 0 and 100 %. The tone values of ink are prepared with different solvents that are measured with spectrophotometer (Fig. 3). The results of Fig. 3, ethyl acetate based inks' tone values are approximate to plate's tone values. Ethyl acetate has the least boiling point and the highest evaporating rate (according to *n*-buthyl acetate = 1) (Table-4). The ink which is prepared with water's ink past sedimented. So it wasn't used for the test prints.

TABLE-4
PROPERTIES OF SOLVENTS[7]

Solvent	Density at 4 ºC	b.p. (ºC)	Evap. rate (Bu Ac = 10)	Flash point (ºC)
Ethanol	0.79	81	33	13.9
Ethyl acetate	0.90	77	62	-5
Ethoxy propanol	0.90	132	4.9	49
Water	1.00	100	18	–
Methoxy propanol	0.96	140-50	3.4	47
Ethyl alcohol-ethyl acetate (50:50)	0.79-0.90	77-81	33-62	13.9-(–)5
Methoxy propyl acetate	0.92	121	8.3	36

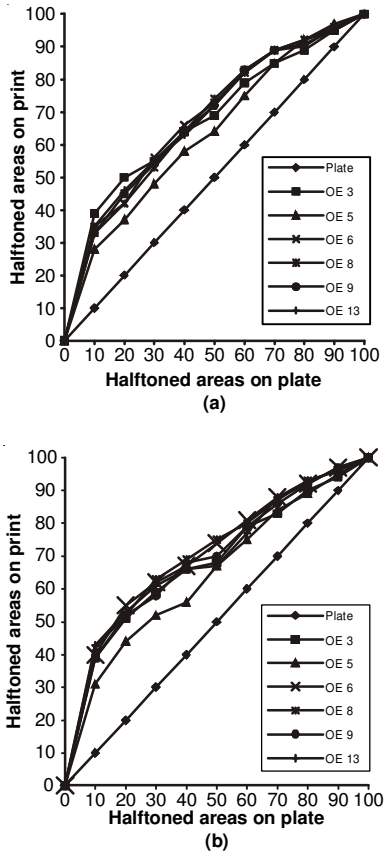

Fig. 3. Tone values of ink which is prepared with different solvents (a) coated (b) uncoated

The ink, which is prepared with ethyl acetate has low boiling point, a high drying velocity and low dot gain but it dries fast on printing process. So ethyl acetate is not used alone in flexo inks. Because of this ethyl alcohol, the combination with ethyl acetate (50:50) was used in Flexo test print inks. The ethyl acetate's lowest boiling point solvent and the highest boiling solvent methoxy propyl acetate's test prints' dot gain can be seen in Fig. 4.

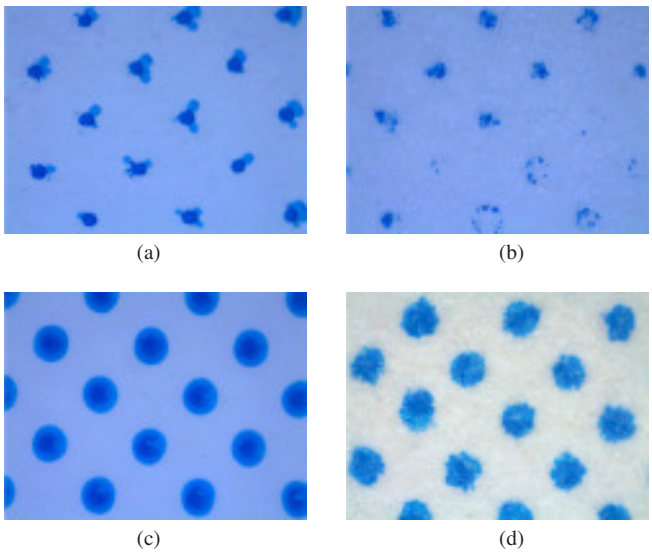

Fig. 4. 5 % half toned area test prints' microscopic photographs of (a) ethyl acetate based ink on coated paper, (b) ethyl acetate based ink on uncoated paper (c) methoxy propyl acetate based ink on coated paper (d) methoxy propyl acetate based ink on uncoated paper

Fig. 4 shows that, ethyl acetate based ink's dot has not time to gain because of its fast drying. On the other hand, methoxy propyl acetate based ink's dot has a very long time to dry because it's dot gain higher value than ethyl acetate based ink. Methoxy propyl acetate based ink's test print has better dot shape than ethyl acetate based ink's. Better dot shape is important for printing. Because it affects the shade of colour.

RESULTS AND DISCUSSION

Solvent volume has inverse proportion with pigment concentration. Pigment concentration has diverse proportion with print density.

When substrate is changed, slight changes occur in the order above due to the adhesion of substrate and the changes in viscosity of the ink solution with different solvents. The explanation which is done for the coated paper is also applicable to uncoated paper.

Even though ethyl alcohol and ethyl acetate are not separate adequately, a 50:50 mixture of these meets the standard. This is because of the increase in the L value of ethyl alcohol based ink and the decrease in b value of ethyl acetate based ink that minimizes the adverse effects of the solvents.

The ink, which is prepared with high boiling point solvent, has low drying velocity and better dot shape.The ink which is prepared with low boiling point solvent, has a high drying velocity and worse dot shape.

Ink paste was dispersed in all solvents except water. Ink past was sedimented in water. Therefore water based ink was not used in test prints.

Conclusion

Ethyl alcohol-ethyl acetate (50:50) based ink is the best of all the other prepared inks when it is compared to all test prints measurements results. As an example to this kind of hybrid ink is ethyl alcohol-ethyl acetate (50:50) combination based ink that has optimum print quality results. But ethyl acetate damages the flexo printing plate. Therefore the ink which is prepared with ethyl acetate may not be used for long run industrial flexo printing processes.

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