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Influence of Ink Viscosity on Dot Gain and Print Density in Flexography

EFE N. GENCOGLU

Department of Printing Education, Faculty of Technical Education, Marmara University, Goztepe-34722, Istanbul, Turkey

Corresponding author: E-mail: egencoglu@marmara.edu.tr

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Flexo printing systems are mainly used in packaging applications. Substrates, anilox rolls, ink types, viscosity levels of inks, which are used in flexo printing systems have an effect on print density and dot area in printing. In the study, test printings were performed with the above parameters in IGT F1 test printing machine, printings were measured by densitometer and evaluations were made through the obtained data. A higher level of print density was achieved in printings made with solvent- and water-based inks on coated papers when compared to the printings made on uncoated papers. Higher levels of print density were obtained on uncoated papers with water-based inks and on coated papers with solvent-based inks. It was observed that dot area values were same in printings performed with water- and solvent-based inks of 17 viscosity level on coated and uncoated papers. Thus, viscosity value of ink should be 17 in printings to be performed with water- and solvent-based inks under optimum printing room conditions.

Key Words: Flexography, Flexo ink, Dot gain, Print quality, Print density.

INTRODUCTION

Flexo printing is a relief printing process. It differs from conventional relief printing in the printing plate and in the printing ink that is used. Another difference exists in the ink transfer process itself. Printing is primarily carried out on a rotary basis; the printing substrate is processed in reels. Sheet fed printing machines are only used in direct printing of corrugated board[1].

Flexographic printing process is a rotary relief method of printing, which uses a roller engraved with fine cells (Anilox) to transfer a precise volume of ink to raised surface of the plate and then using the pressure, to transfer the inked image to substrate. The plate properties affect the volume of ink transferred to the substrate through two principle mechanisms. The first one is the surface energy of the plate and the second one is the size of the dots transferring ink to create fine details in the illustrations[2].

The printing technology requires only a slight contact pressure to enable reliable ink transfer from printing plate to substrate. This contact pressure must, however, be exerted as evenly as possible on all printing locations along the contact area and during the entire print length. Eccentricities in the cylindrical form and radial deviations can be compensated by setting a somewhat higher pressure. The satisfactory preliminary requirements for even printout of the entire print image are met if a contact pressure can be maintained with only slight fluctuations. Soft, flexible printing plates facilitate a good print result even with such low contact pressure and printing can be done even on corrugated board without damaging it[3].

During flexographic printing, the printed screen dots expand as a consequence of the pressure in the printing nip. Not only the substrate but also the flexographic print form is compressed in the nip and this leads to an expansion of the dot on the print form and produces a larger printed dot. This dot gain may be enhanced by ink spreading on the substrate after the print nip. In addition, ink can spread on the paper or be absorbed into the paper, adding additional area to the dots and causing the measured and illusory dot gain to be greater[4].

The deformation of raised dots on the plate as they are subjected to the engagement will affect the final printed dot size. Dot gain may be defined optically or physically. Optical dot gain measures the reflectance spectrum of incident light on the tonal dots at predefined wavelengths and relates the reflectance of 100 % coverage. Physical dot gain is defined as the growth in the printed dot size, in comparison to the original dot size on the plate. In flexographic printing, dot gain can occur either by the dots on the plate that deform as they are compressed, or by ink spreading on the substrate as it is squeezed in the printing nip[5].

The combined physical and optical dot gain may be estimated from measured reflectance values through the use of Murray-Davies equation (Murray 1936):

$$R = fR_i + (1-f)R_0$$

where, R is the reflectance of the image and R_i and R_0 are the reflectance values of the solid print and the substrate, respectively and f is the fractional dot area, $0 \le f \le 1$.

Print density is another important parameter for every print because a too low print density results in a pale print. Print density, D, is related to the reflectance as follows:

$$D = \log_{10} R_0 / R_1$$

where, R_1 is the reflectance of the printed solid tone or half tone value and R_0 is the reflectance of the unprinted substrate. The perceived strength of a colour is thus not linearly related to the reflectance, but there is a logarithmic relationship[6].

EXPERIMENTAL

In this study, test flexographic printing plates containing a halftone scale with dot coverages of 10, 20, 30, 50, 50, 60, 0, 80, 90, 100 % in 40 lpi. Resolution were prepared.

Coverage typically varies from 1 up to 100 %, also known as a solid. Low coverage (less than 10 %) are commonly referred to as highlights; coverage between 10 and 60 % are referred to as midtones and high coverages (60-100 %) are referred to as shadows[4].

During the preparation of flexographic printing plates, DuPont DFH photopolymer digital thermal plates were used and the thickness of the plate was 1.7 mm and its hardness was 75º Sh A. Flexographic printing plates were prepared with relief depths of 0.6 mm.

Test prints were performed by IGT F1 proofer with a printing force of 250 N/M and printing speed of 0.30 m/s. The anilox rolls used are shown in Table-1.

TABLE-1

Anilox	Cell frequency (lpi)	Volume (mL/m^2)
an1	150	16
an2	200	11
an3	250	9

Coated and uncoated papers were used as substrates. During the test prints, the ambient conditions were 22 ºC and RH 50. Print density and dot area measurements were carried out by X-rite spectroeye spectral photometer. Spectrophotometer's measurement conditions are observer angle 2º, illumination D50 (5000K), geometry 0/45; polarization filter was used in density and dot area measurements. During the test prints, 90 g/m^2 uncoated and 115 g/m^2 coated papers were used as substrates.

The print quality is determined by many factors and wetting of the ink on the printing substrate is one of the most central factors.[7]

Generally speaking, in printing industry, the factor, which determines the quality of printing is the relationship between substrate and ink. In the study, two different types of ink were used. In the structure of the water-based one of the inks, dyestuff, acrylic resin, silicone derivative foam crusher and water as solvent were used.

When formulating the water-based ink, it is important to choose the right blend of polymers to achieve the required balance of properties[8-10].

As for the other ink, it is composed of dyestuff, nitro cellulose resin, silicone derivative foam crusher and ethyl alcohol as solvent. Boiling point of ethyl alcohol is 78.5 °C. But water boils at 100 ºC. This information shows that evaporation will have different impacts on drying of these two inks having the same content and it is concluded that solvent-based ink will dry more quickly by taking into account the fact that ethyl alcohol, which has a lower boiling point will evaporate more quickly than water. 14, 17, 20 sec (25 ºC/din cup 4) viscosities of both inks were adjusted through their solvents and their impacts on printing were examined.

Graphics showing the printing densities and dot area values were drawn at the end of the densitometric measurements performed on the test printings (Fig. 1).

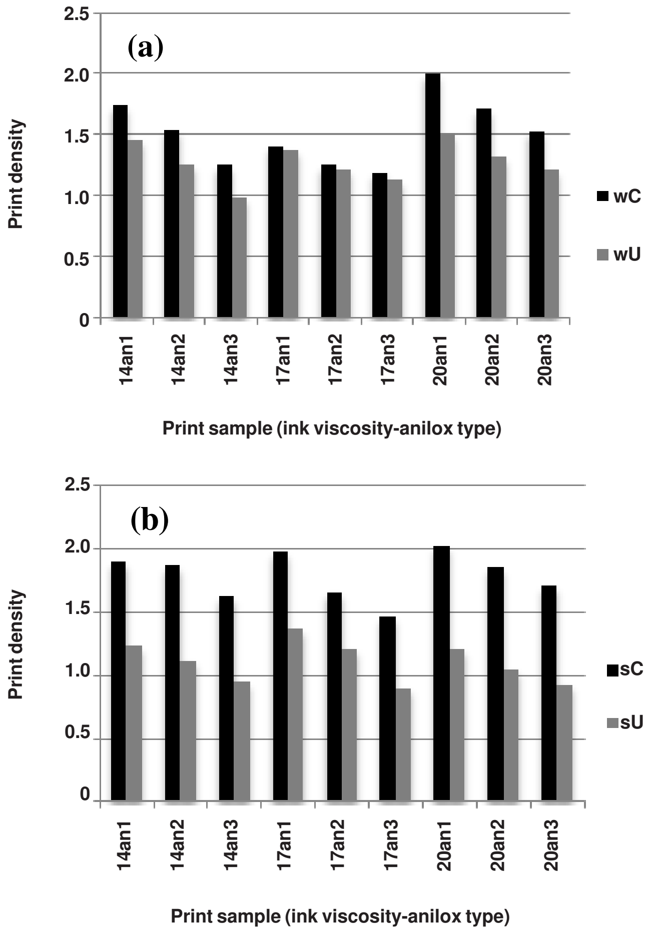

Fig. 1. Comparison of print densities of printings performed on coated and uncoated papers with water-based (a) and solvent-based (b) inks

In Fig. 1a, graphic of the print density measurements of printings made on coated and uncoated papers with water-based ink is presented. In this graphic, it can be detected that print densities are always higher in coated papers than uncoated papers in printings performed by using an1, an2 and an3 aniloxes with water-based ink having a viscosity of 14, 17 and 20. As can be seen in the Fig. 1b, print density values measured in the uncoated paper are lower than the values measured in the coated paper in printings made with solvent-based ink, as well. It was observed that print densities of both types of ink increased in parallel with the increase of anilox volume in printings carried out with both of the inks.

While the comparison of the print densities of water- and solvent-based inks on coated paper is indicated in the Fig. 2a, comparison of the print densities of water-and solvent-based inks on uncoated paper is indicated in the Fig. 2b. It was detected that in the printings made on coated paper, print density values of solvent-based ink are higher in comparison to water-based ink. However, as seen in Fig. 2b showing the values related to uncoated paper printing, print density values measured from printings made with water-based ink are higher than the print density values measured from printings made with solvent-based ink.

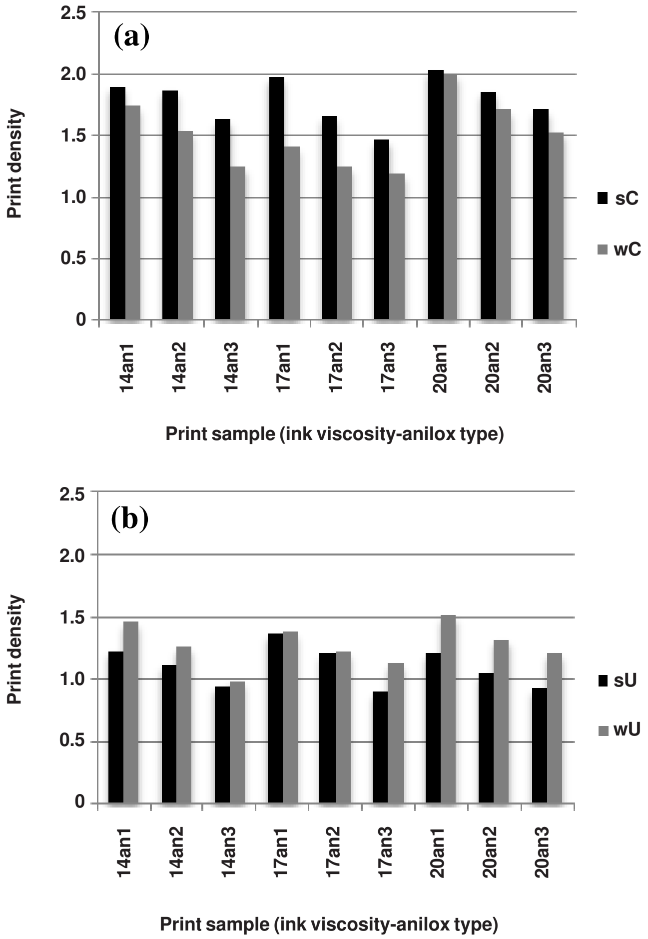

Fig. 2. Comparison of print densities of printings performed on coated and uncoated papers with water-based (a) and solvent-based (b) inks

Effects of printing variables on screen dots were assessed through dot area measurements taken from test printings. Three aniloxes of different properties were used in the printings. It was determined that the increase in the anilox volumes leads to the increase of dot gain as well as its directly proportional effect on print densities.

Dot area graphics of printings obtained from an1, an2 and an3 aniloxes show similarity and only difference is the increase in the values. Thus, graphics presented in the Fig. 3 and Fig. 4 were drawn out of dot area measurements of printings made with only an1 anilox.

It is observed in the Fig. 3 that water-based ink produces much more dot gain than the solvent-based ink at viscosity values of 14 and 20 in the printings made on coated paper with 14(a), 17(b) and 20(c) viscosity water-based and solvent-based inks. However, it is observed in the Fig. 4 that solvent-based ink produces more dot gain than the water-based ink at viscosity values of 14 and 20 in contrary to Fig. 3. As can be observed from the Fig. 3b and Fig. 4b, dot area values of solvent- and water-based inks on coated and uncoated papers are nearly the same at the viscosity value of 17.

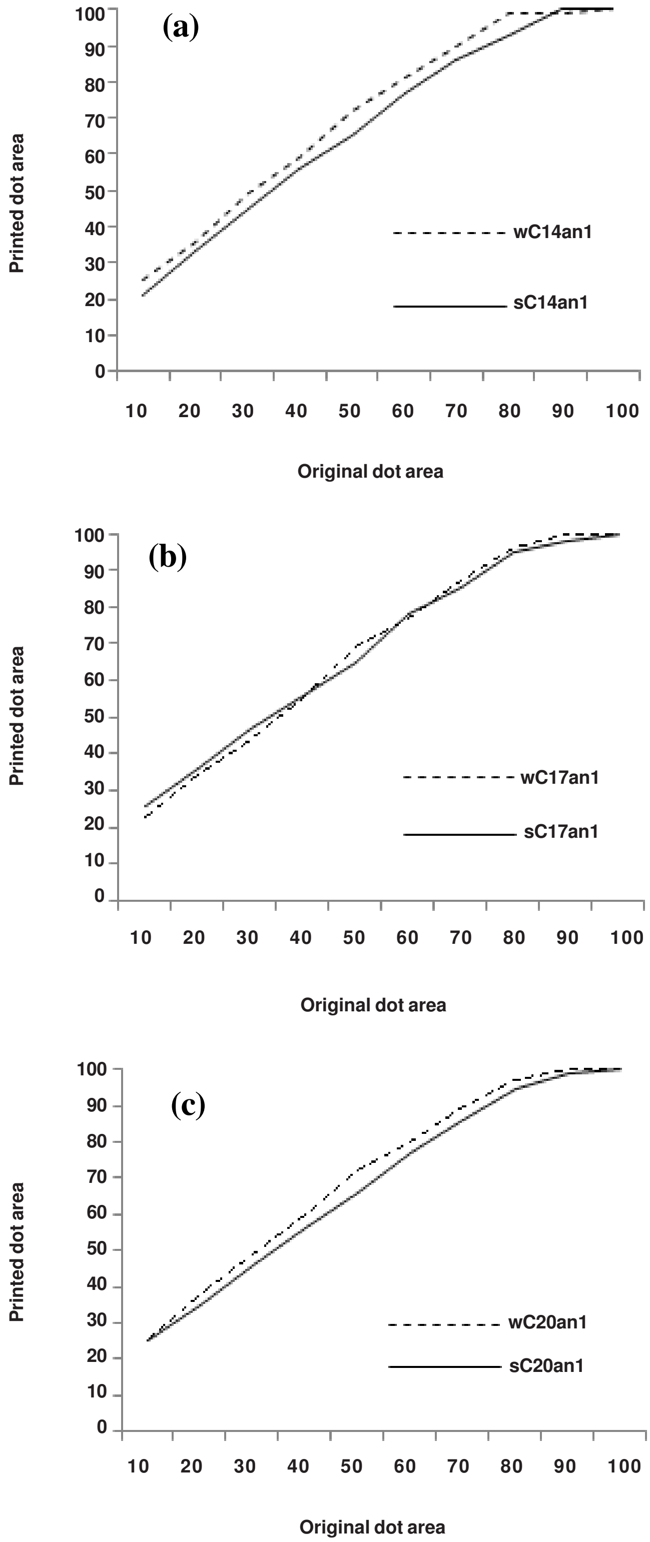

Fig. 3. Tone values of printings made on coated (c) papers with water-based (w) and solvent-based (s) inks having viscosities of 14, 17, 20

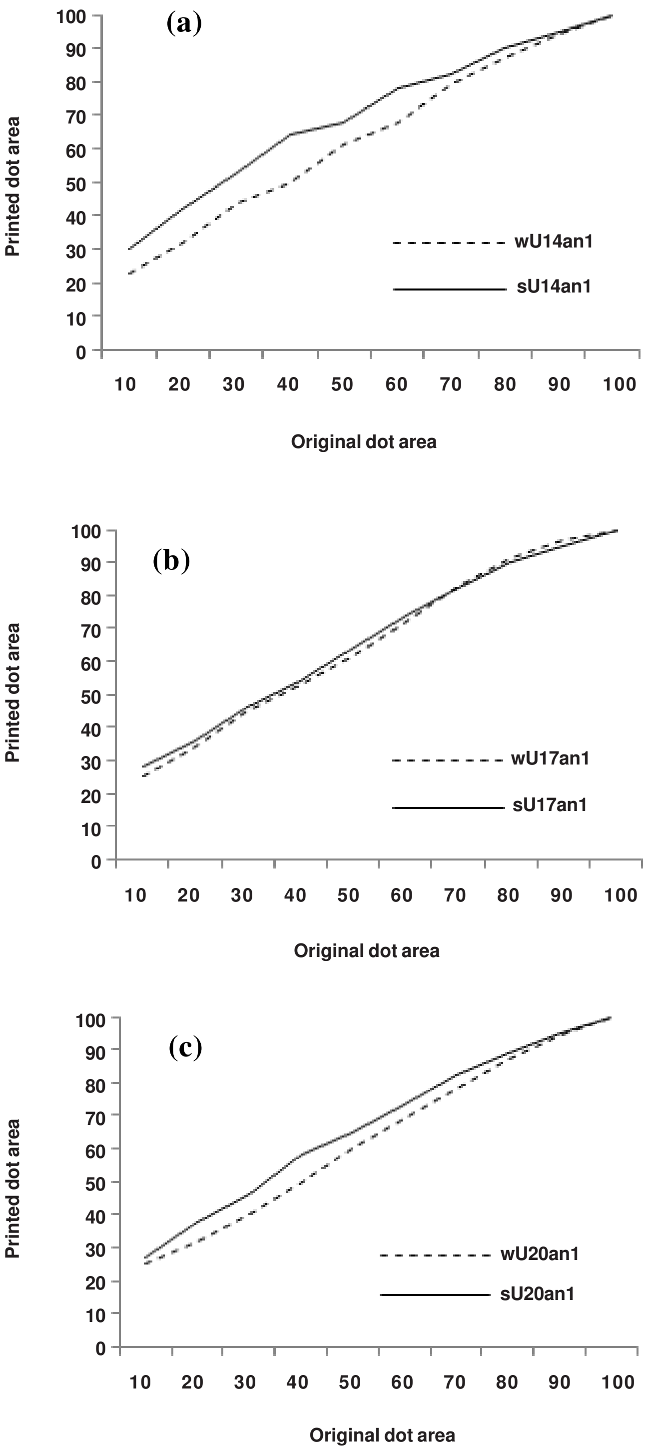

Fig. 4. Tone values of printings made on uncoated (c) papers with water-based (w) and solvent-based (s) inks having viscosities of 14, 17, 20.

RESULTS AND DISCUSSION

As it is clear from the performed print density measurements, a higher level of print density was obtained in the printings that were conducted with water- and solvent-based inks on coated paper than those performed on uncoated paper. Therefore, ink consumption would be lesser in printings made on coated papers with both types of ink. Water and ethyl alcohol carry away pigments and bonding phases from inks within, which they are solvents to some extent while they proceed in the uncoated paper due to hydrophilic materials used in paper production and due to the fact that fiber textures of uncoated paper are open and accordingly, a fall is observed in the print density. However, in the printing made on coated paper, fiber cavities of paper decrease due to the film structure that coating surface forms and this eliminates the penetration of ink through the paper.

Second result obtained as regards to the print density is that higher densities are achieved with water-based inks on uncoated papers and with solvent-based inks on coated papers. Ink saving will be possible when the selection of ink is made by taking this result into consideration in the printings to be performed.

Dot area values obtained in the printing made with water-based inks at viscosity values of 14 and 20 on coated paper are higher than the values obtained with solvent-based ink. As for printings conducted on uncoated paper, dot area values are higher in the solvent-based ink. This is inversely proportional to the print density results that are obtained. In other words, while a higher print density could be achieved with water-based inks on uncoated papers, dot area values were found to be lower. As for coated paper values, while a higher density could be achieved with solvent-based inks, dot area values were found to be lower.

Increase of dot area values during printing is called as dot gain. Dot gain is not a printing fault but it has to be taken under control. In order to take dot gain under control more easily, it will be better to perform printing at high print density, which will produce less dot gain. Thus, it is more appropriate to choose solvent-based inks for coated papers and water-based inks for uncoated papers.

It is observed in the performed dot area measurements that dot area values are the same in the printings conducted on coated paper by using 17 viscosity solvent- and water-based inks. This fact is also valid for uncoated paper type. Therefore, viscosity value must be 17 in the printings to be performed with water-based and solvent-based inks under optimum printing room conditions.

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