The Impact of Ink Viscosity on the Enhancement of Rotogravure Optical Print Quality

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Abstract:
This purpose of this paper is to examine the impact of ink viscosity on gravure optical print quality. The paper is a case study carried out in a well known gravure printing house in Egypt.
The research methodology and the analysis has employed an interpretive approach. The experimental approach has been used, since the aim was to find the correlation between ink viscosity and gravure optical print quality.
This paper shows that a small difference in viscosity can produce major variations in density and contrast print quality. also dot sharpness is very much influenced by viscosity. lower viscosity will often show dot gain, causing the image to lose its sharpness and print (dirty). Ink that is run at a high viscosity may also cause inconsistent ink densities on the substrate, causing mottling.
As a result, it finds that ink is transferred the substrate that the ink viscosity influence the optical print quality and smoothness of dots. Ink must flow out of the cells to give a smooth and unblemished print surface.
As a main conclusion, keeping viscosity regulated helps to maintain print quality to great extent.

Keywords:
- ***Gravure***
- ***ink viscosity***
- ***dot gain***
- ***density***
- ***print quality***
- ***mottling***

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1. Introduction

Rotogravure printing is the most common gravure based process in use today. In rotogravure, the pattern is engraved on a metal roller, allowing the pattern to be printed continuously. A schematic of the process is shown in figure (1). A modern graphics press typically has at least four different printing heads for the traditional CMYK (cyan, magenta, yellow, key (black)) color separation, with the heads connected in series [(1)].

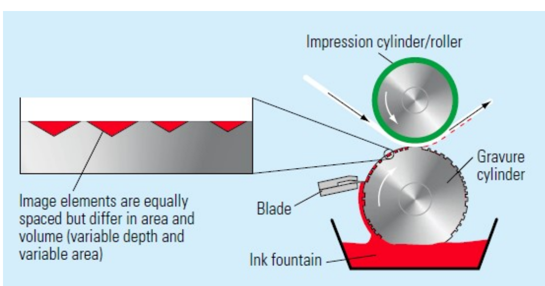


Fig. 1: Gravure Printing (Schematic Diagram) (1)

Gravure, the most reliable and efficient printing technique, is known for the limited variables in the printing technique, is known for the limited variables in the printing process. These limited variables, in turn, pave the way to unswerving print quality throughout a run, the print quality is characterized by the precision with which dot reproduction takes place [(1)].

1.1. Gravure inks

Gravure inks are typically composed of four basic components: solvent, colorant, ink vehicle, and additives. The purpose of the colorant is to provide color. The ink vehicle disperses the colorant and provides printing and end-use properties of the ink. It contains resins and other materials that can be used to bind the colorant when the ink dries. The solvent dissolves the resins in the vehicle and can be used to alter the drying or printing characteristics of the ink. Additives can be used to achieve a specific performance of the ink and include materials such as wax, surfactants, and corrosion inhibitors [(3)]. A typical gravure ink composition ratio is shown in figure (2).

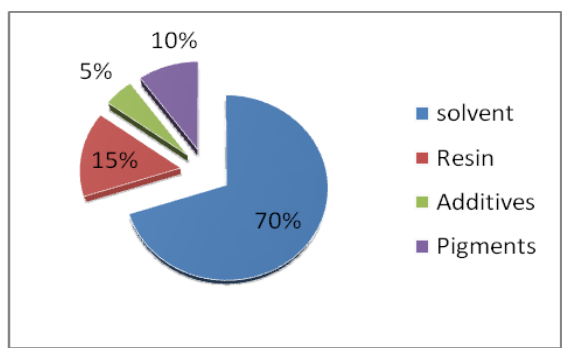


Fig. 2: Ratio of Gravure Ink Components

Gravure inks typically have very low viscosity. This is in part due to the need for the ink to be able to quickly fill the gravure cells as the image carrier travels through an ink fountain at high speeds. In the gravure process, the ink typically dries very quickly after being deposited, so that the image can move to the next printing station without being altered. Additional drying systems are often used to increase drying speed [4].

Viscosity is a measure of a fluid's resistance to flow, varying with temperature and agitation or rate of flow. The variation is not a constant factor, but different for each ink formulation. It is an important characteristic of gravure ink that should be mentored and maintained on press.

It directly influences print quality, printability, drying speed, adhesion, gloss, and more.

Factors that affect viscosity on press include: the ink's rheological characteristics, printing speed, the solvent system's evaporation rate, cell shape and range, the doctor blade ink wiping characteristics, print design parameters, the nature of the substrate, etc. The quality is verified by checking the reproduction of fine structures, range of tone values, trapping precision, image contrast, solid densities, dot gain, and more. In addition to the measurement of test elements (objective analysis), print quality is also checked visually (subjective analysis). This analysis adds a physiological element to the image quality [5].

In the gravure printing technology, the viscosity of inks is measured using an efflux cup. The cup is a standardized tool consisting of a cup with a rounded base and a hole in the bottom. The cup is filled with ink and the amount of time for the ink to flow out is recorded. Although very simple and easy to operate, this method is subject to errors of up to 20%, depending on the method used [6].

2. Experimental Work

2.1. Methodology

The layout was prepared including a multi-color image and test elements that included registration marks, flag marks balls and beads, a tracker line, positive and reverse text, vignettes, a grayscale, hairline elements, and a barcode.

The cylinder was electromechanically engraved with a fine compressed for black at a 70-lpcm screen ruling. The trials were conducted on a multi-color rotogravure press with viscosities from 16 -30 sec. as measured by a Zhan Cup #2. After printing, ten samples from each trial were selected for analysis. The samples were analyzed on the basis of the various densitometry parameters. The effect of viscosity on the various parameters chosen for analysis was evaluated[7], table (1) shows the experimental conditions.

Table 1: Experimental Conditions

Machine:	Cerutti R960/2 – 10 units
Black line screen ruling:	70-lpcm
Black cell angle:	30°
Diamond angle:	120°
Cell shape:	Fine compressed
Ink used:	Black (Nitro cellulose inks)
Solvent used:	Ethyl Acetate & IPA
substrate width:	120.00 mm
Substrate type:	Polyester
Substrate thickness:	12 microns
Doctor blade ;	70 microns lamella (positive angle)
Actual printing speed:	150 m/min.
impression pressure:	2 kg/cm^2
Densitometer :	SpectroDens (Techkon)

Limitations: The ink temperature was not monitored due to the restrictions imposed by the machine's features.

2.2. Checking Parameters

Reflection Density: The light-stopping capability of the ink film or substrate. Density is a function of the percentage of light reflected, and it is the measure of ink film thickness.

Density is defined as:

Density = log10 (1/R)

R – reflectance

2.2.1. Print Contrast :

Print Contrast = ("Ds – Dt" /Ds) x 100

Where Ds – Density of solid

Dt – Density of tint

2.2.2. Print Analysis

The print quality achieved by each trial was evaluated by analyzing ten samples for each trial. Two types of analyses were done :

1- Subjective (Visual)
2- Objective

The subjective (visual) analysis helps to evaluate the various elements of print quality achieved[8].

3. Results and Discuss

After make ready of rotogravure printing machine by fixing all printing process parameters, such as type of gravure cylinder, pressure ratio, tension value, pressure and contact angle of doctor blade with gravure cylinder, level of ink in ink fountain, circulation ink supply, and dryer temperature. Changing only one parameter, which was viscosity values of black ink, measurement of standard color bar of each printed sample has been made to compare between them.

3.1. The effect of ink viscosity on the density and contrast of printed ink

Measuring the densitometry parameters such as density and contrast analysis. It is especially important to note that the viscosity rate of gravure inks should be impacted on the density value of printed ink on substrate, as shown in figure (3), which can be marked that the densitometeric values and ink viscosities exposed the nonlinear or erratic behavior of ink. This erratic behavior depends upon various factors such as cell opening, cell specifications, ink release, speed, viscosity, substrate variations, etc.

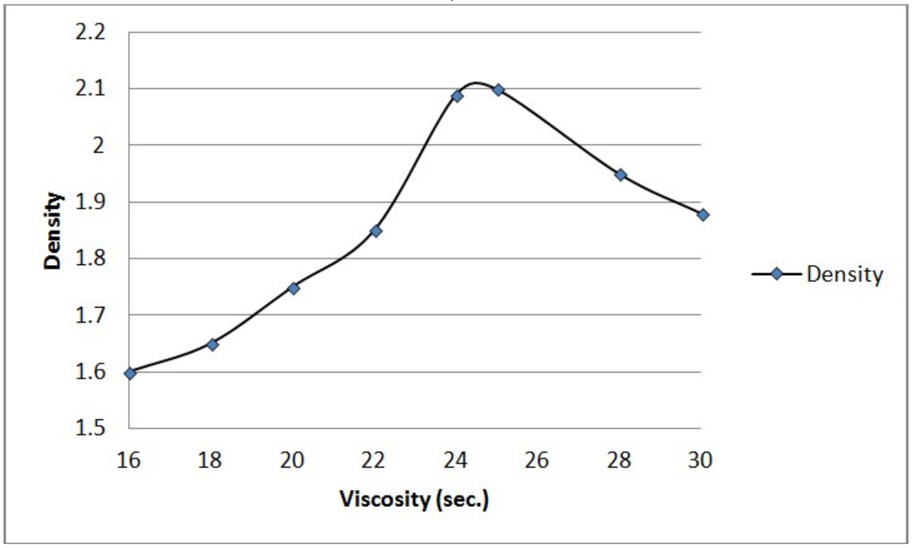


Fig. 3: The relationship between ink viscosity and printing density

Measuring the densitometry parameters such as density and contrast, and trap values composed the objective analysis. The densitometeric values and ink viscosities exposed the nonlinear or erratic behavior of ink. This erratic behavior depends upon various factors such as cell opening, cell specifications, ink release, speed, viscosity, substrate variations, etc.

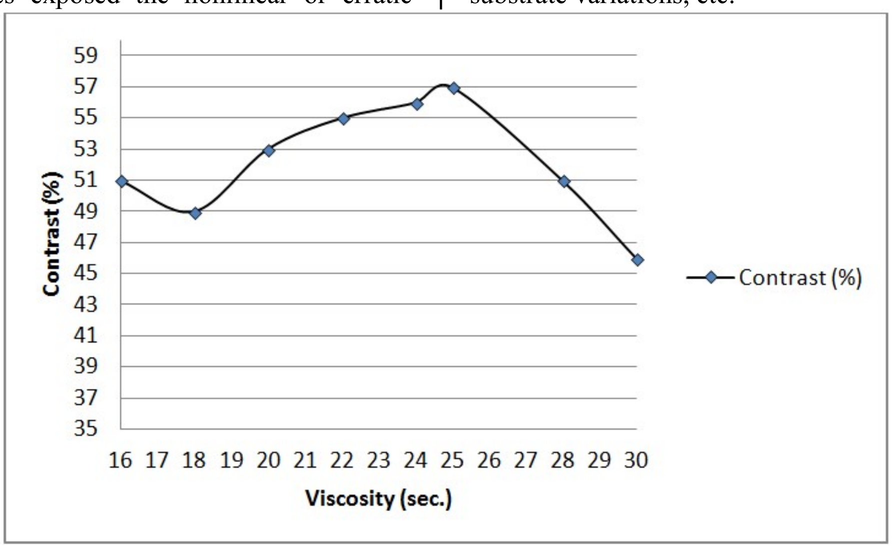
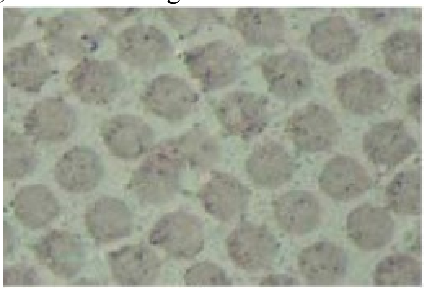


Fig. 4: Relationship of ink viscosity and printing contrast

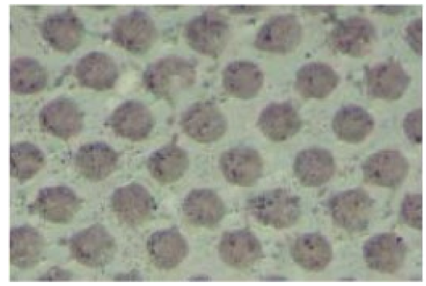
From the graph plotted for density and viscosity, it can be observed that as the ink viscosity decreases, print density also decreases after reaching a saturation point. This holds true for black. The peak density value for black was achieved at 25 sec. At 22 sec, the density value is also slightly higher than the neighboring viscosity values.
If one had started at 16 seconds and not gone beyond 20 seconds, the true optimum value at 22 – 25 seconds viscosity would never have been found. Note also that the density readings are the same at several different viscosities, with higher and lower values between.
It can be observed that black has its highest contrast at 22 and 25 sec.
Finally, it can be noted that all print trials exhibited a good print contrast level. At 22 and 25 sec viscosities.

3.2. Dot Structure Analysis

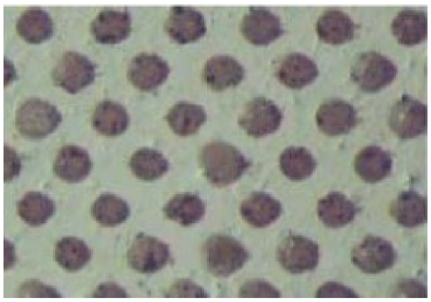
The dots were grabbed using a digital microscope at a magnified level. The image grabbing was done at 30% of black patch. The dot structure analyses provided a clear picture of the print quality, as shown in figure 5.



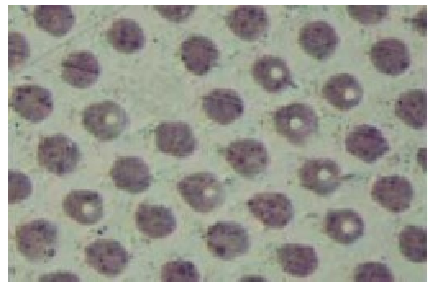
16 sec.



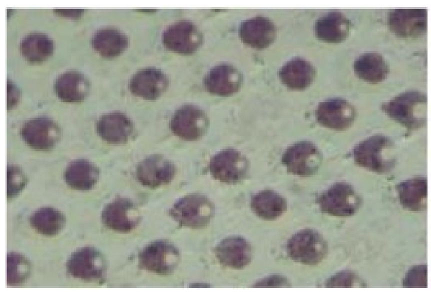
19 sec



25sec



28 sec



30 sec

Fig. 5: Dot Structure Analysis

It can be observed that at 18 sec. the dots are lighter and larger in size. The larger size is due to the low ink viscosity and subsequent spreading of the ink on the substrate. Although low viscosity eases ink transfer from the cells to the substrate, it will result in a messy print having limited sharpness. The lightness of the dots can be explained by the ample quantity of solvent in the ink, reducing the solid ink constituent.

At 19 sec., the dots exhibited improved darkness and sharpness, but the dots still did not having clear edges and, hence, did not the required sharpness.

At 22 sec., the dots behaved more optimally for black. The dots looked sharper and darker.

At 22 sec. and 25 sec., although the dots seemed to be sharp, there were some problems such as missing dots and doughnut. Viscous ink was dried in the gravure cells, which restricted the transfer of the ink from those cells – called "cell clogging".

As the ink temperature increased, the ink filling the gravure cylinder cells took a concave shape leaving an air bubble to be trapped between the ink and the substrate.

By analyzing all the grabbed images, it can be concluded that as the viscosity increases, the dots become rounder, sharper, and darker. Dots of both the low and high – viscosity trials demonstrated problems such as spreading, missing dots, and doughnuts. The best dot structure was observed at 22 sec. to 25 sec. for black color.

3.3. Visual Inspection

In addition to these objective and dot structure analysis, visual analysis were also done. Mottling, the improper laydown of ink on the substrate, was one of the major analysis tools, as shown in figure 6.

Fig. 6: Mottling problem

It can be obvious that print Density is Uneven, due to too much ink being carried, as a reason of low viscosity ink, which may look mottled on substrate with uneven holdout.

As a result of ink viscosity changes for the all details of printed graphic design, it can see it in the figure 7.

(a) (b) (c)

Fig. 7: Variation of products appearance according to different value of viscosities
(a) Dark appearance (Ink viscosity = 30 sec.)
(b) Standard appearance (Ink viscosity = 25 sec.)
(c) Light appearance (Ink viscosity = 16 sec.)

4. Conclusion

Through analyzing on the optical print quality impact by the viscosities of gravure ink, the conclusions are following:

- The vary curve of ink density is different for different viscosity values and the densities doesn't always increase with viscosity increasing (more seconds in unit volume), but it is better with more density value. The value of density doesn't always increase with viscosity increasing, but it can be decreased after reaching a saturation point. 25 seconds is a best viscosity to be selected for black ink.
- Different viscosity value of ink, up 16 seconds to 30 seconds, the contrast properties isn't better with ink viscosity more bigger or smaller. But from 22-25 seconds, contrast is better for ink viscosity.
- As an objective analysis, increasing of ink viscosity caused more darkened of print appearance, and cause mottling problem.
- For dot structure analysis, it can be concluded that as the viscosity increases, the dots become rounder, sharper, and darker. Dots of both the low and high - viscosity trials demonstrated problems such as spreading, missing dots, and doughnuts. The best dot structure was observed at 22 second to 25 second for black color.

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