Influence of Media and Ink Characteristics on the Quality of Color Ink Jet Reproduction of Fine Art Pictures

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Abstract

Printing reproduction of fine art pictures is always a demanding task. On the one hand, the first quality criteria are the extent of color gamut and the fidelity of the reproduction. On the other hand, the choice of the texture of the substrate adds authenticity to the printed result, but may reduce the color gamut.

In this study, four different fine art substrates were thoroughly characterized: optical properties (brightness, reflectance and gloss) and surface properties (roughness, surface energy, absorption characteristics and printability) were analyzed.

Print tests were conducted on ink-jet printers, with test-forms allowing the description of color gamut.

The objective quality criteria were the color gamut volume, the optical density on solid colors and the tone value increase. In addition, the quality of reproduction of grays and saturated colors was evaluated and the performance of ICC profiles were also measured on the printed samples.

Finally, a subjective analysis was conducted on these samples, which showed that the objective measurements are not necessarily sufficient to describe the whole reproduction.

Introduction

Ink-jet process is currently used in many fields of color reproduction. In the present work, the reproduction of fine art pictures is considered. This application is characterized by a high level of required quality. The color fidelity and consistency are of course the first quality criteria. Moreover, textured papers are often chosen, in order to try to simulate the original painter's canvas. Unfortunately, these special substrates are generally rough, compared to classical ink-jet papers. This implies an accurate preparation of the printing. This work describes the preliminary characterizations conducted on special papers before printing, in order to create adequately the ICC profiles for the reproduction of a fine art picture.

According to the studies conducted on the paper properties, and their influence on ink-jet printing quality, the main factors affecting the ink spreading, thus the printed result, are the optical properties (brightness, gloss, opacity) and the surface properties (smoothness, surface energy, liquid absorption).[2-4] Besides, the inertial effects of the droplet impinging onto the substrates are also of prime importance. Thus, in parallel, the main characteristics of the ink must be considered: its nature (pigment- or dye-based, solvent- or water-based) and its properties (mainly viscosity and surface tension). The printer characteristics intervene in this stage: droplet size and speed. Most of the studies available on these aspects concern polymer-swellable coated papers or micro-porous papers.

Materials and Methods

Four substrates specifically used for fine art reproduction were used in this study: Textured (T), Soft (S), Coated (C), papers and one canvas (Cv). They were characterized by the classical methods of paper analysis: optical properties (brightness, reflectance and gloss) and surface properties (roughness, surface energy, absorption characteristics and printability).

Then, these samples were printed with a specific test form in order to quantify their capability to reproduce fine art works. The procedure of calibration is described in Ref. [1].

In parallel, an example of picture was also printed, with the same settings, as an illustration of the observations made on the test form.

Optical Properties:

Table 1 presents the optical properties of the paper samples.

The opacity was measured according to the NF Q03 040 standard; the brightness is the intrinsic reflectance factor of the paper (R_∞), measured at 457 nm (according to NF Q03039); the gloss was measured under 60° angle. The thickness of these special substrates is quite high, which explains their high opacity also. Papers T, S and canvas Cv had similar brightness, while paper C had a slight yellow hue.

Table 1. Optical Properties of the Papers

	T	S	C	Cv
Thickness (µm)	**426**	**363**	**250**	**384**
Opacity (%)	**97**	**97**	**98**	**98**
Brightness (%)	**87.8**	**85.9**	**67.6**	**86.7**
Gloss (%)	**9.7**	**16.3**	**2.5**	**15.8**

Surface Properties

Table 2 presents the surface characteristics of the paper samples.

The Bekk smoothness and the Parker Print Surf roughness (which gives the mean depth of the surface pores) of the samples were measured. All these papers have a very rough surface, characterized by very low Bekk values. For seek of comparison, a coated paper for offset printing may have a Bekk roughness around 1000s, while the Bekk value for a laser printing paper is around 50s. Thus, the mean pore size is relatively high. For comparison, a paper for news has a mean pore size around 3 to 6 µm.

The absorption properties, determined by the Cobb experiment, gives the water volume absorbed per second by the paper. This static evaluation shows that paper Cv absorbs water more rapidly than the other substrates, which could be due to its surface composition.

Table 2. Surface Properties of the Papers

	T	S	C	Cv
Bekk smoothness (s)	**-**	**3.5**	**3.1**	**0.3**
PPS roughness (µm)	**9.5**	**6.6**	**8.2**	**8.6**
Cobb absorption (g/m^2)	**47.2**	**43.8**	**46.9**	**64.1**
Surface energy (mJ/m^2)	**37**	**57**	**63**	**64**

The surface energy of the papers was determined by the technique of contact angle measurement and by the calculation based on the Owens-Wendt theory. The limit of this determination lies in the approximation of the evaluation of the contact angle. The calculation is made with the apparent and not the intrinsic contact angle. This artifact often leads to an over-estimation of the surface energy.[5] However, it gives an indication on the wettability of the ink. Besides, this determination is helpful to characterize the polar or dispersive character of the surface analyzed. For instance, the surface energies of papers T and S were essentially dispersive, whereas paper C and Cv had a significant polar component. The latter may imply a better affinity with a water-based ink.

Printing Conditions and Ink Properties

The papers were printed on a DesignJet HP5000, equipped with a series of 6 pigmented water-based inks: Cyan, Light cyan, Magenta, Light magenta, Yellow and Black. These inks had about the same viscosity: 3.5 mPa.s (measured on a cone-plate rheometer, at 20°C and a 2500 s^{-1} shear rate).

The mean diameter of the ink pigments was between 50 and 100nm, which is relatively low.

The surface tension of these inks was measured with the DuNoüy ring method, at room temperature, and was found to be 25mNm^{-1}. This low surface tension, compared with the surface energies of the papers, should make possible a good wetting of the surfaces by these inks.

Figure 1 represents the reflectance spectra of the 6 inks printed on Paper C, measured with the X-Rite spectrophotometer SP62. Table 3 regroups the corresponding L*a*b* values, calculated under the D65/10°-gloss excluded conditions.

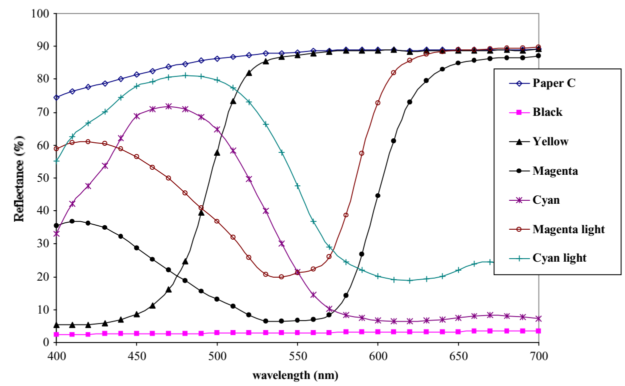

Figure 1. Reflectance spectra of the inks printed on Paper C

Table 3. L*a*b* Values of the Inks Printed on Paper C (D65/10°) – Specular Excluded

	L*	a*	b*
Magenta	52.9	58.7	-11.63
Magenta light	69.5	43.5	-15.5
Cyan	60.7	-31.1	-40.1
Cyan light	74.6	-30.9	-26.0
Yellow	90.9	-9.8	80.8
Black	20.3	0.72	2.52

Results – Consequences on Print Quality

After printing on paper C, the tone increase values (or "dot gain") were calculated from optical density measurements on the four primary colors. No significant difference was noted between the four-color process and the six-color process. The tone increase was maximum around 25% coverage, and could reach up to 50% in this area for black ink, as shown on Figure 2. These values are typical for ink-jet printing, but may be considered as excessive in the context of precise color reproduction. This was emphasized elsewhere,[1] and the strategies of corrections described there were used in the present work.

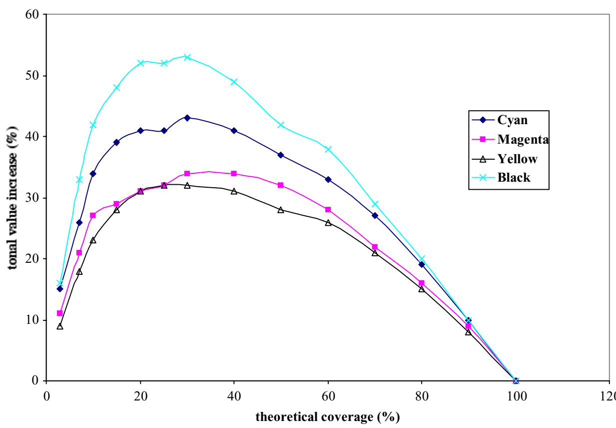

Figure 2. Tone increase values of primary inks on Paper C

Given the results of the first printing without any correction (bleeding , slow drying of inks in dark areas, and lack of luminosity in light areas), two different profiles were created. Both are based on the principle of Under Color Removal (UCR), which implies the reduction of total amount of ink printed in gray zones.

The color differences between the original (an IT8 test form) and the printed results were thoroughly analyzed. The IT8 form was used in this study classifies the colors, according to their luminance, their chroma and their hue, independently. A systematic study of the color differences along the different zones of the form test provides information of interest about the capability of a paper to reproduce a group of colors.

The six-ink process turned out to be less efficient in this context. The mean color differences were larger, for each paper, with this setting. This can be explained first by the high roughness of the papers, but also by the size of the ink droplets (15pL) delivered by the printer. It was observed more generally that these papers are not appropriate to receive at the same time a large amount of ink. The first ink printed is not yet dry when the second impinges on the paper. Consequently, curling was sometimes observed in the zones of high ink coverage, even with the UCR correction.

Figures 3a and 3b present an example of results obtained for the reproduction of one series of patches of the test form on paper T. The colors are represented by their projection on a (a*,b*) plan, L* being constant. The colors of the original are distributed on a circle (Fig.3a), whereas the figure formed by the colors of the reproduction on paper T corresponds to a distortion of the initial circle. Similar observations were done on the other substrates. These tests allow among others to determine the zone of colors, which will be more difficult to reproduce with one paper, and to compare the paper performances.

The volumes of the color gamuts were also calculated by the method of determinants.[6] Table 4 presents the comparative values obtained, for the different papers. This characterization provides an additional information, comparable with other substrates or printing processes.

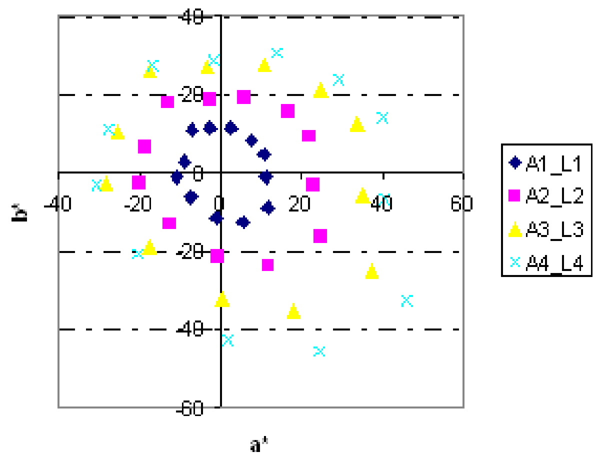

Figure 3a. (a, b*) diagram, L* constant - original*

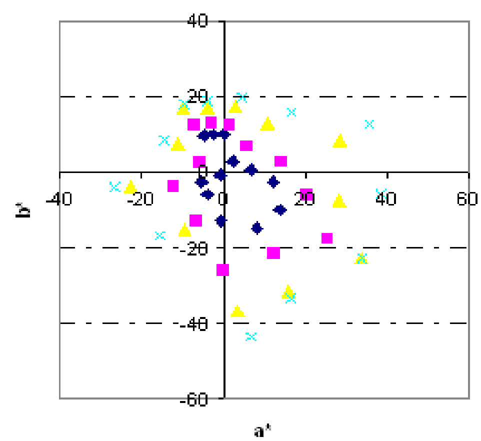

Figure 3b. (a, b*) diagram, L* constant – reproduction on paper T*

Table 4. Volume of the Gamuts Obtained on the Papers

Substrate	Gamut Volume
T	230 720
S	244 860
C	243 170
Cv	261 080

Given these results and those of table 2, it can be concluded that the larger gamut may be reached on a rough paper, provided it possesses good absorption properties, which ensure quick ink drying.

Conclusion

Optimum image quality and printing performance can be achieved by optimization of ink and media properties, but also by a thoroughly conducted pre-press stage. This implies a preliminary determination of the characteristics of the substrates, in order to optimize the printing process. These characterizations give a better knowledge of the materials, which could help in the prediction of the ink/paper interactions, thus in the choice of the most adequate paper especially in the field on fine art reproduction.

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Biography

Anne Blayo graduated from the French Engineering School of Papermaking and Printing in 1988 and received her Ph.D. at the National Polytechnique Institute of Grenoble in 1994. Her thesis concerned rheological properties of printing inks. Since then, she has been working in the French Engineering School of Papermaking and Printing (EFPG) as a teacher and researcher. Her work is focused on printing inks (chemical composition, physico-chemical and rheological properties) and color-related studies.