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Mottle evaluation of coated cardboards printed in inkjet

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Abstract

In this study the methods suggested in the standards ISO/TS 15311-2 / ISO/IEC 24790 and the method suggested from FOGRA (M-Score) to measure print mottle were conducted and compared with visual evaluations. The aim was to understand if one of them is more adequate for evaluation of mottle in inkjet print on coated cardboards and if pre- and post-treatments on the cardboards have an influence on print mottle.

The measurements showed that the first method has a higher accordance with visual evaluations. A second finding was that a pretreatment with primer and post treatment with IR-radiation to improve ink adhesion and drying can also reduce print mottle.

Background

Logistics efficiency, reduction of capital commitment and especially frequent layout changes as package size, text or pictorial elements lead to increasingly demand of smaller production batches.

This challenge require a new way of thinking in the printing industry: large production volume divided in smaller and multiple production orders. For this demand the digital printing process is a fitting technical and economic solution owing to the short lead time and production of small and exact batch sizes. However, fundamental and technical aspects still have to be investigated.

Inkjet print using water based inks on pigmented surfaces of coated cardboards, for example, present some physicochemical incompatibilities that causes print drawbacks as poor drying and ink smearing. In comparison with plain papers, coated cardboards have a very smooth surface with narrow pores, which causes a slow and inefficient absorption of inkjet inks. Further the in general anionic properties of both the cardboards' coating layers and the inkjet inks impair the adhesion between ink and coated surface.

A previous paper [1] presented a printer concept (Figure 1) with a priming unit using a primer based on a PVOH solution as pretreatment and a drying unit using infrared radiation (mid wavelength) as post-treatment. Used together, the two treatments can reduce the above-mentioned drawbacks. However, these treatments can also influence the ink flow behavior and other unknown print defects can occur. To understand the effect of the primer and the infrared (IR) radiation, qualitative evaluations needs to be conducted.

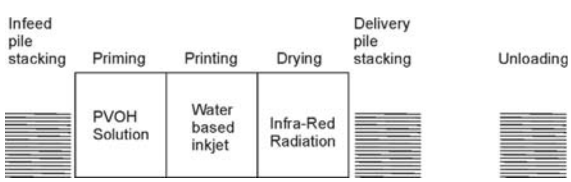

Figure 1. Printer concept with a pre- and post-treatment units

Motivation and problem

The qualitative evaluation of inkjet printing is still under development, but among several aspects to be evaluated, printing mottle is very relevant because inhomogeneity is one of the easiest printing defects to perceive. This study aims to analyze if one of the recent developed methods for printing mottle evaluation is more suitable for inkjet printing of coated cardboards. The basic criterion for this analysis is the numerical accordance between methods and visual evaluations results. A second goal is to analyze if the above-mentioned PVOH primer and the IR radiation increase or reduce printing mottle.

Method and materials

The testing materials, equipments for sample production and laboratory surrounding informations are listed in the Table 1 to 3:

Testing materials	Data
Coated cardboards	Seven commercial FBB and SBB 300 ±5 g/m2
Inks	Canon dye ink CMYK CLI-551
Primer	PVOH 20-98 (4 wt. %) and HPLC water (96 wt. %) Prepared by means of magnetic stirrer with constant temperature until the mixtures became homogenous.

Table 1. Description of testing materials

Equipments for sample production	Data
Printer	Canon / PIXMA iX6850 - Thermal printhead technology – 1200 dpi
Mayer rod (priming)	Wire wound rod – primer transferred weight 1.2 ±0.1g/m^2
Infrared dryer (drying unit)	Elstein / HTS Panel radiators wavelength 2 - 10 µm Panel temperature 500 ±5°C Distance: panel to cardboards 38 ±1 mm distance

Table 2. Description of equipments for samples production

Laboratory surrounding	Data
Spectro-photometer	Konica Minolta / FD-9 Geometry 0°/45° Illuminant D50/2° Measurement illumination condition: M1
Scanner	Epson / Perfection 4990 Photo
Viewing station	GTI Graphic Technology
Evaluation software	M-Score: Matlab Publish Code [2] Mottle in 15311-2 / 24790: Package Tool TS24790_Tool_vers.1.5.1. [3]

Table 3. Description of laboratory surrounding

Two mottle evaluation methods were chosen for this study:

a) Mottle evaluation suggested in the standards ISO/TS 15311-2 [4] and ISO/IEC 24790 [3]

b) Mottle evaluation (M-Score) suggested by FOGRA [2]

These methods differ in several aspects: colors selection, test chart design, consideration of the spatial arrangement of inhomogeneity, data capture and calculation. Due to these differences and mainly because device dependent tests should have a parity with the observers perception, a visual evaluation was also conducted. Another important point is that both standards were developed to evaluate printers' quality and not directly prints' quality.

In a) the test chart suggested in ISO/TS 15311-2 [4] (Figure 2) was used.

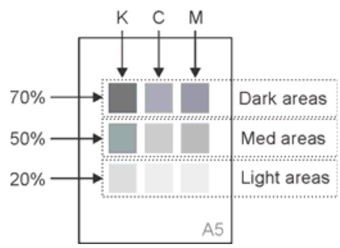

***Figure 2**. Test chart for mottle evaluation according ISO/TS 15311-2 [4]*

Although the test chart and reference values are described in the ISO/TS 15311-2, this refers the ISO/IEC 24790 as method for mottle evaluation.

In this standard print inhomogeneity can be defined in two categories: mottle and graininess. Below a periodical fluctuation of 0.4 line pairs/mm in the print, the deviation is referred as mottle and above this value as graininess.

The method consists in: generate an Opto-Electric Conversion Function by means of maximal reflectance (not printed cardboard) and minimal reflectance values (printed black area), define a region of interest (ROI) in the scanned samples and use the function Mottle Measurement of the software.

The ROI should have at least 645 mm^2 (25.4 x 25.4 mm), a resolution of 1200 dpi (Figure 3) and a blanked margin (gap between 1 and 2). The area is divided in 100 smaller tiles "b". In each tile 14400 points are measured [3].

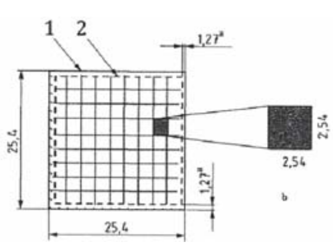

***Figure 3**. ROI for mottle evaluation according 24790 [3]*

In b) both the test chart and the Matlab Publish Code for M-Score Calculation developed by Fogra were used.

An evaluation matrix, based on visual experiments, with an index for different quality levels was developed. This ranges from 0 (bad homogeneity) to 100 (perfect homogeneity). The tests charts are available in the "Image Quality Test Suite" from Fogra in 2 formats. For the tests the A4-Format was chosen. The charts (Figure 4) consist of three different shades of gray composed of CMYK values with a total of 806 measuring fields (31 rows x 26 columns). The 3 CIE L*a*b* coordinates per measurement field are the basis of the calculation. A zero as M-score, for example, corresponds to an image in which extreme value deviations in form of stripes and mottle texture were measured, i.e. the measured values between neighboring fields have a large delta.

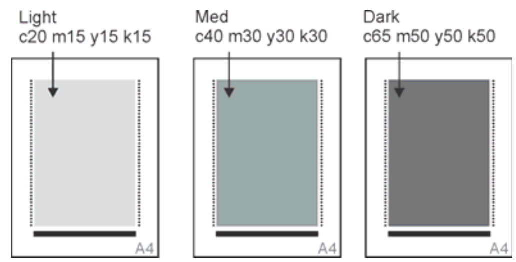

***Figure 4**. Test chart for M-Score measurement according FOGRA*

For the visual evaluation 20 observers (printing skilled students and scientists) were equal distributed in 2 groups ("GA" and "GB").

GA performed the relative visual evaluation and observed all samples as a whole (figure 5), whereas GB performed the absolute visual evaluation observed sample by sample separately (figure 6).

In the printed charts "T" represents the point in time of the visualization. "U" means unprimed samples and "P" means primed and dried with IR radiation samples.

Seven commercial coated cardboards of different suppliers (identified as B-01 to B-07) were printed in a thermal inkjet printer with CMYK dye inks and observed in a GTI Graphic Technology viewing station (ISO 3664:2009 compliance).

The quantity of printed samples are detailed in table 4

***Figure 5**. Relative visual evaluation performed by GA - (exemplarily for the 24790 test samples)*

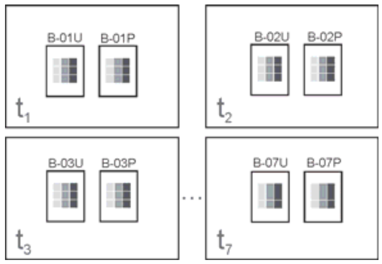

Figure 6*. Absolute visual evaluation performed by GB (exemplarily for the 24790 samples)*

	Printed samples of each coated cardboard	
Method	"U"	"P"
a)	10 prints	10 prints
b)	10 prints	10 prints
	Samples for visual evaluation	
Group	"U"	"P"
GA	3 first prints	3 first prints
GB	3 first prints	3 first prints

Table 4*. Description of test samples*

The observer´s evaluation sheets are presented in the Figure 7 (Mottle by 15311-2/24790) and Figure 8 (M-Score Fogra). The name of the mottle evaluation method, such as informations about the cardboards, pre or post-treatment, was not disclosed to any observer.

B-07 - P	Test 1				
	very good	good	satisfactory	sufficient	poor/bad
Magenta light					
Magenta med					
Magenta dark					
Cyan light					
Cyan med					
Cyan dark					
Black light					
Black med					
Black dark					

Figure 7*. Observer´s evaluation sheet – Mottle 15311-2 / 24790*

B-07 - P	Test 2				
	very good	good	satisfactory	sufficient	poor/bad
Light					
Med					
Dark					

Figure 8*. Observer´s evaluation sheet – M-Score Fogra*

The correlation between measured results and quality level for both methods is not equal. The measured results using M-Score are categorized in a scale from "perfect" (result ≥ 95*)* to "poor" quality (result < 50). In the Standard 15311-2 the measured results are classified in terms of application, i.e. which products can be printed in the achieved quality, for example, "advertisement" (result ≥ 0.5) or "editorial products" (result ≥ 2).

As these classification terms can be interpreted in different ways, according to the observer, a congruent classification for both methods was used for the visual evaluation (Table 5). The quality level "perfect/proof" has not correlation in the Standard 15311-2. Since the tested materials are not for proofing, this level was not considered. This quality also was not achieved in any test, thus not affecting the analyses.

Scales				
M-Score Fogra	Result	Mottle in the 15311-2	Result	Visual evaluation
Perfect (Proof)	≥ 95	-	-	-
Very good	≥ 80	Full-page advertisement	≥ 0.5	Very good
Good	≥ 70	Product advertising	≥ 1	Good
Satisfactory	≥ 60	Editorial	≥ 2	Satisfactory
Adequate	≥ 50	*Not defined*	≥ 3	Sufficient
Poor	< 50	Outside digital print quality	< 4	Poor/Bad

Table 5*. Correlation table between measured results and quality level*

Results

The accordance between device dependent methods and visual evaluations was used as criterion to analyze if one of them is more adequate to the evaluation of print mottle in the samples described above.

In order to illustrate the differences between unprimed "U" and primed "P" samples all results were compared and categorized as "mottle U > mottle P", "mottle U < mottle P" or "mottle U = mottle P" and compared.

Table 6 compares visual evaluations and measurements. In overall, the visual evaluation shows more accordance with the results using the method suggested in the ISO/TS 15311-2 / ISO/IEC 24790. In overall, the highest accordance between visual evaluations of GA (relative) and GB (absolute) occurs by the evaluation with M-Score method.

24790	GA = GB	GA = 24790	GB = 24790
Light	81%	86%	76%
Med	76%	81%	76%
Dark	90%	90%	90%
Overall	82%	**86%**	**81%**
M-Score	GA = GB	GA = M-Score	GB = M-Score
Light	71%	86%	57%
Med	86%	57%	71%
Dark	100%	57%	57%
Overall	**85%**	67%	62%

Table 6*. Percent of equivalent results between visual evaluations and measurements (main results in bold)*

To analyze the effect of primer and IR radiation on print mottle, the absolute difference between "U" and "P" results were calculated. Table 7 shows the percentage of measurements or visual evaluations that evaluate the "P" samples in higher quality level than "U" samples. Almost all measurements showed, that "P" have less mottling than "U", particularly for light areas.

	Visual evaluations		Measurements
Charts 24790 *(s. Figure 2)*	GA	GB	15311-2 / 24790
Light	67%*	76%	52%**
Med	52%	71%	62%
Dark	48%	62%	62%
Overall	*56%*	*70%*	*58%*
	Visual evaluations		Measurements
Charts M-Score *(s. Figure 3)*	GA	GB	M-Score
Light	86%	57%	71%
Med	71%	57%	29%
Dark	57%	57%	71%
Overall	*71%*	*57%*	*57%*

***Table 7**. Percent of evaluations in higher quality level for "P" samples (Quality levels in Table 5)*
** 67% of observers evaluated the prints on primed coated cardboard with higher quality level than on unprimed coated cardboards*
*** 52% of measurements show a higher quality level of prints on primed coated cardboard than on unprimed coated cardboards*

Other observations:

- Visual evaluations (both groups) evaluated the samples in lower quality levels than the measurements by means of the TS24790-Tool or M-Score calculations, especially for "U" samples.
- In the final considerations about the tests, both groups identified the M-Score/Fogra samples as easier to evaluate than the ISO/TS 15311-2 / ISO/IEC 24790 samples. The main argument was that by light areas of cyan and magenta was difficult to observe mottle in the standard viewing distance (400 mm).
- Visual evaluations, measurements by means of the M-Score or TS24790-Tool showed that the homogeneity of B-01, B-03 and B-06 improved more than for the other cardboards.

Conclusions

This study shows that the mottle evaluation method proposed in the standards ISO/TS 15311-2 / ISO/IEC 24790 and by FOGRA are appropriate for the evaluation of printing mottle of inkjet print. The first one had a higher numerical accordance with the visual evaluations. Pretreatment with PVOH based primer and post treatment with IR-radiation improves ink adhesion and drying and can also reduce print mottle.

References

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[2] Fogra Forschungsinstitut für Medientechnologien e.V., "Fogra Forschungsinstitut für Medientechnologien," 2019. [Online]. Available: https://bit.ly/2IMCxjn. [Zugriff am 09 01 2019].

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[4] ISO, "ISO/TS 15311-2:2018 - Graphic technology -- Print quality requirements for printed matter -- Part 2: Commercial print applications utilizing digital printing technologies," ISO, Swizerland, 2018.

Author Biography

Sandra Rosalen studied Industrial Administration and holds a master's degree in Print and Media Technology. She worked for 10 years in the technical management of printing industries, 6 years as technical consultant and for 4 years as lecturer in the Technical Faculty of Print and Media Technology (Sao Paulo). Currently she focuses her researches on packaging production in digital printing systems as research assistance at the University of Wuppertal.

Prof. Dr.-Ing. Johannes Backhaus studied Machinery and holds a doctor´s degree in Machinery/Plastic Processing. After 16 years as manager in several printing factories, since 2002 he holds the professorship of Print Finishing and Packaging Technology at the University of Wuppertal.