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Print Quality Control Management for Papers Containing Optical Brightening Agents

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Abstract— Optical brightening agents (OBAs) or fluorescent whitening agents (FWAs) are chemicals added to paper during the papermaking process to increase the brightness of paper (chemical additives that increase the reflection of blue light (caused by ultraviolet light with a wavelength below 400nm) for the correction of a natural yellow color of paper pulp). Papers with agents for optical brightening are often represented on the market. The aim of this paper is to show that colors reproduced on paper with (Iggesund Incada Silk, 220g/m^2) and without (Iggesund Incada Silk T, 205g/m^2) agents for optical brightening, are different during the same printing conditions. Standard ISO 13655 (Spectral Measurement and Colorimetric Computation for Graphic Arts Images) defines the “M” series of illumination, which provides color management in these conditions.

Index Terms— Print Quality Control, Color Management, Optical Brightening Agents, Incada Silk, ISO 12647-2, ISO 13655, CIEDE2000, Altona Measure 1v1a.

1 INTRODUCTION

Optical brightening agents are often added in the paper manufacturing process in order to increase the reflection of blue light. Nowadays, almost is not possible to find printing paper without contain of optical brightening agent, except in situations in which it is particularly required (for example, the cigarette paper).

Increased reflection of blue light increases the perception of whiteness and "purity" of the paper, with maximum values of reflection at wavelengths of 457 nm [1]. The effect of the whitening agent is active under UV light sources such as daylight and D65 illuminant. For the consumer, colors printed on the paper with optical brightening agent are more "alive" because the optical brightening agent "lie" the human eye by moving the invisible UV light from the day light to the visible blue light. In this case, on the paper, blue light hides natural yellow pulp color as long as UV light falls on the paper.

The impact of brightening agents in paper on printed image color has not been well understood of accurately. Spectrodensitometers use an incandescent illuminant that does not contain a UV component. As a result, no UV light reflectance occurs and the effects of optical brightening agents on perceived color remain unknown.

Measurements taken using standard spectrophotometers may indicate a match between the printed color values and a defined standard or proof, but when viewed with the human eye under UV component lighting, they may appear to not match at all.

2 THEORETICAL PART

Optical brightening agents or fluorescent whitening agents are fluorescent substances. Fluorescence is characteristic of substances to transform energy absorbed by the invisible UV wavelengths to the emission of visible wavelengths. Printing industry in the print quality control process, use instruments geometry $45^0 : 0^0$ or $0^0 : 45^0$ at D50 reference illuminant, mostly derived from tungsten lamp filled with gas, which no coincides entirely with the so-called golden rule "measure as you can see".

Optical brightening agent affect the brightness of the paper by increasing the amount of fluorescence the paper has. Fluorescence is the conversion of non-visible light into visible light. A common way to view fluorescence is under a black light. Often, fluorescence is confused with phosphorescence. Commonly seen in glow in dark items, phosphorescence stores light and then releases it gradually as the electrons relax back to the ground state from their excited state when interacting with the light source previously. Phosphorescence can be seen without a black light in a dark room [2].

Fig.1. Paper with various amounts of optical brightening agents [3].

Fig.2. Considered papers under condition of UV-cut light [3].

Fig.3. Considered papers in daylight simulator for activation of optical brightening agent effect (fourth from left sample contain the highest amount of optical brightening agent effect) [3].

The Konica Minolta FD-7 spectrodensitometer accurately

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evaluates color, including the effect of OBAs, because it illuminates the sample using an LED illuminant that replicates D50 lighting conditions, which is the standard for light booths used for color matching in the pressroom. Konica Minolta claims it is the first instrument capable of providing measurement results under this standard light source, which corresponds to ISO 13655 Measurement Condition M1. The D50 illuminant includes a UV light component, which excites the OBAs and causes them to reflect light in the blue spectrum, and therefore the result is captured in the spectral reflectance curve. [15]

3 Experimental Part

For experimental part of this article, Altona_measure_1v_1a printing test form is used, printed on two types of paper, with optical brightening agent Iggesund Incada Silk (paper whiteness 95.0 L*, 1.0 a*, -5.3 b*, data from paper manufacturer) with 220 g/m^2 and without optical brightening agent Iggesund Incada Silk T (paper whiteness 94.8 L*, -0.23 a*, 1.7 b*, data from paper manufacturer) with 205 g/m^2 [5]. Printing was done on Heidelberg Speed Master SM 74 four-color printing press, with 500 copies on each paper types.

Measured values of CMYK (process color) solid inks density are 1.46 (cian), 1.45 (magenta), 1.32 (yellow) and 1.73 (black). Measurement includes CMYK solid inks, 50% tone values and overprint colors (red (M+Y), green (C+Y) and blue (C+M)) shown via CEILAB values and CIEDE2000 color difference.

The measurement is performed on multiple random samples and then an average value was calculated [6].

Measurement was done with Gretagmacbeth SpectroEye spectrophotometer, analyzing the impact of optical brightening agent on paper brightness and the changes on the measured value of CIELAB colors printed on paper with optical brightening agent and paper without optical brightening agent in various sources of illumination.

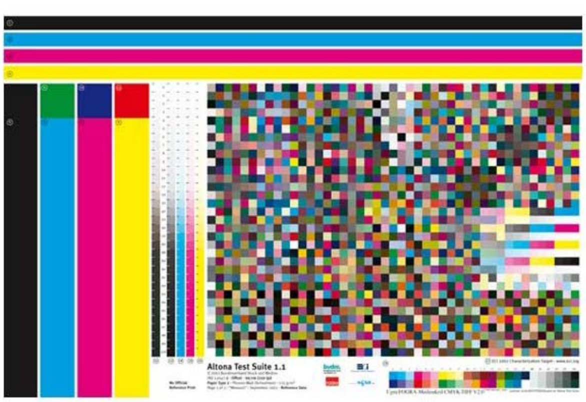

Fig. 4. Altona_measure_1v1a test form.

3.1 Impact of the Optical Brightening Agent on the Paper Whiteness

ISO 13655:2009 standard (Spectral measurement and colorimetric computation for graphic arts images) determining the fluorescence prescribed by calculating the color difference CIEDE2000 [7] by measuring the L* a* b* values obtained in A and D65 illumination.

CIEDE2000 > 0.5 value indicates that the test paper fluoresce due to the presence of optical brightening agent [4].

TABLE 1
Paper whiteness L*a*b* values and color differences CIEDE2000 (A and D65 illuminants), measure was done with SpectroEye spectrophotometer

	L* (A)	a* (A)	b* (A)	L* (D65)	a* (D65)	b* (D65)	ΔE00
Incada Silk	94.11	1.14	-0.9	95.0	1.0	-5.3	3.98
Incada Silk T	94.6	-0.19	1.21	94.8	-0.23	1.7	0.48

3.2 Impact of the Optical Brightening Agent on the Printed Colors

CMYK solid colors difference, 50% tone values and their overprints printed on paper's with optical brightening agent and without optical brightening agent was analyzed by using A and D50 illuminants. The obtained color differences are relevant because of the different application of A and D50 illuminants. UV component from D50 illumination is pleased to encourage paper fluorescence and direct implication of the printed colors.

TABLE 2
CIEDE2000 color differences (A and D50 illuminants), measure was done with SpectroEye spectrophotometer

Incada Silk (with OBAs)	ΔE00	Incada Silk T (without OBAs)	ΔE00
Cyan 50%	1.002	Cyan 50%	0.429
Cyan 100%	0.322	Cyan 100%	0.091
Magenta 50%	1.154	Magenta 50%	0.527
Magenta 100%	0.518	Magenta 100%	0.199
Yellow 50%	1.389	Yellow 50%	0.312
Yellow 100%	0.602	Yellow 100%	0.021
Black 50%	1.406	Black 50%	0.625
Black 100%	0.000	Black 100%	0.000
Red 100%	0.219	Red 100%	0.020
Green 100%	0.095	Green 100%	0.012
Blue 100%	0.121	Blue 100%	0.017

4 Discussion

The experimental part of this article about the effect of optical brightening agent on the paper brightness shows, as recommended by ISO 13655, the paper containing optical brightening agent (measurement performed at A and D50 illuminants) fluoresces with greater intensity depends on the amount of optical brightening agent (Incada Silk ΔE00 = 3.98;

Incada Silk T ΔE00 = 0.48).

The experimental part of the article about the effect of optical brightening agent on CMYK solid inks, 50% tone values and their overprint's shows that because of greater fluorescence as result of optical brightening agent, printed colors are displayed differently in different sources of illuminations.

Measurements show that a higher percentage of ink density on paper with optical brightening agent gives smaller spectral reflection in terms of various illuminations.

Colors with 50% tone values of both types of paper have reached the CIEDE2000 higher values compared to the printed solid colors. This means that creating a profile for accurate reproduction of colors besides the relationship of color and printing surface on the paper with optical brightening agent need to be also analyzed the percentage of colors coverage (ink density).

Black solid in both cases show very small reflection and CIEDE2000 color differences is 0.

According characteristics of paper with optical brightening agent (greater reflection of blue light under UV light) can be expected CIEDE2000 color difference of yellow color to be the biggest because yellow color is complementary to blue color. The measurement shows that CIEDE2000 of the yellow color (50% half tone) have a higher value than cyan and magenta and lower value than black.

Overprints (red, green, blue) have lower values of CIEDE2000 compared with process colors (cyan, magenta, yellow), probably double layers of printed color have influence on color reflection, resulting with lower values of color difference.

5 Conclusion

A high percentage of the presence of paper with optical brightening agent in the market requires changes in the definition of requirements and recommendations for achieving excellence in printing process (successful color management).

ISO 13655 standards prescribes M series of illumination, which provides color management also in these conditions.

Measure condition M0 or the legacy mode is an obsolete measurement mode. Historically instruments used in the graphic arts industry did not use a light source with a defined and/or stable UV content. M0 as a standard expresses that the majority of instruments use a gas-filled tungsten lamp to illuminate the samples rather than D50 and therefore users accept a known weakness. The problem with unstable and undefined UV content is that when measuring fluorescent samples such as papers with optical brighteners, the measurement response does not correlate with the viewing environment where the printed product is used. Although many users have chosen to ignore it, the UV content of a gas filled tungsten lamp also changes over time which means that measurements are unreliable. For legacy reasons and to compare measurements with existing instruments, the Konica Minolta FD-series spectrodensitometers offer the choice of measurement mode M0. Here the spectral power distribution of CIE illuminant A (which is recommended in ISO 13655:2009 for M0) is used to illuminate the sample. Due to the stable UV-content in the Konica Minolta instruments users can at least rely on stable measurements if they need to use M0 for legacy reasons [16]. Measure condition M1 or the all-time desired mode uses standardized viewing conditions in order to minimize issues when communicating color. The relevant standard is ISO 3664, which specifies CIE illuminant D50. Since 2009 the UV-content of D50 has to be met within closer tolerances than before. In order to make sure that optical brighteners "glow" to a similar extent when illuminated during a color measurement as they do in a D50 viewing environment, ISO 13655 introduces the measurement mode M1. Compliance to M1 can be achieved in two ways: Method 1: Illuminant Match and Method 2: UV Calculation. The measurement mode M2 or UV-cut mode was standardized in order to reflect viewing conditions that are free of any UV content such as in a museum. Thus it is often - referred to as "UV-cut". In the past spectrophotometers equipped with a UV-cut filter were used in order to ignore the effect of optical brighteners. It was thought this would make the calculation of ICC profiles easier as UV-introduced metamerism did not effect measurements. The misconception that optical brighteners disturb color measurements is still present among users (and to some degree vendors), indeed many digital printing machines are still delivered with UV-filtered instruments. Optical brighteners do glow bluish depending on the UV-content in the viewing environment (and the light source of the measurement device). If a UV-filtered instrument leads to more pleasing results than an instrument with a tungsten lamp, the UV-content of the viewing environment is simply closer to UV-cut than to the UV-content of a gas-filled-tungsten-lamp.

But most likely it is not UV-free. Thus M2 is not the appropriate solution for most applications and it is only standardized to reflect UV-free viewing conditions [16]. The measurement mode M3 or the offset printer's mode meet the need to control wet sheets during production but the customer pays for the final product which is dry. The biggest difference between wet and dry sheet is the gloss. Measurement mode M3 offers means to predict the density of a dried sheet from a measurement of a wet sheet. This is achieved by using two polarization filters, which minimize the difference in gloss. New conditions of measurement are possible by combining multiple illumination sources in the new generations of instruments including the use of LE diode's (light emitting diode). Measuring instrument that meet the requirements for measuring substrates containing optical brightening agent are X-rite EyeOnePro II and Konica Minolta FD-7.

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