International Joint Conference on Environmental and Light Industry Technologies
21 – 22 November 2012, Budapest, Hungary
Óbuda University

# PRINTING OF RECYCLED CARDBOARDS BY ELECTROPHOTOGRAPHIC AND INKJET TECHNOLOGIES

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***Abstract:***

*High end colour print on demand (POD), digital presses are now well established and growing in the packaging industry. Approximately 1150 these types of installations were running in the world in 2009. 85% of these systems were based on electro photography. Folding cartons are much more difficult to print and convert with POD equipment. The size of the printed image is often a problem and finishing for each of these applications involves specialized equipment. Also the media are in often challenging. The quality of the prints made by different printing technologies is materially influenced by the structure and surface properties of the applied substrates. It is important to know in what quality prints can be made on the recycled cartons by digital printing technologies.*

*Our research focused on the print quality on recycled cardboard substrates. We investigated 3 different types of cardboards, which differed in surface properties. Surface smoothness, and optical characteristics (optical density, tone values increase, colour difference) of the prints produced in Canon Pixma iX 6550 inkjet and Xerox Docucolor 12, Xerox iGen3, Canon ImagePress C1 printers were determined. We compared the results with investigation of a conventional cardboard. Folding cartons produced by digital printing in offset quality is the most important aspect for the folding carton manufacturers. So the reference for the samples was the ISO 12647/2: 2004.*

***Keywords:***

*recycled cardboard, electrophotography, inkjet, suface smoothness, optical properties*

## 1 INTRODUCTION

Folding cartons produced by digital printing in offset quality is the most important for the folding carton manufacturers. High end color print on demand (POD) digital presses are now well established and growing in the packaging industry. Color digital folding cartons are mostly printed by color electro photographic POD presses. Visual print quality is heavily influenced by the applied substrates and inks, ink transfer and fixation processes. It is important to know in what quality prints can be made on the recycled cartons by digital printing technologies [1] [2] [3]

Our work focuses on digital printing characteristics on cardboard substrates. We investigated quality of test prints printed by electrophotographic and inkjet technologies four on different types of cardboard substrates with varies thickness and surface properties.

## 2 EXPERIMENTAL

In our research we studied optical print quality on recycled and conventional cardboards. Duplex 2 layer coated recycled chromo carton, with grey backing (#1), Grafopak 3 layer recycled coated chromo carton, with grey backing (#2 ), GC2-235 3 layer coated chromo carton, with light backing (#3) and GC2-250 3 layer coated chromo carton, with light backing (#4) (Table 1).

*Table 1: Printing substrates*

| cardboard | #1 | #2 | #3 | #4 |
|---|---|---|---|---|
| type | Duplex | Grafopak | GC2-235 | GC2-250 |
| property | 2 layer coated recycled chromo-carton, grey backing | 3 layer coated chromo-carton, grey backing | 3 layer coated chromo-carton, light backing | 3 layer coated chromo-carton, light backing |

Surface properties are listed in the Table 2.

*Table 2: Substrate properties*

| Property | #1 | #2 | #3 | #4 |
|---|---|---|---|---|
| caliper, mm | 0,393 | 0,309 | 0,333 | 0,312 |
| $g/m^2$ | 250 | 250 | 235 | 250 |
| smoothness, s | 50,3 | 105,7 | 65,54 | 210,0 |

The test contained the measuring fields, as well as the test stripes to be used for the purpose of our measurements and it included visual, densitometric and spectrophotometric test elements. It has been printed on A4-sized substrates.
Four different cardboard substrates were printed with three different types of electro photographic printers and an inkjet printer. Each test print was made in one copy, with the use of electro photographic and inkjet printers, under identical circumstances and conditions. Substrate #4 (GC2-250) was not printed by Canon ImagePress C1 electro photographic printer, because of surface problems.
Test printing was performed under normal operating conditions as follows: printing machines: Xerox Docucolor 12, Xerox iGen3, Canon ImagePress C1 electro photographic printers and Canon Pixma iX6550 inkjet printer, T=21-22 ºC, RH 39–44%.

## 3 RESULTS AND DISCUSSION

Our research focused on the digital print quality on cardboard substrates. To perform optical properties on the test prints, an X-Rite SpectroEye spectrophotometer was used. The conditions of measurements were as follows: 380-780 nm spectral range, 0°:45°a measurement geometry, 4.5 mm aperture diameter, D65 filter. Surface smoothness of the substrates, and optical characteristics (optical density, tone values increase, colour difference) of the prints were determined.

### 3.1 Tone Value Increase of CMYK prints

CMYK print optical density values (D) were the highest in the case of Docucolor 12 (C: D=1,19-2,26; M: D=1,62-1,81; Y: D=1,71-1,79; K: D=2,37-2,51), the lowest were produced by Canon Pixma iX6550 printer (C: D=0,91-1,01; M: D=0,88-1,16; Y: D=0,76-0,94; K: D=0,83-1,00).

All substrates produced the highest TVI values with Canon Pixma iX6550 inkjet printer on the 40%-os halftone patch ($TVI_{40}$=18-45%, for all process colours). A lowest TVI values were measured on Canon ImagePress C1 electro photograpchic printer ($TVI_{40}$=5-20%, for all process colorsu) (Table 3). The highest TVI values were seen in case of the cyan process colour (Figure 1).

*Table 3: TVI values on a 40% halftone patch*

| Printer | $TVI_{40}$, % | | | |
|---|---|---|---|---|
| | #1 | #2 | #3 | #4 |
| Docucolor 12 | 10-18 | 6-19 | 11-23 | 13-27 |
| iGen | 12-23 | 13-22 | 16-24 | 18-26 |
| Canon Pixma iX6550 | 36-44 | 32-44 | 32-45 | 18-42 |
| Canon ImagePress C1 | 5-16 | 13-18 | 15-20 | - |

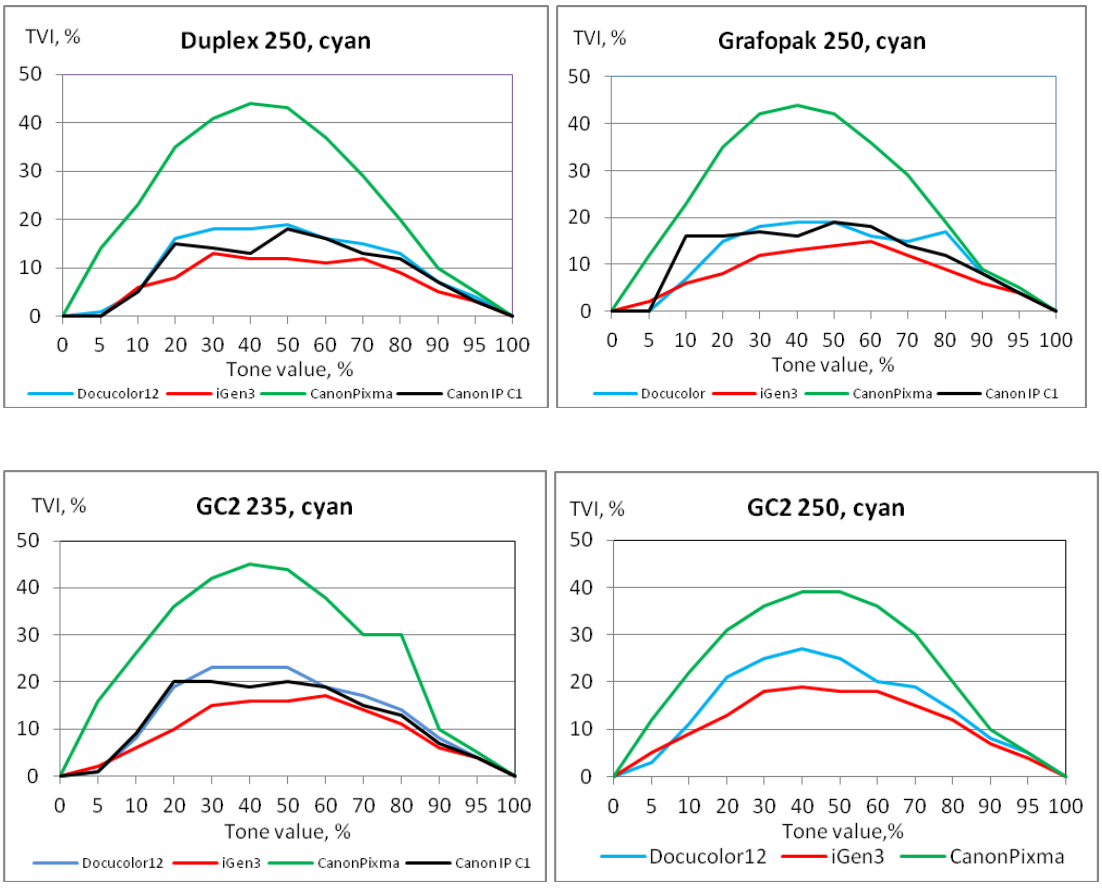


*Figure 1: TVI curves of cyan prints*

### 3.2 Colour differences

Tone value increase will influence color which makes it important to investigate colour differences on the prints. The measurements were performed on color control patches of CMYK and RGB, with the use of the X-rite SpectroEye spectrophotometer. The L*a*b* colour coordinates were measured on the prints, and $\Delta E^*_{ab}$ colour differences in relation to the reference print were calculated. It was choosen sample #4 as the etalon (L=96,17). The highest color differences were found on prints produced by Canon Pixma iX 6550 inkjet printer, on both sets of the process (CMYK) and secondary (RGB) colours (Figure 4 and 5).

*Table 4: $\Delta E^*_{ab}$ colour differencesof the CMYK prints*

| Printer | $\Delta E^*_{ab}$ | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | #1 | | | | #2 | | | | #3 | | | |
| | C | M | Y | K | C | M | Y | K | C | M | Y | K |
| Docucolor 12 | 2,5 | 4,2 | 3,0 | 3,5 | 1,4 | 2,5 | 0,4 | 1,9 | 0,9 | 0,9 | 0,4 | 0,6 |
| iGen | 2,2 | 2,0 | 1,8 | 3,2 | 0,5 | 1,3 | 1,0 | 2,0 | 1,8 | 1,1 | 1,1 | 0,6 |
| Canon Pixma iX 6550 | 2,7 | 4,5 | 3,4 | 7,5 | 1,6 | 2,9 | 6,8 | 0,4 | 4,1 | 5,0 | 3,6 | 3,2 |
| Canon ImagePress C1 | 2,4 | 3,7 | 6,6 | 3,0 | 1,6 | 1,0 | 0,5 | 0,8 | - | - | - | - |

*Table 5: $\Delta E^*_{ab}$ colour differences of the RGB prints*

| Printer | $\Delta E^*_{ab}$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | #1 | | | #2 | | | #3 | | |
| | R | G | B | R | G | B | R | G | B |
| Docucolor 12 | 1,7 | 4,1 | 3,4 | 1,4 | 1,7 | 1,6 | 2,2 | 2,1 | 1,4 |
| iGen | 5,8 | 7,5 | 6,7 | 0,9 | 3,7 | 3,7 | 3,1 | 2,3 | 1,6 |
| Canon Pixma 6550 | 8,2 | 6,2 | 6,1 | 5,1 | 4,3 | 2,4 | 2,4 | 3,2 | 3,0 |
| Canon ImagePress C1 | 4,0 | 5,5 | 2,9 | 2,0 | 2,3 | 1,2 | - | | - |

Colour differences were compared to the (L*a*b*) values of the ISO 12647-2: 2004 offset standard. All $\Delta E^*_{ab}$ values exceeded the tolerance ranges. The smallest CMYK colour difference ($\Delta E^*_{ab}$=3,3-7,7) és RGB colour difference ($\Delta E^*_{ab}$=3,3-9,3) were produced by Canon ImagePress C1 press. The highest colour differences were found on samples printed with Canon Pixma iX6550 ($\Delta E^*_{ab}$=19,0-45,4).

### 3.3 Colour gamuts

The range of reproducible colors (gamut) depends on the printing process and the substrate and other printing materials used. We used a software tool commonly applied in proofing color workflows to visualize and compare the color gamut achievable on the substrates investigated. First, printer profiles were generated using X-Rite EyeOne Pro measurement device and profiling software. A standard

CMYK test chart with 323 patches was printed on the substrates of this study, by both printing presses to sample the printable color solid. The profiles were loaded to the gamut visualization tool, which calculated printable gamut in CIELAB color space volume units. Relative printable gamut sizes are shown in table 6, the largest gamut is taken as reference for every ink-printer combination. The maximum colour range reproduced in the print that have been made with the Canon ImagePress C1 printer on GC2 (250 g/m$^2$) cardboard and the minimum colour range reproduced with the Canon PIXMA iX6550 printer on Duplex cardboard. Considerable differences (approx. 80%) can be observed in between the gamut volumes in the case of inkjet and electro photography printers (Figure 3). We experienced less than 13% colour gamut shrinking in case of all substrates printed with electro photographic technology.

*Table 6: Relative values of computed printable gamut volumes on cardboard substrates using two types of printers, based on spectral measurements of a CMYK test chart containing 323 halftone patches*

| Printer | Relative values of computed printable gamut | | | |
|---|---|---|---|---|
| | #1 | #2 | #3 | #4 |
| Docucolor 12 | 0,90 | 0,91 | 0,94 | 0,97 |
| iGen | 0,82 | 0,86 | 0,87 | 0,90 |
| Canon Pixma iX6550 | **0,17** | 0,25 | 0,20 | 0,23 |
| Canon ImagePress C1 | 0,91 | 0,95 | **1,00** | - |

The largest gamut was produced on substrate #3 printed by Canon ImagePress C1 elektro photographic printer, the smallest was produced on substrate #1 by Canon Pixma iX6550 inkjet printer (Figure 2).

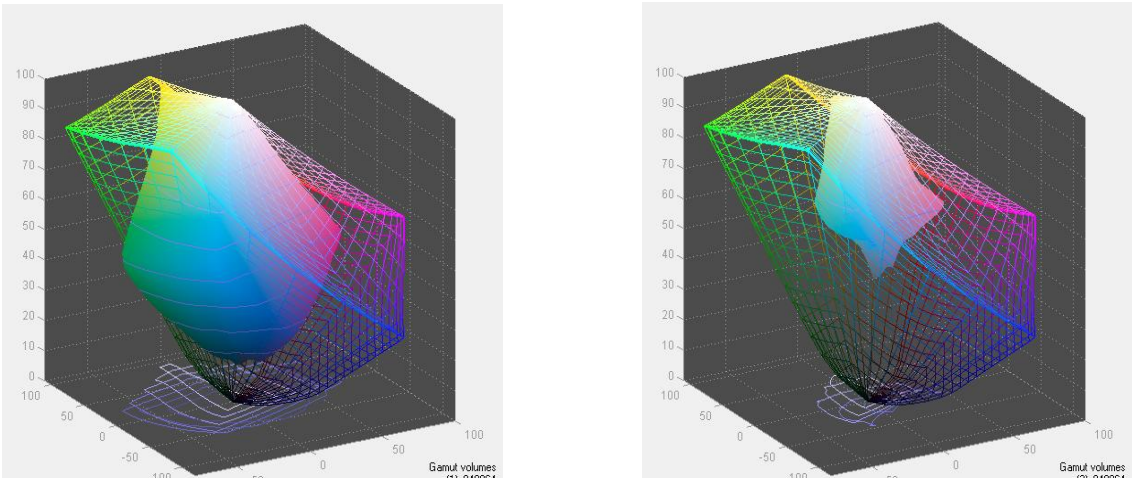


*Figure 2: Colour ranges that can be presented in the CIELAB colour space on cardboard substrates, wherein the spatial mesh body represents the standard sRGB colour space (left: maximum: Canon ImagePress C1/GC2-1; right: minimum: Canon Pixma iX 6550/Duplex)*

## 4. CONCLISIONS

Our research focused on electro photographic and inkjet print quality on cardboard substrates. In the light of the results, it can be stated that the Docucolor12 printer has produced prints of higher optical density on all the cardboards. The largest TVI value and most outstanding reproducible colour range have been found for the GC2-250 cardboard for all devices. In the case of the GC2-235 cardboard, the inkjet technique has resulted in the smallest reproducible colour gamut, whereas the electro photographic of Canon ImagePress C1 printer procedure has yielded the largest reproducible colour gamut. The smallest TVI values were also measured in the case of Canon ImagePress C1. The highest colour difference values were experienced on prints produced by Canon Pixma iX 6550 inkjet printer for the process colours and the secondary colours as well. Colour gamut of Canon PIXMA iX6550 inkjet printer was 75-80% smaller on every substrates. Generally 9-13% colour gamut reduction was experienced on electro photographic prints on all substrates of the study.

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