THE INFLUENCE OF INK CONCENTRATION AND LAYER THICKNESS ON YELLOW COLOUR REPRODUCTION IN LIQUID ELECTROPHOTOGRAHY TONER

Igor Majnarić, Aleš Hladnik, Tadeja Muck, Ivana Bolanča Mirković

Introduction

In obtaining a high-quality colour reproduction, process printing inks (CMYK) and especially their colorants – pigments or dyes – play a decisive role. Ink formulation and the amount of ink being used must meet the requirements of the actual printing technology. In particular, concentration of pigment particles in the yellow ink as well as the final layer thickness of the ink applied to the printing substrate can be varied by a printer to assure the desired reproduction of lighter tones.

The aim of this study was to examine the technological possibilities and limitations related to the use of the yellow process ink within the electrophotographic printing system with the liquid toner – also known as HP ElectroInk. The results should also provide some directions on how to improve the reproduction of yellow colour, obtain higher colour saturation, and consequently, to achieve higher print quality with larger colour gamut.

During the printing process, to attain a larger colour gamut it is common to apply a higher amount of the colorant onto the printing substrate. Technically, this can be accomplished in one of two ways: either by increasing the concentration of the pigmented toner particles in ink or by increasing the number of ink layers.

2 Liquid electrophotography toner

The development process in the liquid toner electrophotography is very complicated and consists of several consecutive steps [1]. The final ink layer thickness is primarily influenced by the voltages of the developer drum and the developer rollers. By varying individual voltages, higher colour saturation in prints can be obtained [2].

ElectroInk contains charged pigmented toner particles in a liquid carrier. Similarly to other digital printing technologies, such as dry electrophotography, printing is performed via electrically controlling the location of the toner particles. In its basic state the ink is an emulsion consisting of pigments in a form of a thermal polymer (24-29%), which is dispersed in a non-polar volatile oil (70-75%). The ink also contains additives for increasing the conductivity (about 10 %) [3]. ElectroInk is supplied as a concentrated paste that is loaded into the press in tubular cartridges. Inside the press it is fed into ink supply tanks and diluted with oil, to form a fluid mixture ready for printing.

During the printing process, the ElectroInk structure rapidly alters. Ink viscosity increases due to a high temperature (ϑ = 125 °C) and loss of the volatile solvent. By heating the thermal polymer, the process of plasticity begins causing the polymer to become suitable for adhering to the printing substrate [4].

Particles of the yellow thermal toner have a characteristic fluffly shape with the size ranging from 1 to 5 µm [5, 6]. Such a shape serves primarily to ease the binding of the conductivity-increasing additives. These polar additives adhere to the pigmented toner particles with their positively charged molecular groups. The particles are then ready to move towards a more positive electrostatic field, i.e. a field with a lower negative charge [7, 8, 9].

Further ink film thickness increase on the printing substrate is possible by means of an overprinting. Such a
The influence of ink concentration and layer thickness on yellow colour reproduction in liquid electrophotography toner
I. Majnarić et al.

possibility exists only with satellite electrophotographic machines in which one printing unit is used for printing several inks [10, 11, 12, 13]. In this case the printing is done on the already printed (dried) ink layer.

3 Experimental part

For the experiment we used ECI test chart (target) with 378 colour patches. The chart was printed with the electrophotographic machine HP Indigo S1000 (resolution: 812 × 812 dpi). The printer normally uses four process inks (CMYK) of which the yellow one was modified for the purpose of our study. This (Yellow 74) is an azo-based compound (Dalamar yellow C. I. 11741) with the chemical formula C₁₈H₁₈N₄O₆. The printing substrate was a calandered paper with the grammage of 280 g/m².

By adding various amounts of the pigment, three yellow ink concentrations (C) were prepared – C₁=1.28; C₂=1.61 and C₃=1.98 – characterized by different ink densities as measured by the portable ink density meter EAS-1120-53 that was developed by HP Indigo. In addition, the repetition of individual yellow colour separations was accomplished. In this way YMCK (with one yellow layer; L₁), YYMCK (with two yellow layers; L₂) and YYYMCK prints (with three yellow layers; L₃) were made. Consequently, nine different combinations of yellow ink concentration-ink layer thickness were investigated as schematically displayed in Fig. 1.

![Figure 1](image1.png)

Figure 1 Left: Design of experiments; three yellow ink concentrations (C₁, C₂, C₃) combined with different numbers of yellow ink layers (L₁, L₂, L₃). Top: Total workflow of the study.

Printed colour patches were examined by spectrophotometer X-rite DTP 20 using 0/45° measuring geometry. The obtained L*a*b* values were used for the calculation of colour differences (CIE LAB delta E2000) and colour gamut volumes (Monaco Profiller Platinum Version). Digital images of the printed halftone dots were obtained by Leica DR 2400 optical microscope with a built-in 1,3 megapixels Dinolite camera. Subsequent image analysis was performed by means of ImageJ software [14, 15, 16]. All major processing steps of our study are presented in Fig. 1.

4 Results and discussion

Colorimetric data for the 378 printed colour patches enabled calculations of colour gamut volumes for each of the nine ink concentration – ink layer thickness combinations. CIE a*b* diagrams for the three typical lightness (L*) values are displayed in Figs. 2 and 3.

![Figure 2](image2.png)

Figure 2 2D colour gamuts for test chart patches printed with different concentrations and constant number of layers (= two; L₂) shown for L* = 20 (top), L* = 50 (middle) and L* = 80 (bottom).
Utjecaj koncentracije bojila i debljine nanosa žute na kolornu reprodukciju s tekućim elektrofotografskim tonerom

During printing, the simplest control parameter for halftone value transfer is the measurement of the dot percentage in the halftone patches of the ECI test chart. Variation of the two investigated parameters – yellow ink concentration and ink layer thickness – directly affected the appearance and characteristics of the halftone dots and, consequently, caused the tone value increase (dot gain). Yellow halftone patches at 50 % A (tone value) were subsequently analysed. Fig. 4 shows six typical halftone yellow patches at 50 % A.

Yellow halftone patches at 50 % A were further processed using image analysis approach. Each imaged printed patch was converted into a grayscale and finally into a binary image using intensity thresholding (Otsu's method). Tone value – percentage of area covered by halftone dots – was calculated.

Two-way analysis of variance (ANOVA) results for colour gamut volume and area coverage at the 95 % confidence level are displayed in Tab. 1 and Tab. 2, respectively. Since five measurements were obtained for each of the nine ink concentration – layer thickness combinations, it was also possible to estimate the interaction effect between the two investigated parameters.

During printing, the simplest control parameter for halftone value transfer is the measurement of the dot percentage in the halftone patches of the ECI test chart. Variation of the two investigated parameters – yellow ink concentration and ink layer thickness – directly affected the appearance and characteristics of the halftone dots and, consequently, caused the tone value increase (dot gain). Yellow halftone patches at 50 % A (tone value) were subsequently analysed. Fig. 4 shows six typical halftone yellow patches at 50 % A.

Yellow halftone patches at 50 % A were further processed using image analysis approach. Each imaged printed patch was converted into a grayscale and finally into a binary image using intensity thresholding (Otsu's method). Tone value – percentage of area covered by halftone dots – was calculated.

Two-way analysis of variance (ANOVA) results for colour gamut volume and area coverage at the 95 % confidence level are displayed in Tab. 1 and Tab. 2, respectively. Since five measurements were obtained for each of the nine ink concentration – layer thickness combinations, it was also possible to estimate the interaction effect between the two investigated parameters.
The influence of ink concentration and layer thickness on yellow colour reproduction in liquid electrophotography toner

I. Majnaric et al.

5 Conclusions

Our study suggests that a higher colour gamut volume in yellow colour region can be achieved primarily by multilayer printing, i.e. by increasing the number of yellow ink layers – especially from one to two – and much less by raising the concentration of the pigmented toner particles in the yellow ink. Such an increase in layer thickness, however, has a detrimental effect on the characteristics of the printed halftone dots, causing an undesirable tone value increase (dot gain). Multilayer printing increases the dynamic range but at the same time reduces bit depth of a printed image. Therefore, if we want to increase the colour gamut volume and preserve optimal dynamic range, it is recommended to use two layers printing only for reproducing solid yellow tones.

Acknowledgements

This work was supported by the Ministry of Science, Education and Sports of the Republic of Croatia (New formulations of materials, features prints – code: 128-1281955-1953 and Study on technological factors of graphic design and the systematic improvement of quality - code: 128-1281955-1962).

6 References


Utjecaj koncentracije bojila i debljine nanosa žute na kolornu reprodukciju s tekućim elektrofotografskim tonerom

Assist. Prof. dr. sc. Igor Majnarić
University of Zagreb, Faculty of Graphic Arts,
Getaldićeva 2, 10000 Zagreb, Croatia
E-mail: majnaric@grf.hr

Prof. dr. sc. Ales Hladnik
University of Ljubljana, Faculty of Natural Sciences and Engineering, Department of Textiles,
Snežniška 5, 1000 Ljubljana, Slovenia
E-mail: ales.hladnik@ntf.uni-lj.si

Prof. dr. sc. Tadeja Muck
University of Ljubljana, Faculty of Natural Sciences and Engineering, Department of Textiles,
Snežniška 5, 1000 Ljubljana, Slovenia
E-mail: tadeja.muck@gmail.com

Assist. Prof. dr. sc. Ivana Bolanča Mirković
University of Zagreb, Faculty of Graphic Arts,
Getaldićeva 2, 10000 Zagreb, Croatia
E-mail: ibolanca@grf.hr


Air Pollution 2015 is the 23rd Annual Meeting in the successful series of international conferences organised by the Wessex Institute with full backing of the International Library of Science and Technology.


The conference in this series have discussed and considered many important air pollution issues and the international nature of the attendees reflects the fact that conference findings and conclusions enjoys wide and rapid dissemination amongst the air pollution science and policy communities. Air pollution issues remain one of the most challenging problems facing the international community. The series has demonstrated the wide spread nature of the air pollution phenomena and has explored in depth the impacts of air pollution on human health and the environment.

The series has also recognised, at a very early stage, that science alone will not improve a polluted atmosphere. The scientific knowledge derived from well designed studies needs to be allied with further technical and economic studies in order to ensure cost effective and efficient mitigation. In turn, the science, technology and economic outcomes are necessary but not sufficient. Increasingly the conference has recognised that the outcome of such research needs to be contextualised within well formulated communication strategies that help policy makers and citizens to understand and appreciate the risks and rewards arising from air pollution management. Consequently, the series has enjoyed a wide range of high quality papers that develop the fundamental science of air pollution and an equally important array of presentations that places these new developments within the frame of mitigation and management of air pollution.

This important conference brings together contributions from scientists from around the world to present recent work on various aspects of air pollution phenomena. Notable in each of the conferences in this series is the opportunity to foster scientific exchange between PhD students. New collaborations amongst scientists, and between scientists and policy makers or regulators have grown through contacts made in this series. Each meeting has provided a further opportunity for identifying new areas of air pollution science demanding collaborative investigation.

The conference papers deal with a rich variety of topics. The presentation of case studies of specific regions and cities, including those in emerging countries are particularly encouraged.

**Conference Topics**

- Air pollution modelling
- Monitoring and measuring
- Air quality management
- Indoor air pollution
- Aerosols and particulates
- Emissions
- Air pollution chemistry
- Source identification
- Global and regional studies
- Exposure and health effects
- Economics of air pollution control
- Policy formulation
- Case studies
- Innovative technologies

**Benefits of Attending**

- Conference Proceedings
- Paper presentation
- Networking opportunities
- Access to conference materials
- Access to the Zephyr Library
- Participation in scientific exchange between PhD students
- Collaboration between scientists and policy makers or regulators
- Identification of new areas of air pollution science demanding collaborative investigation

**Conference Secretariat**

Irene Moreno Milan
imimore@wessex.ac.uk

Wessex Institute
Ashurst Lodges, Ashurst, Southampton, SO41 7TA, UK
Tel: +44 (0) 230 929 2923
Fax: +44 (0) 230 928 2900

For more information: http://library.wessex.ac.uk

**Location**

Situated on the eastern coast of Spain, Valencia was founded in 1388 as a Roman colony. The city, which is the third largest in Spain, has the biggest port on the Mediterranean Sea. A large historic city centre makes Valencia a popular tourist destination with many ancient monuments, museums and sights of interest. Valencia is famous for "Las Fallas" - four days and nights of city wide celebrations held each year during March in commemoration of Saint Joseph. Visitors are also drawn to the region for its food with Paella having originated from the city.

**Conference Venue**

The TRYP Valencia Catedral Hotel is situated near the centre of Valencia. Only a short distance from the City of Arts and Sciences, the harbour and downtown, the hotel is close to all that the city has to offer. With 220 rooms all with high speed internet access, a 24 hour fitness centre, pool, sauna, bar and restaurant, the hotel has all the amenities guests may require.

**Air Pollution 2015**

1 - 3 June 2015

Valencia, Spain

Organised by

Wessex Institute, UK

University of the West of England, UK

Sponsored by

WIT Transactions on Ecology and the Environment
The International Journal of Sustainable Development and Planning

wessex.ac.uk/air/2015

**Submission Information**

Papers are invited on the topics outlined and others falling within the scope of the meeting. Abstracts of no more than 500 words should be submitted as soon as possible.

Abstracts should clearly state the purpose, results and conclusions of the work to be described in the final paper. Final acceptance will be based on the full-length paper, which if accepted for publication must be presented at the conference.

The language of the conference will be English.

Online submission: wessex.ac.uk/air2015

Email submission: imimore@wessex.ac.uk

Submit your abstract with ‘Air Pollution 2015’ in the subject line.

Please include your name, full address and conference topic.

CALL FOR PAPERS

23rd International Conference on Modelling, Monitoring and Management of Air Pollution

I - 3 June 2015

Valencia, Spain

Organised by Wessex Institute, UK

University of the West of England, UK

Sponsored by WIT Transactions on Ecology and the Environment

The International Journal of Sustainable Development and Planning

wessex.ac.uk/air2015