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Investigation on the effect of different tone value sum (TAC) of inks on the color reproduction accuracy of heatset web offset images

I.T. Spiridonov*, R.K. Boeva, T.Tz. Bozhkova, Y.V. Nedelchev

Department of Pulp, Paper and Printing Arts, University of Chemical Technology and Metallurgy, 1756 Sofia, Bulgaria

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The goal of the present study is to define the correlation between the tone value sum (total area coverage - TAC) and reproduction accuracy on heatset web offset images printed on LWC paper. In case of incorrect values usage - at relatively high or low levels of tone-value sum, press problems such as big amount ink consumption, poor ink trapping, back transfer and set-off due to insufficient ink drying might be encountered. That's why it is necessary to find and determine the optimal values of color separation parameters for each inks/paper/printing press combination.

A test form has been used that contains different control strips for densitometric, imetric measuring and test charts used for ICC profiles.

The reflection spectra of measured color patches in entire visible spectrum are used for determination the effect of different values of TAC. For study the effect of TAC values on color gamut and color accuracy, we have calculated color differences ΔE*ab, surface area and volumes of 2D cross-sections and 3D shape body in CIE L*a*b* system.

The results achieved are important from scientific and practical point of view. For the first time in an experimental way a well-grounded proof has been achieved with regard to the limits of the tone value sum and variation from the optimal values for TAC for heatset offset press, by provision of differences in compliance with the international standards.

Key words: total area coverage, total ink limit, color separation, spectral measurements, color gamut

INTRODUCTION

The paper presents investigation of the effect of different values of total area coverage of inks (TAC) on CIE Lab color characteristics, color differences and color gamut changes.

Total area coverage is the maximum total dot percentage of cyan, magenta, yellow and black ink used in the darkest areas and generally depends on the printing process and the type of paper. Total area coverage is a key factor for achieving of maximal volume of color gamut, especially in dark areas.

It generally depends on the printing process and the type of the paper. The most important parameters that have a significant influence on the TAC values are the papers, inks and printing presses specifications. For coated papers higher total area coverage than for uncoated papers is used. In addition, for web-fed printing presses, the TAC values are lower than these for sheet-fed printing presses. ISO 12647, Part 2, and organizations such as the German Printing and Media Industries Federation (bvdm) SWOP and GRACoL have different TAC recommendations [1-3].

Total area coverage is a key factor for achieving a maximal volume of color gamut, especially in dark areas. Theoretically, the maximal amount of process inksis 400 %, but in practice that will cause problems with ink trapping, decreasing of adhesion of inks layers, drying troubles, etc. Determination of TAC values depends of the exact CMYK combination, which is achieved with the highest optical density and with the least amount of ink [4-6].

The main goal of this study is development of methodology, which gives objective and analytical assessment, for determination of the optimal value of total area coverage (TAC) of inks in offset printing process. A practical implementation of the correct and optimal value of TAC should improve the print quality, printability, better ink layers adhesion, trapping and reducing the quantity of process inks [7-10].

The optimization and reduction of TAC leads to financial and ecological profits. Reduction of inks amounts used in print-production is a substantial part of decreasing the total printing cost. The ecological aspect of TAC optimizing is reduction of the emissions during manufacturing of the inks and the facilitation removal of the inks during the process of paper recycling [11].

To whom correspondence should be sent.
E-mail: i_spiridonov@abv.bg

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EXPERIMENTAL

A special designed test form has been used for study of the effect of TAC values on color gamut and other reproduction parameters.The test form contains many different components for process control and spectra analyses: 100% solid patches for cyan, magenta, yellow and black – for control of optical density – Dv and characteristics, 80% patches for estimating print contrast, patches for estimating of dot gain and grey balance, strip which contains raster lines in different slope for doubling and slur control, registration marks, test charts containing about 1500 patches for ICC color profiles with different GCR and TAC values and etc. All measuring components are with screen value 60 cm^{-1} (150 lpi).

The paper, which has been used, is 56 g/m^2 LWC paper. A spectro-photometer/densitometer of type SpectroEye of X-rite has been used for measuring of optical density and the characteristics in the CIE Lab system. All measurements are in accordance with ISO 12647-1: D50 illuminant, 2° observer, 0/45 or 45/0 geometry, black backing and excluded polarization filter. The test chart ECI 2002 is measured with i1Profiler software and X-Rite i1i0 spectrophotometer and automatic scanning device. The offset printing machine, which has been used, is five heatset web-fed KOMORI. The value of pH of dampening solution was 5.3 and the temperature – 11°C. The relative humidity of the air in the printing house was 60% and the temperature near by the printing press – 26°C.

We have made two printing runs on the heatset offset printing press. The designation of first one was to make the test of the printing system, and for generating of ICC profile for the exact print conditions. The main goals of second print run, was to make a prints of test charts and images with different TAC settings.

RESULTS AND DISCUSSIONS

In order to achieve the goals of the experiment, series of measurements of Dv and Print Contrast have been performed. For defining the optimal inking by the method of maximum print contrast for Cyan, Magenta, Yellow and Black, the samples have been made by gradual smooth changes in ink quantity - from under-inking to over-inking. A statistical analysis of the results was performed.

Experimentally obtained values of optimal inking expressed by optical density of solid 100% tone - Dv and corresponding values print contrast are shown in Table 1. All of test sheets in this experiment have been printed using the values of optimal inking shown in Table 1.

Investigation and comparison of 3D and 2D color gamuts in dependence total area coverage

The graphically presentation of color gamuts – 3D and 2D, gives valuable and comprehensive information for the colors, that can be reproduced in specific printing and color separation conditions. In this study for precise determination of influence of TAC settings we have investigated the changes in 2D and 3D color gamuts volume and shape.

The color gamut range, especially the volume of the tree dimensional (3D) color gamut body, is one of the most important characteristics of an output device. Research on the color gamut surface size and shape is useful for many color science-related tasks such as visualization, gamut volume and surface calculation, and choosing of a color rendering intent method. Reducing the TAC values clips colors of the dark areas of the color gamut.

3D presentation and comparison of color gamuts for 280% and 300% TAC are presented on figures 1 and 2. Two different software products were used for more precise presentation of specific 3D body shape in dependence of TAC values. It is clearly visible from both figures 1 and 2, that the 3D body of 300% TAC has biggest volume especialy in middle and dark tones. The 3D shapes for 320%, 340% and 400% are not graphically presented, because they are similar and equal to 300% TAC.

Table 1. Experimentally obtained values of optimal inking expressed by Dv and corresponding values print contrast

Process colors	Experimentally obtained values of optimal inking expressed by Dv [Dv]	Print Contrast - Cmax, (highest value) [%]
Black	1.69	41%
Cyan	1.48	33%
Magenta	1.53	36%
Yellow	1.36	32%

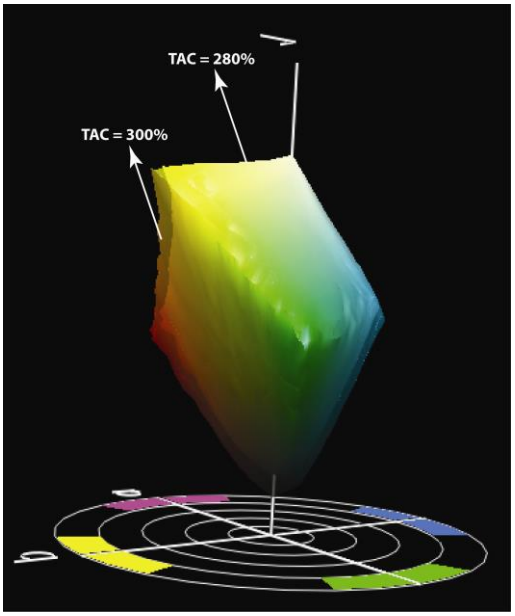


Fig. 1. 3D presentation of color gamuts in dependence of TAC value in CIE Lab, (graph is generated by X-Rite ProfileMaker).

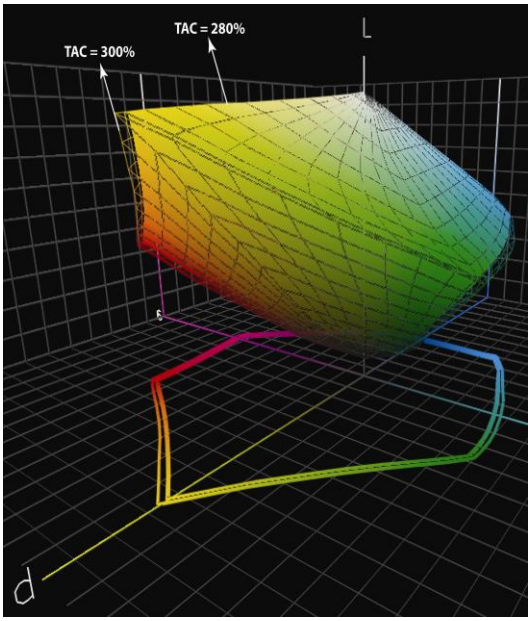


Fig. 2. 3D presentation of color gamuts in dependence of TAC value in CIE Lab, (graph is generated by Chromix Color ThinkPro).

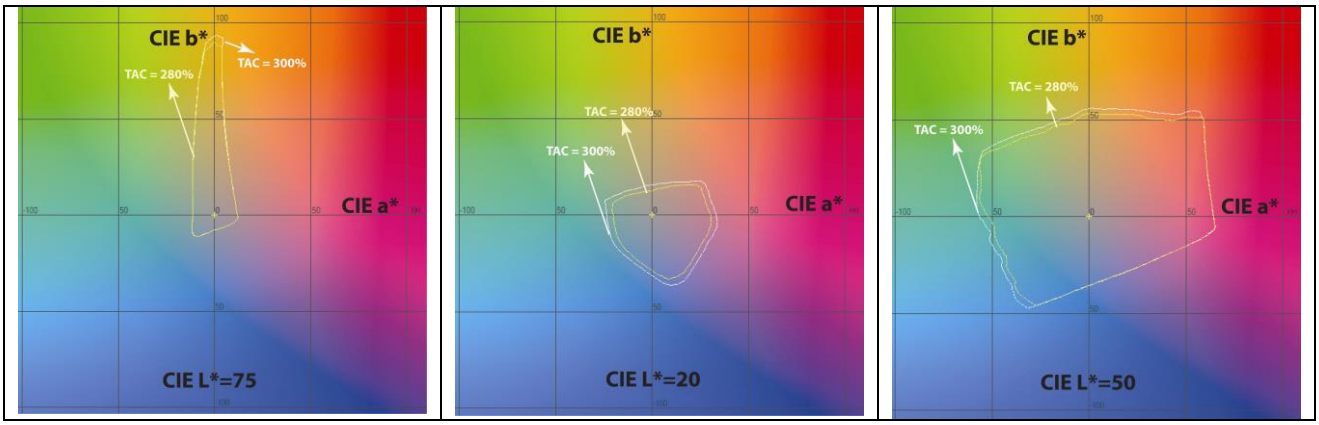
In order to obtain complete assessment of the effect of TAC values on gamuts, we have compared the surface areas of 2D color gamuts for different CIE L* coordinates.

A comparison of 2D color gamuts is performed to obtain comprehensive characterization of colors depending on TAC value. The presentation of 2D color gamuts gives precise and detailed information of colors that can be reproduced in the specific conditions for all tonal range – from highlights to dark tones. These 2D gamuts are cross sections of 3D gamuts at different values of the CIE L*-coordinate. CIE L* is the coordinate corresponding to color lightness and has value from 0 (black) to 100 (white) units. The other two coordinates of the CIE L*a*b* color system - CIE a* and CIE b* correspond to red (+a*) – green (-a), and yellow (+b*) – blue (-b*).

The graphical presentation for the surface areas of 2D-cross sections in highlights, middle and dark tones are presented at Figure 3

Fig. 3 shows, that in the dark tones, at CIE L* = 20 (b) the color gamut at 300 % TAC is the largest one. The smallest color gamut is obtained at 280 % TAC value.

The color gamuts at others TAC values are similar to each other. They have surface area like the color gamut at 300% TAC value and larger than the gamut at 280 % TAC value, that's why they are not presented in the figures.



(a) Light tones at CIE L*=75 (b) Dark tones at CIE L*=20 (c) Middle tones at CIE L*=50

Fig. 3. 2D presentation of color gamuts in dependence of TAC value in CIE Lab.

The conclusion is that TAC values havea relatively significant effect on color gamuts in dark and middle tones. The results show, that the 300% TAC gamut is the optimal value (from 2D and 3D point of view) with relatively big color gamut and lower ink consumption compared to 280%, 320%, 340%, 400%.

Investigation of Color Gamut Volumes - ΔE³, CIE Lmin and Average Color Difference - ΔEab in dependence of total area coverage

For better quantitative analysis and assessment of the effect of TAC on color gamuts we have calculated the color gamut volumes – ΔE^3. Graphical presentation of the results is given in Figure 4. According to the results shown in Figure 4, the biggest color gamut volume is obtained at maximal level of TAC at 400% and the smallest – at minimal level of TAC at 280%. There is a relatively big difference about 8% in volumes of color gamuts between 280% and 300% TAC. The difference between 300%, 320%, 340% and 400% is insignificant – about 1-2 %. That means, that the 300% value of TAC is leading to one of the biggest gamut volumes and in the same time is one of the lowest ink consumption comparing to others technological situations. One of the most important factors that affect human perception is the possibility to reproduce the darkest tones and colors. That is one of the reasons to generate the "rich black" from all process colors – C, M, Y, K. The best way to investigate the darkest colors and tones is measuring and finding the patch with lower lightness coordinate - Lmin in CIE L*a*b* color system.

The graphically presentation of influence of TAC values on CIE Lmin is shown on Figure 5.

The results shows, that total area coverage affects the darkest reproducible color. The biggest difference between different TAC in CIE L*min value is 4.80 units – 280% TAC has Lmin=15.20 and 400% TAC has Lmin=10.40 value. The differences in L*min between 400%, 340%, 320% and 300% TAC are between 0.40-1.70 units. The results shows that the darkest and better from human perception point of view colors could be achieved with 400% TAC value. The worst results are for 280% TAC. The experimental data swows that the Lmin value for 300%, 320% and 340% are almost equal each to other and they are close to the best results for 400% TAC.

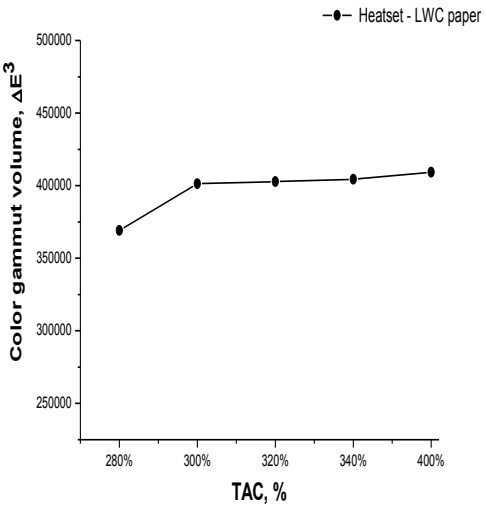


Fig. 4. Color gamut volume in dependence of TAC values.

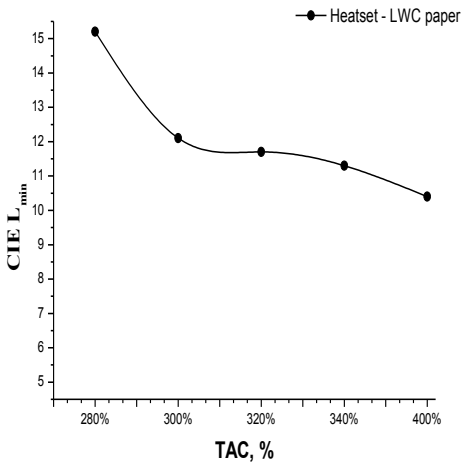


Fig. 5. CIE Lmin in dependence of TAC values.

One of the most important parameters, which defines the effect of TAC on image quality, is the color reproduction accuracy. Color difference expressed by ΔE*ab gives very valuable and reliable information for color reproduction correctness. So we have calculated ΔE*ab from spectral measurement data. The calculations for ΔE*ab were performed to 400 % TAC value as a reference. The obtained results for average colour difference depending on TAC value for all 1485 patches are given in Figure 6.

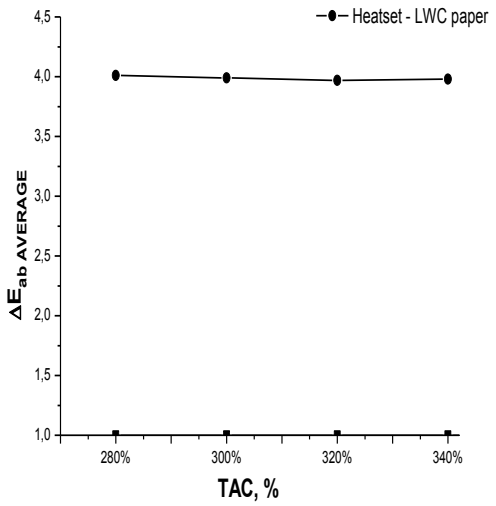


Fig. 6. Average difference in dependence of TAC values.

The graph (Fig. 6) shows that the color difference for printed dark tones for all TAC values is lower than 4.01 units. The lowest value of average color difference is obtained for total area coverage 320 % - about 3.97 units. The difference between them is only 0.04. It could be assumed that the TAC value (280-340%) do not influence color reproduction accuracy.

Except average color difference, we have calculated maximal and minimal color difference from the obtained spectral data for all 1485 patches. The trend and the results for minimal and maximal values are the same like average color difference. So by cause of shortness they are not included in the paper. According to the obtained results for ΔE*ab, it could me made a conclusion, that all TAC values are suitable, but from financial, ecological and for more fast dryness reasons - the lowest TAC values are preferable.

CONCLUSIONS

The results achieved are important from practical point of view. They lead to the conclusion that it is necessarily taking into strict consideration the TAC value, because relatively big differences in color reproduction parameters are occurred.

In an experimental way a well-grounded proof has been achieved for a substantial difference in color reproduction for 4 different TAC values with comparison of different quality parameters.

According to the results of investigation of color reproduction accuracy, switching the TAC values leads to changes in color gamut volumes and shapes (2D and 3D). The changes affect mostly dark and middle tones. There is about 2-8% difference in surface areas and volumes between different TAC values. The results shows, that total area coverage affects the darkest reproducible colour. The difference between different TAC in CIE L*min value is up to 4.80 units.

The evaluation of all color quality reproduction parameters from this research leads to conclusion that the 300% TAC is the best and optimal value of tone value sum. That is the lower TAC value, which gives good color reproduction accuracy, obtained and proofed by experiment performed in real industrial conditions. A practical implementation of the correct and optimal value of 300 % TAC should improve the print quality, printability, better ink layers adhesion, trapping and reducing the quantity of process inks.

We have introduced a new methodology for determination the optimal value of total area coverage by assessing few parameters obtained by measurement of big number of color patches. The methodology includes investigation of reflection spectra, 2D and 3D colour gamuts, color gamut volumes, surface areas of colour gamuts, achievement of darkest printed colour and colour reproduction accuracy. The optimal value of the TAC determined by this new methodology helps to achieve a significant reduction of ink cost and a maximal color gamut volume, i.e. improve the quality of printed image and reduce financial costs.

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ИЗСЛЕДВАНЕ НА ВЛИЯНИЕТО НА СУМАРНОТО КОЛИЧЕСТВО НА МАСТИЛАТА В ТЪМНИТЕ ТОНОВЕ (TAC) ВЪРХУ ТОЧНОСТТА НА ТОНО- И ЦВЕТОВЪЗПРОИЗВЕЖДАНЕТО ПРИ ИЗОБРАЖЕНИЯ ОТПЕЧАТАНИ НА РОЛЕН ОФСЕТОВ ХИЙТСЕТ ПЕЧАТ

И.Т. Спиридонов*, Р.К. Боева, Т.Цв. Божкова, Я.В. Неделчев

**Катедра „Целулоза, хартия и полиграфия", Химикотехнологичен и металургичен Университет, бул. Климент Охридски 8., София 1756, България*

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(Резюме)

Целта на настоящото изследване е разработване на методика за дефиниране на оптимални стойности на сумарното количество на мастилата в тъмните тонове (TAC) и определяне влиянието му върху точността на тоно- и цветовъзпроизвеждането при ролния хийтсет офсетов печат върху LWC хартия. При избор на неоптимални стойности на TAC – по-ниски и по-високи от необходимата, се получават редица проблеми като висок разход на мастило, лоша адхезия на мастилата, ниски стойности на трапинга, копиране при печат, бавно съхнене на мастилата и др. Ето защо е изключително важно да се определят оптимални стойности на параметрите на цветоотделяне за всяка различна комбинация мастило/печатна машина/формена технология/хартия.

За постигане на целите на експеримента е моделирана специална тестова форма, съдържаща множество различни контролни елементи за денситометрични, колориметрични измервания и моделни скали за генериране на ICC профили.

Чрез изследване на резултатите получени от измерените спектрални данни във видимата част на спектъра на тестовите контролни скали и полета е определено влиянието на различните стойности на TAC върху цветовия обхват и точността на тоно- и цветовъзпроизвеждането. Изчислени са цветовите разлики ΔE*ab, площта на 2D разрезите и обемите на 3D тримерното тяло на цветовите обхвати в системата CIE L*a*b*.

Постигнатите резултати и изводи имат научен и научно-приложен характер и практическо приложение. За първи път по експериментален път са определени границите на вариране и оптималните стойности на TAC за хийтсет ролен офсетов печат, спазвайки всички дефинирани цветови толеранси на международните ISO стандарти.

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