Light Fastness Comparison of Xerography and Inkjet Presswork

Cui Xiao-meng[1], Chen Guang-xue[1], Xia Zheng[2], Jin Yan[1]; [1]State Key Laboratory of Pulp & Paper Engineering, South China University of Technology, Guangzhou, China; [2]College of Graphic Arts, QuFu Normal University, RiZhao, China*

Abstract

Following the development and combination of digital printing techniques and digital distribution in publishing industry, more and more books are printed by digital printing equipments. The stability for storage became one of the focuses in digital printing research. The aim of this research work is to investigate the different storage resistance property between digital xerography and inkjet printing presswork. In this paper, a fastness experiment, carried out in completely natural lighting conditions, was presented. A mathematic model of ink aging performance was got from the curve fitting of test results. The key influence impacts in prints aging were compared and analyzed according to the change of density between before and after sun lighting. Finally, the fastness properties of the two categories of digital prints were generalized.

Introduction

Recently, digital technology has been widely used in many different areas such as documents printing, home application and on-demand printing. Following the development and combination of digital printing and digital distribution techniques, it will not be a long time before digital printing technology worked as a main method for book and periodical printing, so the stability for storage attracts extensive attention in digital printing application field.

In various digital printing techniques, the xerography which use specific liquid electronic ink was mainly applied in the on-demand printing of high-grade personalized books and magazines, because the image quality is more similar to conventional offset printing. One the other hand, the digital ink-jet printing, now widely used in Labels, business graphics of variable data printing, is considered to be the most technique of the potential development. As the speed and print quality improved, its application is extending to the printing in publishing fields. Xerography and inkjet printing are regard as the representatives of digital printing technologies in the field of book publishing in the future.

There are many differences between xerography and inkjet printing, e.g. water-based ink are employed in inkjet printing but solvent-based ink in xerography, correspondingly the papers is different too. Differences in principle and materials cause different resistance performance for storage, which will determine the application prospects in book publishing. In recent years, due to the ink-jet printing become the focus of graphic reproduction research, most anti-aging publications are concentrated in the ink-jet printed and comparative study about the two kinds of digital printing products has not been down. In addition, there are still different understandings about the aging because it was doubt that the results got by the artificial aging test which is only to accelerate the aging process of paper is different from obtained in the natural aging process.

In this study, the experiment was carried out in full natural light irradiation conditions, the bleaching phenomena of the two digital prints were compared by measuring the density decay.

Experimental Part

Methods and materials

Samples

According to the application in industry, total of six kinds of three categories of paper, i.e. coated, uncoated and matte paper of xerography printing and inkjet printing, were selected to be used in the experiment, as shown in the following table 1.

Table 1 The type and number of paper used in the experiment

NO.	NAME OF PAPER	GRAMMAGE
1#	semi-glossy proof paper for IJ	150
2#	semi-matte proof paper for IJ	130
3#	matte proof paper for IJ	110
H1	coated paper for xerography	157
H2	uncoated paper for xerography	157
H3	matte paper for xerography	110

Printing equipments

Xerography device: HP Indigo 7000 digital press
HP ElectroInk Specific liquid electronic ink
Inkjet printing device: Epson stylus Pro 7880C
Epson eight-color ultra Chrome K3 ink
EFI Colorproof XF software driver

Besides, the ECI2002CMYK i1_i0 PM5.0.7color target, GretagMacbeth Profile maker 5.0.8 software, X-rite Eye-one IO and X-rite Spectroeye spectrometer were used to implement the printing and measurement operation.

Methodology

In both printing progress, the color management was simply used to correct the gradation to get better color output effect, but the source device space and target device space are not loaded in. The operation parameter of xerography is: the temperature of blanket is 143℃; the number of runs of PIP is 20100; the LUT setting is liner; the temperature of ink is 30□; the density setting of ink is 1.70.

EFI Colorproof XF software was used to drive and control the inkjet printing device. First, generate printer Linearization and ICC profile. Then loaded the profile documents in the EFI Colorproof XF control setting and output the digital color target.

Project supported by the National Natural Science Foundation of China (Grant No. 60972134) and the Fundamental Research Funds for the Central Universities, SCUT.
*Corresponding author. E-mail: guangxuecn@yahoo.com.cn.

Place the prints indoors for 1 day, after that measure and record the density of gradation of CMYK by X-rite Spectroeye.

The influence to prints of humidity has been presented in previous study [1]. In order to reduce the interference of humidity in the experiment, the prints were packaged into colorless transparent plastic bags. Then the sheets were attached on the windows, printed sides towards the colorless transparent glass. For this glass, the UVA band, 300~400nm wavelength UV of ultraviolet light, can go through. After exposure for 25 days, measured the color density value by the X-rite spectrometer and analyzed.

Mathematical formula and evaluation method of print fastness

Color reappearance on prints displayed by the ink attached to the paper surface, so the overall change in color printing, including two factors: the color changes of paper and ink. If assume the paper change is uniform no matter covered by ink or not, the relationship between paper fastness and ink fastness can be described by the following Equation (1).

$$G(x,y) - f(x,y) = \Delta D_i + \Delta D_p \quad (1)$$

Where G(x, y) denote density of one point on prints after ageing; f(x,y) denotes density of one point on prints before ageing; ΔD_i denotes density change of ink; ΔD_p denotes density change of paper。

For the area ratio of ink to paper white is different in different locations, we should analyze the dominant factor to fading according to gradation. The method is: compare the density values of ink with the value of paper; if the change of ink density is greater than that of the paper, it indicates the ageing of the printed ink is the main factors. On the contrary, it shows ageing of the paper is the main factor.

Results and discussion

Analysis of paper ageing

Paper yellowing is a natural process of paper ageing, which is caused by the sunlight, moisture, and the air [2]. Paper is made up of mainly by fiber of wood or non-wood plant, the main components of which are celluloses, hemicelluloses and lignin. Pure cellulose does not absorb visible light but absorbs UV. After absorption, cellulose chains is shortened, the average degree of polymerization decreased and carboxyl compounds are generated. Meanwhile, the paper in acid and alkaline hydrolysis and photo-oxidation degradation may generate chromophore such as formaldehyde, furan, quinone, methoxy quinone and stilbene, resulting in discoloration of paper [3].

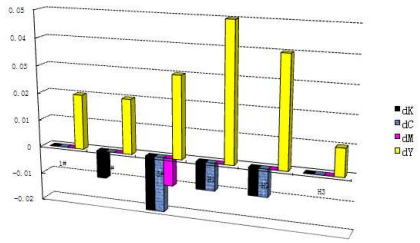


Figure 1.*Color density change of 6 kinds of paper in experiment after ageing*

In the first stage of the investigation, the density changes of printing substrates (papers) during photothermy accelerated ageing were measured. The measured values of three types of paper are presented in Figure 1.

In figure 1, Negative value of the color parameter values indicate the density decrease after ageing, oppositely, positive value indicate the density is increased. As seen in the figure, six kinds of paper were yellowish after-sun. Among them, coated and uncoated paper used for xerography turned more yellow than inkjet printing and the density of C and K is negative reveal the overall lightness is slightly increased and the appearance is more slant yellow and red. But the matt paper used for inkjet printing changed much than that for xerography. Generally, in all papers the, yellowish level of 3# matt paper for xerography is the lowest, and the hardest is H1.

Analysis of ink ageing

In addition to paper change, the ink will also have ageing by ultraviolet light bleaching. On the bases of those measurements, the difference in density, which appeared after ageing, have been calculated according to Equation (2), which was derived from Equation (1).

$$\Delta D_i = G(x,y) - f(x,y) - \Delta D_p \quad (2)$$

Calculate the density change value of four-color ink on 6 papers and plot the converts in figure 2.

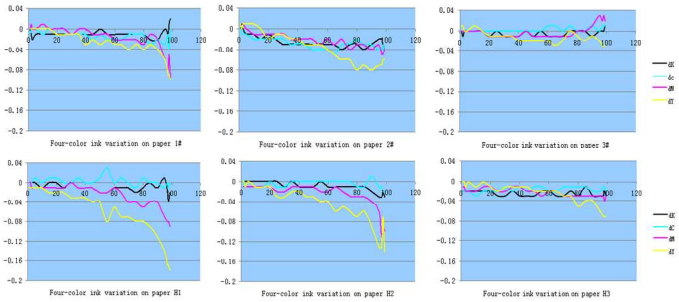


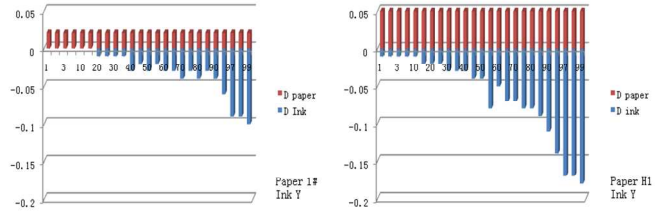
Figure 2. *Change of four-color ink of tone wedge on six kinds of papers*

First, the fastness abilities of inkjet print and xerographic print were compared: at begin, the type of paper is classified, e.g. if the proof number contains the number 1, it is a coated paper; contains 2 is uncoated paper; contains 3 is matte paper. By comparing the fastness of the two prints of same paper category in figure 2, we drew the conclusion about the fastness level: 1#<H1, 2#<H2, 3#<H3. It is indicated that use the same type of substrates and in the same natural irradiation conditions, the fastness of xerography is more serious than that of inkjet printing.

Second, the fastness level is different for different color ink: the decrement of many curves in Fig.2, for instance the curve of yellow ink on H3, increased following the tone grade rising from 0% to 100%. Comparing the fade value of inks on six types of papers, we drew another conclusion: on both digital printing products, the fastness of cyan and black ink is better than magenta ink, and that of yellow ink is worst.

Analysis of impact factors of print fastness

To both of digital prints, the effects on coated paper are much better than other two kinds of paper. So the two prints use of coated paper were analyzed according to the method proposed in 1.3 and the density change of papers and inks were plotted in Fig.3.



(a) (b)

Figure 3. *Schematic of comparison of paper and ink between digital inkjet print and xerography print*

From the Figure 3 it is clearly seen that the ink change in high tone is very slight, so the fading was mainly caused by the density change of paper. But in shadow or middle tone, density change of ink is much more than paper, so the ink fading become the key impact factor. The property of the combination of paper and ink lead the high key image significantly influenced by the fastness of paper. But for most whole tone or low key image, the fastness of print was mainly restricted by the property of ink.

To books which contain wordage and image, the change of solid is less than 0.4, as well as the maximum decrement less than 0.5%, so the visual contrast is mainly influenced by the color change of paper.

In above figure 3, the density decline in low tone in figure (a) is less than the value in figure (b), meanwhile, the density change in figure (b) is larger than that in figure (a). This change decreased the contrast of yellow ink. So In this experiment, the appearance of ageing is that the yellowish level of xerographic prints is higher than inkjet prints.

Discipline of ink fastness

If the fastness of ink is assume to be equal in different tone, the relationship between decrement and dot area coverage should be a single linear growth trend. But the density of C and K changed few as the dot area increases. In order to make further analysis of ink fastness, the ratio of ink change between before and after ageing was calculated. Considering the accumulated error

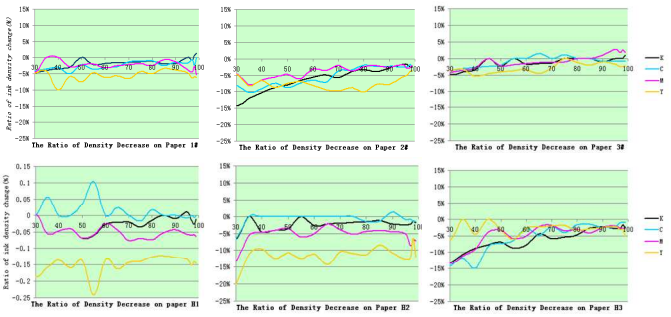


Figure 4. *Ratio of density change in middle and low tone*

caused by measurement and calculation may influence the accuracy in high tone significantly, the tone among 30% to 100% was offered. The relationship between density change rate and dot percentage is plotted in the figure 4.

As can be seen from the Figure 4, the curves of Y and M ink approximately parallel to the axis, and the curves of B and C is similar. Then the mathematic model of ink ageing performance was got from the curve fitting of test results. The fitting curves were plotted in figure 5.

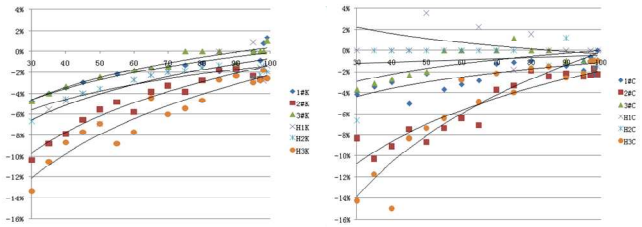


Figure 5.*Curve fitting schematic of ink density decline ratio against dot percentage*

The curve fitting formulas and correlation coefficients were listed in table 2 and table 3. For all K inks, the most correlation coefficients are around 0.9 that indicate there is a very good positive correlation between two parameters.

Table 2 Curve fitting formulas of ink K

Ink K	Logarithm Fitting	Correlation coefficient
1#	y = 0.0375ln(x) - 0.174	R^2 = 0.8225
2#	y = 0.0695ln(x) - 0.3335	R^2 = 0.9464
3#	y = 0.0415ln(x) - 0.1872	R^2 = 0.9263
H1	y = 0.0488ln(x) - 0.2314	R^2 = 0.6710
H2	y = 0.0351ln(x) - 0.1754	R^2 = 0.8133
H3	y = 0.0821ln(x) - 0.4005	R^2 = 0.9138

Table 3 Curve fitting formulas of ink C

Ink C	Logarithm Fitting	Correlation Coefficient
1#	y=0.0738ln(x) - 0.359	R^2=0.8625
2#	y=0.0271ln(x) - 0.1361	R^2=0.5887
3#	y=0.0245ln(x) - 0.1127	R^2=0.5179
H1	y=0.0738ln(x) - 0.359	R^2=0.2134
H2	y=0.0116ln(x) - 0.0564	R^2=0.0687
H3	y=0.1144ln(x) - 0.5284	R^2 =0.8800

Except paper HI and H2, the correlation coefficients of C ink are all more than 0.5, so there is a good positive correlation. From this we can get a new function about the fastness of ink as the following Equation 3.

$$F(x) = a \ln(x) - b \quad (3)$$

Where x denotes dot percentage; F(x) denotes density decline ratio of ink; a & b denotes regulation factors.

In the experiment, using the square method to fit the curve of M, Y and both C ink on paper H1 and H2, a straight line approximately paralleling to the X-axis was achieved, but the correlation coefficient is not any more than 0.4. It is indicated that the relationship between the density decline ratio and dot area amplify is similarly constant to a certain degree.

Conclusions

In this study the fastness property in completely sunlight conditions of both digital inkjet print and xerography have been investigated. The results have shown that besides for the bright tone image, the fastness of ink is the main impact factor for most whole tone graphic reproduction. On the contrary, to the text-based book print, the fastness of paper is the main impact factor. Taking into account of all impact factors of paper and ink, the conclusion was summarized, i.e. the fastness of inkjet printing is better than xerography.

An empirical formula about ink fastness was primary created through curve-fitting method. Because of the formula was achieved based on analysis of data after experiment, the calculate accuracy was limited by the measurement accuracy of prints before ageing. It should be perfected in the following work.

References

[1] Rita Hofmann, Juerg Reber, Humidity diffusion of dye-based IJ Prints, IS&Ts NIP25, Int. Conf. on Dig. Print. Technol.126 (2009).

[2] Mirica Debeljak, Diana Gregor Svetec, The durability of UV ink-jet prints on special papers upon accelerated ageing, IS&Ts NIP25, Int. Conf. on Dig. Print. Technol.130 (2009).

[3] Roger Bollstrom etc. A multilayer coated fiber-based substrate suitable for printed functionality, Organic Electronic, Published by Elsevier B.V. pg.88.(2009).

Author Biography

Cui Xiao-meng, female, lecturer. a PhD candidate in South China University of Technology. She received her B.D. from Tianjin University of Science and Technology and received her M.D. from Wuhan University. Her work focuses on color image process, digital printing technique, etc. E-mail:scut_xiaomengcui@163.com

Chen Guang-Xue, male, doctor, professor. Now, he works in South China University of Technology, Guangzhou, China. He is a member of Chinese Society for Image Science and Technology (CSIST). His work focuses on color image process, digital printing technique and so on. E-mail:guangxuecn@yahoo.com.cn.