

Image Quality Improvement by Clear Toner in Xerography

Osamu Ide, Yasunari Kishimoto, Masayuki Kurimoto*
Fuji Xerox Co., Ltd
Kanagawa, Japan

Abstract

A uniform layer of a clear toner was applied to full color xerographic images to improve image quality. Xerographic print differ from lithographic prints in the surface structure, because xerography deposits toner on uncoated paper in much higher mass density than lithographic inks. Therefore, the gloss of prints strongly depends on the image density. We tried to cover a full color image with a uniform layer of the clear toner to provide better print appearance. By this method, the specular gloss became much uniform and the grainy noise remarkably reduced. Noise reduction was attributed to the decrease of gloss fluctuation with image surface flattening and prevention of image disturbance during transfer and fusing. The subjective impression of a pictorial image also improved.

Introduction

Image quality of color xerography has been improved remarkably in this decade. Digital image processing has been very powerful to improve color reproduction and macroscopic image sharpness. The xerographic color gamut was extended almost equivalent to that of lithography by using flashing pigments and polyester resins with low molecular weight for color toners.[1, 2] Microscopically, the toner size reduction was very effective to improve graininess and resolution.[3] However the subjective impression of pictorial images was much inferior to that of lithography.

The geometric structures of xerographic images are very different from those of lithography and photography. Especially, the surface structure of the image which depends on the paper substrate and the pile structure of color toners strongly affects image qualities. Coated papers with a smooth surface are usually used in lithography, while uncoated papers with a rough surface are employed in xerography. Even if a coated paper is used in which the fiber structure is completely masked, still larger mass density of color toners degrades image quality. Kurimoto reported that a monochromatic toner image rose from the paper plane about 5micron, which was ten times or more as large as the image thickness in offset printing.[4]

The xerographic surface structure causes two problems relating to image quality. The one is the gloss difference on the image coverage, the other is noise.

As for the gloss, highlight area mainly reflects the paper property. On uncoated paper, as the coverage increases, the gloss gradually rises as far as the color toners are design to provide a glossy solid image for better color saturation. On coated paper, still the gloss depends on the coverage existing a minimum around 50% coverage due to the noticeable height of individual dots. The low gloss in medium coverage expects to reduce the color gamut.

Concerning the noise, the large mass density of color toners and the rough surface of the paper tend to increase unstable mechanical dot gain during transfer and fusing, thus strongly increasing the noise in halftone areas. Moreover, micro fluctuation of the gloss becomes apparent towards shadow areas reflecting the fiber structure.

From the above descriptions, it is evident that the modification of the surface structure in xerography will be effective for quality improvement. There are many patents base on the use of a clear toner.[5, 6] Clear toner can be used in two way, one being complementary deposition to an image, another uniform deposition on entire image area. In either way, the property difference between image and background areas will substantially disappear.

This paper describes the effects of clear toner uniformly deposited on full color xerographic images on image quality.

Experimental

Toners

Cyan, Magenta and Yellow toners for A-Color 630 manufactured by Fuji Xerox were employed to make base color images. The clear toner was composed of a 7 micron diameter resin powder on which SiO_2 and TiO_2 were allowed to adhere for charge controlling. The resin was a low molecular weight, linear polyester common to the color toners.

Image Formation

Experiments were carried out with an apparatus modified from A-Color 630, a laser color printer of Fuji Xerox. The original K (black) development housing was charged with the clear toner developer, and the order of development was changed from the original K, Y, M, C to Y, M, C, Clear. In the present experiment, the clear toner was always applied uniformly.

Two kinds of 200 lines/inch line screened color image were developed; one being a magenta step wedge for image quality measurements, and the second a scene containing a lady, a Macbeth Color Checker, etc., for subjective evaluation.

By using uncoated paper(J-paper, a product of Fuji Xerox) the standard xerographic processes for A-Color (magnetic two component development, electrostatic transfer and heat roll fusing) were carried out to form a full color image covered with a uniform layer of the clear toner. The developing conditions for each color image were fixed so as to give 6.5g/m2 of toner mass density for solid area, while those for clear toner was changed from 5.2 to 12 g/m^2.

Measurements of Image Quality

The specular gloss was measured with GM-26D(Murakami Color Res. Lab.). The incidental angle of light upon the image was 75 degree. CIE Lab (Illuminant: D50, 2 degree standard observer) values were measured with X-rite 968. Lightness fluctuations within a halftone patch were measured and, by taking into account the spatial frequency response of human vision, converted into graininess scale.[7, 8] The dependence of visual response on image density was not considered.

Results and Discussions

Gloss dependence on Density

The specular gloss of the halftone magenta step wedge on which the clear toner developed in several different mass density as a function of input coverage of magenta image is shown in Figure 1. The gloss of the image without clear toner (before the application of clear toner) strongly depended on input coverage with a difference of more than 40 gloss unit and reaching a maximum of 48 at the solid area. When the wedge was covered with a clear toner layer, the above dependence decreased with the mass density of clear toner along with a marked increase of gloss over the entire coverage range. The figure shows that 12g/m^2 of clear toner is needed to achieve the equivalent characteristics in gloss to offset prints on coated paper.

Graininess

Figure 2 shows the graininess scale of the halftone magenta images of several coverage as a function of the mass density of clear toner. Except 10% coverage, it is evident that the clear toner layer can effectively suppress image graininess. Since the xerographic print has a far rougher surface than the offset print, the graininess suppression at the middle and shadow region, taking into consideration the result of Figure 1, is likely to be achieved by the reduction of microscopic gloss fluctuation. The result at 10% coverage will be discussed later.

Dot Gain

Honjo et al. reported that the amount of the dot gain on the area modulation images could be evaluated by the locus on CIE x-y chromaticity coordinates of a halftone step wedge.[9] On an ideal hard dot image without dot gain, the color change with coverage should be calculated by Neugebauer equation. This shows that the locus is linear connecting between the coordinates of the paper and the solid image. The deviation from this relation shows the amount of dot gain.

Figure 3 shows CIE x-y chromaticity coordinates of halftone magenta step wedges on which the clear toner was developed in varied mass density. The figure indicates that the clear toner layer worked to decrease dot gain. There are two types of dot gain, i.e., mechanical and optical. As the microphotographs of images will tell, it is strongly suggested that mechanical dot gain decreased.

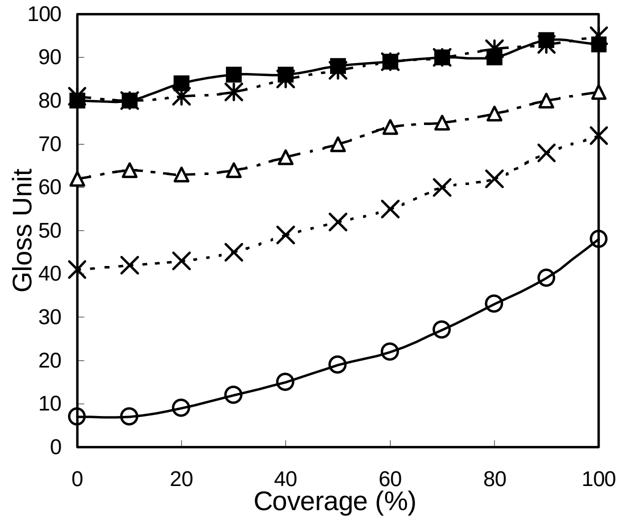

Figure 1: The gloss of magenta step wedges on which the clear toner developed in several different mass density as a function of magenta image coverage. Parameters are as follows ;
■ : 12.0 g/m^2, △ : 8.0 g/m^2, × : 5.2 g/m^2,
○ : No Clear, ✱ : Offset Print

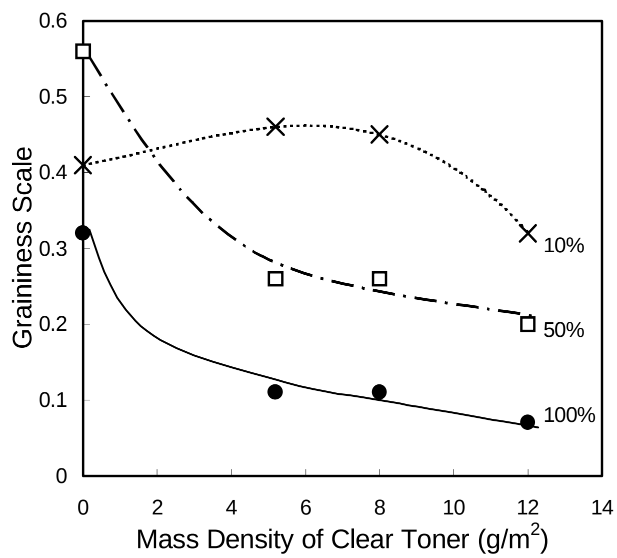

Figure 2 : The graininess of the halftone images as a function of the mass density of clear toner. The number in this figure means the magenta image coverage.

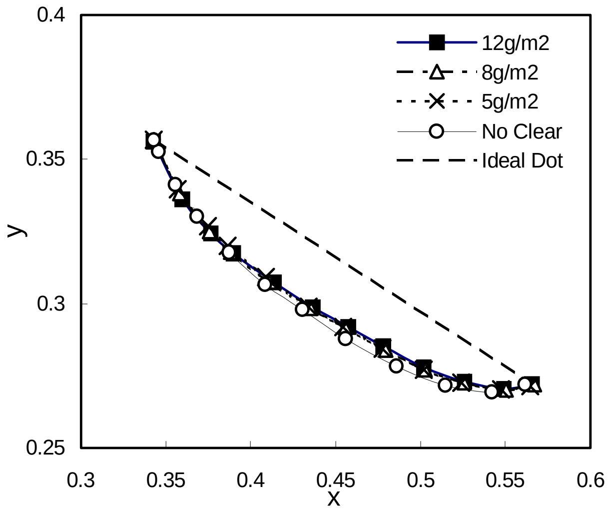

Figure 3: CIE x-y chromaticity coordinates of halftone magenta step wedges on which the clear toner was developed as a parameter of the mass density of clear toner.

Observation of Image Structure

Figure 4 shows the microphotograph of the magenta halftone image with a uniform layer of clear toner. The reference photograph without clear toner layer is shown in Figure 5

Comparison of the two figures indicate the mechanism with which clear toner works to reduce graininess. Fig.5 shows disturbed lines and microscopic gloss fluctuation, both caused by a fairly free flow of color toner along paper fiber. In Fig.4, it is clear that the line disturbance as well as the gloss fluctuation due to the fiber structure markedly decreased.

When one directly views the image in Fig.5, the exposed paper area looks matt without gloss while the toner-covered area looks glossy but with a gloss variation dominated by the fiber structure of paper. The specular gloss is given by the average of the two areas. Since the print is observed at a viewing distance of dissolving the screen structure, the observer's recognition of gloss corresponds to the measured value of specular gloss, but at the same time he tends to judge the gloss variation as a kind of noise.

The decrease of the mechanical dot gain by using the clear toner is detected to compare Figure 4 with Figure 5. The color toner flow along the paper fiber is observed in Figure 5. The difference of the dot gain between Figure 4 and Figure 5 seems to be not so much, but the change of the dot gain is surely detected in Figure 3. The dot gain reduction would work to reduce noise by the fluctuation of diffuse reflection component.

In the case that the small amount of the clear toner was developed on the highlight images in Figure 2, the graininess of those images were not better than without the clear toner.

The one reason could be explained by the change of the gloss fluctuation. The effect of the paper surface structure on the noise in highlight images should be grater than that in the higher coverage images, for most of the area is covered only with the clear toner. It is interpreted that the clear toner mass less than 8g/m2 was not enough to make up for the rough surface structure of the paper and it employed to compensate only for the very high frequency component of the structure. The images without clear toner, the gloss of low coverage areas is low because the exposed paper is matt. When the exposed paper is covered with clear toner in low mass density, the clear toner on the naked paper acts to add a microscopic gloss fluctuation.

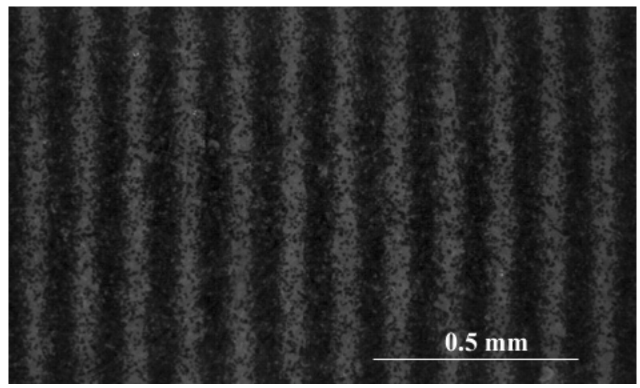

Figure 4: The Microphotograph of the 50% coverage Magenta image with the clear toner of 12.0g/m2 developed mass

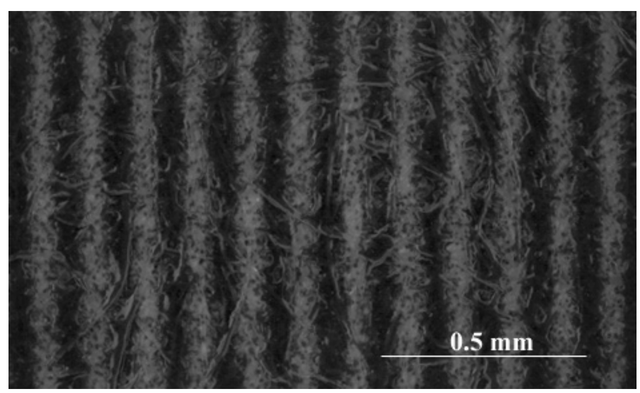

Figure 5: The Microphotograph of the 50% coverage Magenta image without clear toner

The second reason was explained as follows. It seems that the noise of the diffuse reflection component on the highlight images increased by the clear toner. The L* difference between the images of 10% coverage with and without clear toner was 8. The clear toner layer seems to prevent the color toners from penetrating into the paper and each color toner particle contributed to the color reproduction. Therefore, the diffuse reflection component noise of the highlight images with clear toner was inferior to that without clear toner.

The gloss fluctuation of the images with the clear toner layer of $12g/m^2$ mass density was better than that without clear toner. It is interpreted that the total noise of the images with sufficient amount of clear toner was superior to that without clear toner.

It is difficult from these photographs to discuss the quantitative effect on noise between the microscopic gloss variation and the fluctuation of diffuse reflection component.

Subjective impression

The subjective impression of a full color image on J-paper remarkably improved with the use of clear toner. The uniform gloss and the noise reduction seems contributing to a better print appearance.

Conclusion

By using a uniform layer of the clear toner in xerography, the surface structure of the color images could be modified to provide better print appearance. The specular gloss became much uniform and the noise remarkably reduced. Noise reduction was attributed to the decrease of gloss fluctuation with image surface flattening and prevention of image disturbance during transfer and fusing. The dot gain analysis using CIE x-y chromaticity coordinates and the microscopic photographs of the halftone images corresponded with the above consideration. The subjective impression of a pictorial image also improved.

Acknowledgments

The Authors would like to thank Satoru Honjo and Sizuo Tatsuoka for valuable discussions. The reserch was supported by Dale Green, Charles Hains and Thomas Hanna who work for Xerox.

References

1. H.Akagi et al , Procgs. of IS&T's the 9th International NIP congress , p17-20 (1993) , Yokohama , Japan.
2. M.Nakamura , Procgs. of IS&T's the 10th International NIP congress , p178-182 (1994) , New Orleans , LA.
3. K.Shigehiro et al , Procgs. of IS&T's the 9th International NIP congress , p97-100 (1993) , Yokohama , Japan.
4. M.Kurimoto and F.Watanabe , Denshishasin ,**35** , p131-134 (1996)
5. Y.Kawabata et al , Japanese Laid Open Patent 58374 (1988)
6. T.Haneda et al , Japanese Laid Open Patent 204669 (1992)
7. R.P.Dooley and R.Shaw , Appl.Photogr.Eng. , **5** , p190-196 (1979)
8. Y.Hirose , Japan Hard copy , p189-192 (1988)
9. S.Honjo, S.Taguchi and T.Suzuki , Procgs. of Neugebouer Memorial Seminar on Color Reproduction, Tokyo , Japan (1989)