High Image Quality and Stability of Full Color Digital Electrophotographic System

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Abstract

The requirements for digital electrophotography have been becoming higher and higher from the viewpoint of high image quality and stability. Significant points are as follows:

1. *Uniformity of solid image (density and gloss)*
2. *Fine reproduction of isolated dots*
3. *Stability of color balance (gray balance)*
4. *Accuracy of color registration*

In order to meet these demands, we have newly developed xerographic materials, technologies of mechanical design and imaging process technologies, which include the development of small size chemical toner containing wax, the reduction of pulse repetition period jitter, and the improvement of process control technologies respectively.

In this paper, we would like to introduce our latest results related to imaging process technologies, especially fine reproduction of isolated dots.

Introduction

A digital full color MFP (Multi Function Printer) is beginning to infiltrate offices rapidly in recent years. It is because the image quality and stability of color print have improved dramatically, with the spread of 4-drum tandem engine that can print at the same speed as B/W printing. A typical system of 4-drum tandem engine is shown in Figure 1. The mainstream of the early tandem engine was a direct transfer system that transfers the color toner one by one on the paper directly. Recently, the intermediate transfer system as shown in Figure 1 has been gaining popularity. The intermediate transfer system has the merit of being less influenced by paper characteristics compared with a direct transfer system.

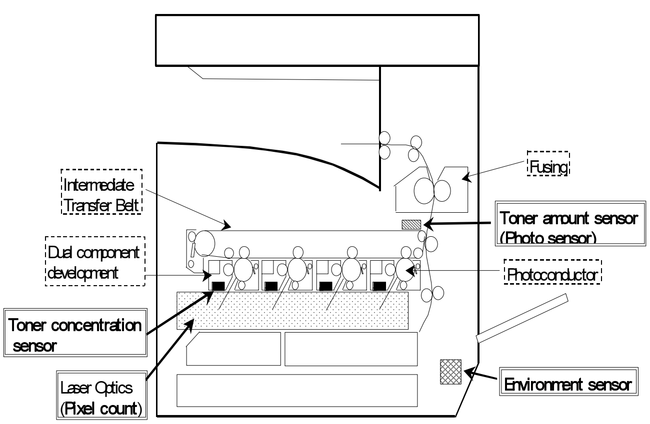

***Figure 1.** Intermediate transfer system of tandem engine*

For the achievement of high image quality and stability by a digital full color MFP, it is important to stabilize each color quality and maintain the balance between four colors. To say nothing of uniformity and stability of solid image, the reproducibility of isolated dots is a basic function for the digital image. The stability of density, smooth gloss and decrease of noise such as the pulse repetition period jitter contribute to the excellent solid image. On the other hand, stable reproduction of small dots is becoming an important issue. Furthermore, in addition to the stability of each color quality, the balance between four colors becomes an important factor, which determines full color image quality. As balance between four colors, the balance of each image density and the accuracy of color registration are important.

In this paper, it reports on the technology in the digital full color MFP for offices, regarding to the stability control of solid image density and dot reproducibility. Moreover, the electrophotographic system and materials, which achieve further small dot reproduction, are discussed.

Stability control of solid image density

In an electrophotographic system, environmental conditions, such as temperature and humidity, and the properties deterioration of xerographic materials by print stress are easy to influence the image quality. By changes in properties of toner, carrier, photoconductor, and other chemical materials, the development and the transfer capability are easily changed and image density changes a lot as a result. Therefore, in order to control image density in an electrophotographic system, physical properties signals are detected using several sensors, and process parameters in each unit are controlled according to the signals. This control system is called “Process Control”.

Typical detected signals are as follows:

1. Environmental conditions (temperature and humidity)
2. Surface potential of a photoconductor
3. Toner amount
   (on a photoconductor or an intermediate transfer belt)
4. Toner concentration in a development unit
5. Number of printed dots (consumed toner)

Process parameters controlled according to these signals are as follows:

1. Charging bias
2. Exposure energy
3. Development bias
4. Toner supply to a development unit
5. Transfer bias

In the latest tandem machine for offices, there is also a demand of small size and low cost, so surface potential detection of a photoconductor is rarely performed. And for toner amount detection, it is common to detect four colors on the intermediate transfer belt using common sensor. Furthermore, in digital MFP, the amount of consumed toner can be predicted by counting the number of printed dots, and it can also apply to stabilization of toner concentration control in a development unit.

An example of the image density control in the tandem engine (Figure 1) for offices is shown in the flow chart of Figure 2. And toner concentration control is shown in the flow chart of Figure 3.

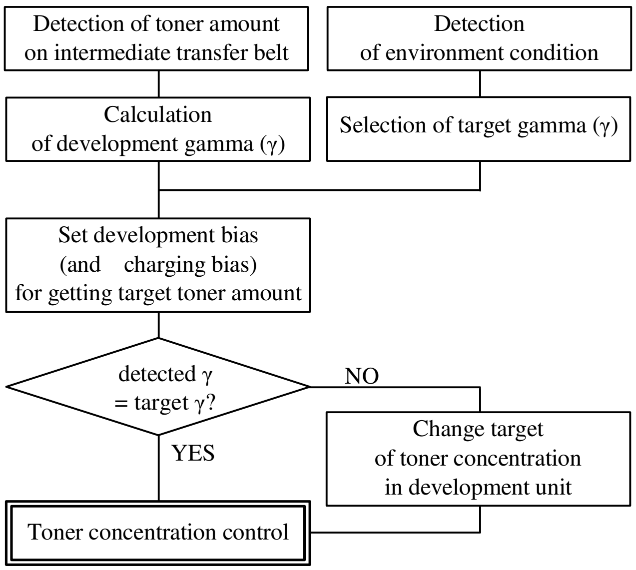

Figure 2. *Flow chart of Image density control*

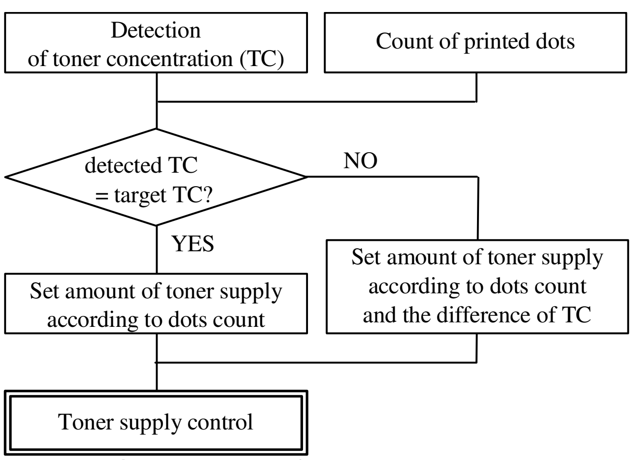

Figure 3. *Flow chart of toner concentration control*

First of all, the current development gamma is calculated with detecting the toner patterns on the intermediate transfer belt by the toner amount sensor (photo sensor). Incidentally, development gamma means development capability to development potential. And the necessary development potential is decided for getting the target toner amount according to the detected gamma. Exposure energy sets up the level with which exposure potential of photoconductor is saturated. Therefore, development bias is chosen for getting the desired development potential. In consideration of margin of background development and carrier adhesion, the charging bias is set up to development bias. When the detected current gamma has shifted from the target gamma, the target toner concentration is changed so that it may be set to target gamma. And also, target gamma is appropriately chosen according to environmental conditions.

The amount of toner supply is controlled to become the target toner concentration according to the signal of a toner concentration sensor. In order to raise the accuracy of this toner concentration control, the actually consumed amount of toners is guessed from the count of printed dots, and it feeds back to the amount of toner supply.

Finally, solid image density is stably controlled by above-mentioned procedure.

Reproduction and stable control of a dot

In a digital image, stable reproducibility of a dot is important factor. When solid image density is stably controlled by bias conditions according to the development gamma as mentioned above, will the reproduction of a dot also become stable? Figure 4 indicates a dot diameter at the time of above-mentioned image density control. Although the solid image density is controlled as expected, the diameter of a dot is still unstable.

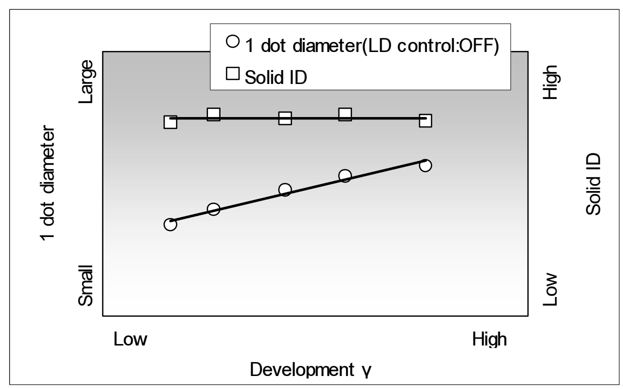

Figure 4. *Dot diameter and solid image density*

In addition to stable reproducibility of a dot, its size is also an important factor. If a dot size is large, it is easy to get stable reproduction, but a dot stands out and it becomes rough granularity. Conversely, if a dot size is too small, the print image becomes uneven and unclear because of unstable dot reproduction. Figure 5 shows how the dot size and the dispersion of the dot diameter change according to the exposure energy. As for a small dot, dispersion becomes large, and so reproduction of a dot is unstable.

Keeping stable dot size that changes by image density control is realized by controlling exposure energy according to development gamma. In that case, the exposure energy is chosen on the minimum level with which a dot is stably formed (small dispersion) and exposure potential is saturated. The result of the dot size in the case controlling exposure energy according to development gamma and of the image density is shown in Figure 6. By controlling development bias and exposure energy appropriately, as shown in Figure 6, the stability of image density and the stable reproduction of a dot can be well balanced.

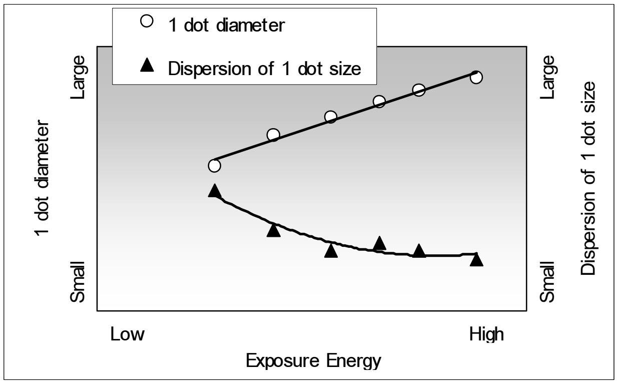

Figure 5. *Dot diameter and its dispersion*

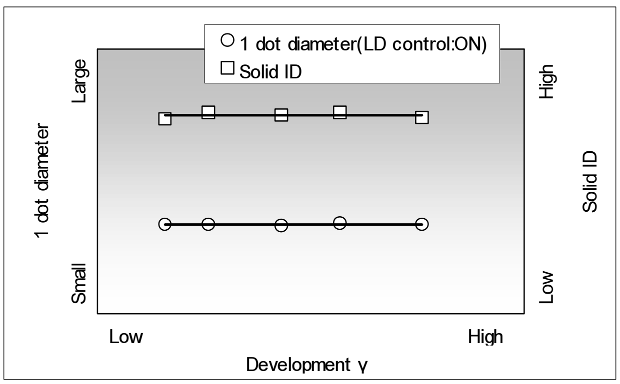

Figure 6. *Dot diameter and solid image density*

Reproduction of a further small dot

In full color digital electrophotographic system, what is the smallest dot size required from the viewpoint of image quality? For example, in the 600dpi image, about 60 micrometers diameter is required as a dot size. This is larger than the pixel size of 600dpi, and it is necessary size in a dot with which the diagonal line of 45 degrees connects theoretically. However, if this size is the minimum size of the printed dots, a dot is visible and so granularity becomes worse. The ideal minimum size of the printed dot should be invisible level, and the size is about 30 micrometers or less. In digital electrophotographic system, the stable dot reproduction of this invisible level is considered as one target towards high image quality. The factors for a small dot reproduction in each imaging process are as follows:

Latent image formation

For stable reproduction of a small dot, sharp and deep latent image formation is required. For that purpose, the binary exposure or a few level exposure by narrow beam using 650nm LD (short wavelength, for DVD Laser Diode) is effective, for example (Figure 7). And thinner CTL (Charge Transport Layer) of photoconductor is also effective.

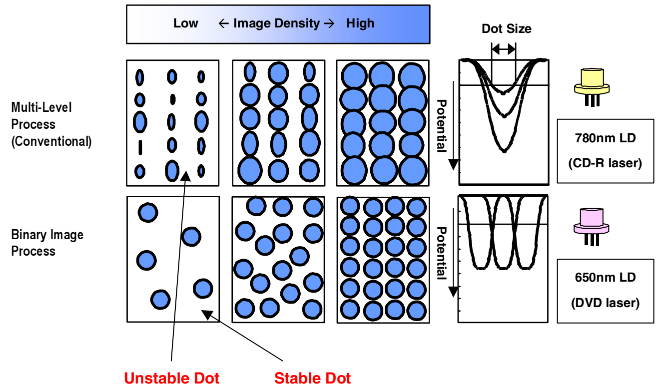

Figure 7.*Illustration of exposure image*

Development

In development, it is important to have reproducibility faithful to a latent image, and high development capability is required. For that purpose, it is also one effective method to make the development gap to a photoconductor narrower.

The reproducibility of a small dot improves dramatically by using toner of small particle size with sharp particle distribution (for example, small size chemical toner). Figure 8 shows the picture of isolated dots developed with the toner of various particle sizes. The dot images formed to the latent image of a different level by changing exposure energy are shown. Figure 9 shows the measurement value of a dot diameter and of the diameter dispersion at that time. By using the small size toner, it turns out clearly that the reproducibility of a small dot is improved. Next, Figure 10 shows the picture of isolated dots developed with the spherical toner of various particle sizes. Figure 11 also shows the measurement value of a dot diameter and of the diameter dispersion at Figure 10. In the case of the spherical toner, the reproducibility of a small dot by low exposure energy is also improved according to toner size. Moreover, by using the spherical toner, the reproducibility to the latent image is stable, not dependent on its toner size. The results suggest that the spherical toner has the advantage in reproducibility and faithfulness to a latent image.

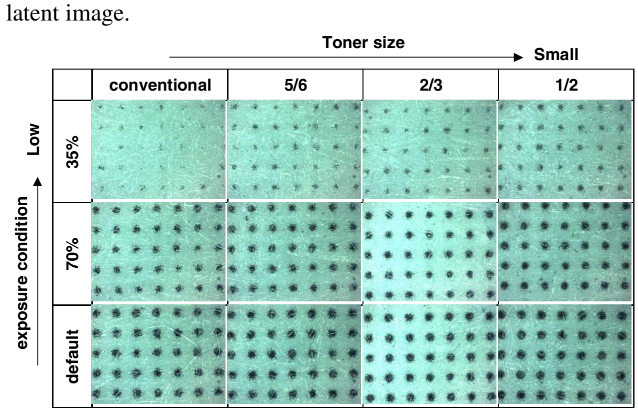

Figure 8. *1-dot image formed by using the various toner sizes*

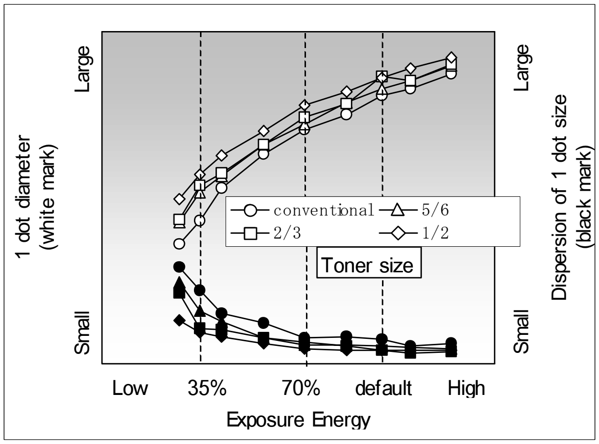

Figure 9. Dot diameter and its dispersion

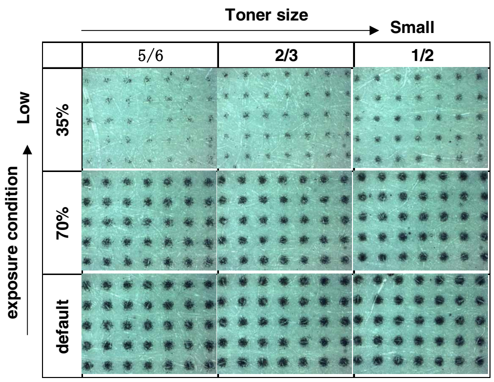

Figure 10. 1-dot image formed by using spherical toner

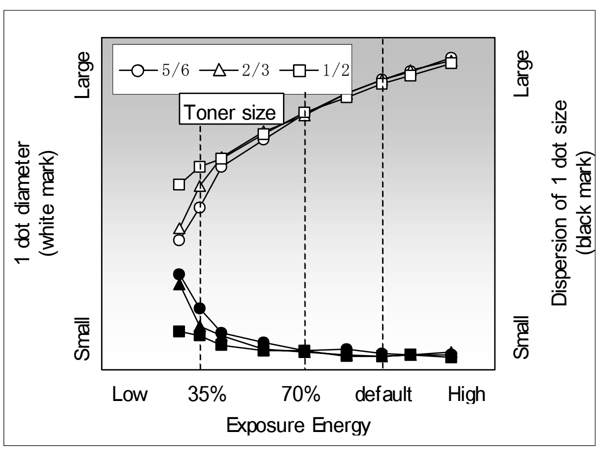

Figure 11. Dot diameter and its dispersion at Figure 10

Transfer and Fusing process

From a viewpoint of reproduction of a small dot, in transfer and fusing process, it is important to suppress deterioration of dot reproduction at each process. At transfer process in a tandem system, charge distribution of toner becomes broad by electric discharge at the transfer nip, and it tends to deteriorate image quality due to the reverse transfer at the following station. The important parameters that suppress such image deterioration are electric resistance of the intermediate transfer belt and the formation of the transfer nip.

Degradation by fusing process is produced by melting and spreading toner image. In order to suppress this degradation, using small size toner, and making pile height of toner image lower are effective.

By optimizing the various processes mentioned above (forming a latent image deeply sharply, developing the latent image faithfully by high development capability, using small size toner, and optimizing transfer and fusing process), is it possible to realize the stable dot reproduction of the invisible level? We confirmed the possibility of a stable small dot reproduction of 30 micrometers or less. We will be able to realize the high image quality and stability of digital electrophotographic system by fine reproduction of a small dot.

Conclusion

This report described the density stabilization of a solid image density and stable reproduction of a dot, which are important factors for high quality of a digital full color image. Moreover, possibility of the stable reproduction of the further small dot was clarified. The future indicator for high image quality and stability of full color digital electrophotographic system were shown.

References

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Author Biography

Masumi Sato received his MA in applied physics from the University of Nagoya and joined Ricoh Company Ltd. in 1989. Since then he has been working in research and development section at Ricoh. In recent years, he has been engaging in development color laser engine. He is a member of The Imaging Society of Japan.