An Experimental Study on Developing Characteristics Using Highly Concentrated Liquid Toner

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Abstract

Although liquid development using submicrometer-sized toner particles is suitable for achieving high image quality including half-tone images, conventional liquid developing units are limited in speed and cause chemical pollution. Furthermore, the need for a built-in toner density control unit makes the printer equipment complex. To solve these problems, a liquid developing unit using highly concentrated liquid toner that can develop the latent image in a small developing area without any toner density control is available. This unit contains a developing roller that also works as a filming roller and squeezing roller. Optimal developing conditions that yield a high-quality image with a noise-free background are described.

Introduction

In recent years, demand for high-quality short-run printing has increased, and a liquid development process using liquid toner is attractive because it can achieve high image quality and resolution. The liquid toner consists of an insulating liquid carrier and charged submicrometer toner particles suspended in the carrier. The liquid toner contacts the receiving medium where the latent image is formed, and develops it faithfully by electrophoresis.

The conventional liquid development process uses a low toner concentration, typically less than 1wt%. To obtain enough toner particles to develop the latent image, it is necessary to supply a large quantity of fresh liquid toner to the developing area, which requires a toner circulation system and a toner density control unit. Consumption of such a large quantity of liquid toner causes pollution, and the toner circulation system and toner density control unit make the printer equipment complex.

In order to solve these problems, a liquid developing unit using highly concentrated liquid toner (over 10wt%) is investigated. This increases the number of effective toner particles for developing the latent image and decreases liquid toner consumption. To make the unit in a simple system, we chose to use the developing roller system.

One serious problem to be solved is background noise. In this paper, we mainly discuss the filming of ink around the developing roller and developing conditions that eliminate background noise based on experimental studies to investigate the feasibility of the new developing unit.

Experimental Apparatus

Figure 1 shows a schematic view of our new liquid developing unit. Highly concentrated liquid toner fills the ink bottle, and the developing roller is partially immersed in it. The rotation of the developing roller causes the liquid toner to be drawn up around it. The filming blade contacts the developing roller, and the thickness of the ink lamina around the developing roller is controlled.

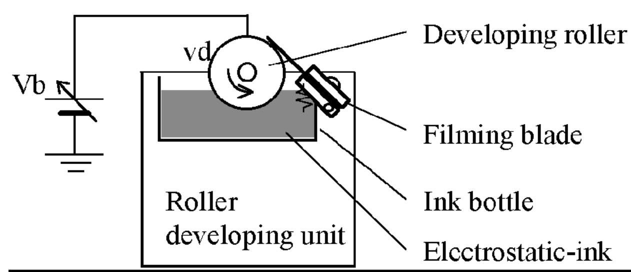

Figure 1. Schematic view of liquid developing unit.

The highly concentrated liquid toner used in this experiment consists of toner particles composed of resin including pigment, charge control agent, and dispersion polymer. The particles are suspended in iso-paraffin. The toner particle size is about 0.5µm, toner density is 15wt%, and toner viscosity is $7.8x10^{-3}$Pa • s.

Figure 2 shows a schematic view of the experimental apparatus. We used electrostatic printing paper as a receiving medium and put it on a paper feeding drum. The latent image is formed on the receiving medium by the charging unit while the receiving medium is fed by the paper feeding drum. In this system, a scorotron is used as the charging unit. The latent image is developed by the liquid toner filmed around the developing roller into a toned image. There is a developing gap between the developing roller and the paper feeding drum. The accuracy of parallelism between the paper feeding drum and the developing roller and gap is adjusted by θ and Z stages. The developing roller rotates in the same direction as the paper feeding drum and it squeezes off the excess liquid toner. The grid of the scorotron is masked except for about a 30-mm width perpendicular to the paper feeding direction and forms a slit-shaped latent image on the receiving medium. The surface potential of the latent image and the optical density of the toned image on the receiving medium are measured. The surface potential of the latent image is adjusted by selecting the zener diode which is connected to the grid of the scorotron.

Filming of Ink Around the Developing Roller

The filming of ink around the development roller is important in making a new liquid developing unit using highly concentrated liquid toner. We investigated two types of filming system, a "slit blade type" and a "rough roller type". Both these have a very simple construction consisting only of a filming blade and a developing roller.

The slit blade filming system is schematically shown in Fig. 3. Its surface has a slit pattern whose cross-sectional shape (width W, depth D, and pitch P) controls the thickness of the ink lamina around the developing roller. Figure 4 shows the relationship between the specific peripheral velocity of the developing roller and the specific thickness of the ink lamina shaped around it. In following figures, the thickness that can supply enough toner to develop the latent image te and the peripheral velocity of paper feeding drum vp are bases of specific values. We tested several slit blade cross-sectional shapes (A-F) and measured the ink lamina thicknesses ti with a wet thickness gauge (Kumagai Riki Kogyo Japan).

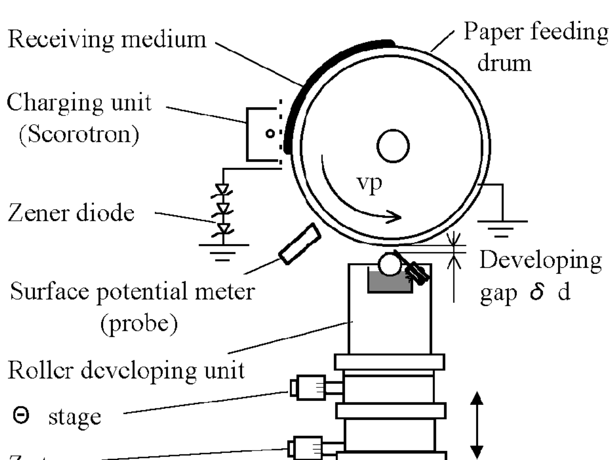

Figure 2. Schematic view of experimental apparatus (printing system).

The results show that the thickness of the ink lamina shaped around the developing roller can be controlled by the cross-sectional shape of the slit blade and does not depend on the peripheral velocity of the developing roller.

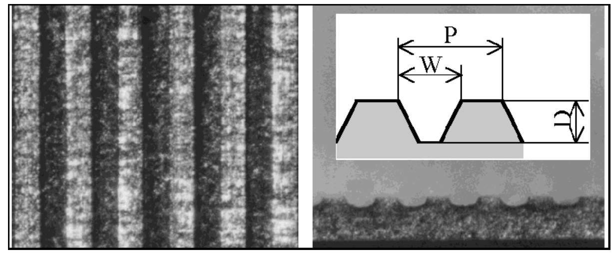

Figure 3. Overview of slit blade (a) top view, (b) side view

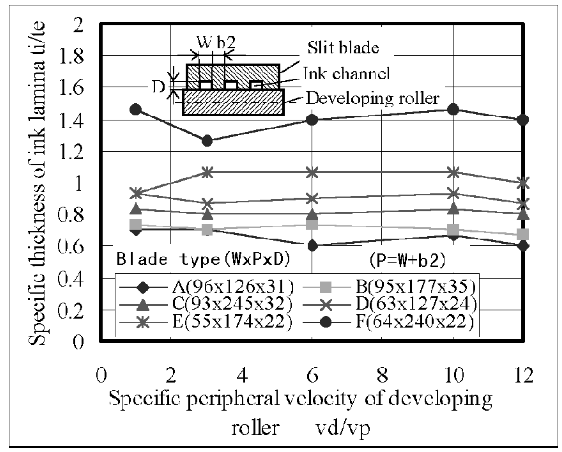

Figure 4. Relationship between specific peripheral velocity of developing roller and specific thickness of ink lamina shaped around it.

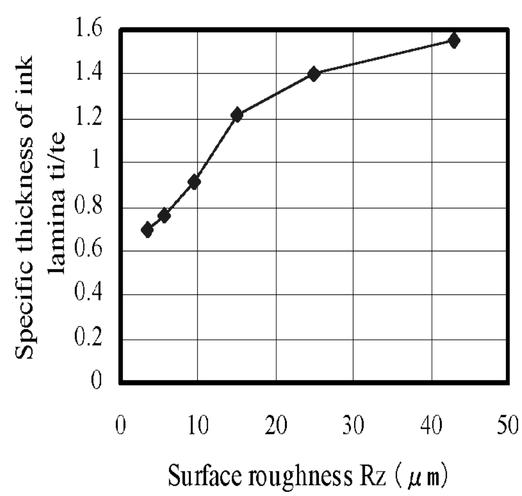

Figure 5. Relationship between surface roughness of developing roller and specific thickness of ink lamina shapd around it.

In the rough roller filming system, the developing roller is sandblasted and its surface roughness is controlled. A planar filming blade contacts the developing roller, and the ink lamina thickness around it can be controlled by its surface roughness, as shown by the measured results plotted in Fig. 5.

Developing Conditions Without Background Noise

To obtain good print quality, the optical density of the toned image must exceed 1.3 without any background noise. In designing a liquid developing unit using highly concentrated liquid toner, background noise is the major problem to be solved. Therefore, we investigated the developing bias voltage applied between the paper feeding drum and developing roller. Since toner particles in highly concentrated ink are positively charged, a negative developing bias applied to the developing roller is effective for eliminating background noise. The following discussion is based on using the slit blade filming system.

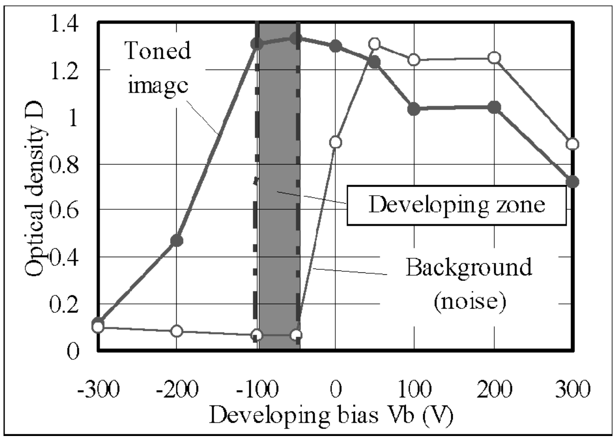

Figure 6. Relationship between developing bias voltage and optical density of toned image on the paper.

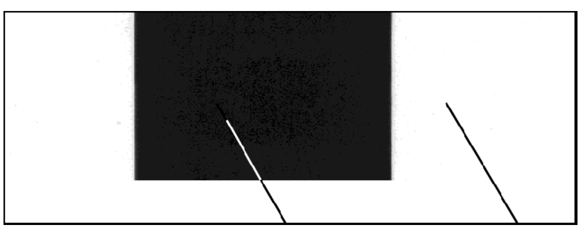

Figure 7. Toned image on the paper.

Figure 6 shows the relationship between the developing bias voltage and optical density of toned image on the paper. The surface potential was fixed at -140 V and positive bias was also applied. The results show that the optical density of the toned image and the background noise decreased with increasing negative developing bias. When the developing bias was in the range of -50 to -100 V, we got sufficient optical density without any background noise, as shown in Fig. 7.

Toned Image Background

Figure 8 shows the relationship between the specific peripheral velocity of the developing roller and the optical density of the toned image on the paper for three different developing gaps (δd/ti is 0, 0.7, and 2.0). Slit blade F was used and the specific ink thickness around the developing roller ti/te was 1.5. Negative velocities mean that the developing roller rotated in the same direction as the paper feeding drum, i.e., the peripheral velocity vectors of the developing roller and paper feed roller had opposite directions, which we call "counter rotation". Positive velocities mean the developing roller rotated in the opposite direction to the paper feeding drum, which we call "co-rotation".

The optical density of the toned image was saturated and independent of the developing gap, except when the peripheral velocity of the developing roller was lower than that of the paper feed roller. It was low when the velocities were equal. And it decreased with decreasing ink thickness around the developing roller (not shown in this figure). These results show that when the specific peripheral velocity of the developing roller vd/vp was higher than ±3, the toner supply was enough to neutralize the -140 V of the latent image.

On the other hand, the optical density of the background became low when the developing gap was wider than the ink thickness around the developing roller (δd/ti > 1). With counter rotation, the optical density of the background noise increased with the peripheral velocity of the developing roller, while with co-rotation, it hardly depended on the peripheral velocity of the developing roller or on the developing gap.

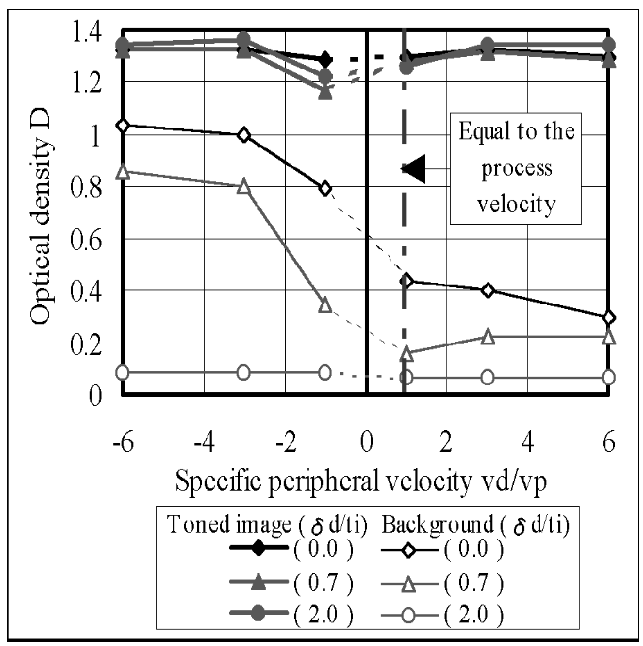

Figure 8. Relationship between specific peripheral velocity of developing roller and optical density of toned image on the paper (Specific ink thickness around developing roller: 1.5).

Figure 9 shows the relationship between developing gap and ink thickness ratio δd/ti and optical density of the background on the paper for three specific ink thicknesses around the developing roller (0.7, 1.0, and 1.5) when the specific peripheral velocity of the developing roller vd/vp was fixed at -3. The optical density of the background decreased with decreasing ink thickness around or increasing gap. When the gap was wider than the ink thickness (δd/ti > 1), background noise was eliminated.

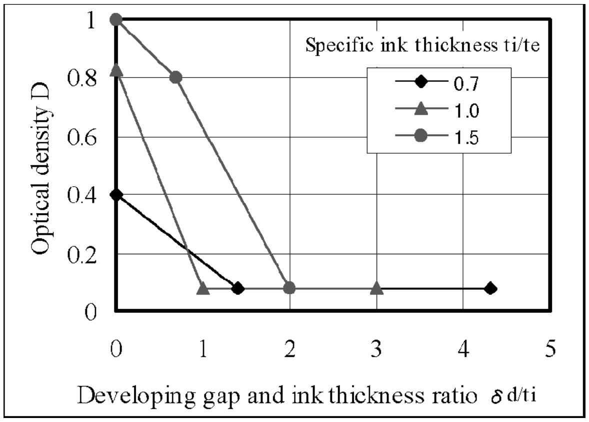

Figure 9. Relationship between developing gap and optical density of background on the paper (vd/vp=-3).

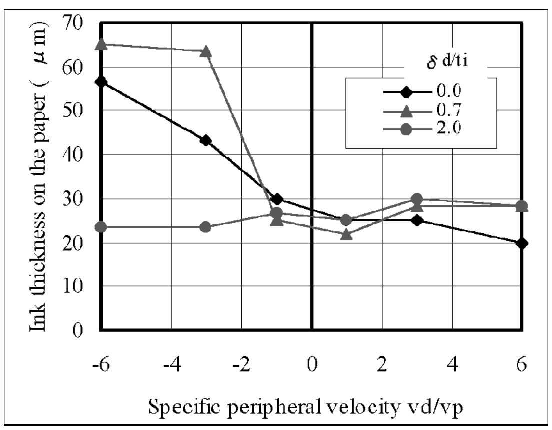

Figure 10. Relationship between specific peripheral velocity of developing roller and ink thickness on the paper (Specific ink thickness around developing roller: 1.5).

These results show that co-rotation gives better conditions for noise-free development. However, counter rotation is required to avoid drifting of the toned image and to obtain a squeezing effect. Moreover, counter rotation allows us to keep the developing gap larger than the thickness of the ink lamina shaped around the developing roller.

To understand the phenomenon as shown in Figs. 8 and 9, let us consider the relationship between the specific peripheral velocity of the developing roller vd/vp and the thickness of ink on the paper. Figure 10 shows this relationship when the specific ink thickness around the developing roller ti/te was 1.5, which is the same condition as in Fig. 8. These results show that with counter rotation and a narrower developing gap than the ink thickness around the developing roller (δd/ti < 1), the excess liquid toner stagnated and was spread on the receiving medium to make background noise. This stagnancy increased as the peripheral velocity of the developing roller increased or the developing gap decreased. These results explain the phenomenon shown in Figs. 8 and 9 well. We also found the same characteristics for the rough roller filming system.

Under the optimal developing conditions discussed above, we could obtain high image quality. An example is shown in Fig. 11.

Figure 11. Print sample (Specific Ink thickness: 1.5, δd/ti: 2, vd/vp =–3).

Conclusion

A liquid developing unit using highly concentrated liquid toner can develop a latent image in a small developing area without any toner density control. When a slit blade is used to film the ink around the developing roller, the thickness of ink lamina can be controlled by the cross-sectional shape of the slit blade. By applying a developing bias and making the developing gap wider than the thickness of the ink lamina shaped around the developing roller, we can achieve noise-free development. In our new liquid developing unit, the developing roller acts also as the filming roller and squeezing roller. Optimal developing conditions, which are described in this paper, yield a high-quality image with a noise-free background.

References

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Biography

Shogo Matsumoto received his master's degree in Mechanical Engineering from the Science University of Tokyo in 1988 and joined the Mechanical Engineering Research Laboratory of Hitachi Ltd. He has been engaged in the development of non-impact printing systems.