 

# Contact Development Using Highly Concentrated Liquid Toner

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## Abstract

A liquid development system using a highly concentrated liquid toner has been developed. In this system, the liquid toner is applied as a thin film on the surface of the developing roller, and the roller is brought into contact with an electrostatic medium on which an electrostatic image is developed. The system doesn't require any subtle adjustments of the distance between the developing roller and the medium. Although the system uses highly concentrated liquid toner and contact development, which are usually difficult to handle and can easily cause serious fogging, a clear image can be obtained if certain parameters are optimized. These parameters are the specific peripheral velocity of the developing roller, the electric field between the developing roller and the medium, and the pressure on the contact surface. As a result of this optimization, continuous tone imaging is provided by this system.

## Introduction

Recently a liquid development process is widely investigated to achieve higher quality print images. In most conventional liquid development processes, the percentage of toner in the carrier is less than 1 wt% and the process is complex because this low concentration of toner makes it necessary to use a circulation system as well as a concentration control unit to keep the toner concentration nearly constant. To improve this disadvantage, the authors investigated a liquid developing unit using a highly concentrated liquid toner which density of the toner is over 10wt%, and reported in an earlier paper that the new developing system could eliminate the background noise by applying the optimal developing bias potential between the electrostatic medium and the developing roller, and by settling the developing gap between the medium and the roller greater than the thickness of the ink lamina shaped on the roller[3]. This new developing unit thus needs to form a thin lamina of ink on the roller as well as to regulate the gap between the roller and the electrostatic medium.

In this paper, a liquid developing system in which the roller is brought into contact with the medium during the developing process, a process we call contact development, is investigated. The investigation of the contact development is significant for two reasons. One is that enables us to make a system that does not require fine adjustment of the roller position. Another is that even if the roller is not in contact with the medium, it needs to be brought closer position to the medium when the process speed becomes faster in order to assure that the liquid toner on the roller makes contact with the medium during the development. Also, the roller can accidentally contact with the medium when the distance is too close. To achieve the contact development using highly concentrated liquid toner and at the same time to prevent background noise, the developing conditions of the contact development are investigated.

## Experimental Apparatus

The schematic diagram of the experimental apparatus is shown in Figure 1. The ink tank is filled with highly concentrated liquid toner in which the lower part of the developing roller is immersed. A lamina of the liquid toner s forms on the rotating roller and the thickness of the lamina is kept within the allowed range by the filming blade held against the roller. The backboard electrode located above the roller is grounded, and a developing bias potential Vb is applied between the roller and the electrode. The electrostatic medium on which the latent image is formed passes between the roller and the electrode at the speed *vp* while the developing roller rotates, against the direction the medium is carried, at the speed *vd*. The line pressure P on the backboard electrode ensures that the electrostatic medium is in contact with the developing roller.

The surface of the developing roller is sandblasted to a specific degree of roughness. This roughness enables the liquid toner to pass through the contact surface of the roller to the filming blade and determines the thickness of the ink lamina on the roller.

With this experimental apparatus, we examined the contact developing process: we developed the latent images on the electrostatic medium and measured their optical density.

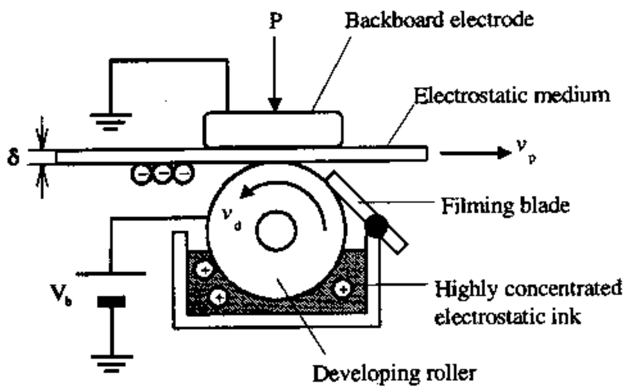


*Figure 1. Schematic diagram of apparatus.*

## Results

**(1) Thickness of the Ink Lamina**

The thickness of the ink lamina on the roller can be regulated in either of two ways: one is a "slit blade type" and the other is a "rough roller type". The former one regulates the thickness with the cross-sectional shape of the slit between the filming blade and the roller while the latter one does it with the surface roughness of the roller. It is shown in our previous paper, however, that the background noise wouldn't be eliminated if the gap was less than the thickness of the ink lamina in the case of the former type. The latter one is better for the contact development because it provides the channel for ink to flow between the roller and the electrostatic medium. Without this channel, ink would stagnate at the forehand of the contact surface and would cause background noise. Only the latter type of ink-lamina-thickness regulation is discussed in this paper. The top view of the surface of the roller is shown in Figure 2. The surface roughness is measured by the ten point height of irregularities (Rz) because it's one of the suitable parameters to reflect the effect of the cross-sectional area of the ink channel between the roller and the blade. Figure 3 shows, for various degrees of surface roughness, the relationship between the specific peripheral velocity of the roller and the thickness of the ink lamina on the roller. The surface roughness Rz is the parameter in the figure. It is obvious that the thickness of the ink lamina is not determined by the peripheral velocity of the roller but by its surface roughness of the roller, and Figure 4 shows the relationship between the surface roughness Rz of the roller and the thickness of the ink lamina on the roller.

**(2) Bias potential between the roller and the medium**

In contact development the adhesion of the toner driven by the forces from the liquid is apt to cause background noise. A bias potential is therefore applied between the developing roller and the backboard electrode so that the toner particles are forced to be driven toward the roller by the electric field generated by the potential.

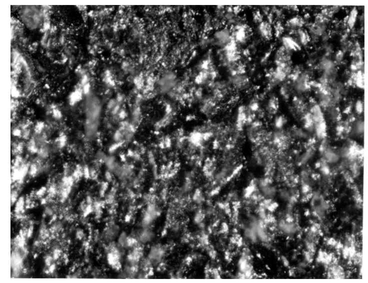

*Figure 2. Top view of the roller surface.*

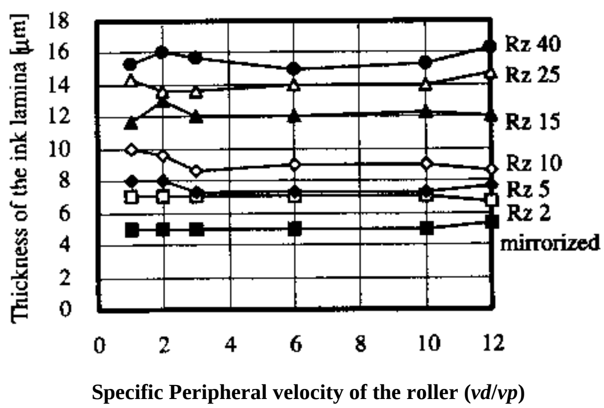


*Figure 3. The relationship between the specific peripheral velocity of the roller and the thickness of the ink lamina*

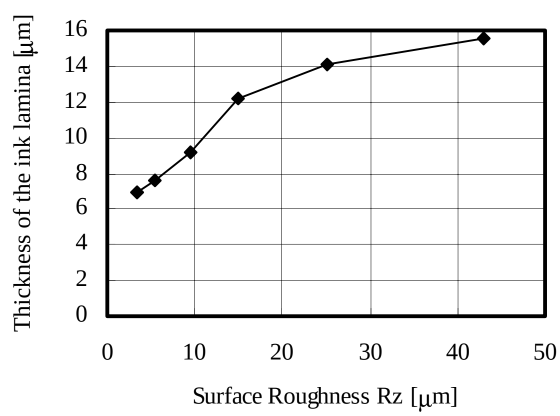


*Figure 4. The relationship between the surface roughness Rz of the roller and the thickness of the ink lamina*

Figure 5 shows - for two rollers (the type-A having smaller value of Rz than the type-B has - the relationship between the electric field strength Vb/δ corresponding to the bias potential and the optical density of both the image and the background. It is shown that the optical density of the image remains low in the case of Type-A and that the background noise is more apparent in the case of Type-B. Therefore it's necessary to regulate the surface thickness of the roller in a certain range. Type-B shows better performance.

As for the bias potential, the optical density becomes lower as the higher negative bias potential is applied. A high bias potential decreases the optical density of the image because the electric field generated by the potential drives the particles toward the roller to overcome the adhesive force. When the electric field strength is between 0 and -200 kV/m, the optical density of the background is a bit too high to cause the background noise, while the optical density of the image is lower than the necessary density, i.e. 0.8, at the electric field strength more than -300 kV/m.

The result shows that the optimal electric field strength, that provides the optical density of the image high enough while keeping that of the background low, is between -200 and -300 kV/m.

**(3) Peripheral Velocity of the Roller**

The optical densities of both the image and the background are measured for several specific peripheral velocities of the roller (vd/vp). The relationships between the specific peripheral velocity of the roller and the optical density for each roller are shown in Figure 6. Only so called "counter rotation", the case that the roller rotates in the opposite direction to the one the medium is carried, is considered because the undesirable dispersion of the toner along the stream direction occurs and decreases the clarity of image in the case of so called "co-rotation", when the roller rotates in the same direction as the medium is carried. The optical density of the image increases with increasing specific peripheral velocity and in the case of the type-A roller reaches about 0.65 when the specific peripheral velocity is -4. The optical density of the image is low when the type-A roller is used because the ink lamina on the roller is not thick enough to supply enough ink to neutralize the electrostatic potential on the medium.

In the case of the type-B roller, the optical density of the image increases from 0.60 to 0.95 as the specific peripheral velocity increases from -0.5 to -2, and it decreases to 0.79 as the specific peripheral velocity increases from -2 to -4. At the lower velocities the optical density increases to neutralize the electrostatic potential as the amount of ink supply increases. At the higher velocities, on the other hand, the optical density of the image decreases as the velocity increases. This decrease can be explained as follows: the effective thickness of the ink lamina diminishes as the stagnant point of the ink channel, where the velocity of ink flow is zero, shifts nearer to the medium as the rotation of the roller becomes faster.

For both rollers the optical density of the background is independent of the specific peripheral velocity of the roller. These results show that optical density of the image can be kept high and that of the background kept low by using the type-B roller and a specific peripheral velocity between -2 and -3.

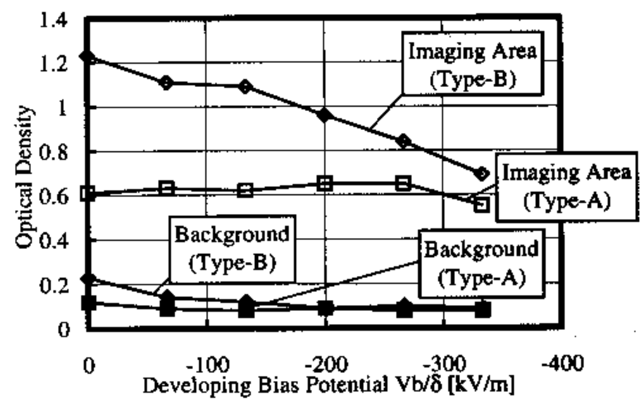


*Figure 5. The relationship between the bias potential and the optical density*

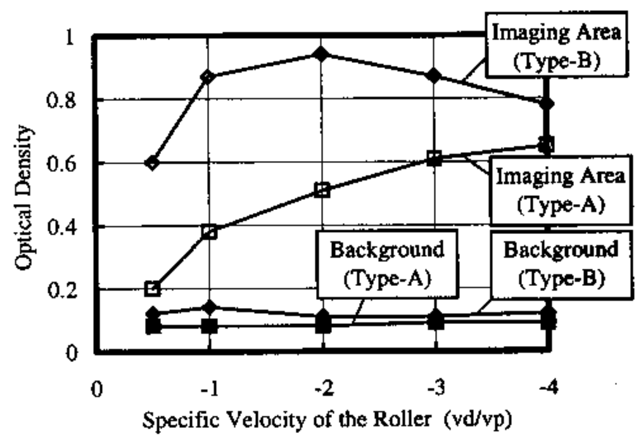


*Figure 6. The relationship between the specific peripheral velocity of the roller and the optical density*

**(4) Line Pressure**

The line pressure is applied on the backboard electrode toward the developing roller and the effect on the optical density is investigated. As is shown in Figure 7, the optical densities of both the image and the background increase a little as the pressure on the backboard electrode increases up to 12.0 N/m. It's a reflection of the background noise observed to be enhanced and enlarged as the pressure becomes higher. Therefore, lower pressure is better for realizing high optical density of the image without the background noise.

**(5) Continuously Toned Image**

Figure 8 shows the relationship between the ratio of the electrostatic potential on the electrostatic medium to the one which corresponds to 1.3 of the optical density of the image and the optical density under the optimal conditions shown in the discussions above. The optical density of the image continuously increases as the ratio increases, while the optical density of the background remains constant.

 

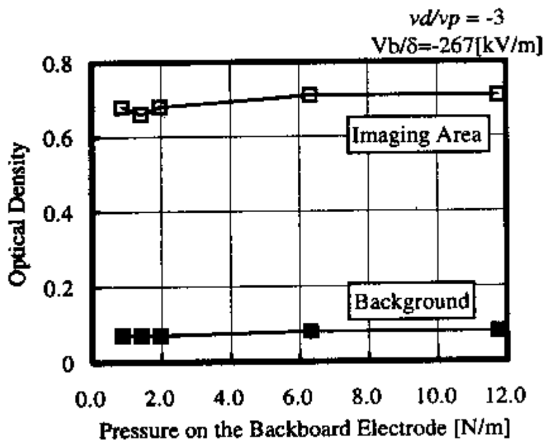


*Figure 7. The relationship between the pressure on the backboard electrode and the optical density*

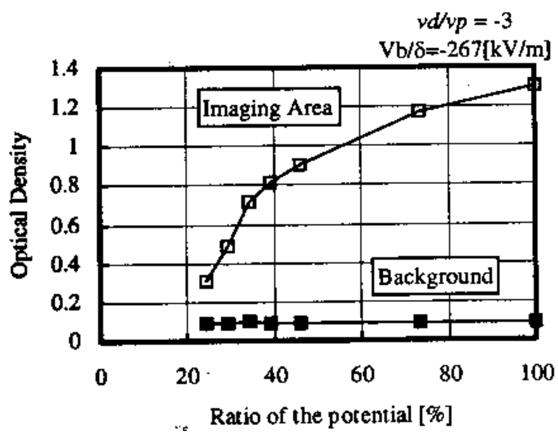


*Figure 8. The relationship between the ratio of the electrostatic potential to the maximum one and the optical density*

The result shows that continuous tone development corresponding to the potential level of the latent image is available under the optimal conditions.

## Conclusion

A liquid development system using a sandblasted developing roller on which a lamina of highly concentrated liquid toner is formed is discussed. The thickness of the lamina is shown to be regulated by the surface roughness of the roller. Even though the roller is brought into contact with the electrostatic medium, an image with a high optical density can be obtained without background noise if the specific peripheral velocity of the roller, the bias potential applied between the roller and the backboard electrode, and the pressure applied to the backboard electrode, are set appropriately.

Furthermore, the continuous tone image corresponding to the potential level of the latent image is shown to be available by the contact development under the optimal conditions.

## References

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## Biography

Akira Mori received his B.E. in Aeronautics from Kyoto University in 1994 and his M.E. in Aeronautics and Astronautics from the University of Tokyo in 1996. He joined the Mechanical Engineering Research Laboratory of Hitachi Ltd. in 1996 and currently works on non-impact printing systems.