Numerical Simulation of the Toner Jet Method for Nonimpact Printing

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Abstract

The toner jet method has been previously proposed to perform electrophotographic nonimpact printing easily. To clarify the fundamental properties of this method, the jet behavior of toner is studied through simulation on a personal computer. The mesh electrode is assumed to be inserted halfway between the development roller and the paper-back electrode. This is done to control the locus and the distribution path of toner from the magnetic development roller electrode to the electrode on the back of the paper receiver. The electric field applied between the magnetic development roller and the paper-back electrode is higher than the field between the mesh electrode and the magnetic development roller. The locus and the distribubon of toner particles developed on the paper are simulated by changing the applied voltage in each row and each column of the mesh electrode. It is assumed that the jet behavior of toner particles from the magnetic development roller to paper is controllable. In conclusion, the useful role of the mesh electrode in the image quality of the toner jet method is suggested.

1. Introduction

Several types[1-3] of printing devices, such as heat-transfer printers, dot-impact printers, ink-jet printers, and laser beam printers, have been developed as practical implementations of impact and nonimpact printing techniques. The superiority and inferiority of these devices have been determined by their reliability, image quality, processing speed, and price. To improve on these shortcomings, the toner jet method has been proposed.[4] In this method, a direct visible image is formed by toner particles attracted to the paper that is placed on the paper-back electrode. The proper electrostatic field is applied by a mesh electrode located between the magnetic development roller and the paper-back electrode. To clarify the fundamental aspect of this method, the locus of the toner particles from the magnetic development roller to the paper through the mesh electrode and the distribution of toner particles adhered to the paper were simulated with a persons computer PC-9801 VX 41. When the electrostatic field from the mesh electrode was controlled in an optimum fashion, we observed the reduction of scattering of toner particles.

We discuss the role of the mesh electrode field on image quality in the toner jet method.

2. Experiment

2.1 Processing Device Layout

As shown in Figure 1, the processing device of the toner jet method is characterized by the arrangement of the mesh electrode. Each square aperture of the mesh is surrounded with wire electrodes in the row direction (x) and column direction (y). To control the jet movement of toner, which is predominantly governed by the applied voltage between the magnetic development roller electrode and the paper-back electrode, the electrostatic field is performed by separately applying a particular potential at the wire electrodes.

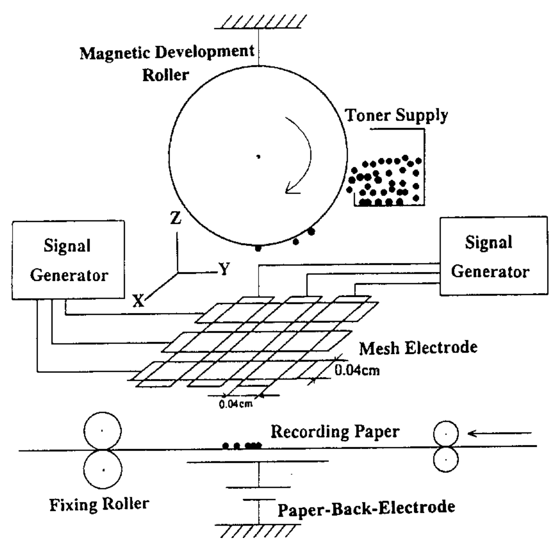

Figure 1. Illustration of processing device.

2.2 Simulation Procedure

As shown in Figure 2, the model simulating the movement of toner particles from the magnetic development roller to the mesh electrode and from the mesh electrode to paper was assumed to establish the motion equation of toner particles in the electric field.

The assumptions of the model were as follows:

1. The surface of the magnetic development roller is treated as plain, because the surface area against the aperture of the mesh electrode is very narrow.
2. The centrifugal force caused by the slow rotation of the magnetic development roller is negligible when the motion equation is established.
3. The magnetic force of the magnetic development roller does not have any effect on the electric field created by the electrodes.
4. Toner particles are spherical, and the size and electric charge of toner particles are uniform. Each toner particle has a diameter of 10 μm and each toner particle's charge is –5 fC.
5. The magnetic force of toner particles should be neglected.
6. The thickness of the mesh electrode is estimated to be zero.
7. The simulation is considered to be available for one of the apertures in the mesh electrode.
8. The distance between the magnetic development roller and the conductive element of the mesh electrode is assumed to be sufficiently large.
9. The applied potential of each mesh electrode does not change when the toner is passed through the mesh electrode.

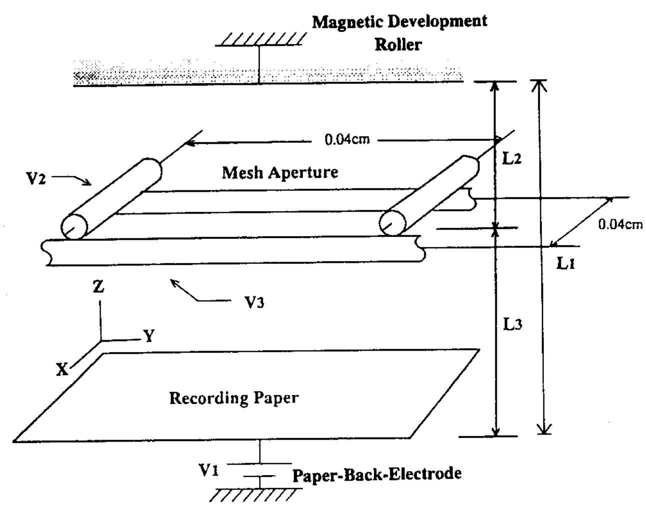

Figure 2. Model of simulation of the movement of the toner particle.

As shown in Fig. 2 in the simulation model, the distances from the magnetic development roller to the paper (the paper-back electrode) and to the aperture of the mesh electrode are represented by L_1 and L_2, respectively. Thus, the distance between the mesh electrode and the paper-back electrode is L_3. The applied voltage of the paper-back electrode surface and the mesh electrode in the row (x) and column (y) directions against the magnetic development roller are represented by V_1, V_2, and V_3. The derivation of the motion equation of the toner is made by combining the force from the electric field assumed in the above simulation model, the force by gravity, and the viscosity of the atmosphere.

In direction x,

$$m\frac{d^2x}{dt^2}+6\pi\eta a\frac{dx}{dt}=qE_x, \tag{1}$$

$$x=-\frac{mqE_x}{(6\pi\eta a)^2}\left[1-\exp\left(-\frac{6\pi\eta a}{m}t\right)\right]+\frac{qE_x}{(6\pi\eta a)}t; \tag{2}$$

In direction y,

$$m\frac{d^2y}{dt^2}+6\pi\eta a\frac{dy}{dt}=qE_y, \tag{3}$$

$$y=-\frac{mqE_y}{(6\pi\eta a)^2}\left[1-\exp\left(-\frac{6\pi\eta a}{m}t\right)\right]+\frac{qE_y}{(6\pi\eta a)}t; \tag{4}$$

in direction z (the vertical direction),

$$m\frac{d^2z}{dt^2}+6\pi\eta a\frac{dt}{dz}=qE_z+mg, \tag{5}$$

$$z=-\frac{m(mg+qE_z)}{(6\pi\eta a)^2}\left[1-\exp\left(-\frac{6\pi\eta a}{m}t\right)\right]+\frac{qE_z}{(6\pi\eta a)}t; \tag{6}$$

where

m = mass of each toner particle (grams)
η = viscosity of atmosphere (grams per second centimeters)
a = radius of toner (centimeters)
mg = force by gravity (dyne)
q = toner charge (coulomb)
qE = force by electric field (dyne)
t = fall time (seconds).

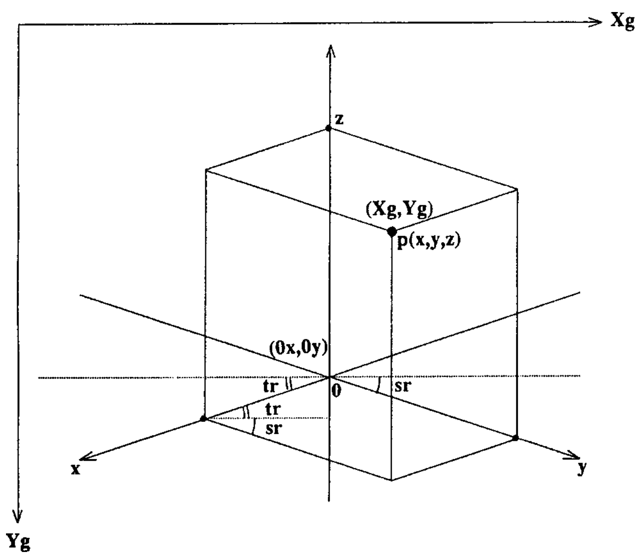

Figure 3. Three-dimensional display.

To create a 3-D image on the computer display from the 3-D data obtained by the motion equation of toner, the following transference was performed

$$Xg = Ox + r_2y\cos(sr) - r_1x\cos(tr)\ , \tag{7}$$

$$Yg = Oy + r_1x\sin(tr) - r_2y\sin(sr) - z\ , \tag{8}$$

where

r_1, r_2 = reduction rate
Ox, Oy = the origin of a 2-D orthogonal coordinate system on the computer display
sr, tr = angles of x and y directions from the horizontal line.

The transference of 3-D data to the 3-D display is illustrated in Fig. 3.

3. Results and Discussion

The locus of jet movement of toner particles from the magnetic development roller to the paper and the distribution of toner particles forming the image on the paper were simulated based on the motion equation of the toner particle, changing the assumed applied potential at the mesh electrode under the fixed conditions in gaps L_2 and L_3 and the paperback electrode potential V_1.

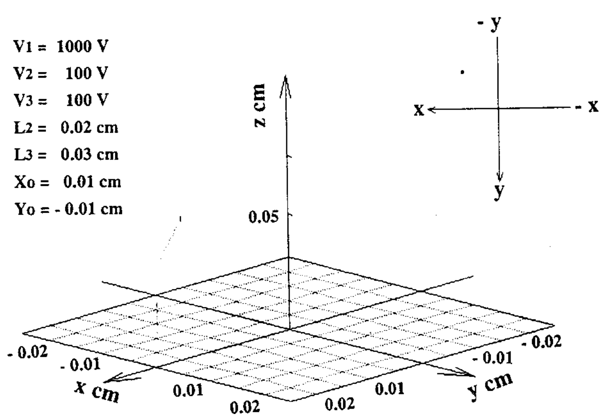

Figure 4. Motion locus of particle.

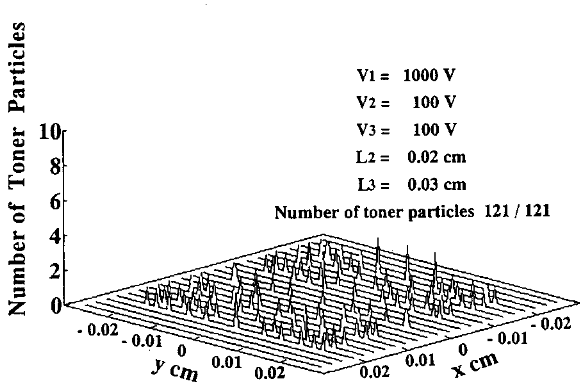

Figure 5. Distribution of toner particles.

In the first case, when V_1 is 1000 V, V_2 and V_3 are 100 V, L_2 is 0.02 cm, and L_3 *is* 0.03 cm, the 3-D display of the locus and distribution of the toner is demonstrated on the computer screen as shown in Figs. 4 and 5. Figure 5 suggests that the rather large amount of toner was jetted away from the magnetic development roller toward the mesh electrode because of the effect of its positive potential. The toner moved in a path nearby the electrode wires rather than by the central part of the aperture of the mesh electrode, and the adherence of part of the toner to the mesh electrode suggests that the toner is negatively charged. The adherence of part of the toner to the mesh electrode appears to reduce the scattering of excess toner on the paper.

In the second case, if the applied potential of one direction was highly negative, the movement of the toner was somewhat complicated, that is to say, the repulsive force to the toner was not negligible at the negatively polarized electrode. At the middle of these negative electrodes, each repulsive force induced by them was almost canceled and the effect of positive electrodes was sustained. Figure 6 presents the resulting distribution of toner particles.

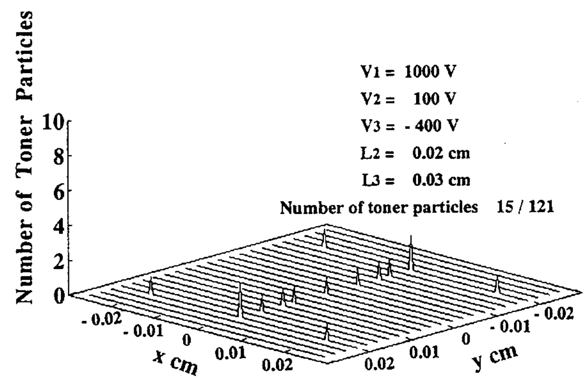

Figure 6. Distribution of toner particles

In the third case, if applied potentials V_2 and V_3 were slightly negative, the amount of toner left from the magnetic development roller might be less than that expected in the first case, because the potential gradient between the magnetic development roller and the mesh electrode was smaller. In this case, the toner easily passed through the central part of the aperture of the mesh electrode, suffering the repulsive force caused by the negative potential at the mesh electrodes, as shown in Figs. 7 and 8. The figures seem to indicate that the focusing of toner occurred on the central point of the aperture. This phenomenon should give good image resolution.

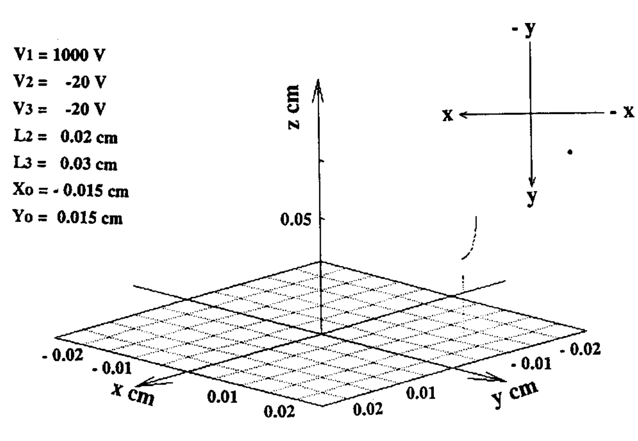

Figure 7. Motion locus of particle.

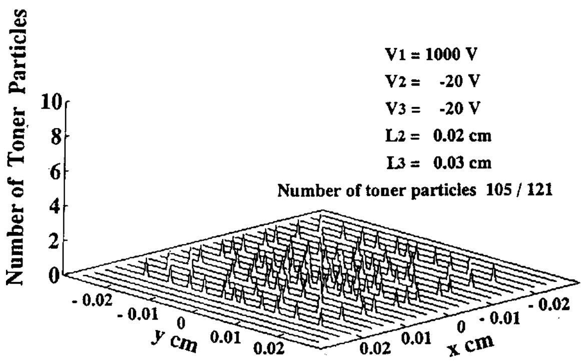

Figure 8. Distribution of toner particles.

In the fourth case, if applied potentials V_2 and V_3 were more negative, in comparison with the preceding case, we found it difficult to expect a particular amount of toner jet from the magnetic development roller. Figures 9 and 10 show the effect of the strong repulsive force on the toner by the mesh electrode.

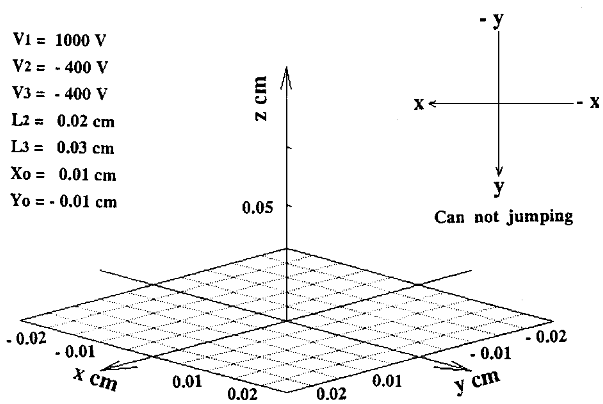

Figure 9. Motion locus of particle.

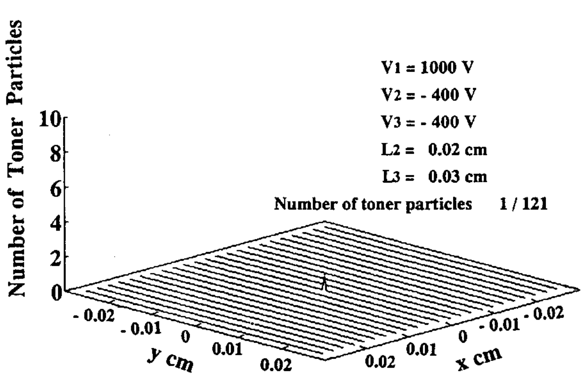

Figure 10. Distribution of toner particles.

These results suggest that the amount of toner jetted away from the magnetic development roller and the locus of moving toner are controlled by the potential gradient between the magnetic development roller and the mesh electrode or the paper-back electrode and the potential of the mesh electrode itself. To further confirm this phenomenon, an additional simulation was carried out in which the distance between the magnetic development roller and the mesh electrode was changed. Figure 11 indicates a good agreement with the above consideration.

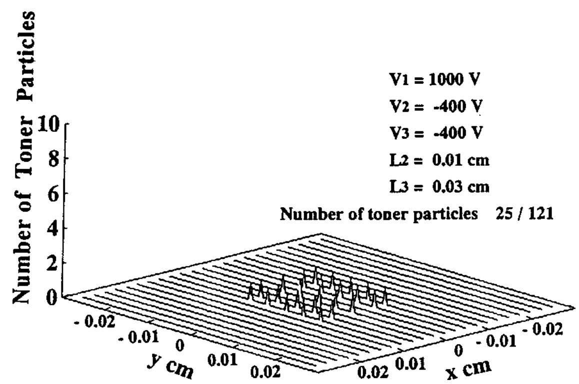

Figure 11. Distribution of toner particles.

Summary

To analyze the fundamental aspects of the toner jet method, the locus of the toner from the magnetic development roller to the paper through the mesh electrode and the distribution of toner adhered to the paper were simulated with a personal computer PC-9801 VX41. The results show that the locus and the distribution of toner were widely changed when an applied potential of the mesh electrode was controlled in the negative to positive charges. With these results, the reduction of scattering of the toner and high image resolution are expected with the toner jet method under the optimum condition.

References

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