Visualization Study of an Interaction Between Airflow and Scattering Toner

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Abstract

A scattering toner (sometimes called toner cloud) is one of the big problems in a two-component development system, especially in the color imaging system. The scattering toner phenomena are analyzed by microscopic visuali-zation technique and interactions with airflow caused by the magnetic carrier brush are clarified. The boundary area between color developer and photoconductor (nip area) are observed using a high-speed camera with a microscopic lens. A special sucking airflow is generated at the edge of developer case and the scattering toner phenomena in the nip area are restrained by this airflow. The decreasing pressure in the developer case is resulted from the movement of the magnetic carrier brush on the surface of the developer sleeve. As the result two contrary airflows exist close to each other. One is the airflow on the surface of the sleeve produced by rotating roller and the other is by the movement of the magnetic carrier brush. In addition, the stronger is the sprinkling movement of the magnetic carrier brush, the more scattering toner phenomena are observed.

Introduction

A latent image on the photoconductor is shaped by irradiation of laser beam corresponding to image density. In the two-component developing system, toners are charged frictionally with magnetic carrier, and develop latent image by transferring from magnetic carrier brush. However, abnormal electric charge toner is easy to detached and floats from magnetic carrier brush, and stains on the paper or internal wall of the copier unit.

A technique to reduce the scattering toner pollution is more and more important in the near future. Because the use of smaller sized developer (carriers and toner particles) are more difficult than that of larger size. Spaces for devices (fans, blowers and ducts) in a machine must be smaller.

So far analyses for scattering toner are done in the point of toner charge characteristics. They concluded that the main causes are resulted from forces, which are larger than a combination force between carriers, and toners are affected. For example such as a deterioration of charge characteristic in career surface, or existence of reverse-charged toner in a developer.

However in the actual developing processes, the other physical processes are considered to deal with the phenomenon. For example, they are a centrifugal force by the rotation of the photoconductor and the magnetic sleeve, airflow, a physical shock and stress by contacting a photoconductor a drum, a sleeve, a casing walls, etc. The more precise analysis of the scattering toner needs to conclude such influences.

Experimental Methods

The microscopic airflow is visualized at nip area, which is boundary between magnetic sleeve and rotating photoconductor. (Figure 1)

Using visualization method the scattering toner effect is observed to be resulted from the static pressure of the airflow and the movement of the magnetic carrier brush. The rotation speed and gap distance of the photoconductor drum and sleeve are corresponded with that of the actual machine.

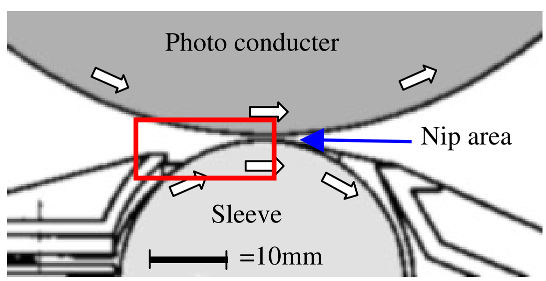

Figure 1. Visualized area in developer unit.

In visualization system a high-speed camera (KODAK model4540) and He-Ne gas laser unit are used. The camera mounts microscopic lens, and the area is illuminated by sheet laser light (Figure 2). A smoke is used as the tracer to visualize the airflow. It is the imperfect burned paraffin smoke.

The developing powder characteristics are shown in the Table 1.

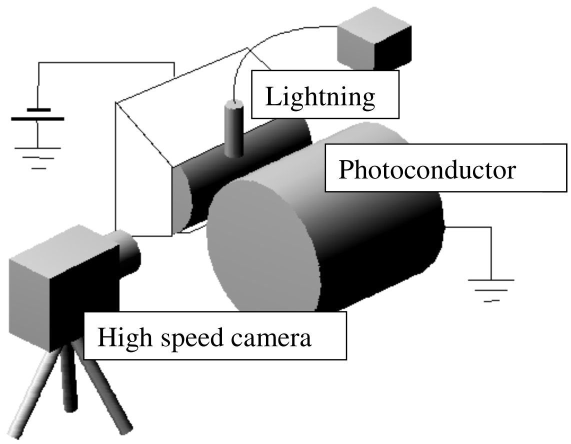

Figure 2. Visualization System.

Table 1. Toner Characteristics

Mean Carrier size (m)	90×10^{-6}
Mean Toner size (m)	9×10^{-6}
Toner Q/M (C/kg)	0.01

Results

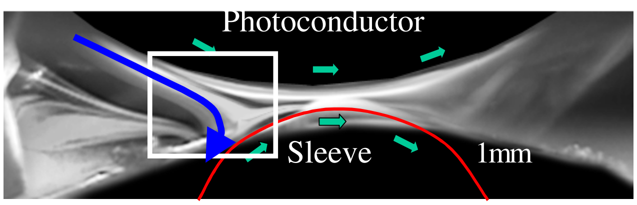

Figure 3. Visualized airflow image around the nip area.

1. Air Curtain at the Edge of Sleeve Casing

An example of visualize airflow image in nip area is shown in Figure 3. In the white rectangle area, inlet port flow is observed in front of the nip area.

Figure 4 is the enlarged image of the flow. The boundary layer formed on the sleeve, and the layer is not mixed with the outer flow. Air-curtain is observed to be sucked into the casement of the sleeve. The curtain flow has an ability, which shuts a scattering toner into the nip area.

The mechanism why such air-curtain is occurred is described as follows. Usually the “assistant magnetic poles”, which adjust the magnitude of main magnetic pole, are situated at the edge of sleeve casing wall (Figure 5). At the area the magnetic brush stands to induce air from the sleeve case. So the pressure inside the sleeve casing is decompressed. As the result, the air outside of the casing wall flows into the sleeve casing. The air fulfills the functions to shield the scattering toner.

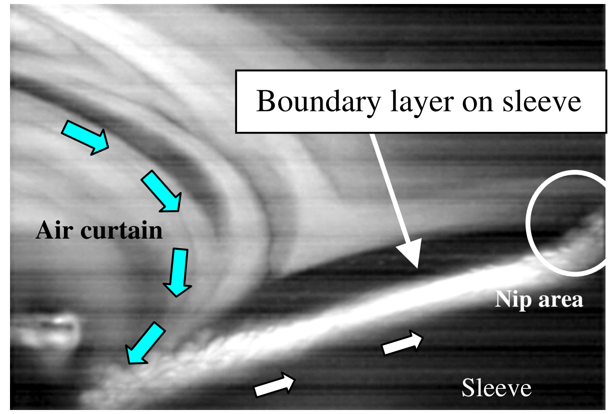

Figure 4. Visualized image by high-speed camera.

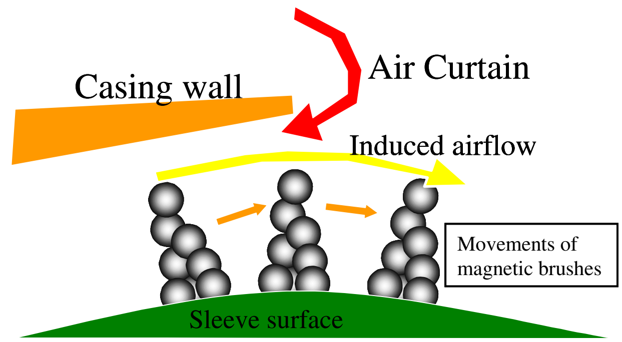

Figure 5. Mechanism of the air curtain.

As above-mentioned, the movement of magnetic brush induces the air-curtain at the edge of the casing wall. So using the DPM (Discrete Phase Model) the air curtain are represented by a numerical simulation. The model is the calculation method of the discrete phase trajectory using a Lagrange formulation that includes the discrete phase inertia. It can represent the brush movement effects to airflow. At first the change of particle momentum is calculated, and the value is transferred to the continuous phase (airflow). Until the values are converged the calculation is iterated.

Figure 6 shows the results of the airflow simulation at the white rectangle area of Figure 3. The upper image is the result not using the DPM model, the former one is using. The simulation conditions are shown in Table 2.

Table 2. The Simulation Conditions

Diameter of particle (carrier)	60×10-6(m)
Average velocity of carriers	0.5(m/s)
A ratio of particles to area size	10%
Rotation speed of photoconductor	0.1(m/s)
Rotation speed of sleeve	0.25(m/s)
Pressure-loss of the area occupied magnetic brush	10Pa/(m/s) (linear)

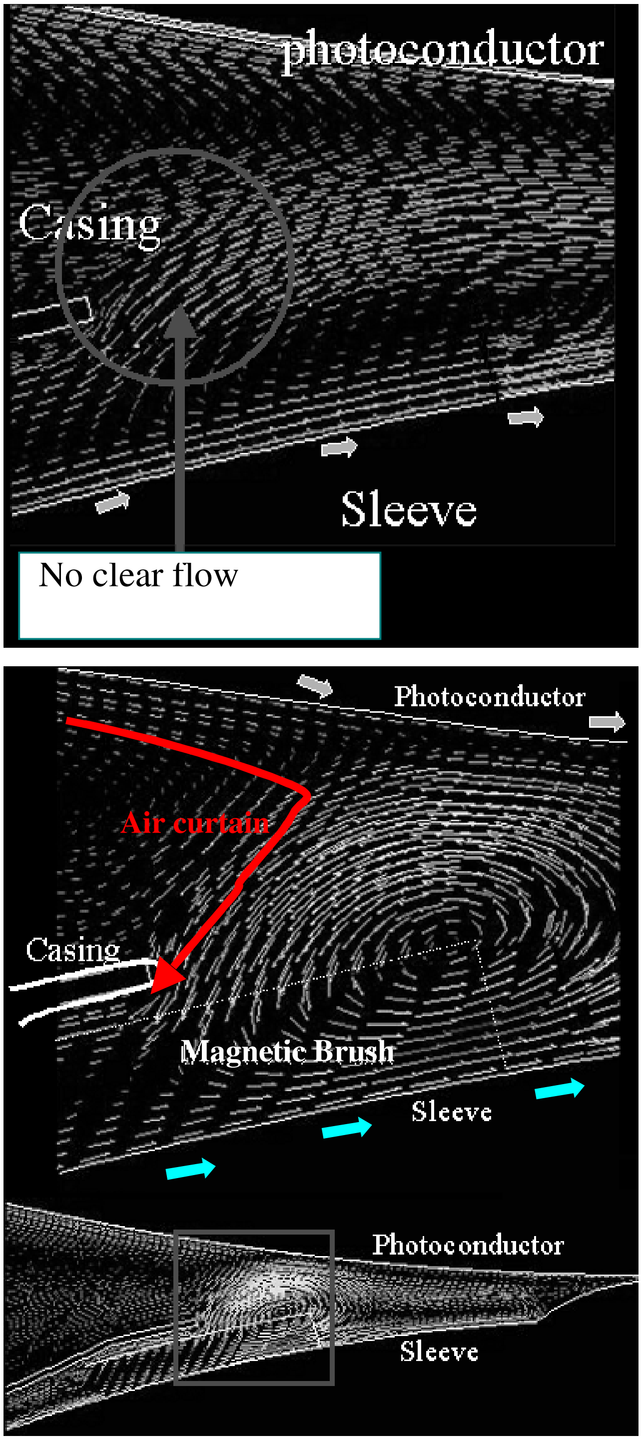

Figure 6. Airflow at the edge of the sleeve casing. The result not using DPM (Upper one). The result using DPM (Lower one)

Usual airflow model cannot simulate the air curtain induced by the movement of the magnetic brush. So if the air designer wants to control the air curtain effect, he should consider the characteristics of the magnetic pole. For example the situation of assistant magnetic pole.

2. The Cause of the Scattering Toner

Many studies have concluded that the most affective factor of the scattering toner is the characteristics of developing powder. But in the two-component developing system, it is confirmed that the movement of magnetic carrier brush is closely related with the phenomenon.

Figure 7 shows successive images at every 1/13500s. The magnetic carrier brush shows a very complicate movement when it passes the magnetic pole. This tendency becomes more remarkable according to high-speed printing. In details, the magnetic brush keeps rising accelerated to a certain angle (from 45 to 90 degrees) and then it stops suddenly. At this moment, toners attached to the brush are shaken off like a slingshot. After that the brush keeps shaking and when it passes the magnetic pole, it falls down. By this shock, toners are scattered away again. Much more toners are released from the brush by the shock than the centrifugal force by the rolling of sleeve.

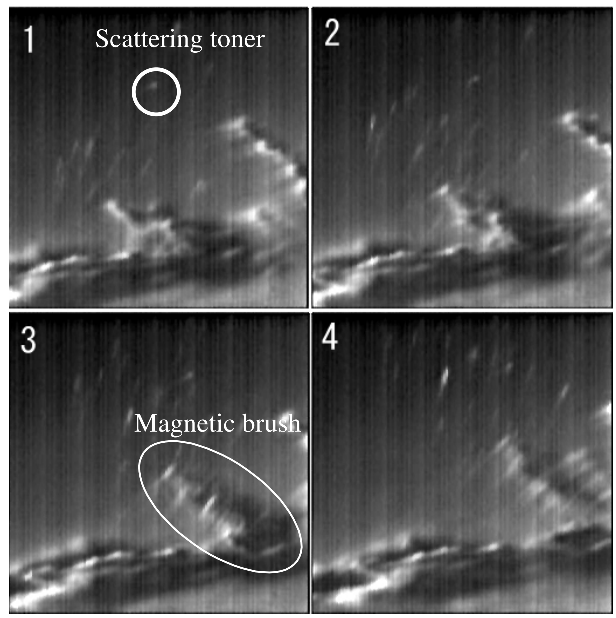

Figure 7. Scattering toners images taken by high-speed camera.

Figure 8 shows that the velocity of brush tips from standing to falling. There are two phases in which velocity of the tip is widely changed. They are corresponded with the phases which toners are released from the brush. The facts suggest that the change of the brush momentum is the cause to occur the scattering toner.

Conclusions

i) The inlet airflow to sleeve casement is occurred in front of the nip area. The movement of the magnetic brush induces the flow. Probably the flow shuts scattering toner in the nip area, and reduces the scattering toner effect.

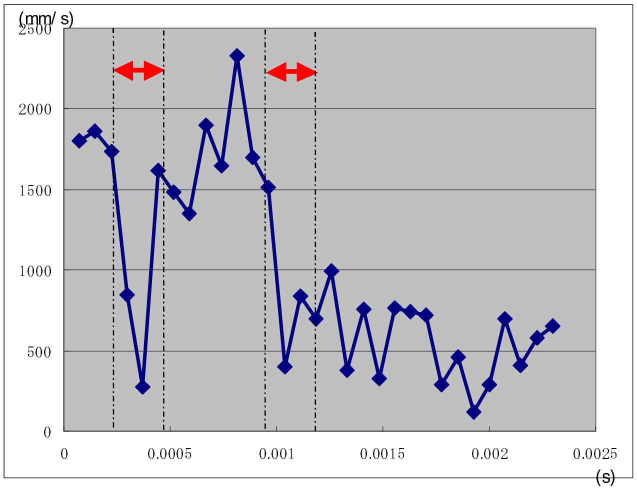

Figure 8. The velocity of the brush tip point.

ii) Scattering toner is caused due to the movement of magnetic carrier brush. Toners attached to the brush are shaken off like a slingshot. Consequently, scattering toner is occurred when brush passes the magnetic pole.

References

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2. K. Iwai and M. Takeuchi, *Japan Hard Copy*, 133 (2000).

Biography

Keisuke Uchida received his Master degree in Mineralogy from the University of Tokyo in 1993. Since 1993 he has worked in the Research and Development Center at Ricoh Co., Ltd. In Yokohama,. His work has focused research in fluid mechanics by visualization, and numerical simulation of airflow. He is a member of the Visualization Society of Japan.