Analysis of Development Uniformity in Two-Component Development System

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Abstract

The method of evaluating development uniformity in two-component development system is proposed. Conventionally, it was known that the arrangement of the magnetic brush has influence on image quality. But there are few experimental approaches to quantification of these factors because of the difficulty of the direct observation at development area. Therefore, we pay our attention to the toner pattern generated on a photoconductor. In this method, a photoconductor, on which a solid pattern is developed previously, is prepared, and next, the sleeve and the photoconductor are settled with an interval of development gap. Then, voltage is applied to remove the toner from the photoconductor. As a result, a toner removed pattern can be obtained on the photoconductor. By analyzing this pattern, carrier contact ratio during the developing time is calculated, and some indexes of development uniformity are proposed. It is possible to evaluate the effects of parameters related to the arrangement of magnetic brush, and parameters related to the number of contact times. The relationship between the development uniformity and graininess is measured and it is shown that the proposed method is effective to estimate the graininess.

Introduction

Usually, image quality is measured on paper after fusing. But it is desirable to measure just after development to clarify the effect of development conditions. Furthermore, it is the best that the conditions of toner supply can be measured, because it is considered to be the most effective factor on image quality.

Some trials are performed to observe the behavior of the magnetic brush formed on sleeve. For example, magnetic brush is observed from the side direction (the sleeve axis direction) statically [1] or dynamically. [2] On the other hand, an observation of magnetic brush from vertical direction to the photoconductor is few because it requires some devices to observe the nip area. In our previous work, we investigated the arrangement of the magnetic brush by observing the nip area from inside of the photoconductor using a glass drum. In this method, it was difficult to distinguish the magnetic brush near the photoconductor surface. It causes the inaccurate estimation of graininess, especially in case of DC bias development, because the carrier apart from the photoconductor surface does not contribute to development so much.

Therefore, we propose a new method to evaluate the development uniformity, keeping two points in mind. First, the index of development uniformity will explain the graininess well, and secondly, the evaluation system consists of simple arrangement.

Observation of Development Uniformity

A uniform development can be obtained by uniform toner supply condition. To realize uniform toner supply condition, magnetic brush that transports toner to nip area must have a uniform arrangement. In the proposed method, what we observe is not the magnetic brush, but the toner pattern on the photoconductor, that represents the brush contact conditions. Figure 1 shows the schematic of evaluation system of development uniformity.

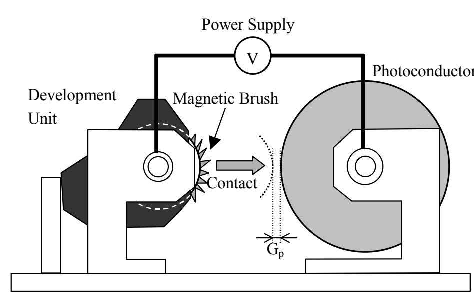


Figure 1. Evaluation system of development uniformity

The evaluation system includes development unit, photoconductor, and DC power supply. Development gap G_p between the sleeve and the photoconductor is adjustable. The sleeve and the photoconductor can rotate independently by each drive motors.

At first, the photoconductor, on which a solid pattern is developed by the same conditions as the actual machine, is prepared. The sleeve and the photoconductor are settled by the gap G_p without driving the motors. Next, the voltage opposite polarity to the usual development is applied.

Then toner near the magnetic brush will be removed from the surface of the photoconductor. As a result, toner removed pattern is generated. Development uniformity is analyzed by observing this pattern with a digital microscope.

The effects of ρ (mass of developer on sleeve) and G_p (development gap) on graininess are known from before.[2] As an example, photographs of toner removed pattern in case of changing the G_p and ρ are shown in Figure 2. In these photographs, developing direction is up to down.

Figure (a) is a result in case of ρ = 59mg/cm^2, G_p = 0.50mm, and (b) is that of a large ρ condition (ρ = 82mg/cm^2), (c) is that of a small G_p condition (G_p = 0.25mm).

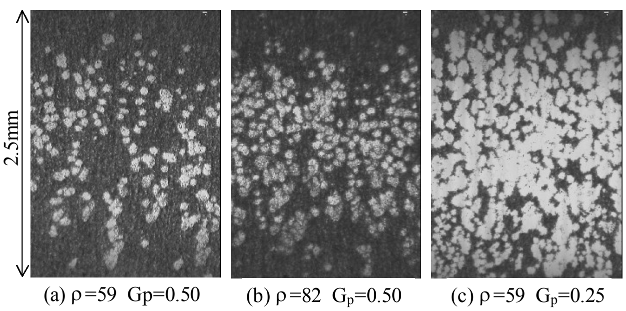


Figure 2. Photographs of toner removed area (in case ρ and G_p changes)

In comparison of (a) and (b), total size of toner removed pattern is larger when ρ is large, and it comes from the number of magnetic brush contacted to the photoconductor surface. Furthermore, toner remained area and toner removed area exist very unevenly in pattern (a). This unevenness degrades the development uniformity.

In comparison of (a) and (c), when G_p is small, magnetic brushes are divided into short and dense brushes according to the brushes will go into the nip area, so the total size of toner removed area becomes large and looks very uniform.

Evaluation of Dynamic Development Uniformity

From these qualitative results, we consider that it is available to estimate the graininess by analyzing the toner removed pattern that represents the magnetic brush contact condition to the photoconductor. But the fact that the graininess is improved on condition of high velocity ratio won't be explained by simply comparison of the static photographs.

To make an index of development uniformity considering velocity ratio k, a total contact number of magnetic brushes during the developing time is evaluated.

Let us consider how many brushes contact to the point A during the developing time. Figure 3 shows a schematic of development area.

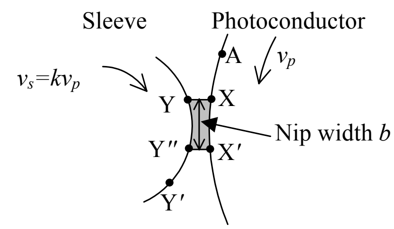


Figure 3. Schematic of development area

Developing time, which is the time while the point A passes the nip area X-X′, is shown as follows:

$$t_d = b / v_p \tag{1}$$

where b is the nip width and v_p is the sleeve velocity. Sleeve rotates the distance between Y-Y′ within t_d as equation (2).

$$v_s \cdot t_d = k \cdot b \tag{2}$$

where k is the velocity ratio of the sleeve velocity v_s to the photoconductor velocity v_p. On the other hand, the distance that the magnetic brush contacts to the point A during the developing time is Y′-Y″, and it can be described as,

$$d = kb - b = b(k-1). \tag{3}$$

So, the development uniformity is determined from the uniformity of toner removed pattern of width d.

Next, the method to quantify the development uniformity is explained. Toner removed pattern is separated into toner removed area and toner remained area. A function g(x, y) is defined at every pixel and set the value 0 or 1, where x is the position on the sleeve axis direction and y is that on the developing direction (up to down direction in the photograph). '1' signifies toner removed, and '0' signifies toner remained.

Then, a probability function P(x) at position x is defined as equation (4).

$$\mathrm{P}(x) = \frac{1}{d}\int_{-\frac{d}{2}}^{\frac{d}{2}} \mathrm{g}(x, y)dy \tag{4}$$

where the origin of y axis is the center of the development nip. P(x)=1 means that magnetic brush contacts always during developing time and P(x)=0 means that magnetic brush never contacts during the developing time. Small variety of P(x) for any x indicates a uniform development.

To quantify the uniformity of this function P(x), a standard deviation $\sigma_{P(x)}$ is calculated as an index of the development uniformity.

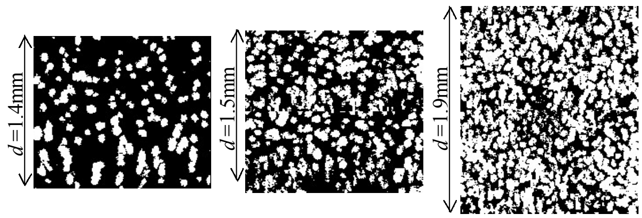
Relationship between ρ and $\sigma_{P(x)}$

Development uniformity is evaluated by an experiment when ρ changes. The experimental conditions are shown in

Table 1. For every condition of ρ, nip width *b* and potential V_1 necessary to develop 0.5mg/cm^2 of toner are measured. Figure 4 shows the photographs of toner removed pattern.

Table 1. Experimental Conditions

Carrier diameter [μm]	55
Toner diameter [μm]	6.8
Velocity ratio *k*	1.54
Development gap G_p [mm]	0.4
Mass of developer on sleeve ρ [mg/cm^2]	41, 57, 82



ρ=41 *ρ=57* *ρ=82*

Figure 4. Binarized photographs of toner removed area considering the width d (ρ=41, 57, 82mg/cm^2)

Toner removed area becomes large when ρ increases. Next, the probability function P(*x*) that shows the carrier contact condition is calculated and shown in Figure 5.

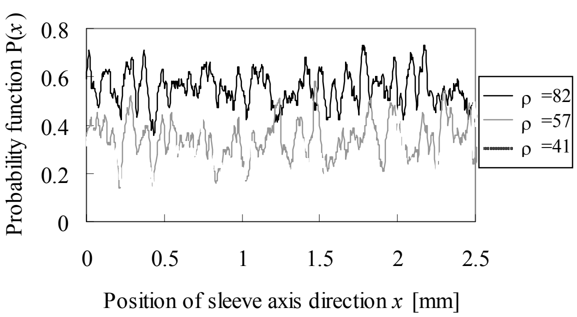


Figure 5. Unevenness of carrier contact probability during developing time

In case of large amount of developer on sleeve (ρ = 82mg/cm^2), the value of probability function P(*x*) is stable and the average probability is large comparison with the case of poor amount of developer (ρ = 41mg/cm^2). To quantify the uniformity of P(*x*), standard deviation $\sigma_{P(x)}$ is calculated and shown in Figure 6.

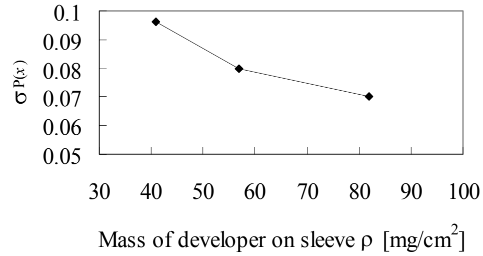


Figure 6. Relationship between ρ and $\sigma_{P(x)}$

It is shown that $\sigma_{P(x)}$ has a high correlation with the mass of developer on sleeve ρ.

Relationship between *k* and $\sigma_{P(x)}$

Next, ρ is fixed to 57mg/cm^2, and *k* is varied to 1.54, 1.89, 2.37. Figure 7 shows the relationship between velocity ratio *k* and $\sigma_{P(x)}$.

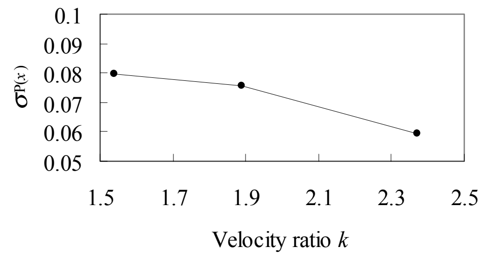


Figure 7. Relationship between k and $\sigma_{P(x)}$

Index of development uniformity $\sigma_{P(x)}$ decreases and shows a good uniformity when the velocity ratio k increases.

These examples show that the proposed index of development uniformity is valid to explain the effect of development parameters.

Development Uniformity Considering Spatial Frequency

Next, figure 8 shows the relationship between $\sigma_{P(x)}$ and graininess of the image.[4] The graininess is measured with a sample outputted from the RICOH digital copier.

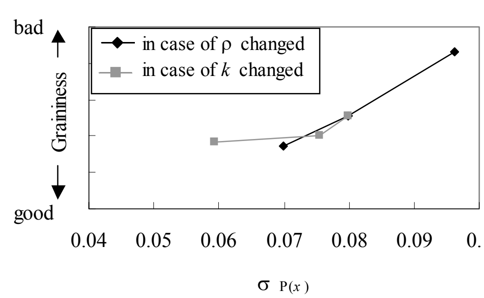


Figure 8. Relationship between $\sigma_{P(x)}$ and graininess

Although a tendency can be read from this result, there is a portion which does not suit in part. That is because the graininess includes the spatial frequency information showing human vision characteristic from its definition. Then, the same method is applied to evaluate the development uniformity. We analyze the function P(x) with FFT and use a visual transfer function (VTF) to consider the human vision characteristic. Finally, a development uniformity index U_d can be calculated as follows:

$$U_d = \int \boldsymbol{P}(f) \cdot \mathrm{VTF}(f) df \quad (5)$$

where $\boldsymbol{P}(f)$ is a FFT of P(x). Small U_d means a uniform development.

Figure 9 shows the relationship between U_d and graininess. The graininess is good when the index of development uniformity U_d is small.

And more, plots when ρ is changed and k is changed are on the same curve. This indicates that the proposed index of development uniformity U_d is useful to evaluate the effects of various parameters of development process.

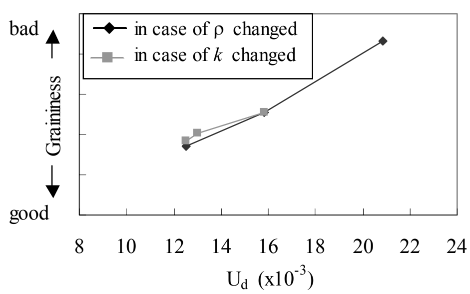


Figure 9. Relationship between Ud and graininess

Conclusion

A new method to evaluate the effect of development parameters on image quality is proposed. In this method, development uniformity is observed as uniformity of toner removed pattern on the photoconductor.

Indexes that indicate the development uniformity from several viewpoints, are also proposed. The relationship between the index values and graininess is shown by the experimental results, and it shows the effectiveness of this method.

References

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Biography

Ichiro Kadota received his B.E and M.E degrees in mechanical engineering in 1998 and 2000 from Keio University, respectively. He joined Ricoh in 2000 as a member of imaging technology division, and has been working in the field of two-component development system of electrophotography.