Properties of Toner Layer in Single Component Developing Process

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Abstract

In a non-magnetic single component developing system, properties of a toner layer formed on a developing roller influences significantly the developing performance and the output image qualities. The properties of the toner layer can be evaluated by measuring the supplied toner mass, m/a and the toner charge, q/m. A development unit consisting of a developing roller, a toner supply roller and a regulating blade connected with a bias voltage supply was used in this study. The properties of the toner layer formed on the developing roller depend on the bias voltages. Changes in the bias voltages connected to the toner supply roller and the regulating blade cause changes in the supplied toner mass and the toner charge, respectively.

Development characteristics were measured by the separation of the toner layer by an electric field applied between a metal plate and the developing roller. Results of the development characteristics were compared with theoretical values calculated by using development equations, and the charge distribution in the toner layer thickness direction was studied. The charge distribution within the toner layer was found to be not uniform, and the toners at the center region of the toner layer in the thickness direction were charged at a lower charge level than those at other regions. It was also confirmed that the charge distribution within the toner layer except for the developing roller side changed associated with changes in the bias voltage connected to the regulating blade.

Introduction

Non-magnetic single component developing systems have widely been used in practical electrophotographic machines due to their compactness and low cost, which have also been studied as a developing method for electrophotographic color printers. In a conventional non-magnetic single component developing system, the toner charge and the toner supply have been controlled by the optimization of tribocharging and mechanical design of the developing system.[1] However, the output image qualities by the conventional system are often insufficient of the stability. This is due to a change in properties of the toner layer formed on a developing roller. In order to solve this problem, experimental measurements of the properties of the toner layer, especially a charge distribution within the toner layer, are required.

The toner charge in a single component developing system is usually measured by a faraday cage equipment of suction or blow-off type. Although an average of toner charge can be measured by this equipment, information about the charge distribution within the toner layer is not available. Recently, a development unit consisting of a developing roller, a toner supply roller and a regulating blade connected with a bias voltage supply was proposed and has been studied.[2~6]

Our purpose in this study is to grasp the change of properties of toner layer formed on the developing roller in the development unit. First, a relationship between the changes in bias voltages connected to the toner supply roller and the regulating blade and the change in properties of toner layer ware evaluated. Next, development characteristics ware measured by developing the toner to a metal plate with various bias voltages. Finally, the experimental development characteristics were compared with theoretical values calculated by using development equations, and the charge distribution in the toner layer thickness direction was discussed.

Experimental

Developing Unit

Figure 1 shows the scheme of the development unit used in this study. The developing roller is made of a metal cylinder whose surface are treated by sandblast method. The toner supply roller is made of rayon fibers whose electrical resistivity is controlled to be $10^7 \Omega$-cm. The regulating blade is made of silicone rubber whose resistivity is controlled to be 10^6 Ω-cm with carbon black. All of them are connected with each bias voltage supply. Here, the bias voltages for the developing roller, the toner supply roller and the regulating blade are expressed as V_D, V_F and V_B, respectively. The bias voltages applied to the developing roller, the toner supply roller, the regulating blade are -600V, from -500 to -800V and from -300V to -900V, respectively.

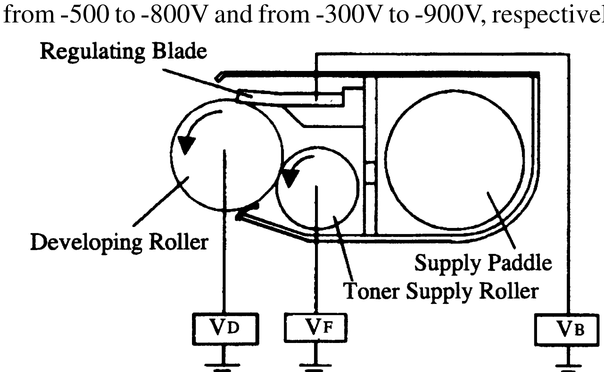

Figure 1. Scheme of the experimental unit.

The developing roller and the toner supply roller rotate at a velocity of 90 mm/s in the directions indicated in Figure 1. The tope of the fibers of the toner supply roller contacts the developing roller, and performs supplying toner to the developing roller and removing toner remained on the developing roller after development. The regulating blade are abutted on the developing roller at its abdominal portion including its edge.

An insulating negative charge type toner with an average diameter of 7 µm made of polyester was used as the sample toner.

Measurements

The toner layers on the developing roller were formed at various combinations of V_F and V_B.

The average toner charge q/m of the toner layer formed on the developing roller can be given by the following equation.

$$\frac{q}{m} = \frac{2\varepsilon_0 \varepsilon_t V_t}{\rho P t^2} \tag{1}$$

where ε_0 , ε_t , V_t , ρ, P and t are permittivity of vacuum, relative dielectric constant of the toner, potential of the toner layer, density of the toner, volume fraction occupied by the toner and toner layer thickness, respectively. The toner layer thickness is given by the following equation with the toner mass per unit area, m/a.

$$t = (m/a)/(\rho P) \tag{2}$$

The development characteristics were measured by developing a metal plate connected to a bias voltage supply by contact development method. The metal plate is made of stainless steel, whose thickness is 20 µm. The plate was supported onto a polyurethane foam plate and pressed against the developing roller at the pressure of 35g/cm. The bias voltage applied to the metal plate was from -400V to -800V. Here, the bias voltage for the metal plate is expressed by V_P.

The development characteristics were evaluated by the toner mass transferred to the metal plate following or against the difference between V_D and V_P. For convenience, V_{DF}, V_{DB} and V_{PD} are used as the expression of potential difference between V_D and bias voltages applied to other parts, i.e., $V_{DF} = V_D - V_F$, $V_{DB} = V_D - V_B$ and $V_{PD} = V_P - V_D$.

All the measurements were made under the environmental condition of 18~20°C and 47~50% RH.

Results and Discussion

Average q/m and m/a

Figures 2 and 3 show the toner mass, m/a and the potential, V_t of the toner layer formed on the developing roller for various bias conditions, respectively. Figure 4 shows the average toner charge, q/m calculated by the eqs. (1) and (2). The toner mass, m/a increased with an increase in V_{DF}, and was minimum at $V_{DB} = 0$ for a certain value of V_{DF}. Since the toner layer formation on the developing roller was not stable because of its small toner mass and its large potential deference, V_{DB}, m/a could not be measured at V_{DB} = -300V and 300V for V_{DF} = -100V. The potential of the toner layer increased with an increase in V_{DB}, especially for $V_{DB} > 0$, regardless of V_{DF}, and increased with an increase in V_{DF}. The average toner charge q/m decreased with an increase of V_{DF} and with a decrease in V_{DB}.

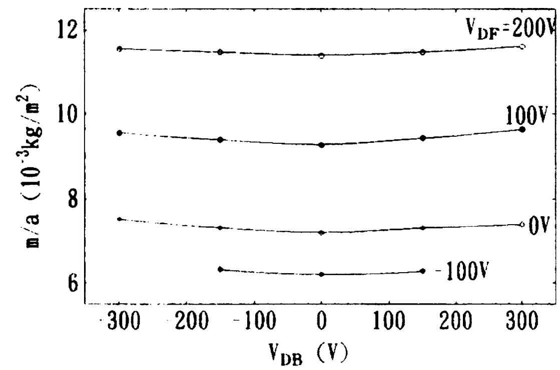

Figure 2. The toner mass per unit area of the toner layer at various bias conditions.

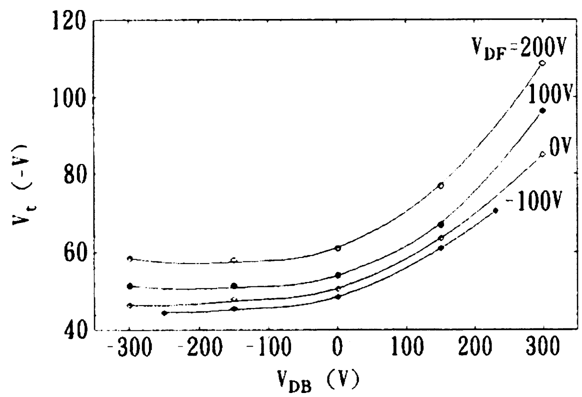

Figure 3. The potential of the toner layer at various bias conditions.

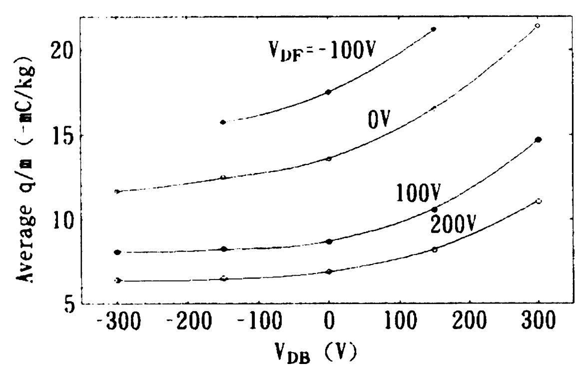

Figure 4. Average q/m of the toner layer at various bias conditions.

In order to clarify the reason of the changes of m/a associated with the change in V_{DB}, the pressure of the regulating blade against the developing roller was measured by a pressure sensor. The result is given in Figure 5. Although the measured values were different somewhat from the blade pressure during the practical operation because of the sensor thickness of 0.2 mm, the blade pressure decreased with an increase in the difference between V_D and V_B. This result suggests that the change in m/a with V_{DB} is attributable to the change in the blade pressure against the developing roller with V_{DB}.

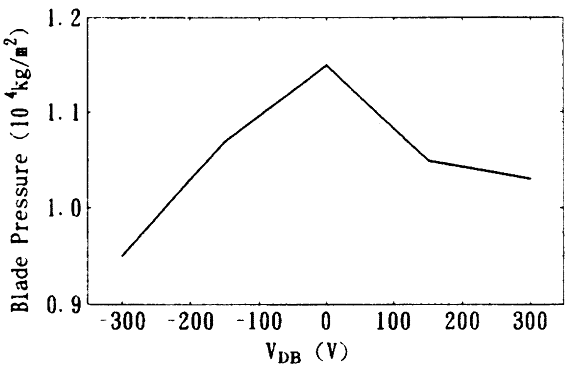

Figure 5. Relationship between the blade pressure and V_{DB}.

The change in the average toner charge q/m is considered to be caused by a process described below: The decrease in the average toner charge q/m with an increase in V_{DF} was occurred by the fact that the toner charge could not be saturated because the toner mass increased with an increase in V_{DF}. As to the change in the average toner charge q/m with the change in V_{DB} for a certain V_{DF}, the q/m decreased due to the increase in toner mass for $V_{DB} < 0$, while the amount of toner charge increased largely due to the charge injection from the regulating blade connected to the bias voltage supply for $V_{DB} > 0$.

From above discussion, it was confirmed that the increase in V_{DF} caused the increase in the toner mass, and the increase of V_{DB} caused the increase in the toner charge for $V_{DB} > 0$.

Development Characteristics

The development characteristics at V_{DF} = 0V and V_{DF} = 200V are shown in Figures 6 and 7, respectively. The development characteristics calculated by the following equation are also given in both figures.[7]

$$m_C = \frac{m_0}{2} - \frac{\varepsilon_t (V_P - V_D)}{tq} \qquad (2)$$

where m_c, m_0 and q are developed toner mass per unit area, toner mass per unit area and average toner charge of the toner layer formed on the developing roller. This equation is called as development equation, by which the development characteristics can be calculated under the condition of the uniform charge distribution within the toner layer.

The experimental characteristics curves approached the calculated ones as the V_{DB} increased for each V_{DF}. This result indicates that the toner charge within the toner layer approached uniform distribution as the V_{DB} increased.

The developed toner mass at V_{PD} = 0 decreased with an increase in V_{DB}. The developed toner mass at V_{PD} = 0 correspond to the toner mass when all the amount of charge of the toner layer were divided into halves. These results indicates that there are lower charge toner particles at the surface of the toner layer when V_{DB} is small.

The experimental characteristics curves indicated that the toner was developed even under the condition of $m_c = 0$ calculated from Equation (3). This phenomenon may be caused by the fact that the toner particles at the surface of the toner layer are charged by contacting with the metal plate. The developed toner mass at V_{DB} = -300V was larger than those at other V_{DB}. These results indicated that the toner charge at the surface of the toner layer at V_{DB} = -300V was unstable and influenced seriously by the contact with the metal plate. In addition, the experimental characteristics curves indicated also that some toner particles remained on the developing roller under the condition of $m_c = m_0$ calculated from Equation (3). This result suggests that the toner particles on the roller surface adhere to the developing roller with strong forces. This strong adhesion forces are considered to increase significantly with a decrease in the distance like van der Waals force.

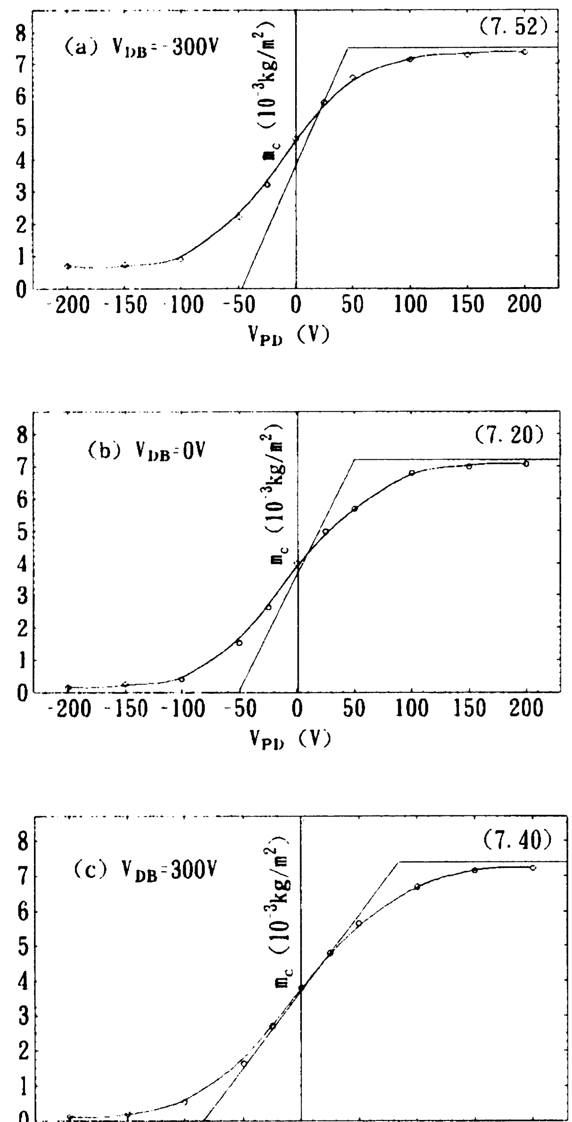

Figure 6. Development characteristics at V_{DF} = 0V.

Charge Distribution within Toner Layer

From the development characteristics, it can be considered that the contact between the toner layer and the metal plate does not influence the charging behavior of the toner layer so much. Charge distributions of the toner layer in thickness direction were studied by comparing the experimental characteristics curves with the calculated ones. However, the experimental data near both the surface side and the roller side within the toner layer were excepted for further discussion because of a large discrepancy between the experimental and theoretical results.

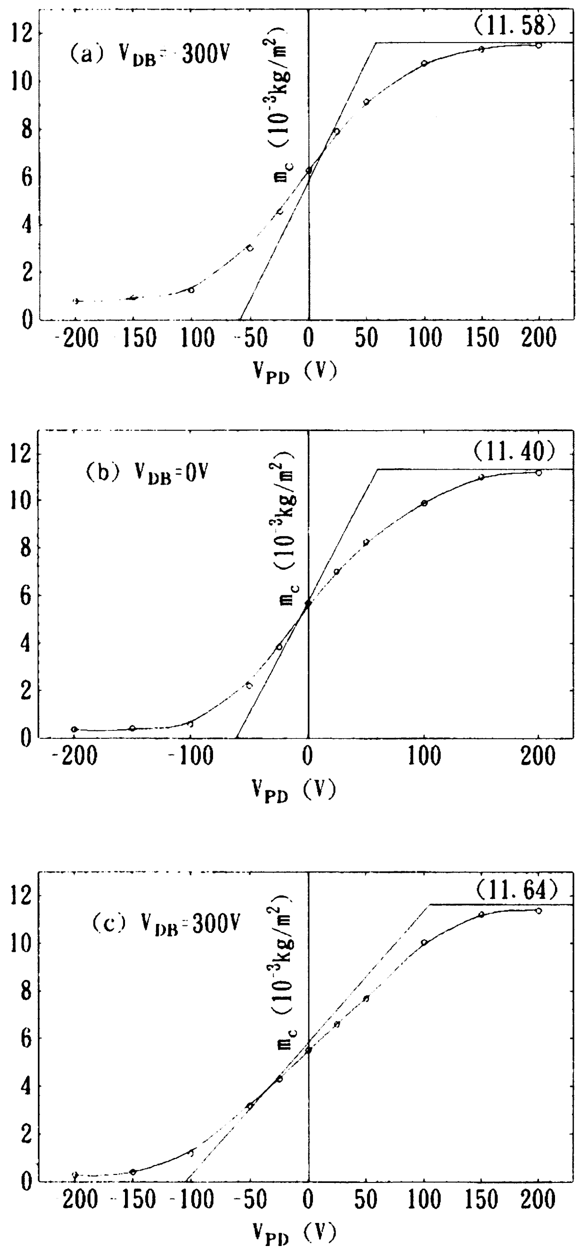

Figure 7. Development characteristics at V_{DF} = 200V.

The results are shown in Figures 8 and 9. These results revealed that the charge distributed in the toner layer as the toner particles at the center region charged more weakly than those at the surface and bottom layers.

The results were also indicated that the charge distribution shifted in higher direction with an increase in V_{DB}, while the amount of toner charge on the developing roller surface did not change with V_{DB}. It should be noted that the toner layer was charged uniformly except for the bottom and surface layers at V_{DF} = 200V and V_{DB} = 300V. The following results were obtained.

(1) The toner particles in the toner layer got large charge by the developing roller and the regulating blade.
(2) The toner particles on the developing roller surface were not influenced by V_{DB}.
(3) The change in V_{DB} caused the change in the charge distribution within the toner layer toner except for the region near to the developing roller.
(4) The change in the average toner charge was attributable to the change in the charge distributions except for the region near to the developing roller.
(5) The charge distributions at V_{DB} = 300V shifted largely in higher direction from that at V_{DB} = 0V, since the toner layer was charged strongly by the charge injection from the regulating blade.
(6) It was suggested that the toner layer could be charged uniformly by an optimized combination of each bias voltage.

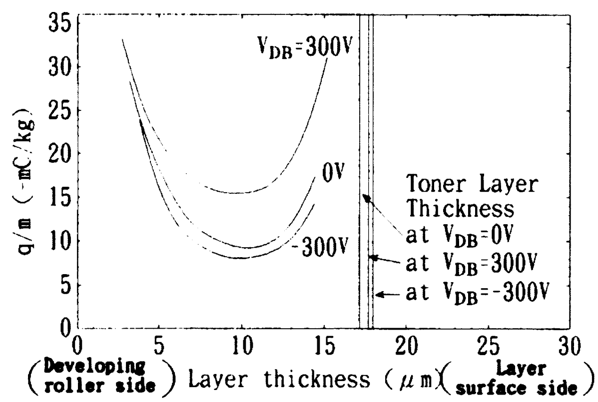

Figure 8. Charge distributions in the toner layer in thickness direction at V_{DF} = 0V.

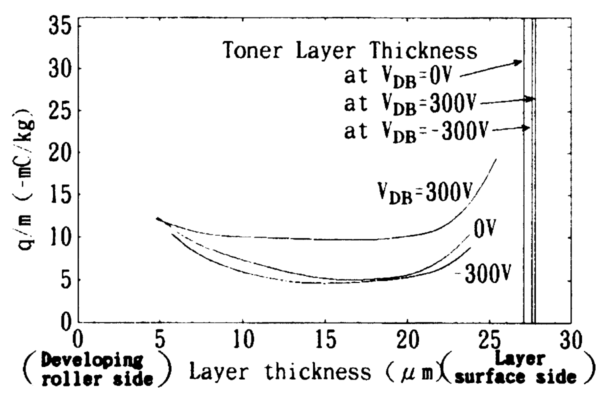

Figure 9. Charge distributions in the toner layer in thickness direction at V_{DF} = 200V.

Conclusions

The change in the properties of the toner layer formed on the developing roller was evaluated in the non-magnetic single component developing unit consisting of a developing roller, a toner supply roller and a regulating blade connected with their own bias voltage supply. The supplied toner mass and the average toner charge were measured, and the development characteristics were evaluated. The charge distribution within the toner layer were examined. The following conclusions were obtained.

(1) Changes in V_F and V_B caused the changes in supplied toner mass and toner charge, respectively.
(2) The experimental development characteristics approached the calculated ones as V_{DB} increased.
(3) The charge distribution within the toner layer in thickness direction was not uniform, and the toner particles at the center region of the toner layer were charged more weakly than those at other regions.
(4) The toner charge on the developing roller side was not influenced by V_{DB}.
(5) The charge distribution shifted in higher direction with V_{DB}, which may be due to charge injection from the regulating blade applied bias voltages.

Acknowledgments

The authors would like to thank Mr. T. Kaneko and Mr. T. Ou for their help. We would also like to thank PPC Engineering and Production Division, Niigata NEC Ltd. for support of this study.

This work was supported in part by a Grant-in Aid for General Scientific Research from the Ministry of Education, Science, Sports and Culture.

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