Analysis of Mono-Component Toner Charging and Design of a High Durability Development Roller

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Abstract

The charging mechanism of toner in the mono-component non-magnetic toner developing system was studied experimentally. A microscopic current measurement technique was used to analyze the dynamics of toner charging. A current was observed to flow through each part (i.e. the development roller, doctor blade, and supply roller) during rotation of the roller with toner attached on its surface. The current holds a strong relationship to the toner charge and supplied toner mass. Development rollers with various surface properties were prepared for this study. The currents and toner charge were measured for each roller both before and after a running test. The experimental results confirmed that the toner charge decreases during the running tests. Finally design features of a high durability development roller will be proposed.

Introduction

In the mono-component non-magnetic toner developing system, proper toner charging and mass transport are important factors to produce fine and high quality images. It is also very important to ensure the development roller has high durability for maintaining the fine and high quality images during the lifetime of a development cartridge. One of the authors of this paper, G.S.P. Castle and L.B. Schein proposed a model of contact charging between insulators, and demonstrated that most of the published experimental results were fitted to this model.[1] Robert Nash, et al. studied dynamics of toner charging by observing time-dependence of toner charge.[2] Yamaguchi et al. reported toner charging behavior in a non-magnetic developing system.[3] There are very few reports which focus on the change in toner charge and electrostatic properties of development roller during a long time running test. Figure 1 shows the typical result of a running test of q/m (charge to mass ratio) for an experimental roller with a semiconducting coating resin layer that contains carbon black (hereafter, CB). The purpose of this report is to clarify the mechanism of toner charge decrease during the running test (durability test). In this paper we focus especially on the influence of electrostatic properties of development roller surface on the charging of toner. For that purpose measurements were made of toner charge, toner mass on the development roller, surface properties of a roller and process currents in a laser printer. The experimental results suggest an important role of development roller surface in the toner charging.

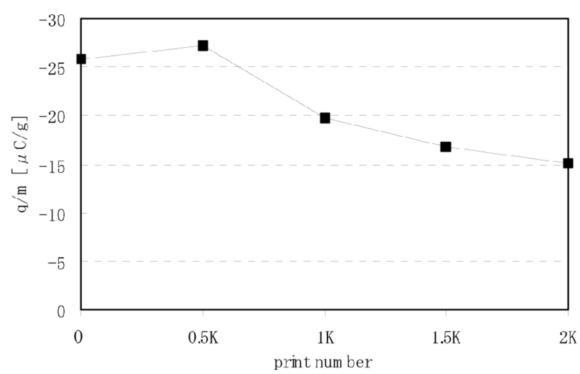

Figure 1. Decrease in q/m at running

Experimental

(1) Development Rollers

Development rollers consisting of an elastic polyurethane base and a coating resin layer were prepared in this study. The fundamental characteristics of the rollers are given in Table 1. The reference roller (#1) has the problem of having a decreasing q/m with a long time running test. No CB is contained in the surface resin layer of roller #2. The electrical resistance of the surface layer was changed by changing CB contents for rollers #3, #4 and #5. The diameter and length of roller are 20mm and 345mm, respectively. The diameter of roller shaft is 12mm.

Table 1. Fundamental Characteristics of Development Rollers

No.	CB contents of surface layer	Roller resistance log [Ω]	Surface resistance log [Ω]	Surface roughness Rz [μm]
#1	25%	6.5	8.0	1.9
#2	0%	over	over	1.6
#3	20%	8.3	10.5	1.7
#4	30%	6.3	6.9	1.6
#5	40%	6.0	5.1	1.8

(2) Machine and Toner

We used a commercial laser beam printer (hereafter, LBP) and its toner cartridge for this study. A non-magnetic mono component toner was employed, which was negative type. The doctor blade is made of stainless steel. Rotation rate of the development roller was 171 rpm. (0.35 s/rotation))

(3) Measurement of Toner Charge

A suction type Faraday cage was used to measure the toner charge and its mass. Toner on the surface of development roller was collected in the Faraday cage through the vacuum pipe. The OPC drum was removed from the machine for toner charge measurements. Toner mass/area ratio (m/a) was calculated from the toner mass collected in the Faraday cage and area of the development roller from where toner was removed.

(4) Running Tests

Running test was carried out until 6,000(6k) copies of 5% black image. In order to get precise data of q/m, the same development cartridge was used. Toner charge and toner mass were measured before and after the running test.

(5) Measurements of Current at Each Part in Development Process

Electrometers were connected between each development unit part (blade, development roller and toner supply roller) and GND as shown in Figure 2. The OPC drum was removed in the measurements. The development process currents were monitored by the three electrometers and the current data were sent to a computer through a GP-IB buss.

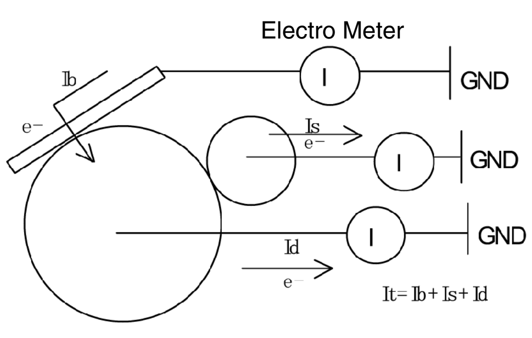

Figure 2. Scheme of current measurements (arrow indicates electron flow).

Results

(1) Toner Charge and Mass Transfer Results for Roller #1

Values of q/m of before and after running test are shown in Figure 3, when all the parts (development roller, blade, supply roller) were connected to GND. The magnitudes of q/m decrease significantly after a running test, while the m/a slightly increases. These results are related to surface properties of the development rollers and the physical configuration of the toner supply system in the LBP. Toner is supplied to the development roller from the semi conducting supply roller, which is set above the development roller as shown in Figure 2. Surface roughness of the development roller, which affects toner transfer, was increased by the running test. Thus m/a increased after the running test.

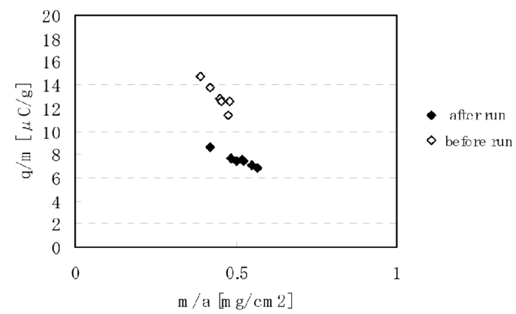

Figure 3. q/m before and after running for roller #1, grounded.

(2) Running Test of Roller #2 (Without CB in the Resin Layer)

Results of the running test for roller #2 are shown in Figure 4. Although a slight decrease in q/m was observed by the running test, but the q/m was still fairly high after the running test, compared to roller #1 (Figure 3). These results suggest that CB in the surface layer influences the toner charging mechanism.

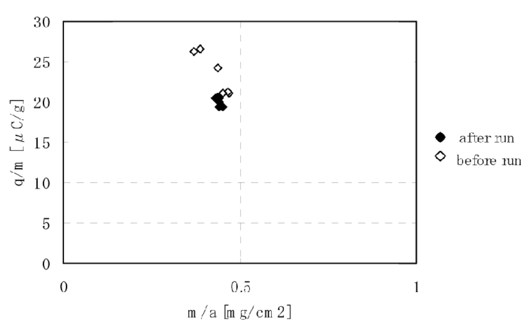

Figure 4. q/m before and after running for roller #2, grounded.

(3) Microscopic Current Measurements

Each part of the development unit was connected to GND and the currents of each part (Id: through development roller, Ib: through blade, Is: through supply roller, It: total current) were measured in the development process. Figure 5 shows the results of these current measurements for roller #1 before the running test. Current flow was observed in each part when the roller was rotating. Direction of the current flow is shown in Figure 2. The total current, which is the algebraic sum of each current, is approximately zero. It means that no significant current leakage through other parts occurred in this development system. In order to understand the cause of these currents, the toner was emptied completely from the cartridge and the currents were measured in the same way. No current was observed in this case. Therefore, it can be concluded that the currents observed originated from the tribo-charging of the toner and/or toner transfer.

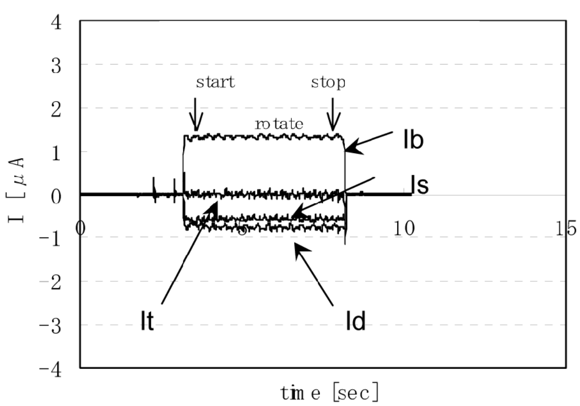

Figure 5. Currents through each part grounded for roller #1.

Discussion

We measured the current for rollers #1 and #2, and calculated their average values. The observed currents of before and after the running test for each roller are shown in Figure 6. No significant change in current was observed for #2 roller before and after the running tests whereas larger changes are seen for roller #1. These changes in current with the running test appear to correspond to the change in q/m. In the case of roller #1, Ib and Id increase and Is decreases after the running test. It is considered that charged toner is removed from the developing roller by the supply roller and Is must be related to the amount of toner charging. The decrease in Is may be attributable to decrease in q/m after the running test.

Increases in Ib and Id can be explained in several ways. Conductivity of roller #1 is much higher than that of roller #2, thus Id of roller #1 is larger than that of roller #2. We measured surface resistance of these rollers after the running test. The results are given in Table 2. The surface resistance of roller #1 decreased slightly after the running test. Therefore the current from blade to development roller increased after the running test.

We also measured Id, Ib and Is before the running test for rollers #3, #4 and #5. Figure 7 shows the results of each current. From the absolute values of each current, the roller #1 seems to have changed to a roller equivalent to a high CB content surface layer after the running test.

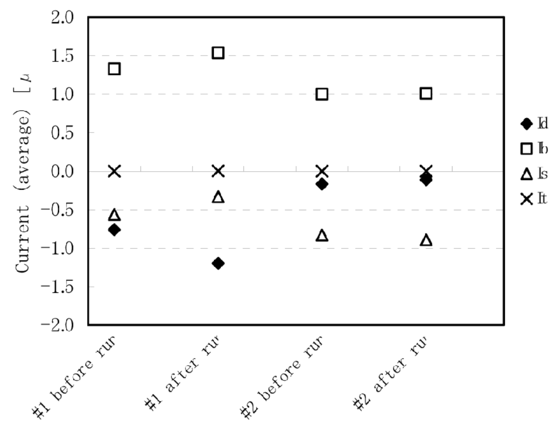

Figure 6. Currents before and after running (Rollers #1 and #2).

Table 2. Roller resistance before and after running.

	Condition	Roller Resistance log [Ω]	Surface Resistance log [Ω]
#1	Before test	6.5	8.0
	After test	6.5	7.5
#2	Before test	Over	Over
	After test	Over	Over

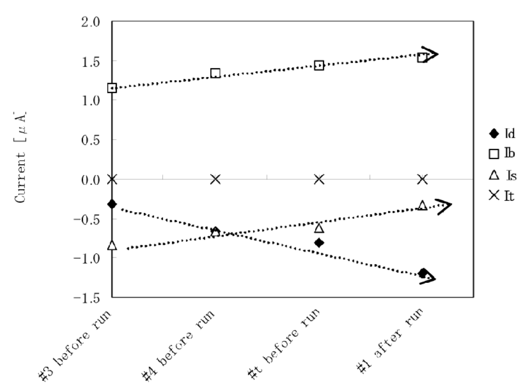

Figure 7. Comparison of currents for rollers #1, #2 (before running test) and roller #1 (after running test).

In the current measurement system, Id, Ib and Is must be related with q/a (= q/m x m/a). All the data are plotted in Figures 8, 9 and 10 and fitted to a best line extrapolation. When the toner does not charge, which means q/a=0, Is goes to 0 and –Id equals to Ib. It means that all the tribo-charge leaks through the development roller and toners remain with no charge. Thus no charge shift is observed at the supply roller. If we use an insulating resin surface layer for the development roller, Id=0 and the maximum q/a level is estimated to be 10[nC/cm^2]. These figures are very suggestive for the roller design.

From the printing performance requirement (high image density and low back ground), high resistance rollers such as roller #2 cannot be applied in the practical market. We proposed a double-layered structure for the development rollers to meet these requirements. The base roller is coated with a high conducting layer, then over coated with a thin resin layer without CB. The feature of the test roller (roller #8) is shown in Table 3. The conductivity of the roller is almost similar to that of #1 roller. Figure 11 shows the q/m and m/a before and after running test for roller #8. The toner charge, q/m, does not decrease after the running test in this roller. The results of the current measurements are shown in Figure 12. Each current in roller #8 is similar to those in roller #2.

Table 3. Two layered roller feature.

	CB contents of lower layer	CB contents of surface layer	Resistance of [Ω]	Surface Resistance log [Ω]	Surface Roughness Rz [μm]
#8	40%	0	6.3	5.6	2.7

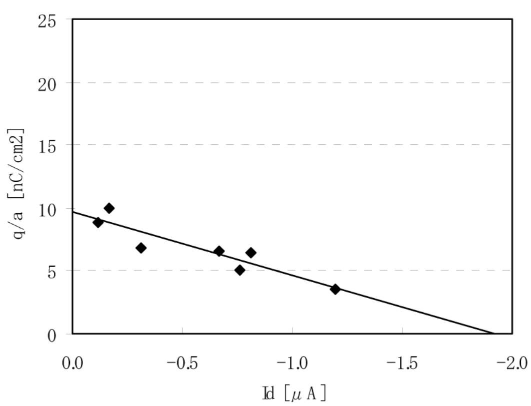

Figure 8. Relationship between q/a and development roller current (Id)

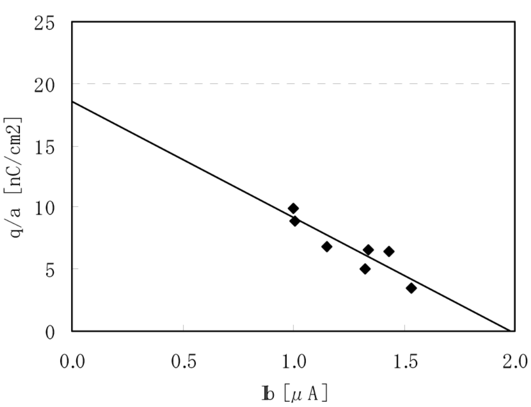

Figure 9. Relationship between q/a and blade current (Ib).

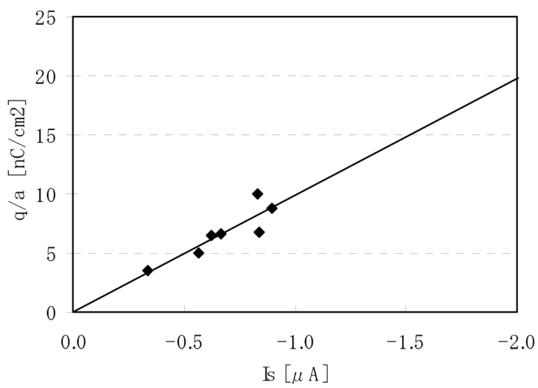

Figure 10. Relationship between q/m supply current (Is).

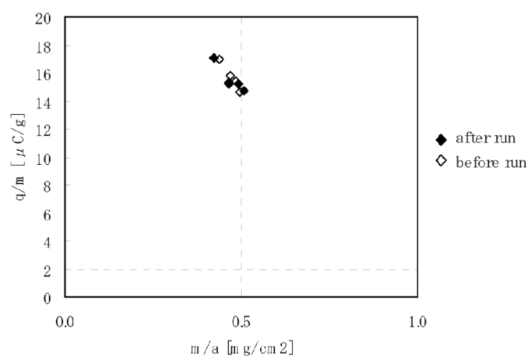

Figure 11. q/m vs. m/a before and after running test.

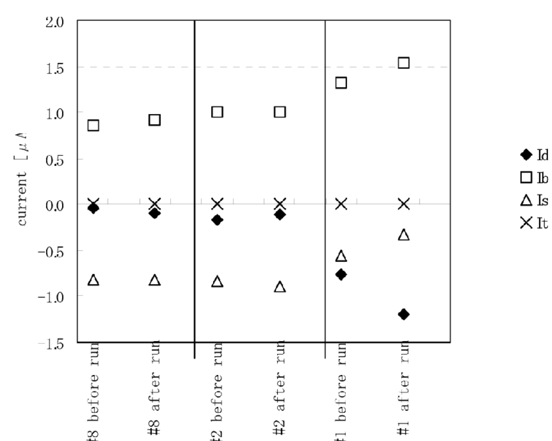

Figure 12. Currents Id, Ib, Is and It for roller #8, #2 and #1.

The conductivity of roller #8 is similar to that of roller #1. However, observed currents were different with each other. These results indicate that bulk conductivity of the roller is not the main factor for the current in the toner charging process. It is shown that the electrostatic properties of the roller surface are important factor for observed currents. These currents have strong relationship with q/m.

It can be said that the toner charging is more strongly affected by the roller surface characteristic than its bulk conductivity.

Conclusion

The mechanism of the decrease in toner charge is discussed for a long term running test in a mono-component non-magnetic toner system by using microscopic current measurement technique. It was discovered that a current was observed to flow through each part (i.e. the development roller, blade, and supply roller) during the roller rotation with toner attached to its surface. This current has a strong relationship to the toner charge q/m and toner mass q/a. It was clear that this technique is useful for discussing the toner charging and toner transfer mechanism. The relationship between the currents through each part and the q/a is very suggestive for the design of a high durability development roller. A development roller with double surface layers was designed for to produce a high durability roller. This roller has a sufficiently low bulk resistance and a high surface resistance. The newly designed roller gives a stable toner charge level during the life test and produces good imaging density.

References

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Biography

Koji Takagi received the B. Eng. and M. Eng. degrees from Yokohama National University Japan in 1985, 1987. In 1987 he joined Bridgestone Corporation and is working for the R&D division. He is now studying at the Department of Electrical Engineering at Ibaraki University.