The Effect of Toner Additives on Mono-Component, Non-Magnetic Toner Charging using a Current Measurement Technique

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Abstract

In the mono-component non-magnetic toner development system, the toner is charged by contacting with the system parts, such as a doctor blade, a development roller and a supply roller. In such systems the toner charging and fluidity is conventionally controlled by the use of extra-particulate additives on the toner surface. However, the influences of the additives on the charging and fluidity of the toner are still not completely understood. In this study we investigated the effect of using sub-micron sized inorganic extra-particulates on the dynamics of the toner charging mechanism by measuring the currents flowing through each of the system parts. Development rollers having various surface properties and toners having different surface concentrations of the toner additives were prepared. By using the current measurement technique, we examined the influences of the additive on the toner charging in the development process. It is shown that the system currents and resulting toner charges are very dependent on the amount of the additives. As a result, we concluded that these additives affect not only the toner mass transport but also the charge transfer.

Introduction

Proper toner charging and mass transport are important factors necessary for fine and high quality images in the electro-photographic process. It is very important to understand the dynamics of toner charging for designing the toner development system. Previously we presented a technique using current measurement for looking at the toner charging and the toner transport mechanism.[1,2] For proper toner charging and mass transport, we can control the fluidity and charging ability of toners not only by designing the resin and compounds of toners but also by using extra-particulates as toner additives. The additives are generally inorganic particles (i.e., SiO_2, TiO_2, etc.) that are smaller than the toner particles, i.e. in the sub-micron range. These additives make toners more fluid and are also used as one means to control toner charge. The mechanism of improvement of fluidity may be attributable to the fact that the toner additives decrease the contact areas of the toner particles.[3] The effects of additives on toner charging may be due to the increase in fluidity or charging of the additives themselves. However, the effect of toner additives on toner charging in the development process has not yet been completely clarified.[4,5] In this paper, we focus on the effect of toner additives on the charge transfer mechanism of toners. For that purpose, we measured the toner charge on a series of development rollers having different surface properties and the resulting process currents in a development system with various toners having different concentrations of toner additive. The influence of additives on the toner charge and the process currents are discussed. Finally we propose a clarification of the role of the toner additives on the charge transfer mechanism in toners.

Experimental

Toners

We prepared a pulverized negative charging toner, which consisted of polyester resin, pigments and other compounds (i.e. a charge control agent etc.). The mean particle size (d0.5) based on weight of the toner was 7.9 μm. We used fine silica particles (mean size: the order of 100 nm) as the toner additive changing its concentration as 0, 0.5, 1.0, 1.5% of toner mass.

Development Rollers

Development rollers consisting of an elastic polyurethane base coated with a thin resin layer were prepared. The fundamental characteristics of the rollers are given in Table 1. Rollers NC10 to NC30 can be characterized as having an insulating surface layer and are arranged in the order of the thickness of the surface layer: approximately 5 μm for NC10, 10 μm for NC20, 20 μm for NC30. Another trend of these rollers is that as the thickness of surface layer increases, the surface roughness Rz decreases as shown in Table 1. Rollers CB10 to CB30 and CBL6 can be characterized as having a semi-conductive surface layer changing the contents or grade of carbon black. The structure of Carbon L6 is different from the other carbon used for CB10 to CB30, and the Carbon L6 produces the most conductive surface of all the rollers tested. The roller resistance was measured by applying a dc voltage of 100 V between the roller shaft and a metal plate that was contacted with the roller surface.

Machine

We used a commercial toner cartridge for a laser beam printer in this study. The cartridge has a doctor blade made of stainless steel and a supply roller made of polyurethane foam. First, we modified this cartridge to rotate without an OPC drum and fabricated a driving system for this cartridge. Then, we replaced the development roller with that for measurements and filled a definite amount of toner into the cartridge. In the experiments, we drove the cartridge for toner transport to give a rotation speed of the development roller of 250 rpm.

Table 1: Fundamental Characteristics of Development Rollers

	Surface layer Resin concentration	CB contents	Log roller resistance applied voltage : 100V (Ω)	Surface roughness Rz (μm)
NC10	10%	0	7.8	6.1
NC15	15%	0	7.8	3.7
NC20	20%	0	8.2	1.3
NC25	25%	0	8.4	1.0
NC30	30%	0	9.5	1.0
CB10	20%	10%	7.8	1.2
CB20	20%	20%	7.8	1.1
CB30	20%	30%	7.4	1.2
CBL6	20%	30%	6.0	2.4

The diameter and length of the roller was 20 mm and 345 mm, respectively, and the diameter of the roller shaft was 12 mm.

Measurements of Toner Charge on the Surface of Development Rollers

A suction type Faraday cage was used for this measurement. After driving the development system, toner on the surface of the development roller was suctioned and collected in the Faraday cage using a vacuum pump. The suction area on the roller surface was constant thus allowing the calculation of the toner charge/area ratio (q/a).

Measurement of Current at Each Part in Development Process

Three electrometers were connected between each development unit part of the machine (blade, development roller, supply roller) and ground. In this system we did not apply any external bias voltages. The development process currents were monitored by the electrometers and the current data were transferred to a personal computer through a GP-IB bus. The roller was rotated for 3.5 seconds and the current was monitored all through the process from start to stop of rotation. The value of the current was determined from the average over 3 seconds from the start to the stop point.

Results

Toner Charges on the Surface of Development Rollers

Figures 1 shows the toner charge (q/a) deposited on the development roller for all conditions. Each graph of Fig. 1: (a) - (d) shows the data for toners with 0%, 0.5%, 1.0%, 1.5% additive, respectively. The error bars show dispersion of three measurements.

In the case of no toner additive, graph (a), it can be seen that the toner charge on the development rollers that have thicker insulating surface layers, NC20 - NC30, had higher magnitudes reaching values in the range from -12.6 to -14.4 nC/cm^2. However as the thickness of the insulating layer decreases (NC10, NC15) or for the cases where the surface layer is semiconducting (CB10 - CBL6), the toner charge ranges from -5.2 to -8.9 nC/cm^2. However, as the amount of toner additive increased, the toner charge for NC10, NC15 and CB10 - CB30 also increased as seen by comparing graphs from (a) to (d). As a result, at 1.5% additive added, the toner charge approached similar values for most rollers although the toner charge still decreased as the conductivity of the surface layer of the rollers increased.

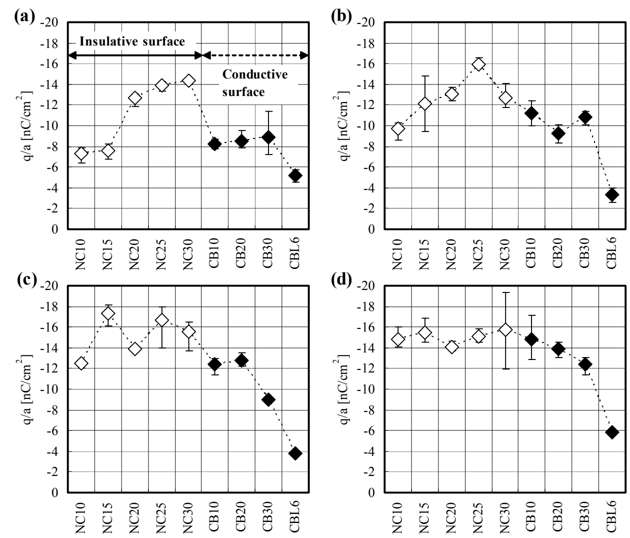

Figure 1. Toner q/a of all development rollers: (a) no additive toner, (b) 0.5% additive, (c) 1.0%, (d) 1.5%

Current Measurements

An example of typical current data is shown in Fig. 2 (Ib: blade current, Id: development roller current, Is: supply roller current, It = Ib+Id+Is: total current), for the case of toner having 1.5% additive transported by the NC10 roller. The currents through each part had a constant direction in all measurements for any of the toners and development rollers used. The currents through the blade (Ib) were in a direction indicating negative charge injection into the toners and the currents through the development rollers (Id) and supply roller (Is) were opposite to those. The total current (It) was negligibly small for all measurements, suggesting no current leakage from the system.

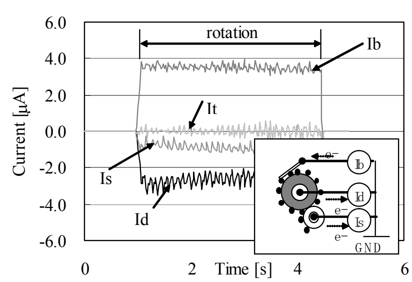

Figure 2. Currents through each part for NC10 roller with 1.5% additive toner.

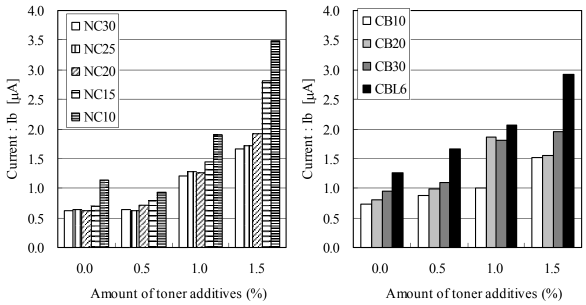

Figure 3. Relationship between currents through doctor blade: Ib and toner additive amount

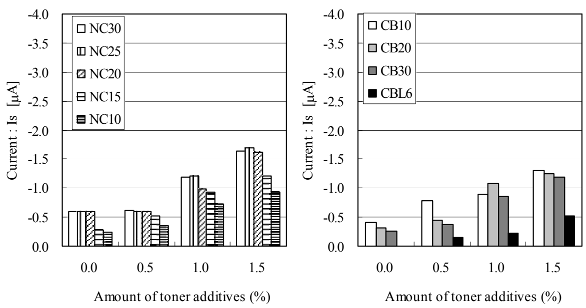

Figure 4. Relationship between currents through supply roller: Is and toner additive amount

Figures 3 and 4 show the currents through the doctor blade and supply roller, respectively, for all cases of each development roller. In general, with an increase in the amount of toner additive, both currents, Ib and Id, increased for all the development rollers. The currents through each part also depend on the properties of the development rollers. It was found that when the surface layer of the roller decreases in thickness (as from NC30 to NC10), the currents through the doctor blade increase, while the currents through the supply roller decrease. Similarly, when the surface layer becomes more conductive, a similar trend is observed. As reported previously both of currents are influenced by the resistance of development roller[1] and also perhaps influenced by other properties such as the surface roughness. The current through the development roller Id was estimated by the relationship: It=Ib+Id+Is~ 0, that is, approximately - (Ib+Is).

Discussion

The Effect of Toner Additive on Toner Charging

Referring to Fig 1, in the case of no toner additive, the toner charge (q/a) was small for the development rollers that have thinner surface layers (NC10, NC15) or conductive surface layers (CB10 - CBL6). As previously discussed it is considered that in these cases where the roller resistance is lowest, charge may leak to the development roller[1]. However, with an increase in the amount of toner additive, the toner charge approaches a similar value for all insulating surface rollers (NC10 - NC30). The dependence on the surface conductivity of the development rollers is clearly revealed from the results for CB10 - CBL6. The increase in toner fluidity, which is caused by the presence of the additive, increases the frequency of contact between toner and the blade and promotes toner charging when passing the doctor blade. As a result, toner charging was stabilized for the different development rollers. As shown in Fig.3, it can be seen that the currents through the doctor blade (Ib) were significantly increased as the toner additive concentration increased. The current through the doctor blade (Ib) flows as a result of charge injection onto the toners. It was previously proved that no currents were generated in the system with no toner or without rotation of the development roller.[2] These results indicate that the charge transfer from the doctor blade to the toner is enhanced with an increase of the toner additive concentration. Moreover, the increase of the current through the doctor blade in proportion to the amount of the additives is large compared with that of the toner charge. It means that all of charge transferred from the doctor blade does not remain within the toner but some of the charge flows into the development roller. This can be observed as the current through the development roller (Id). As described above, it is considered that the toner additives increase the toner fluidity so that the charge transfer from the blade to toner is promoted, and as a result this contributes to stabilizing the toner charging when passing the blade. However, because of the effect of charge leakage, toner charge decreases depending on the surface conductivity of the development roller even though the charge transfer is enhanced.

The Effect of Toner Additive on Toner Reset Process

The origin of the current through the supply roller (Is), is considered to be a result of toner charge and the ratio of removing /attaching of toner in the resetting process by the supply roller[1]. In order to analyze the effect of the toner additive on the toner resetting, the correlations between toner charge (q/a) and the currents through the supply roller (Is), are shown in Figure 5. The plots differ depending on the surface properties of development roller for each toner additive concentration. In the case of no additive shown in Fig. 5-(a), the plot of the lowest q/a was obtained for the most conductive surface roller, CBL6 and the higher q/a values were obtained for the thicker insulating surface layer rollers: NC20 - NC30. The correlation between q/a and Is for all rollers are shown as a best fit linear line for each toner. These correlation lines show the efficiency of toner reset. As shown in Fig. 5-(d), with the highest concentration of toner additive, the correlation line is in direct proportion passing through the origin of the graph. However, with a decrease in the amount of toner additive, the correlation line shifts to reduce Is, and its intercept on the q/a axis increases as from Fig. 5-(d) to (a). Since Is also reflects the q/a of the removed toner, if the current, Is, decreases even though the toner charge dose not change much, it means that the toner resetting becomes incomplete, that is, not all the toner is removed by the supply roller. Therefore the shift of the correlation line shown in Fig. 5 reflects the efficiency of toner removal. The improvement of toner fluidity caused by the additive thus reduces the amount of non-removable toner. Furthermore, this effect can be observed as increasing the current through the supply roller, Is, in this measurement. Thus improvement in the efficiency of toner resetting is another effect of the use of toner additives in the development system.

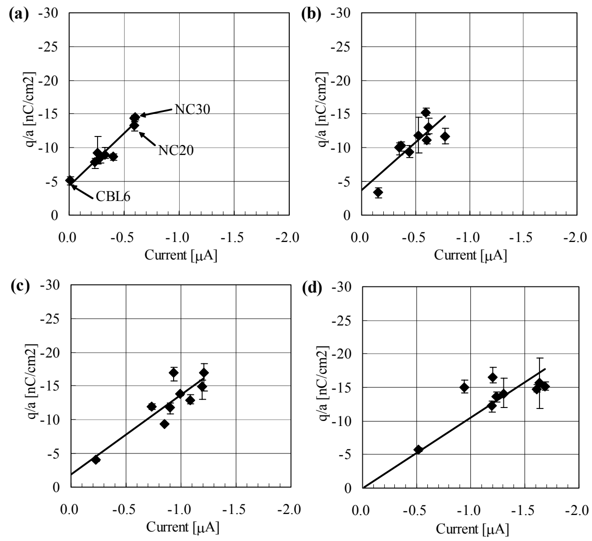

Figure 5. Relationship between q/a and Is. (a) 0% additive, (b) 0.5%, (c) 1.0%, (d) 1.5%

Conclusion

Toner dynamics and the effect of toner additives can be analyzed by using a current measurement technique. By comparing the correlation between toner charge and the system currents, we find that there are two effects caused by the improved fluidity provided by the toner additive. One of the effects is that the currents through the doctor blade increase and the toner charge reaches a saturation value for the system with an increase in the amount of additive. It is considered that toner additives promote the charge transfer of toners from the blade to the development roller by improving the toner fluidity. In addition, the other effect of the toner additive is to reduce the amount non-removable toner on the development rollers during the reset by the supply roller.

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Author Biography

Hiroyuki Anzai received the B.Sci. and M.Sci.Degrees from Tokyo Institute of Technology Japan in 2000,2002. In 2002 he joined Bridgestone Corporation and is working for the R&D division.