Quantitative Charge Spectrometer

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Abstract

The measurement of the actual toner charge distribution, for both positive and negatively charged particles, in an electrophotographic development system would be useful in evaluating and optimizing the development system. We report the development of a charge spectrometer, for a contact monocomponent development system, which measures the charge distribution for the toner particles, as well as the percentage of wrong sign toner.

Introduction

As it has become clear that wrong sign toner (WST) particles in electrophotographic development systems are responsible for image defects, efforts to measure and understand toner charge distributions have increased. WST particles have been shown to be indirectly responsible for background development[1-3] and directly responsible for edge raggedness.[4] Low charged wrong (and right) sign toner particles can create toner dust inside a copier or laser printer, leading to reliability problems.

Other motivations for measuring toner charge distributions exist. For example, it is known that it would be advantageous to lower the average toner charge to mass ratio, Q/M, in development systems.[5] Attempts to lower Q/M usually result in increased amounts of wrong sign toner. Therefore, lowering Q/M requires narrowing the toner charge distribution, which requires understanding the source of and minimizing the amount of wrong sign toner. Furthermore, the study of toner charging is but one example of the unsolved insulator electrostatic charging problem.[5] Recent advances in the theory of insulator charging, by studying toner-carrier charging properties,[6] further motivates the desire for a tool which can quantitatively characterize the charge distribution of toner particles.

It is the purpose of this report to describe a quantitative charge spectrometer (QCS) which measures for the first time[7] the amount of wrong sign toner and Q/M quantitatively, as determined by independent techniques. This QCS mates a new toner injection system to a known charge spectrometer that utilizes laminar air flow and crossed electric fields[8]. The injection system is specifically designed for a contact monocomponent development system, although its principles are extendible to other monocomponent systems.

Principles of Operation

This new quantitative charge spectrometer differs from a previously reported spectrometer[8] only by the injection system. The function of the injection system is to obtain a representative sample of charged toner particles. To assure that the sample is representative, the injector needs to strip toner completely at the injection location and deliver these particles into the deflection chamber with minimal loss. In addition, it cannot impart additional charges to the toner that may occur from collisions with the surfaces of the injector.

To achieve these objectives, we have designed a new particle injection system which strips toner from the roller of a contact monocomponent development system with near 100% efficiency using a high velocity air stream which entrains the toner. The air flow is driven by a 95 psi pressure drop between the inlet and exit of the injector tube (see Figure 1). Air flow is nearly straight with smooth transitions in tube diameter to minimize the collision of toner particles with the injector tube walls. It is comprised of a 32 μm diameter tube region with a small (< 250 μm long) opening in the side of the tube that allows toner to enter the air stream. The tube diameter gradually widens to 250 μm diameter and stays at that diameter for most of its length. Near the injector exit location, the tube diameter widens gradually to 2.17 mm where the injector air flow enters the chamber.

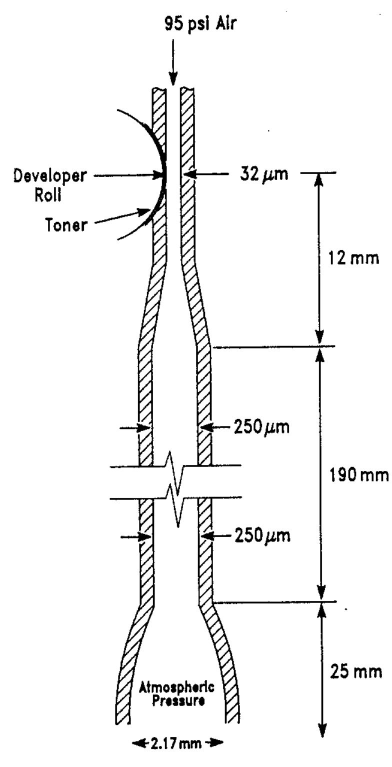

Figure 1. Schematic diagram of the new injection system.

Qualification Tests

In order to qualify the new injector design, two tests were performed. These were (1) varying doctor blade bias of a contact nonmagnetic monocomponent development system (see Sections 9.6 and 12-9.6 in Reference [5] and (2) testing toner with "high" and "low" background development. These tests were selected because (1) provides a test of variable Q/M while (1) and (2) provide a test of variable wrong sign toner concentration (based on vacuum pencil measurements and observations of background development).

By varying the doctor blade bias with respect to the developer roll, from +250 to -500 V, the average Q/M on the developer roll can be varied from approximately –5 to –18 μC/g with significantly more background development as the bias becomes positive. This gives us the ability to test the charge spectrometer's accuracy and repeatability over a wide range of Q/M values while observing changes in the amount of WST (assuming WST determines background development). The toner adder roll is held at –125 V with respect to the developer roll, and the doctor blade bias was set to one of five different voltages: +250 V, +125 V, 0 V, -325 V, and -500 V, all with respect to the developer roll. The developer roll was then turned for twenty revolutions at 3.2 ips in a standard IBM 4019 LaserPrinter cartridge and placed against the injection system.

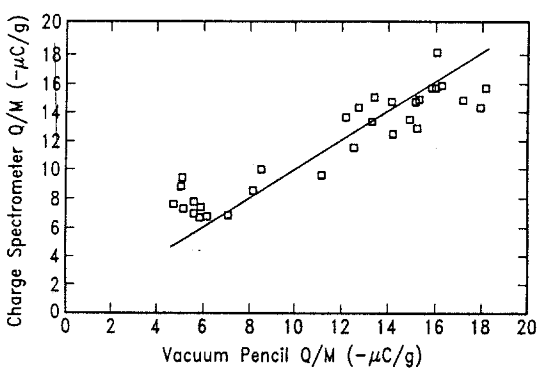

Figure 2. Comparison of Q/M for the QCS and vacuum pencil as a function of doctor blade bias.

Figure 2 shows Q/M calculated from the charge spectrometer data compared to Q/M measured directly with a vacuum pencil. The charge spectrometer accurately determines Q/M up to about -16 μC/g. The percentage of WST (by area) versus doctor blade bias is shown in Figure 3. Percentage of WST by area is used because it is more indicative of a change in reflectance on paper. Clearly, as the doctor blade bias becomes more positive, the amount of WST dramatically increases. The Q/d distribution, shown in Figure 4, clearly shows the shift of Q/D and an increase in the amount of WST as the bias is changed. The amount of WST is compared with direct measurements of background development below.

Having shown that the new charge spectrometer injector system works at an acceptable level for detecting gross changes in the average Q/M, an attempt was made to distinguish subtle differences. Toners were obtained that had very similar vacuum pencil Q/M values but varied by a factor of 2 or 3 in terms of the amount of background development (BD) produced. One of the toners had a BD level of 3 mg/page while the other had a BD level of 8 mg/page. Both toners had vacuum pencil Q/M values in the range of 14-16 μC/g.

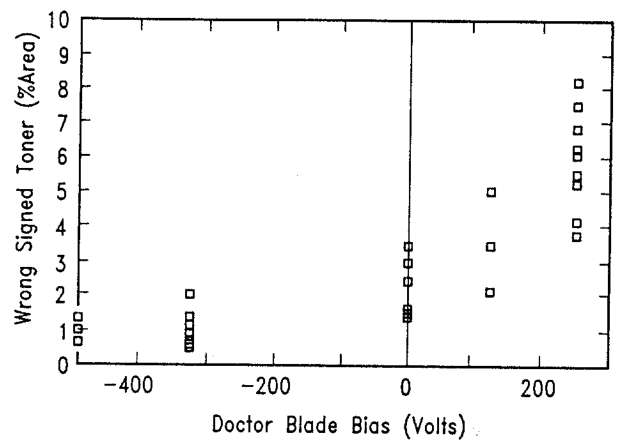

Figure 3. Percent wrong sign toner as a function of the doctor blade bias as determined by the QCS.

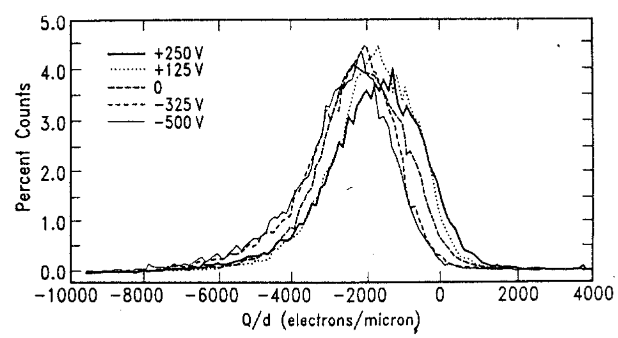

Figure 4. The Q/d distribution (summed over all toner diameters) as a function of the doctor blade bias.

Standard, unmodified IBM 4019 LaserPrinter cartridges were filled with these toners. The BD levels were tested using two separate techniques. First, the 4019 LaserPrinter was "crash stopped" (i.e., the cover was opened) during the printing cycle of a solid white page. The M/A on the photoconductor was measured using a vacuum lift-off technique. Next, print samples were generated on the 4019 and optical density OD measurements were made of the background. These measurements showed that the BD level of the two toners were different by a factor of 2 - 3 (see Figure 5).

These toners were then run on the charge spectrometer. The charge spectrometer confirmed the average Q/M values were virtually indistinguishable and did show a difference in the amount of wrong sign toner. The high-BD toners exhibited a wrong sign toner percentage of 0.36%, whereas the low-BD toners exhibited a WST percentage of 0.11%, the same factor of 3 difference detected by the OD and M/A methods (Figure 5). The optical percentage area is the area covered by the toner divided by the M/A on the photoreceptor for a white page times the speed ratio of 1.6.

Included in Figure 5 are similar measurements for the doctor blade bias test, which shows quantitative agreement between the amount of WST as measured by the charge spectrometer and background development as measured by OD measurement. Semiquantitative agreement with M/A on the photoreceptor is obtained. (It is noted that this measurement involves such small amounts of toner mass that equilibration of the toner with the RH in the laboratory is required after each vacuum pencil measurement.) An expanded view of the Q/d distributions near zero Q/d is given in Figures 6 and 7 for the low and high BD toners, clearly showing that the change in the amount of WST is due to a subtle change in the tails of the distributions.

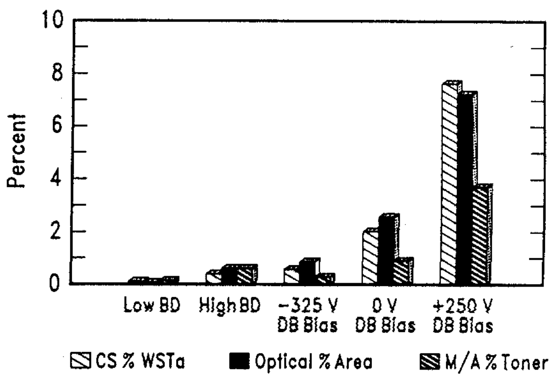

Figure 5. Comparison of (1) the percent WST as determined by the QCS, (2) the optically determined percent area coverage from a print and (3) the percent M/A (M/A on the photoreceptor as compared to M/A on roller times the speed ratio) for 3 doctor blade biases and 2 toners with differing background development.

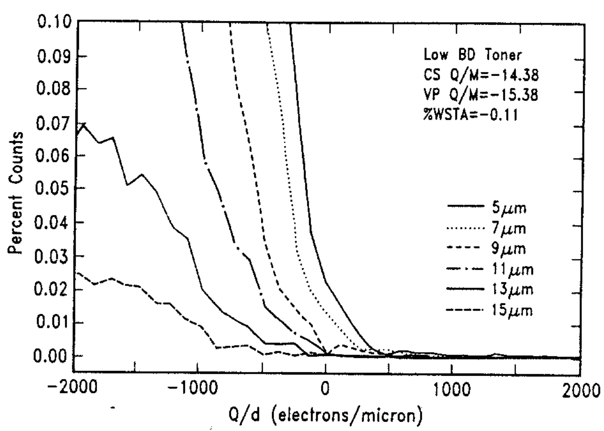

Figure 6. Detail of the Q/d distribution for the low BD toner.

Conclusions

A new injection system has been described for the charge spectrometer. This new injection system strips toner from a roller using a high velocity air stream which entrains the toner. The air flow is driven by a 95 psi pressure drop between the inlet and exit of an injector tube of varying diameter

With this new injection system, we have been able to measure Q/M and the percent wrong sign toner quantitatively for the first time, to our knowledge. Two tests were described which qualified the instrument described. In the first test the doctor blade bias was varied. In this case the quantitative charge spectrometer detected not only the change in Q/M but also a change in the percent of WST. In the second test, two toners with the same Q/M, but differing background development were tested. The charge spectrometer detected a difference in the amount of WST, which quantitatively correlated with the amount of background development as determined by independent techniques.

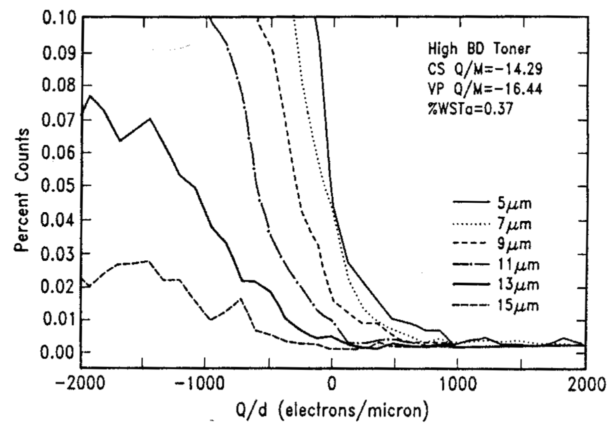

Figure 7. Detail of the Q/d distribution for the high BD toner.

Acknowledgment

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