The Effects of Q/M and M/A on a Nonmagnetic Monocomponent Contact Development System under Different DC Bias Voltages*

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The toner charge-to-mass ratio (Q/M) and toner mass per unit area (M/A) on both the developing roll and organic photoconductor (OPC) drum in a nonmagnetic monocomponent contact development system were studied by adjusting the dc bias. The bias between the developing roll and toner-adding roll from –200 to 200 V (V_{dr}–V_{tar}), and the bias between the developing roll and doctor blade from –400 to 600 V (V_{dr}–V_b) were the ranges of interest. The development potential between the developing roll and the OPC drum was kept at a constant value of 220 V. The developing roll, 2.0 cm in diameter, is made of soft polyurethane with a bulk electrical resistivity of 10^{10} Ω-cm. The OPC drum used here has a diameter of 3.0 cm. The average Q/M ratio of toner on the developing roll is larger than that on the OPC drum corresponding to each V_{dr}–V_b when V_{dr}–V_{tar} is changing from 0 to 200 V. The Q/M ratios are affected by V_{dr}–V_b more on the OPC drum than on the developing roll. M/A ratios on both the developing roll and the OPC drum increased linearly as V_{dr}–V_{tar} was increased from –100 to 50 V and were nearly constant (changing within 0.2 mg/cm^2) under a constant V_{dr}–V_b of 200, 400, and 600 V as V_{dr}–V_{tar} increased from 100 to 200 V.

Journal of Imaging Science and Technology 40: 364–368 (1996)

Introduction

Nonmagnetic monocomponent development systems using a developing roller have been widely studied[1–4] due to the equipment's small size and low cost for color printing. The adjustment of the relative linear velocity of the developing roller and the OPC drum to obtain sufficiently uniform Q/M and M/A for the toner has been studied by Sato, et al.[5] However, the Q/M and M/A are also affected significantly by applying different dc bias voltages in a nonmagnetic monocomponent contact development system. To achieve high printing quality, it is desirable to know how the dc bias affects the Q/M and M/A of toner on both developing roller and toner-adding roller when the relative linear velocity of the developing roller and OPC drum is kept at a constant value.

In this study, an electrophotographic contact-type development unit was used to investigate the effects of Q/M and M/A on both developing roller and OPC drum under different dc bias voltages. The system was studied by adjusting the dc bias between the developing roller and toner-adding roller and/or the dc bias between the developing roller and doctor blade. The development potential was kept at a constant value. The effect of dc bias on the toner transfer ratio from the developing roller to the OPC drum is also discussed.

Experimental

Figure 1 shows the schematic IBM development unit, which makes contact with the OPC drum under a normal force of 0.092 N. The toner used in our experiment was supplied by Lexmark for the IBM4029. The linear velocity of the OPC drum is 4.71 cm/s. The developing roller rotates at a linear velocity of 8 cm/s and is in contact with the OPC drum. The relative linear velocity ratio (v) between the developing roller and the OPC drum is 1.7. The toner-adding roller, made of a conductive sponge, open-cell-type polyurethane foam, has a diameter of 1.4 cm. The toner-adding roller in contact with the developing roller is rotating at a relative linear velocity ratio of 1.09. The development potential between the developing roller and the OPC drum is kept at a constant voltage of –220 V. The OPC drum is directly grounded. The doctor blade is held in contact with the developing roller by a force of approximately 0.097 N. The developing roller, the toner adding roller, and the doctor blade are electrically biased by V_{dr}, V_{tar}, and V_b, respectively.

The dc bias (V_{dr}–V_{tar}) between developing roller and toner-adding roller was gradually adjusted from –200 to 200 V by steps of 50 V, and the dc bias (V_{dr}–V_b) between developing roller and doctor blade was increased from –400 to 600 V in 200 V steps. The M/A and Q/M were measured by using a vacuum suction unit, which includes a filter and a nozzle head, to take samples from both the developing roller and the OPC drum. The head of the suction unit has a 1-cm^2 curved surface fitted to the OPC drum and a 2 cm^2 curved surface fitted to the developing roller. A filter having a pore size of 0.5 μm was used inside the unit to capture the toner particles. The toner mass per unit area was measured by weighing the filter before and after toner suction. The toner was triboelectrically charged while passing between the toner-adding roller and the doctor blade. A coulomb meter was used to measure the charge of the developed toner, and then the charge-to-mass ratio of the toner could be calculated by dividing charge by mass. The toner was scavenged from the OPC drum by a rubber blade after each cycle of toner deposition.

Results and Discussion

Effect of DC Bias Voltage on M/A. We now discuss the effect of dc bias voltage on the M/A of toners for the developing roller and OPC drum. It is important to apply adequate toner mass from the developing roller to the OPC drum to obtain a high enough printed optical density. In

Original manuscript received February 5, 1996. Revised May 10, 1996.

* Presented in part at IS&T's 11th International Congress on Advances in Non-Impact Printing Technologies, October 29-November 3, 1995, Hilton Head, SC.

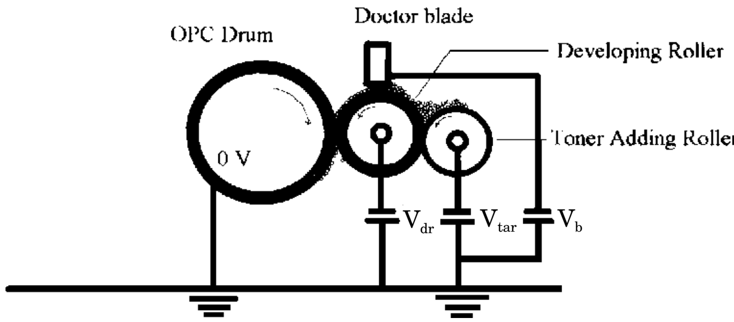

Figure 1. Schematic of the experimental development system.

our experiments, the toner mass and the charge were both regulated by adjusting bias on the doctor blade and the toner-adding roller. Figure 2 shows the toner mass per unit area that was measured on the developing roller under different dc bias voltages of V_{dr}–V_{tar}. The six curves in this figure represent six different dc biases of V_{dr}–V_b. Obviously, we are limited in our attempts to increase M/A by increasing both V_{dr}–V_{tar} and V_{dr}–V_b. The M/A on the developing roller seemed to be saturated when V_{dr}–V_{tar} is 100 V or above. These curves show that the M/A varied linearly as V_{dr}–V_{tar} was adjusted from –100 to 50 V. In this region, we also observed that increasing V_{dr}–V_b increased the M/A rate of rise; the M/A is changed from about 0.002 mg/cm^2 per volt to 0.004 mg/cm^2 per volt. The M/A approached an average value of 0.73 mg/cm^2 for V_{dr}–$V_b \geq 200$ V when V_{dr}–V_{tar} was in the range 100 to 200 V.

We see the effects of dc bias voltages on M/A from another point of view in Fig. 3. The M/A values did not change significantly with V_{dr}–V_b when V_{dr}–V_{tar} was below 0 V, and they became closer to one another when V_{dr}–V_{tar} was beyond 50 V and in the range of V_{dr}–$V_b > 0$.

Figure 4 shows the M/A on the OPC drum. The shapes of these curves are similar to those of the curves in Fig. 2, but the slope of M/A increased from about 0.002 mg/cm^2 per volt to 0.008 mg/cm^2 per volt as V_{dr}–V_b was increased when V_{dr}–V_{tar} was in the range of –100 to 50 V. The M/A on the OPC drum became saturated when V_{dr}–V_{tar} exceeded 100 V, except for V_{dr}–$V_b \leq 0$ V. The M/A approached an average value of 1.13 mg/cm^2 for V_{dr}–$V_b \geq 200$ V when V_{dr}–V_{tar} was in the range 100 to 200 V. This is 1.55 times the M/A on the developing roller in the same bias range.

Figure 5 shows the M/A on the OPC drum from another point of view. We can see that V_{dr}–V_b did not affect the M/A significantly except when V_{dr}–V_{tar} was positive and V_{dr}–V_b was below –200 V.

Effect of DC Bias Voltage on Q/M. We now discuss the effect of dc bias voltage on the Q/M values of toners for the developing roller and OPC drum. The toner transported from the developing roller onto the OPC drum to develop the latent electrostatic image formed on the drum surface is closely influenced by the toner charge. The toner charge must have the correct sign and magnitude to overcome the effects of image force[6] to produce toner development on the OPC drum. Figures 6 and 7 show the toner charge-to-mass ratio on the developing roller and the OPC drum, respectively. The Q/M (– μc/g) reached a constant

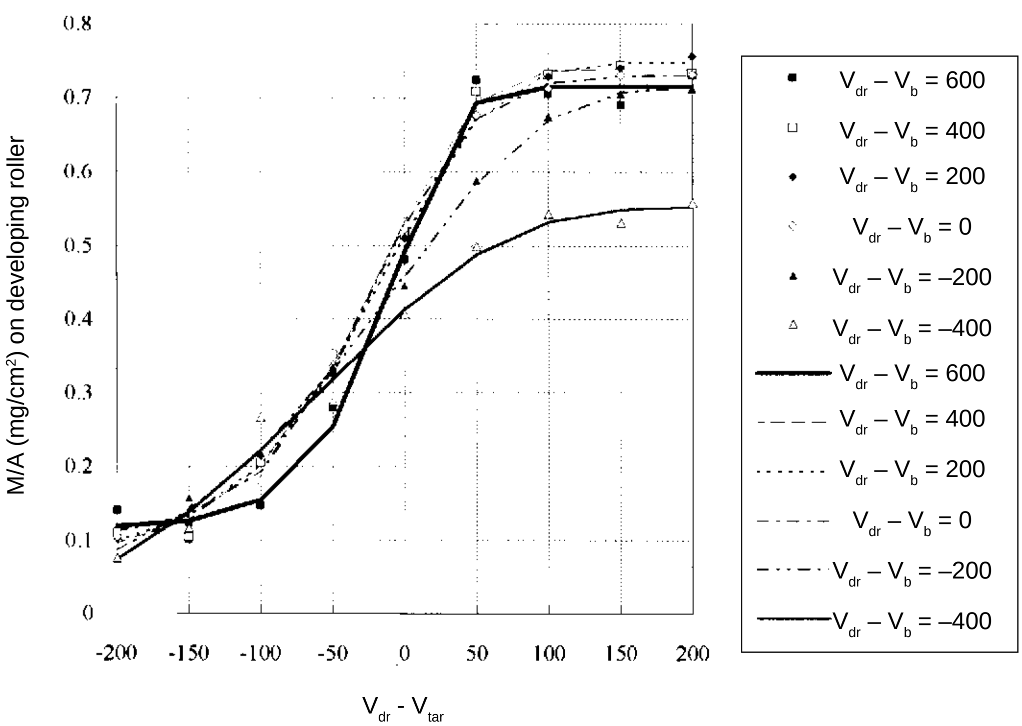

Figure 2. M/A on developing roller.

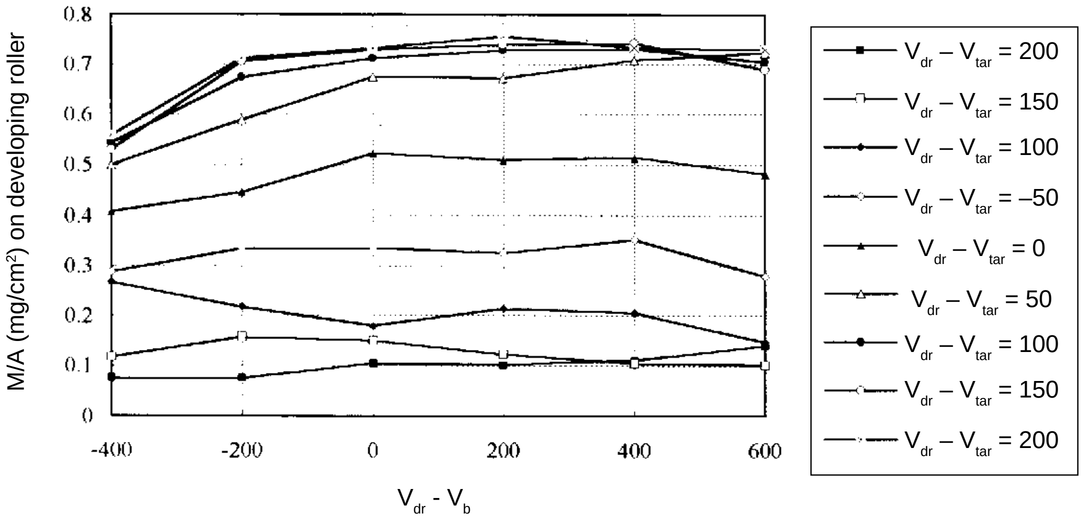

Figure 3. M/A on developing roller.

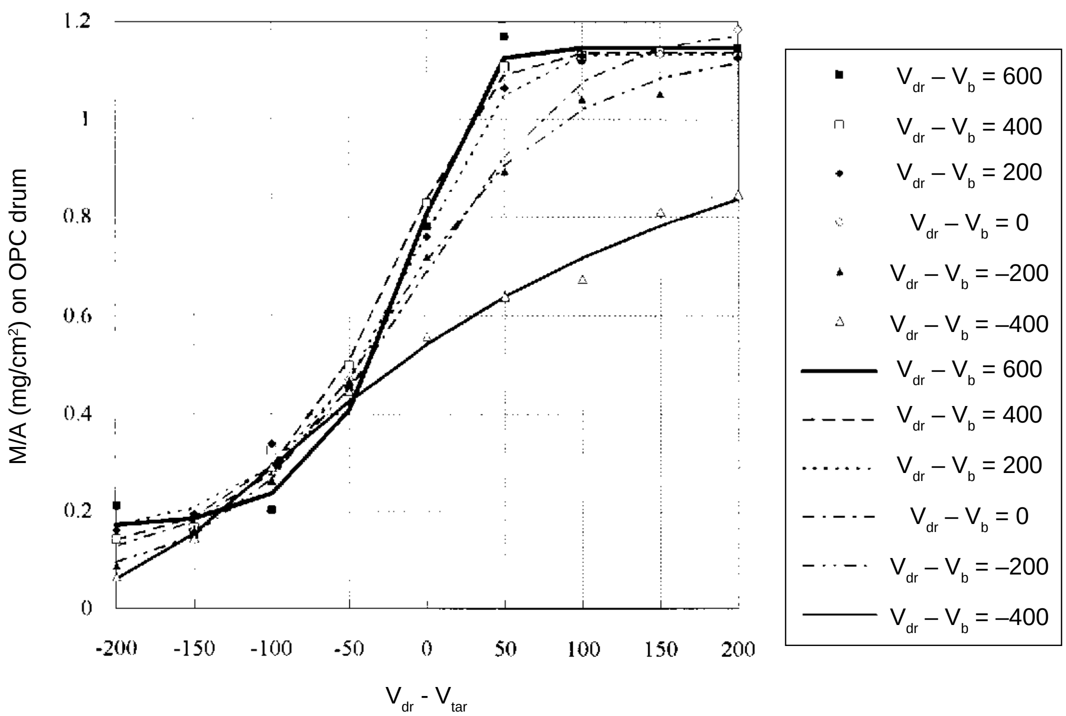

Figure 4. M/A on OPC drum.

value for each curve as V_{dr}–V_{tar} became positive. The average Q/M values were 10.24 on the developing roller and 10.58 on the OPC drum when V_{dr}–V_b = 600 V in the positive region of V_{dr}–V_{tar}. The average Q/M values on the developing roller and the OPC drum at V_{dr}–V_b = –400 V in the positive region of V_{dr}–V_{tar} were 0.94 and 5.3, respectively. In Fig. 6, the Q/M values on the developing roller at V_{dr}–V_b = –400V were very small; however, the corresponding curve on the OPC drum, as shown in Fig. 7, had a minimum value of 5 when the development potential was kept at a constant voltage of –220 V.

We collected the toner particles on the developing roller and observed many wrong-sign toner particles, using the Q/D spectrum meter. This finding revealed that the measured Q/M value on the development roller was an average value of all toners, which included many wrong-sign particles. Only the correct-sign toner particles were transferred to the OPC drum, thus leaving a lot of residual toner on the developing roller. Consequently, the average toner transfer efficiency of V_{dr}–V_b = –400 V was poor, as shown in Fig. 8.

For the purpose of image development, we may want to change the Q/M values but keep the M/A value at a constant value; however, we cannot keep the M/A unchanged while we try to increase Q/M by simply changing the bias on the toner-adding roller or the doctor blade. In Fig. 2, for example, when M/A = 0.5 mg/cm^2 at V_{dr}–V_b = –400 V, the related V_{dr}–V_{tar} is approximately –63 V. This value corresponds to Q/M = –0.2μC/g, as shown in Fig. 6. If we want to raise the Q/M value to –2 μC/g, we must increase V_b in

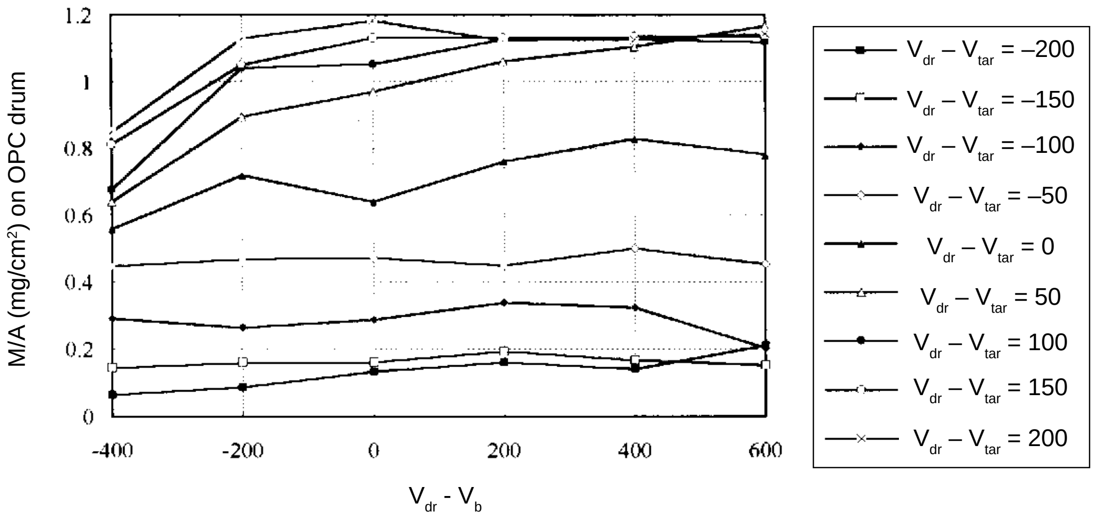

Figure 5. M/A on OPC drum.

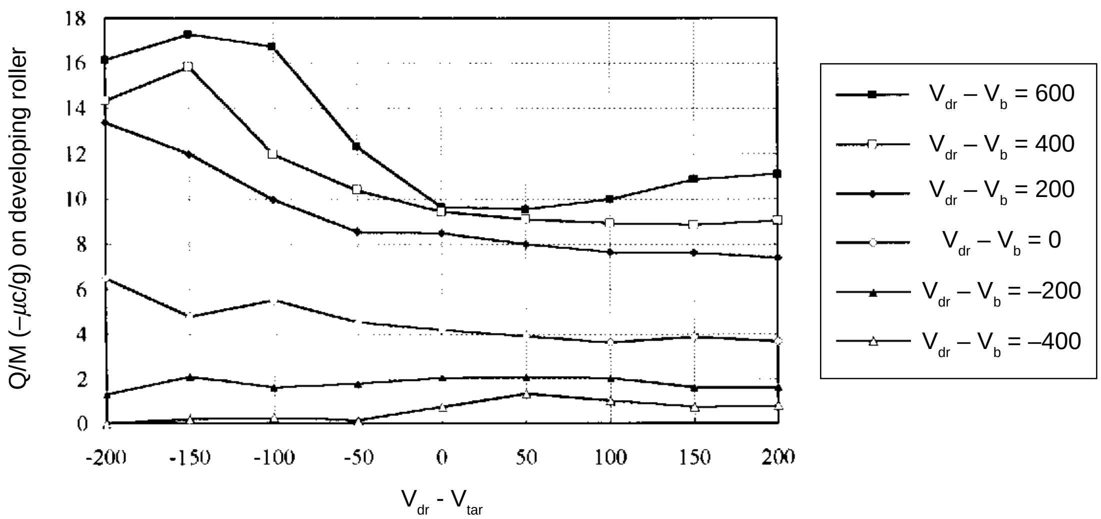

Figure 6. Q/M on developing roller.

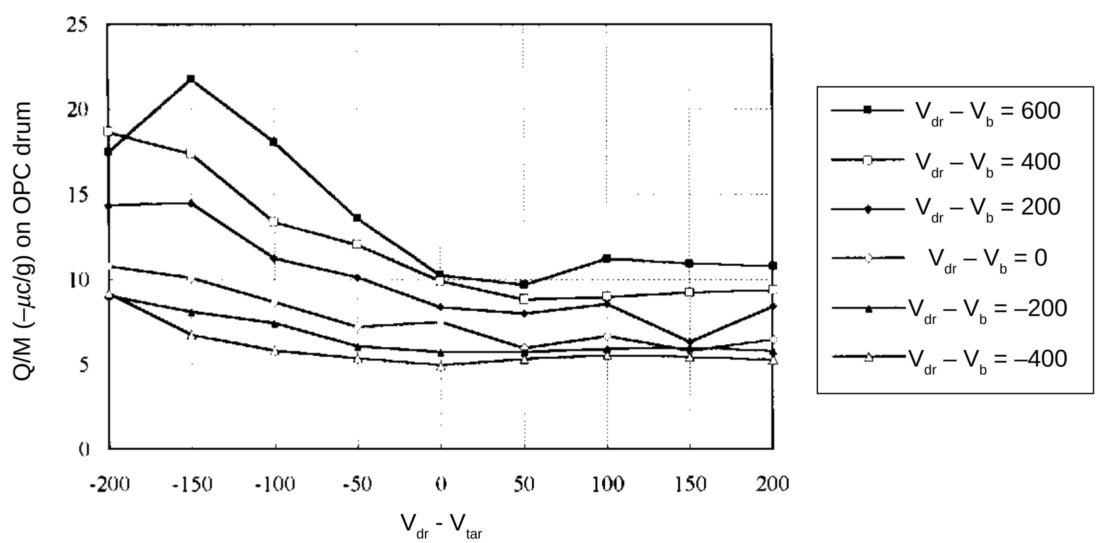

Figure 7. Q/M on OPC drum.

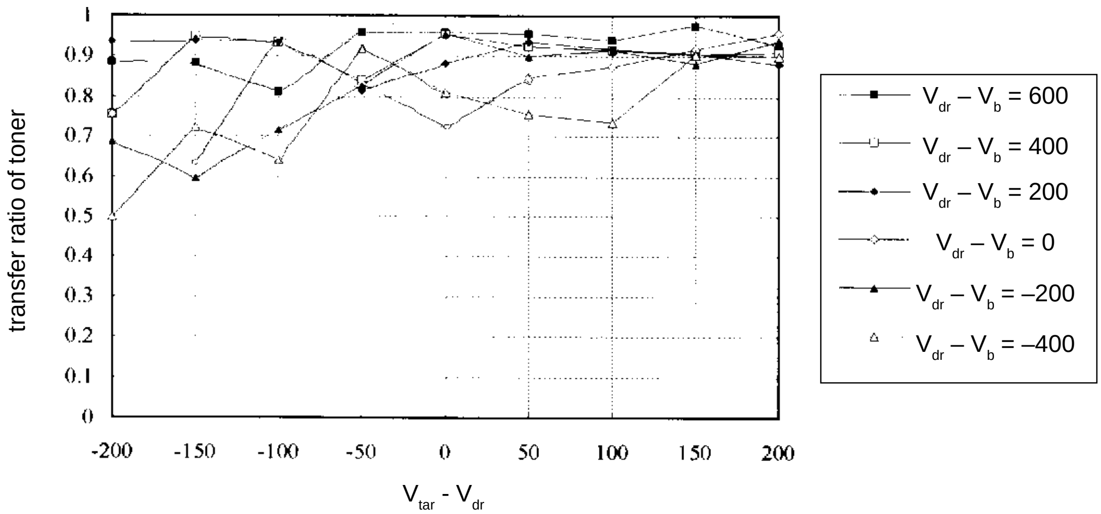

Figure 8. Transfer ratio under different dc bias voltages.

magnitude, for example, $V_{dr}–V_b$ = –200 V. However, the M/A value will reach 0.62 mg/cm^2, as shown in Fig. 2, when V_b is increased. To keep the M/A value at 0.5 mg/cm^2, we must decrease V_{tar} such that $V_{dr}–V_{tar} \cong 17$ V. In the saturation area ($V_{dr}–V_{tar} \geq 100$ V), both the M/A and Q/M values are insensitive to the bias change of the toner-adding roller, but the Q/M values are sensitive to V_b, i.e., we can simply adjust V_b without special concern about the change in M/A values. In practical applications, it may be suitable to operate the development system in this region for convenience.

Effect of DC Bias Voltage on Toner Transfer Ratio. To obtain a background-free printed image, the fraction of wrong-sign toner must be minimized. It is possible to reduce the amount of wrong-sign toner by the use of dc bias. Because the developing roller is usually loaded with a monolayer of toner, the developed mass per unit area reaches the maximum when all of the toner is used[7]:

$$M/A|\max = M/A|\text{roller} * \nu,$$

where ν is the linear velocity ratio of the developing roller to the OPC drum. If we assume the transfer ratio of toner is 100%, we can show the transfer ratio of toner under different dc bias voltages, as in Fig. 8. In general, the toner transfer ratio increased as either $V_{dr}–V_{tar}$ or $V_{dr}–V_b$ increased. The average toner transfer ratio exceeds 90% when both $V_{dr}–V_{tar}$ and $V_{dr}–V_b$ are positive. Also, the effects of $V_{dr}–V_b$ are more obvious than the effects of $V_{dr}–V_{tar}$, even if $V_{dr}–V_{tar}$ is negative. This finding is considered to be the result of additional charging coupled with the electric field created by the dc bias on the doctor blade, which reduces the probability of wrong-sign toner when passing through the doctor blade, as discussed by Thompson.[4] Thus, a clean printing image can be achieved.

Conclusions

The effects of Q/M and M/A on a nonmagnetic monocomponent contact development system under different dc bias voltages are summarized as follows:

1. M/A on developing roller and OPC drum are both saturated when $V_{dr}–V_b \geq 200$ V and $V_{dr}–V_{tar} \geq 50$ V because the development potential is kept at a constant value. The average saturated value is 0.73 mg/cm^2 on the developing roller and 1.13 mg/cm^2 on the OPC drum.
2. M/A is linearly increased on both the developing roller and the OPC drum when $-100 \text{ V} \leq V_{dr} - V_{tar} \leq 50$ V.
3. M/A on the developing roller and the OPC drum is not affected significantly by $V_{dr}–V_b$ when $V_{dr}–V_b$ is in the range of –200 to 600 V.
4. Q/M is affected by $V_{dr}–V_b$ more obviously than by $V_{dr}–V_{tar}$ when $V_{dr}–V_{tar}$ is positive, and the lowest value of $|Q/M|$ of toner transferred to the drum at a constant development potential of 220 V has been observed to be 5 μc/g on average.
5. The higher the value of $V_{dr}–V_b$, the higher the efficiency of toner transfer to the drum.
6. Wrong-sign toner can be reduced by applying appropriate dc bias voltages to obtain background-free printed images.

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