

High-Speed Transfer Method for Colorprinter Using Dielectric Belt

Tsuneo Mizuno, Kunihiko Sato, Masatoshi Kimura, and Masao Konishi
Fujitsu LTD., 1045 Omaru Inagi-shi Tokyo , 206-8503 Japan

Abstract

The electrophotographic printing is the most suitable for color printing of the 50 ppm class, the authors decided to apply conventional technologies as much as possible. However, there were unique technological problems to solve for a color printer, such as the paper transport characteristic and transfer voltage because the tandem method is used for transferring toner images of four colors sequentially.

Therefore, the authors studied the transfer process theoretically and experimentally to achieve ozone-free transfer at a low voltage with stable paper transport. According to the results of this study, a transfer roller was used for the high-speed transfer process using a dielectric belt and the voltage polarity of the dielectric belt was reversed. These measures achieved an ozone-free and low-voltage transfer. Stable paper transport conditions were also clarified to prevent a photoconductive drum from winding paper at the transfer process. In technological terms, it was proved theoretically and experimentally possible to transfer a negative charged toner with a negative transfer voltage under some voltage conditions of the dielectric belt. This added new information to printer process design.

Introductinon

The recent rapid marketing of color printers makes us feel that the age of color hard copies has finally come.

To satisfy the growing expectations for high-speed color printers, the authors planned to develop a business color printer capable of printing fifty A4-size sheets a minute.

Since electrophotographic printing is the most suitable for printing of the 50 ppm class, the authors decided to apply conventional technologies as much as possible. Corona charging was used for precharging and the two-component method for development.

However, there were unique technological problems to solve for a color printer, such as the paper transport characteristic and transfer voltage because the tandem method is used for transferring toner images of four colors sequentially.

A conventional color printer uses a dielectric belt, transfers each color by corona transfer and uses an AC corotron to separate paper. This technology makes a printer a mere ozone generator, far from an ozone-free printer common among low-speed models.

A 50-ppm high-speed color laser printer of the tandem type was developed. Four photoconductive drums were lined to transfer the colors sequentially by the tandem method and a dielectric belt was used for paper transport.

This transfer system had the following three features:

(1) Ozone-free transfer process in a high-speed printer
(2) Low-voltage transfer with a dielectric belt
(3) Stable paper transport to prevent paper winding around the photoconductive drum

Ozone-free Transfer

Corona transfer is the most popular for high-speed laser printers and requires four corotrons for color printing. Belt transport used to use an AC corotron for paper separation and to generate ozone from a total of five corotrons.

Therefore, the authors devised a transfer process of the configuration shown in Figure 1.

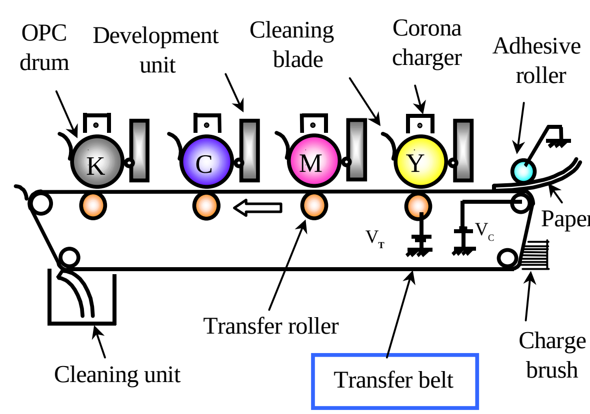

Figure 1. Configuration of the transfer process

Roller transfer was used in place of corona transfer. The transfer process utilizes the dielectric belt characteristics of charge retention with no environmental dependence. The resistivity of the transfer roller was set to $2x10^5$ Ωcm to support high-speed transfer. The low-voltage transfer technology explained was developed to suppress the influence of charge accumulation on the belt during transfer. This technology also suppresses paper adhesion to the belt, resulting in eliminating an AC corotron to neutralize the electric charges on the belt.

The above technological development achieved an ozone-free transfer process.

Low-voltage Transfer

A dielectric belt has the characteristic of retaining a charge. Therefore, every time a transfer voltage is applied, the charge accumulates. As a result, the required transfer voltage becomes high in four transfer operations. To solve this problem, the authors made a theoretical study to reduce the transfer voltage.

Figures 2 and 3 show a transfer model and an equivalent circuit. In Figure 2, the transfer roller voltage is $V_r(t)$, the transfer belt voltage is $V_e(t)$, the paper voltage is $V_p(t)$, the toner layer voltage is $V_n(t)$, and the drum voltage is $V_m(t)$.

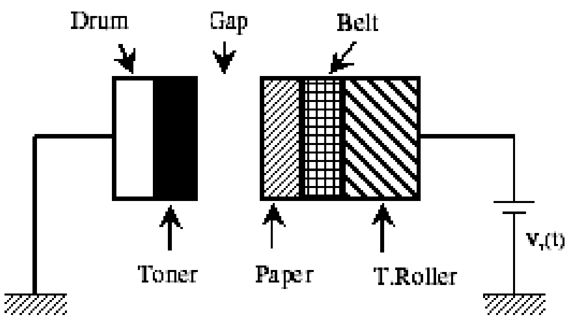

Figure 2. Transfer model

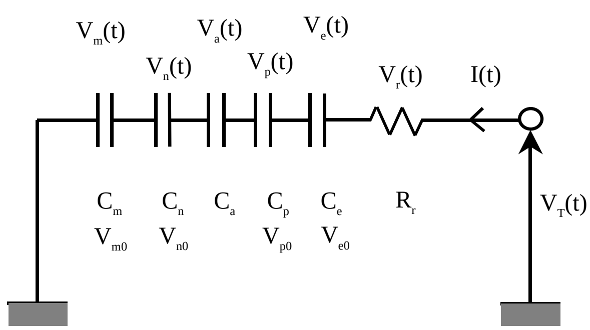

Figure 3. Equivalent circuit

R_r : Equivalent resistance of the transfer roller
C_e : Equivalent capacity of the transfer belt
C_p : Equivalent capacity of the paper
C_a : Equivalent capacity of the air gap
C_n : Equivalent capacity of the toner
C_m : Equivalent capacity of the photoconductive drum
v_{p0} : Initial voltage of the paper
v_{e0} : Initial voltage of the transfer belt
v_{n0} : Initial voltage of the toner layer
v_{m0} : Initial voltage of the photoconductive drum
V_T : Applied bias voltage

Therefore, each layer voltage can be expressed as follows:

$$V_r(t)=(V_T - v_{p0} - v_{e0} - v_{n0} - v_{m0})\ exp(-t/\tau) \quad (1)$$

$$V_e(t)=(C_0/C_e)(V_T - v_{p0} - v_{e0} - v_{n0} - v_{m0})\{1- exp(-t/ \tau)\} + v_{e0} \quad (2)$$

$$V_a(t)=(C_0/C_a)(V_T - v_{p0} - v_{e0} - v_{n0} - v_{m0})\{1- exp(-t/ \tau)\} \quad (3)$$

$$V_p(t)=(C_0/C_p)(V_T - v_{p0} - v_{e0} - v_{n0} - v_{m0})\{1- exp(-t/ \tau)\} + v_{p0} \quad (4)$$

$$V_n(t)=(C_0/C_n)(V_T - v_{p0} - v_{e0} - v_{n0} - v_{m0})\{1- exp(-t/ \tau)\} + v_{n0} \quad (5)$$

$$V_m(t)=(C_0/C_m)(V_T - v_{p0} - v_{e0} - v_{n0} - v_{m0})\{1- exp(-t/ \tau)\} + v_{m0} \quad (6)$$

C_0 and τ represent the combined capacitance and time constant.

$$(1/C_0)=(1/ C_e)+(1/C_p)+(1/ C_a)+(1/ C_n) +(1/ C_m) \quad (7)$$

$$\tau = C_1 R_r \quad (8)$$

Since the toner layer requires a high enough reverse voltage for full transfer,

$$V_n(t) = -v_{n0} \quad (9)$$

Therefore, the relationship between the initial transfer belt voltage and the transfer voltage is as follows:

$$V_T=v_{e0}+v_{p0} +v_{m0} - [2C_n v_{n0} / C_0\{1- exp(-t/ \tau)\}] \quad (10)$$

Figure 4 shows the relationship between the initial transfer belt voltage v_{e0} and the transfer voltage V_T, calculated under $V_n(t) = -v_{no}$. For the calculation, the following parameters were used:

$\rho_r = 2x10^5 \Omega \cdot cm$, ℓ_r= 4mm, ε_0 =8.854x10^{-12}F/m,
ε_e = 3.2, ε_p = 3, ε_n = 2.2, ε_m = 3,
g = 0 (Air gap is negligible.), d_e = 0.1mm,
d_p = 0.1mm, d_n = 22.5µm, d_m = 18µm
v_{no}= -120V, v_{po}=75V, v_{mo}= -50V, t=1ms.

$R_r = \rho_r \ell_r$
$C_e = \varepsilon_0\ \varepsilon_e / d_e$
$C_p = \varepsilon_0\ \varepsilon_p / d_p$
$C_n = \varepsilon_0\ \varepsilon_n / d_n$
$C_m = \varepsilon_0\ \varepsilon_m / d_m$

ρ_r : Resistivity of the transfer roller
ℓ_r : Thickness of the transfer roller
ε_0 : Dielectric constant
ε_n : Relative dielectric constant of the toner
ε_m : Relative dielectric constant of the photoconductive drum
d_e : Thickness of the transfer belt
d_p : Thickness of the paper
d_n : Thickness of the toner
d_m : Thickness of the photoconductive drum

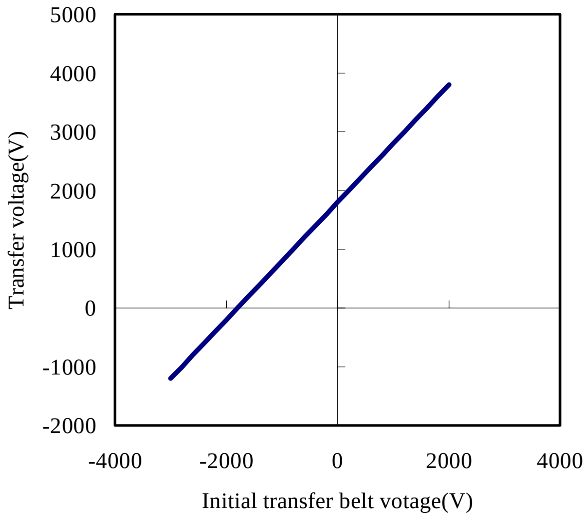

Figure 4. Initial belt voltage and transfer voltage

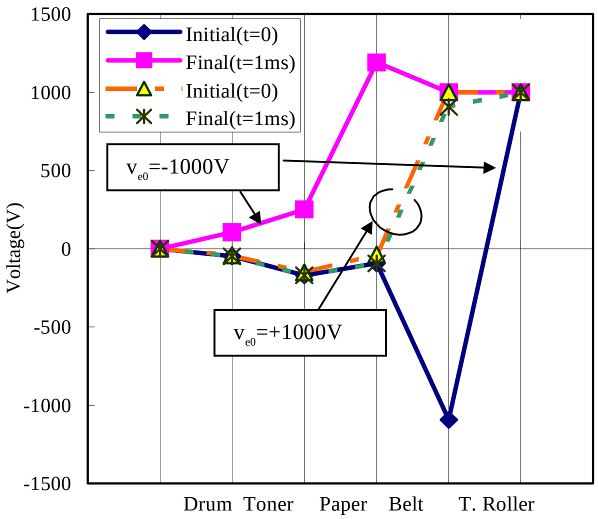

Figure 5. Voltage distribution (transfer section)

In the figure, the more negative the initial belt voltage, the lower the transfer voltage. When the initial belt voltage is -2000 V or less, the toner can be transferred even if the transfer voltage is negative. This is the greatest feature of a dielectric belt that transfers a negative toner by a negative transfer voltage.

To clarify this phenomenon, Figure 5 shows voltage distribution in each section during transfer. For comparison, the initial belt voltage is set at +1000 and -1000 V and the transfer voltage is set at 1000 V.

In the figure, when the initial belt voltage is +1000 V and -1000 V, the inclination is reversed and the voltage at the transfer roller section of low resistance is completely different even when the same 1000 V is applied to the transfer roller. In other words, changing the transfer belt polarity produces an effective voltage difference and lowers the transfer voltage. Therefore, the more negative the initial belt voltage, the lower the transfer voltage. Even a negative toner can be transferred at a negative transfer voltage.

Stable Paper Transport

A dielectric belt sticks and transports paper. A stable transport condition is to prevent the photoconductive drum from winding paper.

Figure 6 shows the results of measuring the relationship between the paper voltage and adhesive force. The adhesive force was measured by pulling the front edge of A4-size paper with a spring scale. The transfer belt voltage was -1000 V. The adhesive force is generated whether the paper voltage is positive or negative. The paper voltage becomes positive if the voltage applied to the adhesive roller is set higher than the transfer belt voltage and negative if set lower.

Then paper winding tendency of the photoconductive roller was checked.

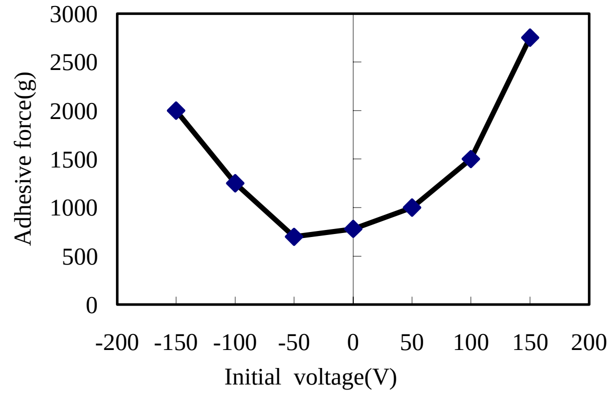

Figure 6. Adhesive force for paper

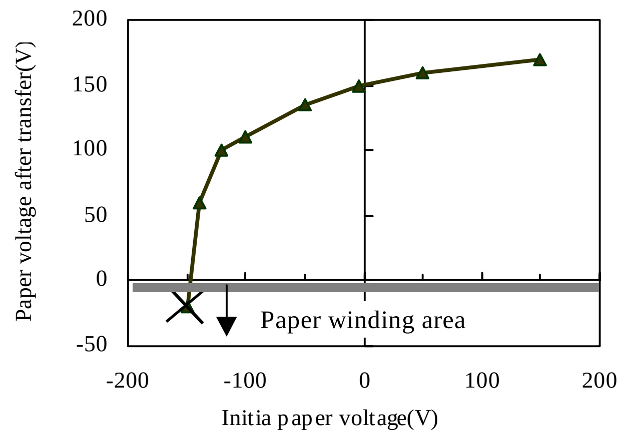

Figure 7. Paper voltage and paper winding area

Figure 7 shows the relationship between the paper voltage and the paper winding area when the transfer belt voltage was -1000 V and the transfer voltage was 1000 V.

The Y-axis indicates the paper voltage after transfer. As clear in the figure, the photoconductive drum winds paper in an area where the paper voltage after transfer is negative.

When the paper polarity is negative and the voltage on the photoconductive drum is positive, the attraction force is generated between these charges when separating paper. For stable paper transport, paper must be charged with a positive voltage before transfer. (The photoconductor surface and paper contact surface should have the same polarity.)

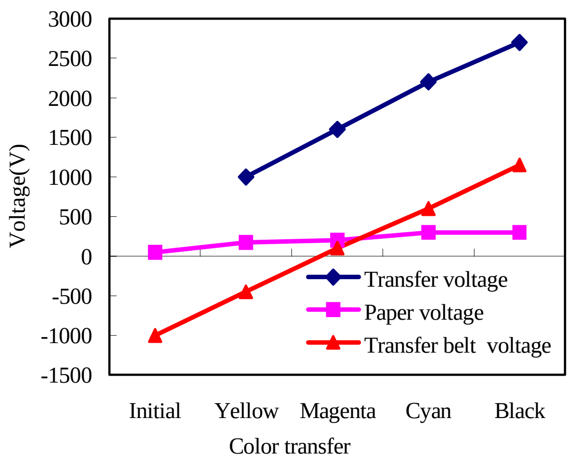

Figure 8. Color transfer voltages

Transfer Characteristic of Color Toner Images

Figure 8 shows the transfer voltage of each color and the belt and paper voltages after transfer. Since the initial voltage of the transfer belt is negative, the transfer voltage for the black color is suppressed to 2700 V even when a charge is accumulated during transfer. If the initial voltage setting of the transfer belt is lowered, the transfer voltage also goes down accordingly.

Conclusion

An ozone-free transfer process was developed to transfer toner images at a low voltage using a dielectric belt. In principle, this technology is applicable to the transfer process not only for high-speed printers but also for low-speed printers. This is the basic transfer technology for color printers.

References

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Biography

Tuneo Mizuno received his B.S. degree in Electronic Engineering from the Shinshu University in 1974 and a M.S. degree in Electronic Engineering from the Shinshu University in 1976. Since 1976, he has worked in the Fujitsu Limited. He engages in development of non-impact printing techniques. His work has primarily focused on the development electrophotographic process. He is a member of the IEICE and The Imaging Society of Japan.

E-mail : mizuno@apt.cs.fujitsu.co.jp