Paper: Evaluations of toner supply capabilities for some typical two-component developing systems

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Abstract

Two-component developing system has an advantage in durability for high speed and heavy-duty use in an electrophotographic laser printer. For achieving high speed and heavy duty printing, the most important factor is toner supply capability from developing rolls to a photo-conductor surface.

In this study, the capability with print speed for each method on the two-component developing system employing magnet rolls composed of rotating sleeves with stationary core including a donor rolls system is examined. For the examinations, some assumptions for factors, which affects to the toner supply capability, and toner mass on the photo-conductor are made.

As a result, we found typical speed ranges and their characteristics for the toner supply capability in the two-component developing systems. 700 mm/s print speed can be achieved by the examined methods. The print speed exceeding 1500 mm/s can be achieved by a method of two-roll use of the rotating sleeve with stationary core magnet rolls of 50 mm diameters with different rotation direction.

Introduction

Two-component developing system has an advantage in durability for high speed and heavy-duty use in an electrophotographic laser printer. For the two-component developing systems, methods employing a rotating sleeve with stationary core and both a sleeve and core rotating magnet rolls are used. The rotating sleeve with stationary core method is mainly used for super-high speed printers, exceeding print speed of 500 mm/s and 100 pages per a minute. In this paper, examinations on toner supply capability from the developing rolls to a photo-conductor surface for the two-component developing system employing the rotating sleeve with stationary core magnet rolls are carried out.[1]

In this category, methods employing a single magnet roll, multi-roll with same rotation direction and multi-roll with different rotation direction are known. Recently, for achieving both the high speed durability and high image quality, a new method using donor rolls for the developing rolls in the two-component developing system have been appeared in the category, which has a rotating sleeve with stationary core magnet roll. [2][3]

For achieving high speed and heavy duty printing, the most important factor is the toner supply capability from the developing rolls to a photo-conductor surface. In this study, the capability with print speed for each method mentioned above is examined.

The toner supply to the photo-conductor for each method is derived from a same experimental base data, which is a relationship between developed toner mass and surface speed ratio of a photo-conductor and developing rolls, by Anzai, et.al.. [1].

As a result, we found typical speed ranges and their characteristics for the toner supply capability from the developing rolls to a photo-conductor surface in the two-component developing systems.

Classifications for Developing Systems

Broadly, the two-component developing systems employing the rotating sleeve with stationary core magnet rolls are classified into two types. One is a magnetic brush developing system, in which magnetic brush touches a photoconductor. The other is a donor roll developing system, in which toner layer without carrier beads is transferred to the photoconductor.

In detail, the former systems are classified into types with single magnet roll, multi-roll with same rotation direction and multi-roll with different rotation direction.

Four types of the developing systems, listed below, are examined in this study. Stationary core magnetic brush developing systems are in 1) – 3). Donor roll developing system is in 4).

1) Single rotating sleeve with stationary core roll with photoconductor rotation direction.
2) Two rotating sleeve with stationary core rolls with photoconductor rotation direction.
3) Two rotating sleeve with stationary core rolls against and with photoconductor rotation directions.
4) A donor rolls developing system.

For the examinations, assumptions for developing roll diameter, which affects to the toner supply capability, and toner mass on the photo-conductor are made as follows. Roll diameters are assumed as 30 mm and 50 mm for single and two-roll uses, 1)-3). For the donor roll method, 4), two donor rolls and a 50 mm diameter magnetic roll behind the donor rolls are assumed. For the image quality, the toner mass on the photo-conductor is assumed as 0.45 mg/cm^2. For developer efficiency, A/φ, 0.23 is employed for the developed toner mass estimation. Developing electric field is assumed to be toner mass ratio between line and solid images, 1.1.

Evaluations for Each Developing System

Single rotating sleeve roll with photoconductor rotation direction

Figure 1 shows a typical developing system for single roll. The magnetic brush is built at a developing gap on the single magnet roll. The toner is developed on the photoconductor there. Developing performance with the magnetic roll rotation is shown in Figure 2. The data are derived from a published literature by Anzai, et.al.. [1] As typical developer efficiency, A/φ, 0.23 is employed for the developed toner mass estimation. For obtaining developed 0.45 mg/cm^2 toner masses on the photoconductor, tangential velocity ratio between the magnetic roll and the photoconductor must be 2.7. Assuming the 30 mm diameter magnet roll and 800 rpm rotation limitation, the photoconductor velocity (i.e. process speed) is derived as 530mm/s. For 50 mm roll diameter of the magnet rolls, the process speed is derived as 880 mm/s.

Two rotating sleeve roll with photoconductor rotation direction

Figure 3 shows a typical developing system for two rotating sleeve rolls with the photoconductor rotation direction. The magnetic brushes are built at the developing gaps on each magnet roll. The toner is developed on the photoconductor at the two portions. For the developed toner mass estimation, the data shown in Figure 2 is employed under the conditions of A/φ=0.23. Figure 4 shows total developing performance with the magnetic roll rotation for two rotating sleeve rolls with the photoconductor rotation direction. To derive the total developing performance, superposition for the data shown in Figure 2 is made. Denoting M_{max} for the maximum developed toner mass, S for the tangential velocity ratio between the magnetic roll and the photoconductor and C for a ratio between the developed toner mass at S and M_{max}, a developed toner mass at an upper roll, M_u, is derived from Equation (1).

$$M_u = C \cdot M_{max} \quad (1)$$

A total developed toner mass including a lower magnet roll, M, is derived with superposing from Equation (2). The second term in Equation (2) expresses a developed toner mass by the lower magnet roll.

$$M = M_u + C \cdot (M_{max} - M_u) \quad (2)$$

For obtaining developed 0.45 mg/cm^2 toner masses on the photoconductor, tangential velocity ratios between the each magnetic roll and the photoconductor must be 2.0. Assuming the 30 mm diameter and 800 rpm rotation limitation for the each magnet roll, the photoconductor velocity (i.e. process speed) is derived as 740 mm/s. The process speed is derived as 1230 mm/s for 50 mm diameter of the magnet rolls.

Two rotating sleeve roll against and with photoconductor rotation direction

Figure 5 shows a typical developing system for two rotating sleeve rolls against and with the photoconductor rotation direction. The developer is supplied to two magnet rolls through each doctor gap, diverged from behind region. The magnetic brushes are built at the developing gaps on each magnet roll. The toner is developed on the photoconductor at the two portions. For the developed toner mass estimation, the data shown in Figure 2 is employed under the conditions of A/φ=0.23. Figure 6 shows total developing performance with the magnetic roll rotation for two rotating sleeve rolls against and with the photoconductor rotation direction. To derive the total developing performance, the data in Figure 2 is used. Denoting S_u and S_l for the tangential velocity ratio between the upper and lower magnetic rolls and the photoconductor, respectively and, C_u and C_l for a ratio of the developed toner masses at S_u and S_l, to M_{max}, respectively, a developed toner mass at an upper roll, M_u, is derived from Equation (1).

$$M_u = C_u \cdot M_{max} \quad (3)$$

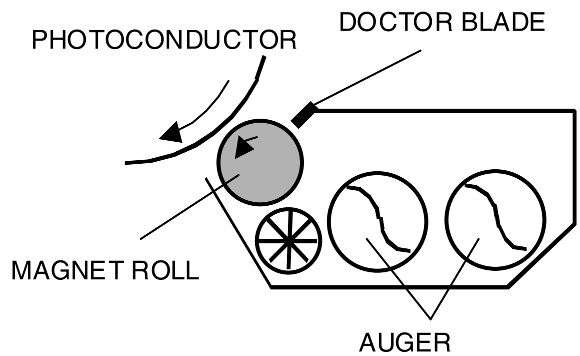

Figure 1. Single Roll Developing System.

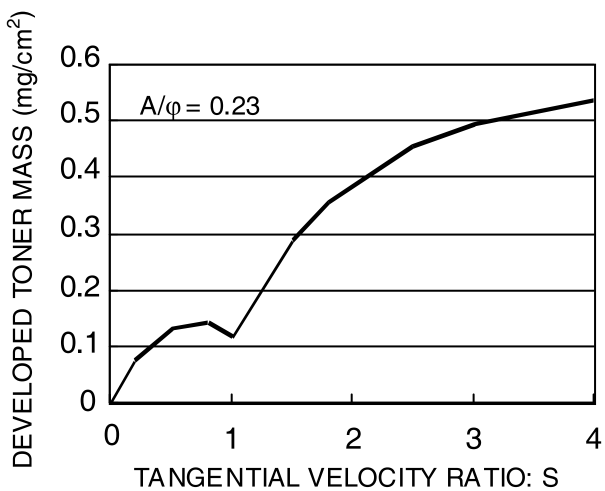

Figure 2. Developing Performance for Single Roll Developing System.

A total developed toner mass including a lower magnet roll, M, is derived with superposing from Equation (4). The second term in Equation (4) expresses a developed toner mass by the lower magnet roll.

$$M = M_u + C_l \cdot (M_{max} - M_u) \quad (4)$$

For obtaining developed 0.45 mg/cm^2 toner masses on the photoconductor, absolute values of the tangential velocity ratios between the each magnetic roll and the photoconductor must be 1.5. Assuming the 30 mm diameter and 800 rpm rotation limitation for the each magnet roll, the photoconductor velocity (i.e. process speed) is derived as 900 mm/s. The process speed is derived as 1500 mm/s for 50 mm diameter of the magnet rolls.

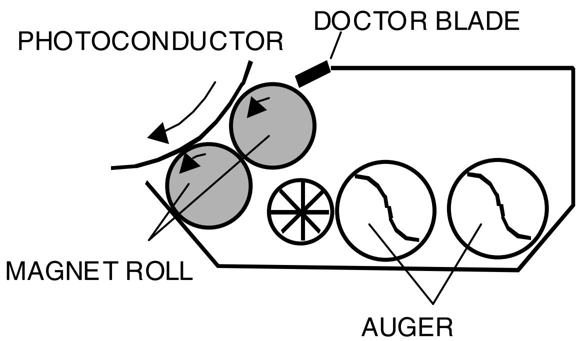

Figure 3. Developing System of Two Rotating Sleeve Rolls with Photoconductor Rotation Direction.

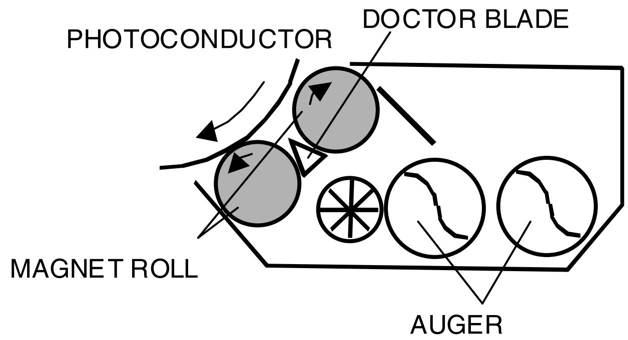

Figure 5. Developing System of Two Rotating Sleeve Rolls Against and With Photoconductor Rotation Direction.

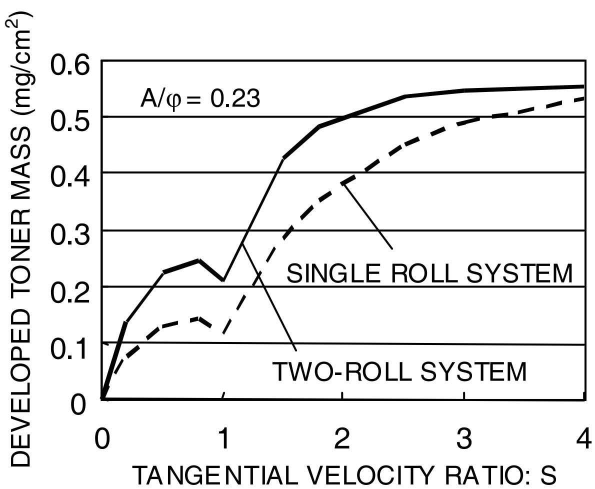

Figure 2. Developing Performance for Two Rotating Sleeve Rolls with Photoconductor Rotation Direction.

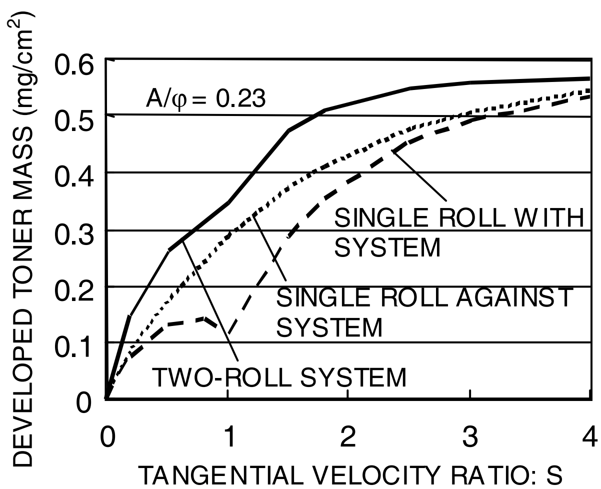

Figure 6. Developing Performance for Two Rotating Sleeve Rolls Against and With Photoconductor Rotation Direction.

Donor rolls developing system

Figure 7 shows a typical donor roll developing system. [2] Two donor rolls for developing are installed and one magnetic roll, with larger diameter, is arranged behind the donor rolls. Thin toner layers are developed on the donor rolls by magnetic brush on the magnetic roll composed of a rotating sleeve with a stationary core. [3] The toner layers on the donor rolls are transferred to the photoconductor. Thus, developing process is carried out. [2][3] Uniform toner layers on the donor rolls must be needed in anytime for avoiding afterimages. Therefore, the thin toner layer on the donor rolls just after development, which have areas of lacked toner corresponding to developed images, must be restored and become uniform by being filled fully with new toner in one rotation. For obtaining such a full development in one rotation, very high development performance to the donor rolls by the magnetic roll is required.

In this study, two donor rolls and a 50 mm diameter magnetic roll behind the donor rolls are assumed for evaluation. Figure 8

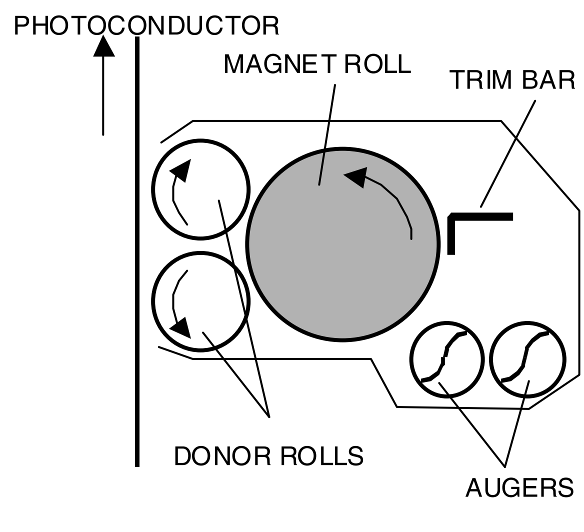

Figure 7. Donor Roll Developing System.

represents developed toner mass with tangential velocity ratio between the magnetic roll and the donor roll. [1] Assuming A/φ=0.26, as same as the evaluations of the magnetic brush developing systems, the tangential velocity ratio 2.9 is needed in the donor roll with the same rotation direction for the magnet roll, upper donor roll, for achieving 90% restoration of the toner layer in one rotation. Thus, very high-speed rotation for the magnet roll is required. This causes speed limitation for the developing system. Assuming 800 rpm rotation limitation for the each magnet roll, the tangential velocity ratio 2.9 derives 720 mm/s photoconductor velocity (i.e. process speed).

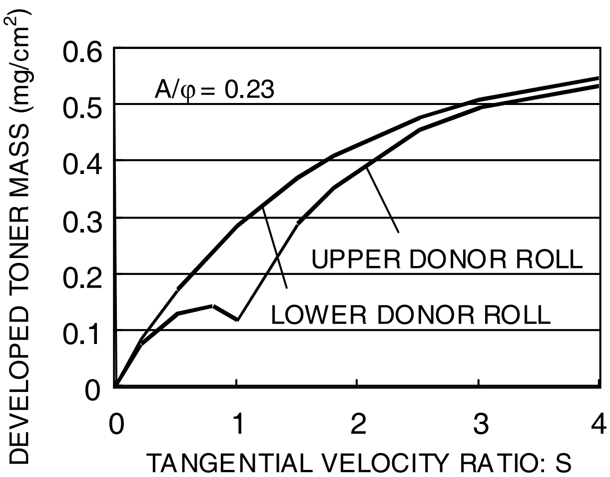

Figure 8. Developing Performance for Donor Rolls.

Performance Comparison

Figure 9 shows a comparison between the developing systems evaluated in this paper. Same conditions, of 0.45 mg/cm^2 toner mass on photoconductor, 0.23 A/φ, 1.1 toner mass ratio between line and solid images, and 800 rpm maximum rotation of the magnet rolls, are used in the evaluation for comparison. Therefore, if the conditions are changed, the performance can be improved in products. 700 mm/s print speed can be achieved by the examined methods. The print speed exceeding 1500 mm/s can be achieved by the method of two-roll use of the rotating sleeve with stationary core magnet rolls of 50 mm diameters with different rotation direction. Comparing the results restricted in the 50 mm roll diameter, the developing system of the two-roll use with different rotation direction has the most capability for the toner supply from the developing rolls to a photoconductor surface. Next to it, the developing systems of the two-roll use with same rotation direction, the single roll use and the donor rolls system are listed by the toner supply capability.

Conclusions

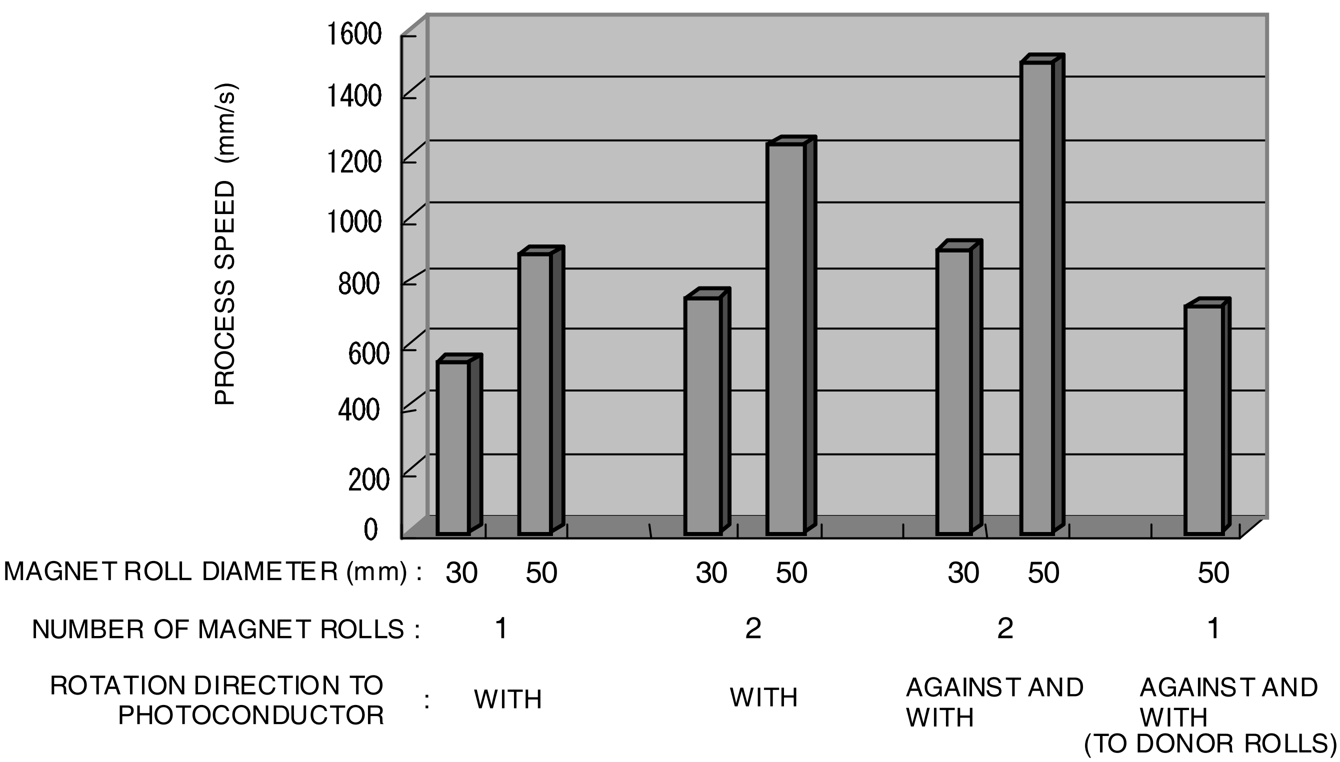

Figure 9. Toner Supply Capability Comparison Between Developing Systems.

Examinations on toner supply capability from magnet rolls employing rotating sleeve with stationary core to a photo-conductor and donor rolls surfaces for some typical two-component developing systems are carried out.

The developing system of two-roll use with different rotation direction, the developing systems of two-roll use with same rotation direction, single roll use and the donor rolls system are listed by the toner supply capability.

References

[1] Masayasu Anzai and Nobuyoshi Hoshi, “Prediction of Deposit Toner Mass by Improved Toner Flow Model for Dual Component Magnetic Brush Development”, Proc. IS&T’s NIP 14, pg.462 (1998)

[2] Raymond Clark and David Craig, “Xerox Nuvera Technology for Image Quality”, Proc. IS&T’s NIP 21, pg.671 (2005)

[3] James R. York, US Patent 6,788,904 B2 (2004)

Author Biography

Teruaki Mitsuya was born in Aichi-Pref., Japan in 1957. He received his BE, ME and Dr. Eng. degrees in 1980, 1984 and 1997, respectively. He has been researching imaging technologies in laser printers, in Hitachi, Ltd. from 1984, California Inst. Tech. from 1994, Hitachi Koki Co., Ltd. from 1995, Hitachi Printing Solutions, Ltd. from 2002 and Ricoh Printing Systems, Ltd. since 2004. He is a member of IS&T, ISJ, ASME, JSME, etc.