

Color Laser Printer :Color Registration by QLPT Mechanism

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Abstract

A small color laser printer using four all-in-one color cartridges and one laser scanning unit (LSU) has been developed. Each color cartridge contains an OPC drum, a charger, a cleaner, and a color developing unit. The cartridges are rotationally switched to produce each color image which is superimposed on an intermediate transfer (IMT) belt. The superimposed full-color image is transferred to paper all at once. The primary feature of this structure is the use of four all-in-one cartridges. It makes color laser printer as easy to use as monochrome ones. When using four OPC drums, each OPC drum has mechanical differences which would normally cause registration errors among colors in conventional mechanisms. The newly developed "QuaLity Positioning Technology" (abbreviated to QLPT) mechanism cancels the registration errors and ensures better image quality. The QLPT mechanism consists of three points, which are

1) Holding and locating mechanism;
2) Solid coupling and synchronizing mechanism;
3) Slipping correction mechanism.

The essence of the QLPT mechanism is described below.

Introduction

Electrophotography has become one of the most popular types of printing technology in copiers and printers for forming monochrome and full-color images. We have developed a new compact full-color laser printer shown in Figure 1 and Table 1, which is named the "Color Revolver".

The printer is equipped with four all-in-one cartridges for each color, an LSU, an IMT belt unit, a transfer roller, and a fuser unit. Each cartridge, which has a sector shape and is assembled into a rotary carousel, contains an OPC drum, a charger, a cleaner, and a developing unit with a non-magnetic mono component contact developing method. The color toner images (yellow, magenta, cyan, black) formed on each drum are sequentially superimposed onto the IMT belt. The full color image formed on the IMT belt is transferred to the paper all at once using a transfer roller.

Jammed paper can be removed by opening the front door of the printer, and the IMT belt can be replaced easily as a unit from the front door. The four color cartridges are removable through the top door. So is the fuser unit through the front top door. Therefore all maintenance operations can be performed from the front of the printer. And the adoption of four all-in-one cartridges eliminates hand-dirtying problems and makes handling of the OPC easier. They make usual maintenance of full color laser printer as easy as that of monochrome lasers.

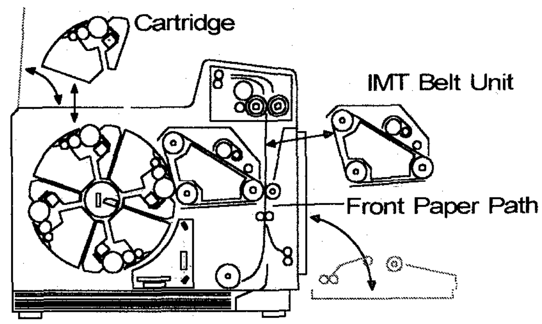

Figure 1. Color Revolver

Table 1. Specification of Color Revolver

Method	Electrophotography
Print speed	3/16 ppm (color/monochrome)
Resolution	600/1200 dpi
Media	Plane paper, envelope, OHP
Media size	A4, B5, letter, legal, postcard
Life of cartridge	10,000 images
Life of IMT belt unit	100,000 images

Problems to be solved

For all color printers, registration among colors has been a very important feature throughout[1)], and monochrome lasers ordinarily using an all-in-one cartridge are free from color registration errors. The Color Revolver using four cartridges contains four OPC drums, while the conventional 4-path structure contains only one. With the Color Revolver, the most worrisome point for high quality images was registration among colors in the sub-scanning direction. Four OPC drums have four different geometric characteristics which can cause fluctuations in the transfer timing onto the IMT belt, which in turn can cause registration errors. So, without a high precision mechanism, the adoption of four drums has been regarded as likely to result in a higher incidence of registration errors than the conventional structure, and similarly in the tandem structure[2)]. The specific points of registration error in the 4-drum structure and the QLPT mechanism as a means of countering this are described below.

Specific registration error caused by 4 drums

An example of a blue image with registration error is shown in Figure 2. In this image, the cyan image is shifted from the magenta image. The Color Revolver is equipped with one LSU, so that the registration errors in the horizontal direction are easy to cancel, in the same way as for conventional 1-drum structures. The magnitude of the registration error in the vertical direction fluctuates along the position from the image head. In Figure 2, d_{ave} indicates the average registration error (called the DC component) in the image, and f(y) indicates the fluctuation (called the AC component). The AC component of the registration error is periodic as described later. The registration error should be below about 100[μ m][3]. The three major causes of specific registration error in a 4 drum structure are described below.

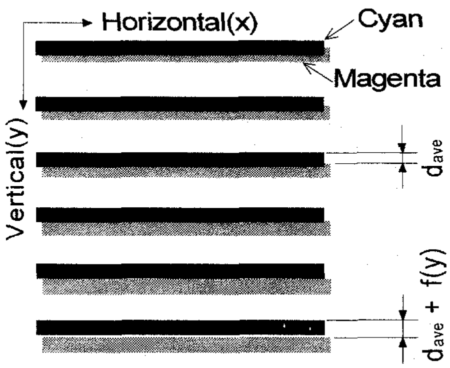

Figure 2. Example of registration error

1.Misalliment of rotation center

Misalignment of the rotation center changes the rotation angle of the OPC drum from the laser exposure to the transfer as shown in Figure 3.

In this Figure, the center of the magenta drum is at normal position O, and the center of the cyan drum is at misalignment position O'. The rotation angle from the exposure to the transfer is 180 degrees for magenta, while that of cyan is θ (not 180 degrees). Even the exposure by the laser scanning unit is done in proper time, with the transfer timing becoming discrepant. Therefore the cyan image which should be transferred over the magenta image is transferred to the shifted position. The registration error caused by this factor is uniform on the paper, and it is shown as the DC component in Figure 2.

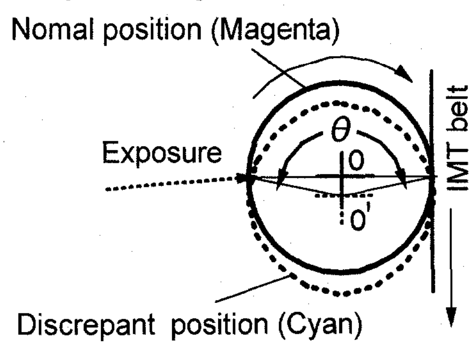

Figure 3. Schematic diagram of center position discrepancy

2.Fluctuation of angular velocity

The usual way to drive an OPC drum is by a gear fixed at one end. A couple of gears transmit peripheral velocity on the pitch circles. The gear has eccentricity in the pitch circle, which causes periodic fluctuations in the angular velocity of the OPC drum. If the four drums each had fixed gears, each drum would have different fluctuations in angular velocity from each other. Fluctuations in angular velocity elongate and shorten the image on the OPC drum. So even if the image head is transferred to the same position, the position at which the later part is transferred will shift periodically. In Figure 4-a, the abscissa indicates the distance from the image heads for one peripheral length of an OPC drum. The fluctuation is repeated in the peripheral length of the drum, and the angular velocity fluctuation indicated in the left ordinate causes the position discrepancy indicated in the right ordinate. The registration error is shown as the distance between the position line for magenta and that for cyan. The maximum quantity of registration error is indicated as d_{max}. The image brought by the velocity fluctuation corresponding to Figure 4-a is shown in Figure 4-b. In this figure, the image should be a blue isosceles triangle. The magenta image is shortened in the former part, and elongated in the latter part. On the other hand, the cyan image is elongated and shortened in the opposite way. So the peaks which should be in accord at the regular position will shift by half of d_{max} to the opposite direction.

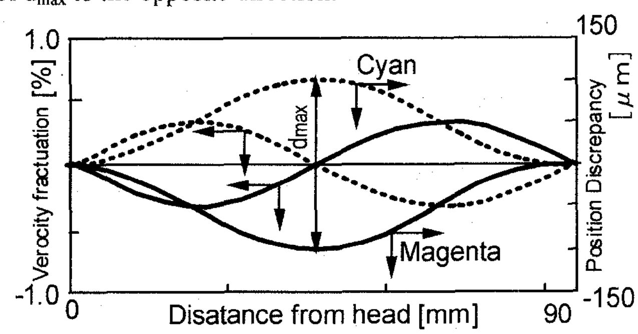

Figure 4-a. Velocity fluctuation and position discrepancy

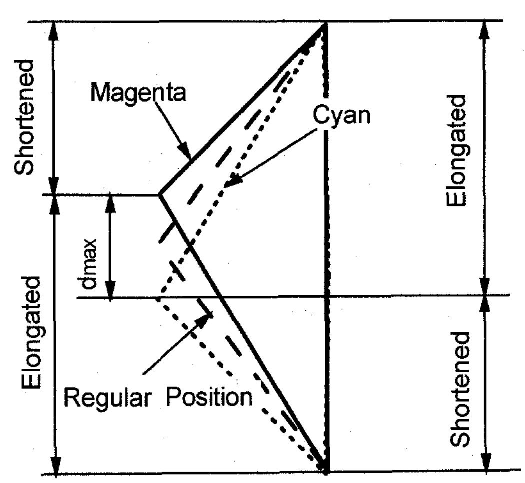

Figure 4-b. Image corresponding to Figure 4-a

3.Eccentricity of OPC drums

Because the four drums have their own specific eccentricity, each drum has a different periodical fluctuation in its surface velocity. Fluctuation in the surface velocity periodically elongates and shortens the image on the OPC drum which is exposed by the scanning laser, similar to the description in the former section. Therefore, if the image formed on the OPC drums are superimposed on the IMT belt as is, even the image head is transferred to the same position, and the latter part will be discrepant as shown in Figure 4.

Structure of QLPT mechanism

The QLPT mechanism is designed to solve the above specific registration errors in a 4-drum structure. The QLPT mechanism consists of three parts as shown in Figure 5. Each part is described in detail below.

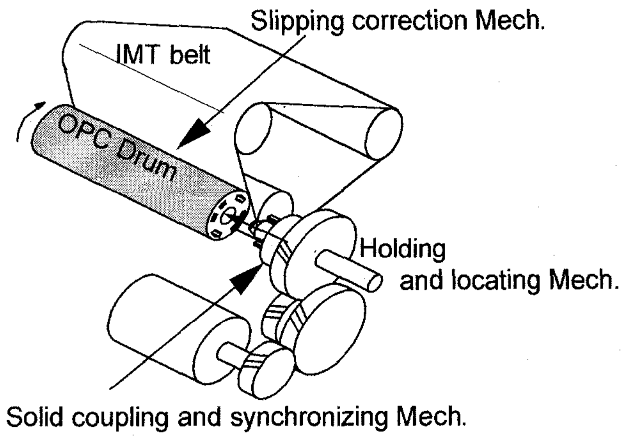

Figure 5. QLPT mechanisms

1.Holding and locating mechanism

In this mechanism, each OPC drum has flanges with a tapered center cavity at the both ends, and the main body of the printer has a couple of rotatable shafts as shown in figure 6. The shafts have tapered ends which are thrust into the tapered center cavity, and locate the OPC drum at the image forming position. As they are held with rotatable shafts, each drum can rotate with the rotation center of the shafts, so that the four OPC drums share an identical rotation center at the image forming position. Even if the geometrical center of the drum is different from the axis of the center cavity, the rotation center is defined by the shafts in the main body. Therefore the drum rotation center is independent of the geometric characteristics of the drums.

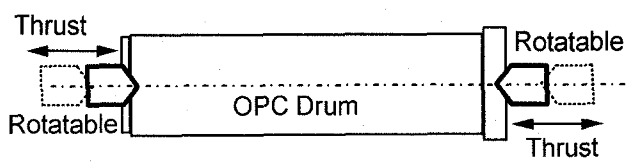

Figure 6.Holding and locating mechanism

2.Solid coupling and synchronizing mechanism

In this mechanism, each OPC drum has a driven coupling at one end, and it is engaged with a driving coupling fixed to one of the center shafts mentioned in the former section, as shown in figure 7. Each coupling has pawls which engage each other. Driven by engaged couplings which rotate around the identical rotation center, each drum should rotate at an identical angular velocity to the driving coupling. So the four drums rotate with identical fluctuations in angular velocity caused by the driving parts in the main body. Because the angular velocity is defined by the driving parts in the main body, the angular velocity of each drum is independent of its geometric characteristics.

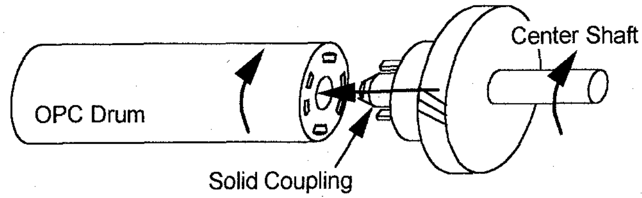

Figure 7. Solid coupling and synchronizing mechanism

The identical fluctuation in angular velocity should also be synchronized on the IMT belt to prevent registration errors. For synchronization, the driving parts in the main body are designed to rotate a whole number of times during one rotation of the IMT belt. This means that the gear ratios shown in Figure 5 are whole and the peripheral length of the IMT belt is multiplied a whole number of times that of the OPC drum and the supporting rollers of the IMT belt.

3.Slipping correction mechanism

By means of the above mechanisms, the drums should rotate with the same fluctuation in angular velocity. Therefore, the only residual problem is the eccentricity of the drums. With this mechanism, the IMT belt is driven independently from the geometrical characteristics of the drums, so the image at the large radius region which is elongated during the exposure will be shortened during the transfer, and the shortened image at the small radius region will be elongated oppositely, as shown in Figure 8. Therefore the image length on the IMT belt should become regular independent of the length on the drum, which depends on the eccentricity of each drum.

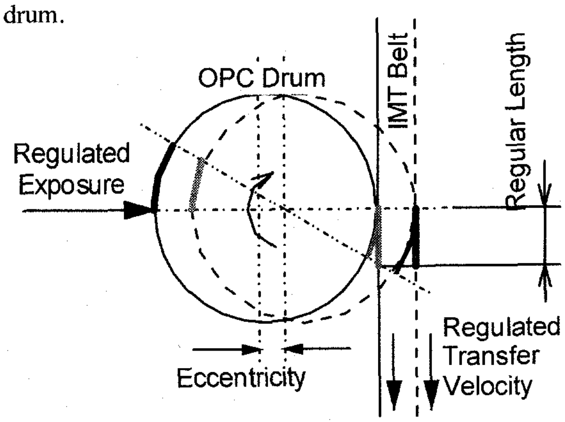

Figure 8. Sliding correction mechanism

Registration Performance

As explained above, the QLPT mechanism can solve specific registration errors for the 4-drum structure without finely machined mechanisms. The equally pitched horizontal blue lines which are printed by the Color Revolver equipped with a QLPT mechanism was investigated. The distance between a magenta line and a cyan line for blue lines was measured by a microscope to determine the registration error.

The distribution of the average registration error in one sheet (DC component) is shown in Figure 9. The DC component is caused by misalignment of the rotation center and discrepancy in the exposure start timing, which depends on laser scanning timing and detection of the belt position. For 600 dpi laser scanning, the scanning pitch is about 40[μ m]. It is equivalent to the distribution width shown in Figure 9. It indicates the misalignment of the rotation center by the QLPT Mechanism is negligible.

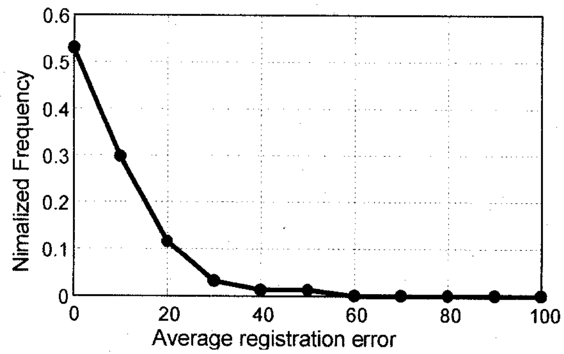

Figure 9. Distribution of DC registration error

The fluctuation in the registration error in one sheet (AC component) is shown in Figure 10. The AC component is caused by discrepancy in fluctuation in the angular velocity and the peripheral velocity. The amplitude of fluctuation is under 10[μ m] and the fluctuation has no periodicity. This indicates that the influence of fluctuation in the angular and the peripheral velocity becomes negligible through use of the QLPT mechanism.

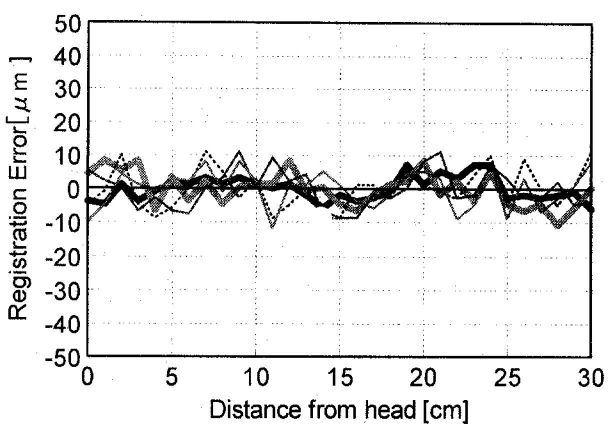

Figure 10. Fluctuation of AC registration error

Conclusion

The specific registration error with the Color Revolver using four color all-in-one cartridges has been investigated. The QLPT mechanism has been designed to counter this error, and consists of the following three sub-mechanisms;

1) Holding and locating mechanism;
2) Solid coupling and synchronizing mechanism;
3) Slipping correction mechanism.

A Color Revolver equipped with the QLPT mechanism could output high quality images without the specific registration error described above. Adopting four all-in-one cartridges, an IMT belt unit, a fuser unit, and front side paper path brought us a convenient color laser printer which is similar to monochrome lasers. The Color Revolver realized both ease of use and high quality electrophotographic images.

References

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Biography

Kenji Asakura received his B.S. degree in the Physics of Mecanical Engineering from Tokyo Institute of Technology in 1986 and his M.S. degree in 1988. Since 1988 he has worked at the technology development section of Matsushita Electric Industrial Co. Ltd. His work has primarily focused on the fundamentals of electrostatic printing methods.

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