An Experimental Design for Non-Contact Type Single Component Non-Magnetic Development System

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Abstract

Single component non-magnetic development systems are widely used in desktop laser printers because of their low cost, small size and color printing ability. In particular, non–contact type single component development systems have been studied and developed for several years because of higher resolution printing.

The performance of the non-contact type developing systems depends on the property of developing roller, the mechanism of the thin layer forming with metering blade based on the toner formulation. In general, there are two kinds of developing roller for the non–contact type. One is hard roller made of aluminum with a coated layer, and the other is soft roller with a conductive elastic rubber.

In recent years, printing speed and resolution in digital printing have been increasing due to various market requirements. However, it is very difficult to have durability at the higher speed because the thinner layer forming should be necessary to prevent toner scattering from developing zone by air flow.

Soft developing roller is very useful to reduce toner stress in the thin toner layer. As a result, the durability of the developing system is improved even at higher speed machine.

We have designed non-contact type single component non-magnetic development system by experimental design method based on the soft developing roller. We performed experiments using 1200 dpi resolution with parameter values obtained through the optimization process.

Introduction

According to a remarkable increase in various graphic and photo image printing, a number of non-contact type development systems have been studied for a long time.

In U.S. Pat. No.3,232,190 to Robert W. Willmott, transfer type development system is disclosed in which the charged toner are stored on a donor member and development is accomplished by transferring the toner from the donor to the image regions on the photo conductive surface across a finite air gap between donor and image surface.[1]

In U.S. Pat. No.3,866,574 to James M. Hardennrook, et al, there is disclosed an developing apparatus by providing a donor member that is adjacent and in spaced relationship to a photoreceptor and providing means for applying a pulsed bias to donor member.[2] The applied pulse is a combination of a short intense electrical pulse to release toner from the donor and start it towards the photoreceptor and a nominal bias to prevent background development.

Magnetic developing method is disclosed to enhance print quality in U.S. Pat. No. 4,292,387 to Junichiro Kanbe, et al, a latent image is developed by subjecting a magnetic developer to the action of an electric field and applying a low frequency alternating voltage to the developing gap.[3]

In U.S. Pat. No. 4,342,822 to Nagao Hosono, et al, there is disclosed an method and apparatus for image development, wherein a space gap between a latent image holding member and a developer carrying member is made wider, at a developing section, than thickness of the developer layer on the surface of the developer carrying member, and both members are opposed each other for developing operation, and wherein the developer to be used is composed of electrically insulated toner particles.[4]

In U.S. Pat. No. 4,600,295 to Koji Sujuki, et al, a image forming apparatus is disclosed in which square wave developing voltage is applied to developer carrying member instead of the conventional sinusoidal AC developing bias.[5] Such square wave developing bias reduces the moving energy of the toner and prevents the discharge between the developing sleeve and photoconductive drum.

A lot of research and development have been focused on the non-contact type single component non-magnetic development system because of its low cost, small size and high resolution printing quality.

The uniformity of half tone image quality is very significant in non-contact type single component non-magnetic development system. In particular, image quality in an electro-photographic printing system is significantly influenced by the charging characteristics of the toner layer formed on a developing roller.

This paper is to provide a developing method for high image quality which is free of uneven half tone density and background at non-image portion, and will describe how to maintain it within the toner cartridge life based on the soft developing roller.

Configuration of Development System

In general, non-contact type single component non-magnetic development system can be characterized by three basic mechanisms: (1) The thin layer forming of the toner on the developing roller, (2) The uniform triboelectric charging of the toner on the developing roller without wrong signed toner, (3) Electric field control system across a gap between developing roller and photo conductive drum. The basic layout for the development is shown in Fig. 1 and Fig. 2.

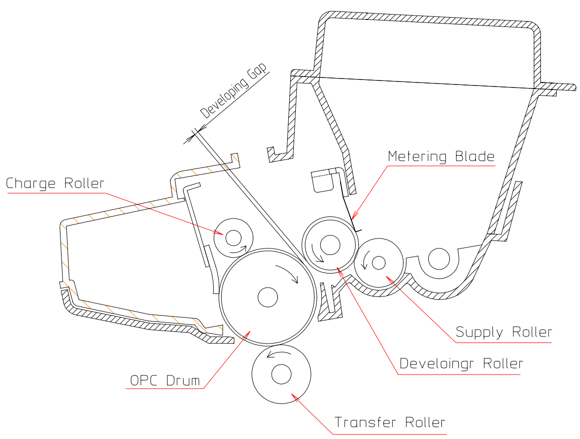

Figure 1. Cross-section drawing of the developing apparatus

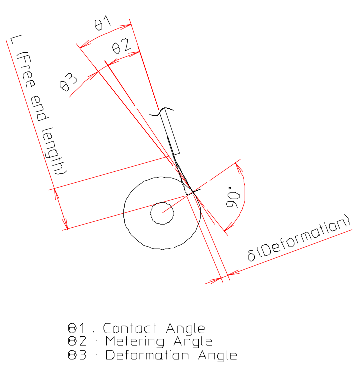

Figure 2. Detail view of metering angle in the metering system

Table 1. The Configuration of Development System

No.	Items	Description	Specification
1	Print speed	30 ppm	A4 size
2	Resolution	1200/600 dpi	Address-ability
3	Cartridge life test	20,000 pages	5% coverage of print duty

Critical Parameters to Print Quality

Thin layer forming operation by metering mechanism is the first step in designing development system, depending on the surface characteristics of metering-blade and developing roller, the particle size distribution of the toner, and the characteristics of toner formulation.

The triboelectric charging of the toner by metering-blade and supply roller is the most important elements of the development system. It is very relative to the material properties of toner, developing roller, supply roller and metering-blade based on triboelectric series.

The charged toner on the developing roller is developed by electric field across air gap between developing roller and photoconductive drum. The electric field can be controlled to compensate image density according to mechanical tolerance and environmental conditions. The key parameters of the development system are shown in Table 2.

Table 2. Testing Parameters

Item	Parameter	Description
Mechanical system	Developing gap	150 ~ 300μm
	Process speed	189mm/sec
	DR/Drum speed ratio	1.1 ~ 1.5
Electric field	Vpp	-1500 ~ -2000V
	Vdc	-200 ~ -400V
	Frequency	1.6 ~ 2.0kHz
	Duty ratio	20 ~ 40%
Developing Roller	Material	NBR (Mono layer)
	Roughness	Rz = 4.5 ~ 9.0
External additives of the toner	Coarse silica	0.5 ~ 1.5Phr
	Fine silica	0.2 ~ 1.0Phr
	Titanium dioxide	0.2 ~ 1.0Phr
Metering-blade	Free end length	11.6 mm
	Material	Stainless steel
	Metering angle	-5° ~ 15°

Experimental

To investigate the characteristics of developing performance according to the charge of toner (q/m) and mass of toner (m/a) on the developing roller, we set up experimental developing apparatus for non-contact type single component development system.

Measurement of the Charge of Toner (q/m)

It is very important to measure the charge of toner (q/m) on the developing roller in the developing zone. We can measure toner charge (q) and mass (m) of toner layer on the roller in each case, then we can calculate the charge of toner (q/m) based on the mass of toner on the surface of the roller.

We use suction-type Faraday Cage through 0.8μm filter with 0.5MPa pressure to collect toner from the roller and to measure toner charge by electrometer.

Measurement of the Mass of Toner (m/a)

The toner layer can be described as the mass of toner (m/a) based on the surface area of the toner layer on the roller. We can measure mass (m) of the toner which is collected from the toner layer on the developing roller in fixed area, then we can calculate the mass of toner (m/a) based on the area of the toner layer on the roller.

Measurement of Background

We evaluate the background level by measurement of optical density at the non-image area of photo-conductive drum. The rank of background level is shown in Table 3.

Table 3. The Rank of Background Level

Rank	Density	Remark
1	0.10 ~ 0.13	Excellent
2	0.14 ~ 0.16	Acceptable
3	0.17 ~ 0.18	Bad
4	0.19 ~	Fail

Results and Discussion

Toner Layer Characteristics

Metering angle is one of the key parameters to control the toner layer by metering blade. As shown in Fig. 3, the characteristics of the mass of toner on the developing roller is reduced as metering angle is increased. As metering angle changes from –2.5° to 5°, the mass of toner is decreased from 1.0mg/cm^2 to 0.5mg/cm^2 gradually. It is desirable to adjust metering angle as 5.5° to obtain stable toner layer, and then we can adjust the layer of toner by the combination of external additives.[6]

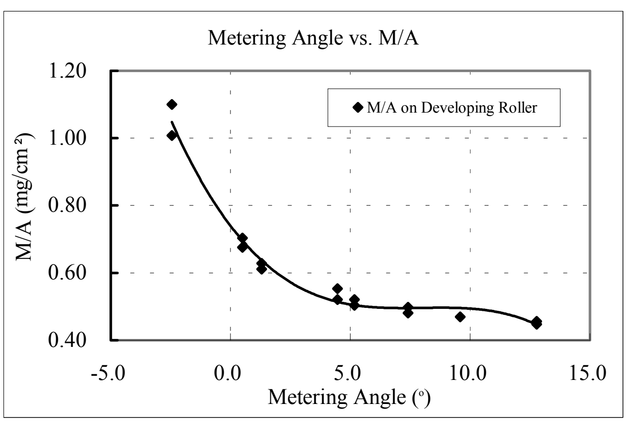

Figure 3. The mass of toner (g/cm^2) according to metering Angle

Toner Charge Characteristics

The trend of toner charging based on the external additives is shown in Fig. 4. The charge of the toner decreases as the amount of titanium dioxide increases.

However, as the amount of fine silica increases, the charge of the toner is increased. Fine silica enhances the performance of triboelectric charge of toner on the developing roller.

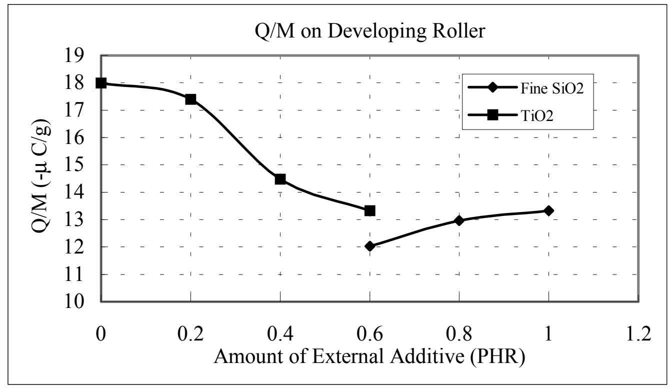

Figure 4. The charge of toner (-μC/g) with external additives

Image Quality Characteristics

In general, to reduce the background level we have to enhance the charge of toner to prevent the generation of wrong signed toner from triboelectric mechanism during printing operation.

The trend of background is shown in Fig. 5 according to the external additives of the toner. The background is improved gradually as the amount of fine silica increases.

But titanium dioxide has quadratic relation with background level. We can find out optimal amount to minimize background.

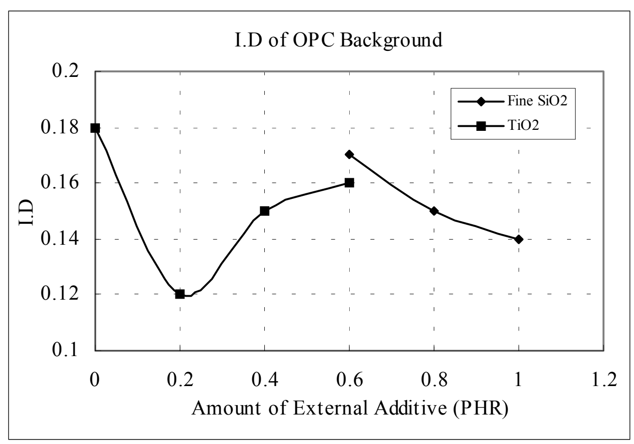

Figure 5. Background according to external additives

We performed several experiments by various kinds of binder resin materials to improve background. Acrylo-Nitril Butadiene Rubber (NBR) is used for binder resin of soft developing roller.

In case of NBR developing roller, background level depends on the amount of acylonitrile(%) of the rubber. In table 4, background level is shown according to the amount of acylonitrile(%). Low Nitrile Rubber causes the development system to bring background regardless of toner formulation.

Table 4. Background According to Materials of the Roller

Item	NBR - A	NBR - B	NBR - C
Acrylo – nitrile (%)	18 %	33 %	42.5%
Background	0.17	0.14	0.14
Parts Name	DN401L	DN3335	DN101L

As shown in Fig. 6, image density is proportion to the speed ratio of developing roller to photoconductive drum. But we have to pay attention to toner stress by metering system. The lower speed ratio reduces toner stress. It is desirable to adjust the speed ratio as 1.20 to obtain stable image density.

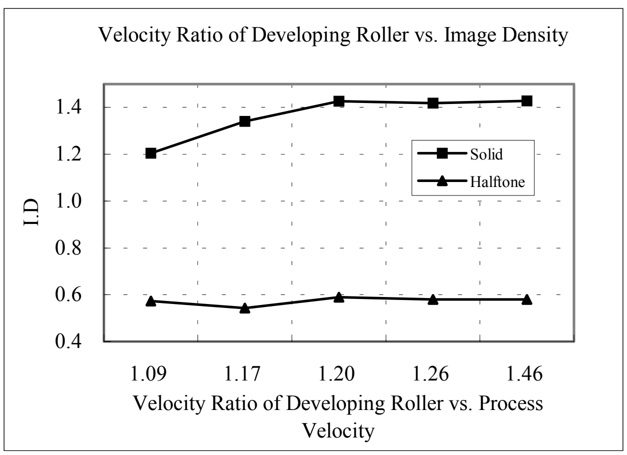

Figure 6. Image density according to the speed ratio of developing roller to photoconductive drum

Result of the Life Test

In general, the serious problems in non-contact type development are the high background level and low image density by toner stress throughout the cartridge life.

To verify the development system in this study, we performed running test with parameter values obtained through optimization process. The test file is consisted of arbitrary character sets with 5% coverage of print duty to evaluate cartridge life.

We succeeded in printing 20,000 pages without serious problems such as background and uneven image density.

The result of running test is shown in Fig. 7 and Fig. 8. Image density such as solid pattern and halftone, and the others such as developing efficiency and background are stable during 20,000 pages printing operation.

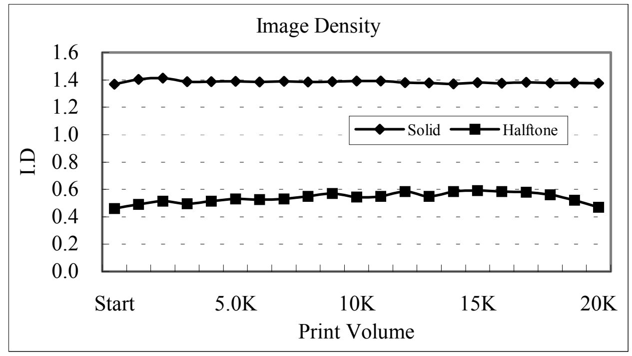

Figure 7. The image density curve according to the printing volume

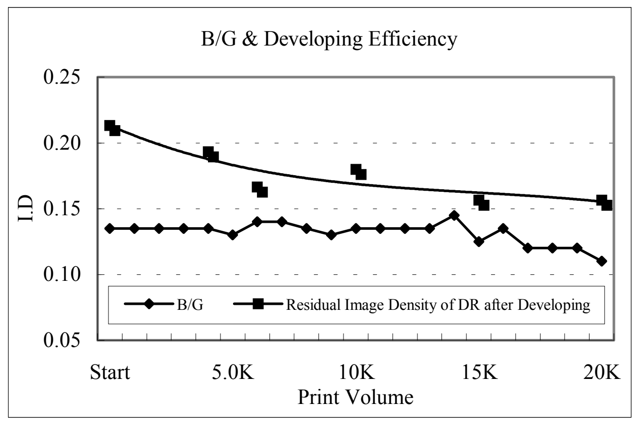

Figure 8. The trend of development characteristics according to the printing volume

Conclusion

The performance of the development system depends on the property of developing roller, the mechanism of the thin toner layer formation with metering blade based on the toner formulation

The result of this experiment can be useful to understand the critical parameters to maintain image quality by using various levels of the design parameters. It is verified to also work very well with 1200 dpi resolution and 30 ppm printing speed during 20,000 pages printing.

To improve the durability of the development system with a conductive elastic developing roller, the formulation of the roller depending the toner is very important. In particular, the medium high nitrile rubber with 33% acryol-nitrile reduces background level in case of Acrylo-Nitril Butadiene Rubber. To obtain stable toner layer, it is desirable that the metering angle has to be greater than 5° in the metering system.

In addition, we can improve image quality by adjusting the amount of external additives such as fine silica and titanium dioxide. It is very helpful to maintain image density during printing operation.

As a result, we can achieve high quality image which is free of uneven half tone density and background at non-image area, and maintain it throughout the toner cartridge life.

References

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Biographies

Jong Moon Eun received his M.S. degree in Mechanical Engineering from Seoul National University, Korea, in 1986 majoring fluid mechanics. He has been developed several kinds of printers at Samsung Electronics. He has been involved in system development of laser beam printing system using electro-photographic process since 1990, and his work is focused on development system for high resolution print quality.

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