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 application. In general, there are two kinds of single component non–magnetic development system. One is contact type development system, and the other is non-contact type single component development system.

In recent years, the resolution in digital printing has been increasing, in response to high image quality. However, it is very difficult to form dots and single lines of high resolution in contact type development system because of the weak electric fringe field. To enhance electric fringe field for high resolution, some range of the gap between the developing roller and the photo conductive drum must be required. As a result, non-contact type single component development system is very useful to form high resolution of single dots and lines.

We have designed non-contact type single component non-magnetic development system to improve the sharpness of image and to achieve high photo quality by experimental design method. 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 insulative 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 photo conductive 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 characteristics of the development system depend on the property of developing roller, the mechanism of the thin toner layer formation with metering blade, and the toner formulation.

The uniformity of half tone image quality is very significant in non-contact type single component non-magnetic development system. In particular, the developing performance and image quality in an electro-photographic process are 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 quality image which is free of uneven half tone density, fogging at non-image portion, and will describe how to maintain it within the toner cartridge life.

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.

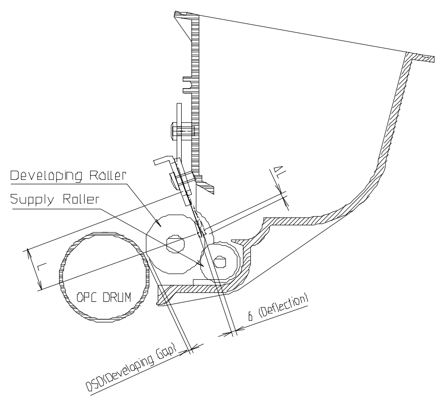

Figure 1. Cross-section drawing of the developing apparatus

The configuration of the development system is shown in Table 1.

Table 1. The Configuration of Development System

No.	Items	Description	Specification
1	Developing method	Non-contact	Single component non-magnetic
2	Print speed	20ppm	A4 size
3	Resolution	1200/600dpi	Addressability
4	Toner	Pulverized	8.0µm
5	Cartridge life	8,000pages	5% coverage of print duty
6	Charging	Roller with DC	(-) charge

Critical Parameters to Print Quality

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

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

Charged toner on the developing roller is developed by electric field across air gap between developing roller and photo conductive 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 is shown in Table 2.

Table 2. Testing Parameter

Item	Parameter	Description
Mechanical system	Developing gap	150 ~ 300µm
	Process speed	124mm/sec
	DR/Drum speed ratio	1.2 ~ 1.5
Electric field	Vpp	-1500 ~ -2000V
	Vdc	-200 ~ -400V
	Frequency	1.6 ~ 2.0kHz
	Duty ratio	20 ~ 40%
Roller	Roughness	1.5 ~ 5.0 Rz
	Coating	Nickel plating
Toner	Resin	Polyester
	Coarse silica	0.5 ~ 1.5Phr
	Fine silica	0.2 ~ 0.5Phr
	Titan oxide	0.5 ~ 1.5Phr
DR-blade	Free end length	15mm
	Thickness	0.12t
	Material	Beryllium
	Delta L	0.3 ~ 1.0mm

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 as shown in Fig. 1.

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)

In general, it is very difficult to measure the thickness of the thin toner layer on the developing roller. 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	0.08 ~ 0.13	Excellent
2	0.14 ~ 0.16	Good
3	0.17 ~ 0.18	Bad
4	0.19 ~	Fail

Measurement of Developing Efficiency

Developing efficiency (η) is defined as the ratio of toner mass after developing to that before developing, as follows.

$$\eta = [\ 1 - (\ M_{after} \,/\, M_{before}\ )\ ] \times 100\ (\%)$$

Where is, M_{after} and M_{before} are the toner mass on the developing roller after and before development.

On the other hand, the toner mass is significantly related with the optical density of the toner layer. As a result, the developing characteristic can be described as the optical density of the layer of toner on the developing roller after development of solid image, as shown in Fig. 2. From the Fig. 2, we can find that as the optical density of the toner layer decreases, the developing efficiency increases.

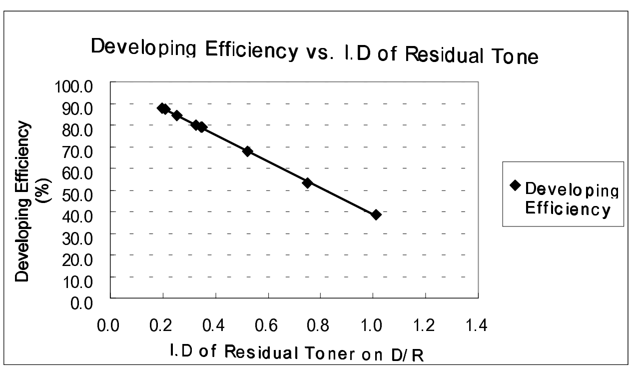

Figure 2. The relationship between developing efficiency and image density of residual toner

Results and Discussion

Toner Layer Characteristics

The thin layer forming of toner is the main issue of single component developing system. The layer of toner can be described as the mass of toner based on the surface area on the developing roller. It depends on the mechanism of metering system and toner formulation itself.

Delta L is one of the key parameter of toner layer. As shown in Fig. 3, the characteristics of the mass of toner on the developing roller is proportion to the delta L of Dr-blade. As delta L changes from 0.1mm to 0.6mm, the mass of toner increases from 0.82mg/cm^2 to 1.1mg/cm^2 gradually. We can see that the change of toner layer is less sensitive when delta L is the range of 0.3mm to 0.6mm.

It is desirable to adjust the delta L as 0.7mm to obtain stable toner layer, and then we can control the layer of toner by the combination of external additives.

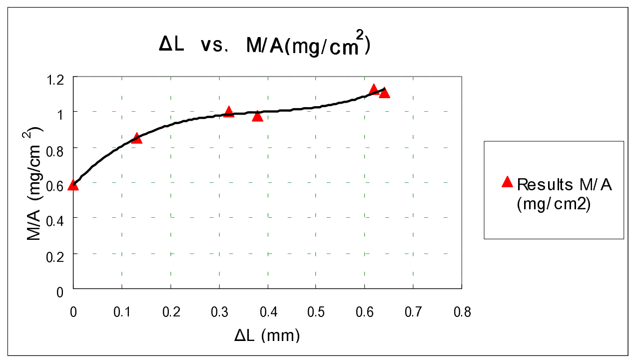

Figure 3. The mass of toner (g/cm^2) according to the delta L

Developing Efficiency

Developing efficiency is one of the most difficult issues of non-contact type development system. In general, the higher q/m toner gives a slope of the development curve that is much less steep.[6] It means that the lower q/m is the better developing efficiency.

The charge of toner has to be lowered to improve developing efficiency as shown in Fig. 4, but it is impossible to lower the charge of toner because of fogging at the non-image area caused by wrong signed toner.

We can understand that developing efficiency of used toner is more sensitive than that of fresh toner according to the charge of toner as shown in Fig. 4. It is desirable to design the charge of the toner around -10 μC/g to improve developing efficiency.

In particular, the efficiency depends on the surface roughness of the roller, such as nickel plated aluminum sleeve.[7, 8] As the surface roughness decreases, the efficiency increases gradually as shown in Fig. 5. It's desirable to adjust the surface roughness to approximately Rz 2.0 because the lower the surface roughness is, the less productivity.

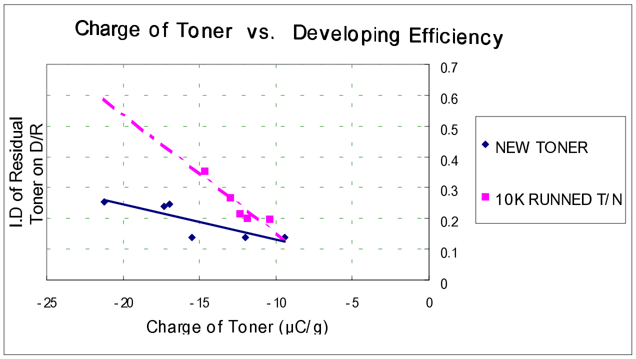

Figure 4. The developing efficiency according to the charge of toner (-μC/g)

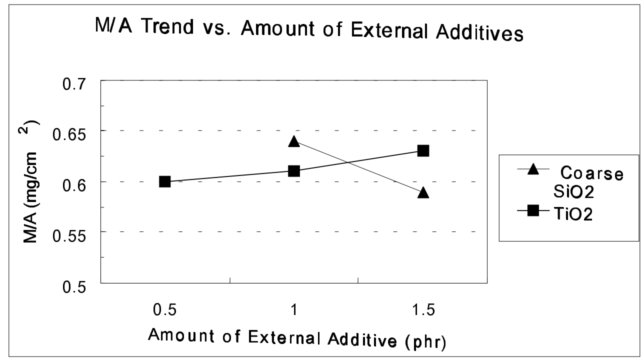

Figure 6. The mass of toner (g/cm²) according to external additives

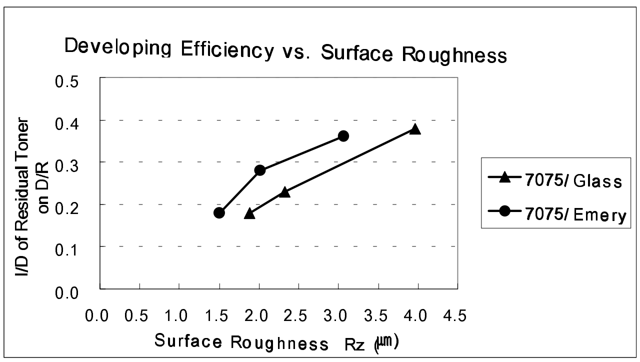

Figure 5. Developing efficiency according to the surface roughness of developing roller

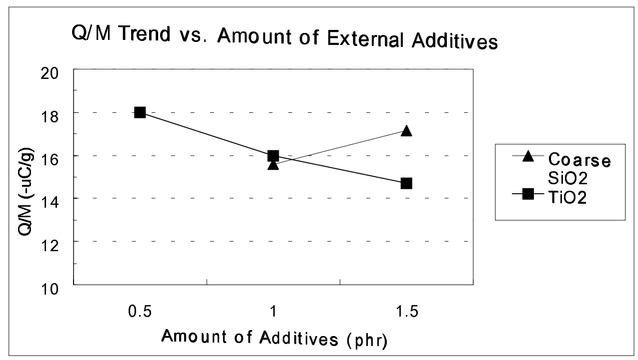

Figure 7. The charge of toner (-μC/g) with external additives

Toner Formulation Characteristics

To investigate the characteristics of developing properties according to the toner formulation, we performed several experiments by adjustment external additives such as several silicas and titan oxides. In this study, the amount of fine silica is fixed as 0.4 Phr.

The characteristic of the mass of toner on the developing roller based on the external additives is shown in Fig. 6.

The toner layer is less sensitive to the amount of titan oxide, but it is very sensitive to the amount of the coarse silica. We can find that the toner layer can be controlled by the combination of coarse and fine silica through this experiment.

The trend of the charge of toner with the external additives is shown in Fig. 7. Titan oxide makes the charge of the toner decrease when the amount increases.

However, as the amount of coarse silica increases, the charge of the toner is increased. We understand that because the toner layer becomes thinner as the amount of it increase as shown in Fig. 6, it will enhance the performance of triboelectric charge of toner on the developing roller.

The trend of developing efficiency is shown in Fig. 8 according to the external additives. It is almost the same as the characteristic of the charge of toner. Titan oxide makes the efficiency increase when the amount increases.

On the other hand, the coarse silica makes the efficiency decrease when the amount increases. We understand that the efficiency depends on the charge of toner.

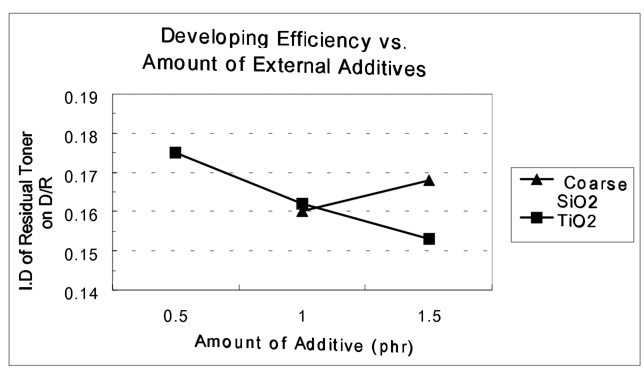

Figure 8. The developing efficiency according to external additives

In general, background is inversely proportional to the charge of toner. In other words, to lower the background level we have to enhance the charge of toner to prevent wrong signed toner from triboelectric mechanism during print operation.

The trend of background is shown in Fig. 9 according to the external additives. The background level is less sensitive to the amount of coarse silica. But the background is improved gradually as the amount of titan oxide increases even though the charge of toner is lowered as shown in Fig. 7.

We have to pay attention to the role of titan oxide in triboelectric charge performance. We understand that it plays important role not to have wrong signed toner even though it decreases the average value of toner charge. It means that we can improve the developing efficiency by down the charge of toner without background on non-image area.

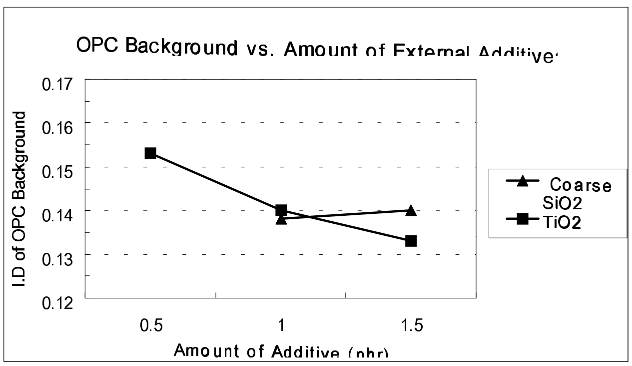

Figure 9. Background according to external additives

Optimization of Design for Development System

To optimize each value of parameters, we performed experiments by adjustment of roughness of developing roller, delta L of Dr-blade, and external additives of toner.

In particular, the combination of coarse and fine silica is very important to maintain the thin layer of toner. We found the optimal parameters by factorial design as follows.

Table 4. Optimization of Developing System

No.	Item	Factor	Remark
1	Dev. roller	Roughness	1.5 ~ 2.5µm
2	Dr-blade	Material	Beryllium
		Thickness	0.12mm
		Delta L	0.7mm
3	Additives of toner	Coarse silica	1.0 Phr
		Fine silica	0.4 Phr
		Titan oxide	1.5 Phr

Result of the Life Test

In general, the serious problems in non-contact type development are high background level and low developing efficiency. These phenomena become more severe in low temperature and low humidity conditions (L/L).

To verify the development system in this study, we performed running test with parameter values obtained through optimization process in low temperature and low humidity condition(10°C/10%RH). The test file is consisted of arbitrary character sets which has 5% coverage of print duty to evaluate cartridge life. We succeeded in printing 8,000 pages without serious problems such as background and uneven image density. The result of running test is shown in Fig. 10 and Fig. 11.

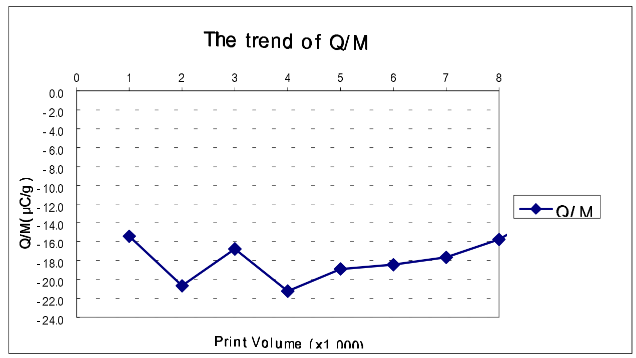

Figure 10. The Variation of toner charge according to the printing volume in L/L condition

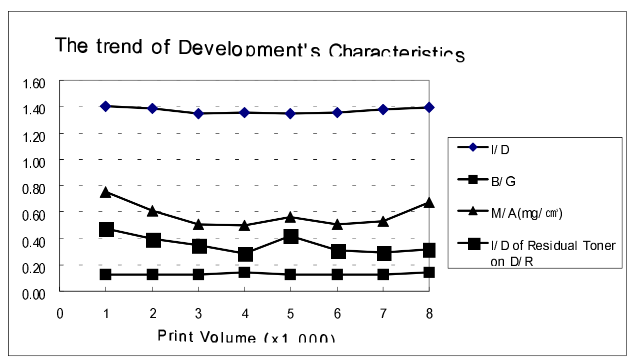

Figure 11. The trend of development characteristics according to the printing volume in L/L condition

As shown in Fig.10 the charge of toner was stable between -15 µC/g ~ -22 µC/g. After running 8,000 pages the charge of toner decreased under -16 µC/g. But there were no background at the non-image area.

As shown in Fig. 11, the developing performance such as developing efficiency, background, the thickness of toner layer, and image density are all stable during 8,000 pages printing operation.

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 and the toner formulation

The result of this experiment can be useful to understand the critical parameters to print quality with various level of the design parameters. It is verified to also work very well with 1200 dpi resolution and 20 ppm printing speed during 8,000 pages printing.

To increase developing efficiency, the surface roughness of developing roller is very important parameters in aluminum sleeve with nickel coating. The smaller roughness of aluminum sleeve is the better efficiency. In addition, developing efficiency is improved by change toner formulation because titan oxide lower the toner charge(q/m) without background.

In particular, two kinds of silicas which has different size and titan oxide are added as external additives. To prevent fogging on the non image area, it is desirable that the ratio of coarse silica to fine silica is greater than 2. Titan oxide with 1.5Phr is very helpful to clear background during printing operation.

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

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Biography

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. He is also a member of ISO/IEC JTC1 SC28 of Korea.

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