Ricoh SD-Development Technology and Pre-mix System for Image Quality

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1.Abstract

We developed a new full-color development unit, which adopted two new technologies together. The first technology named SD-development system (Stable Density development system) decreases declination of TC (toner concentration) on the development roller, to make high qualities for every printout image. The other one is a pre-mix system. The pre-mix system is to replace old developer in the development unit to fresh developer gradually during development units operating, to keep high quality printout images and to extend the developer lifetime longer. The pre-mix system which is adopted on the new development unit makes a remarkable stability with SD-development system.

2.Introduction

In recent years, electrophotographic full-color MFPs and full-color digital printers are used for not only in common documents and presentation documents as we see in the office but also in various situations, such as on-demand printings and graphic designs. As increasing use mentioned above, electro-photographic full-color MFPs and full-color digital printers are expected to have high quality in printing speed, stability and image formation.

As you can see on table 1, the new full-color development unit is designed to adjust on high-speed printing and small particle size chemical toner [1]. Moreover, the two new technologies of the new full-color development unit increased the stability of the imaging density to higher level.

Table. 1 Specification of machine

	usual type		new type	
Copy Speed (A4 paper)	B&W A4	Color A4	B&W A4	Color A4
	60	55	75	70
toner type	usual toner (pulverizing method)		newly developed toner (polymerizing method)	
development unit	usual development unit		new full-color development unit	

3.Improvements of image quality

Figure 1 shows the image density fluctuation improvements of the new type comparing to the usual type. The density fluctuation can be classified into three modes according to printing time.

First, if you print out an image on a sheet, and the image have density fluctuation in the sheet that is called the image density fluctuation in a sheet. The image density fluctuation in a sheet is less than half comparing to usual type.

Second, if you print out an image on dozens of sheets and the image density fluctuation in a sheet increases, that is called the repeat image density fluctuation. The repeat image density fluctuation is about one third of the usual type.

Third one takes longer time to appear than the previous two modes. It is caused by deterioration of properties of toner and carrier. By the deterioration, the image density fluctuates from the first print. Thus the lifetime of the developer extended three times longer than usual type. These remarkable results were achieved by improvement of each development unit functions.

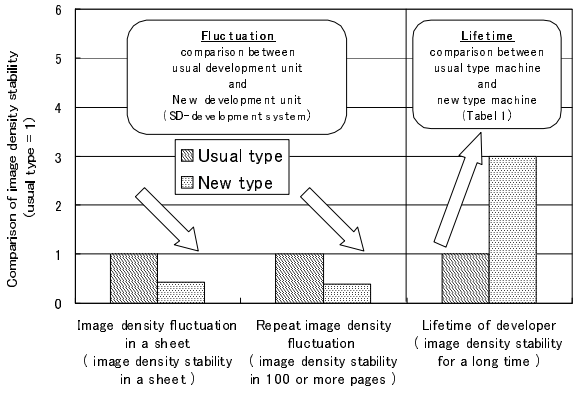

Fig. 1 Improvements of image density stability

4.Technologies to improve image quality

4-1. Functions of development unit

Ideal development unit, for electrophotographic process is expected to have three primary functions as follows:

A. The developer on each part of the development roller should be equal TC.
B. Supplied toner should be dispersed uniformly in the developer.
C. Charging ability of the carrier should be constant and kept.

4-2. Improvement of development unit functions

The new full-color development unit improved each functions mentioned on 4-1. To achieve A, we used an one-way circulation of developer as shown on right part of figure 2 and 3). To achieve B, we adopted a new agitating method to improve the ability of developer agitation. To achieve C, we reduced the stress of the developer occurring around the development roller, and we also used the pre-mix system. The pre-mix system is to replace the old developer to the new developer little by little during the machine printing for restraint of developer deterioration. The one-way circulation, new agitating method, and reduction of the stress around the development roller, are the component technologies of SD-development system. By adopting these technologies to the new full-color development unit, the functions of the new full-color development unit showed remarkable improvement from the usual type.

4-3. The technologies to improve development unit functions

4-3-1. The one-way circulation

Usual type of development unit with two screws is shown on the left side of Figure 2 and 3. In this unit, the screw that lies closer to development roller has supply and recovery function. So the low TC developer used for image development once is re-supplied to the development roller. This causes a very short time fluctuation of TC on the development roller. Besides, the more it goes to the downstream of recovery screw, the more ratio of used developer rises. So the TC has deviation by location (shown in Figure3, F (Front), C (center), R (rear)).

On the other hand, the new type development unit with SD-development system (just call SD-development system hereafter) shown on the right side of Figure 2 and 3 contains three screws. First, the developer in the unit is mixed with supplied toner and conveyed to the end of the agitation screw. Then, the developer is lifted to the supply screw and conveyed to the development area by the development roller. After the development, the developer is recovered from the development roller by the recovery screw, and return to the toner supply area. The unused developer on the supply screw is returned directly to upstream of the agitation screw. As mentioned above, in SD-development system, the high TC developer supplied to the development roller is completely separated from the low TC developer recovered from the roller. Because of the one-way circulation, the used developer is never supplied to the development roller before mixing with new toner. So the time fluctuation of TC is several times less compared to the usual type and the deviation by location (FCR) is also less in this system. In addition, SD-development system's screws and cases are optimized to increase developer conveying efficiency and longitudinal size reduction.

The following is the experimental result of SD-development system. Figure 4 is the TC deviation by position on the development roller. Vertical axis in Figure 4 means the TC deviation of the front, center and rear position on the roller. By use of the usual type development unit, the TC deviation is high from the start, and increases as time being. In contrast, by use of SD-development system, the TC deviation is kept very low level.

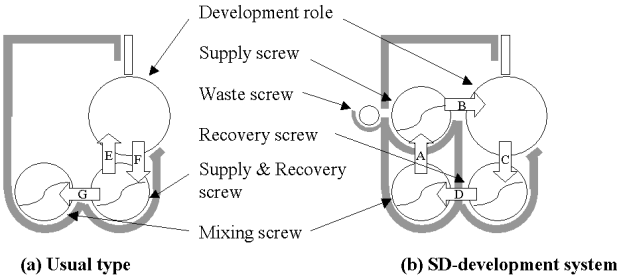

Fig. 2 Cross-section view of development units

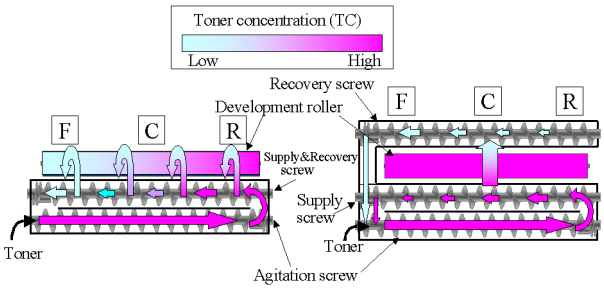

Fig. 3 TC distribution in the development units

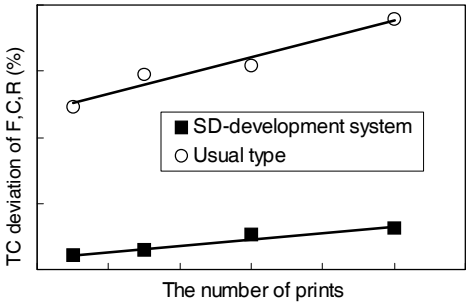

Fig. 4 TC deviation on the development roller

4-3-2. New agitating method

The toner, which isn't agitated enough, contains weakly or oppositely charged toner [2)]. Those kinds of toner might cause degradation of image quality. So the toner supplied to the development unit is necessary to be mixed with developer and diffused enough.

As previously mentioned, in SD-development system, supplied toner is mixed with developer, conveyed to the end of the agitation screw and lifted to the supply screw. This lifting area is packed with developer, then the screw can give strong shear force to developer. This is why SD-development system has high level of agitation function.

Figure 5 shows the variation of TC on the development roller with time. Certain of toner (which increase TC of the developer by 0.4%) were supplied once at the start of each experiment. The peak TC of SD-development system is about 30% of the usual type. In addition, the TC decay time of SD-development system was 20% of the usual type. In this way, SD-development system can reduce TC fluctuation to a very low level.

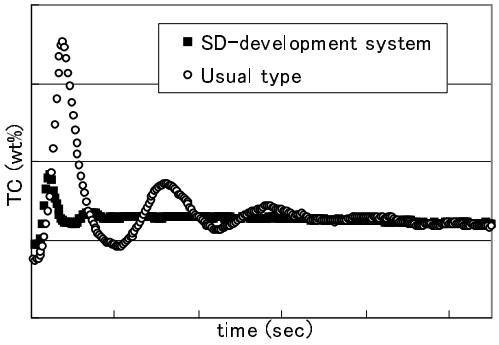

Fig. 5 TC on the development roller vs time (experiment)

4-3-3. Reduction of stress

It is known that the changes of toner such as particle size and amount of additives, and the changes of carrier such as coating thickness and adhesion of toner's additives, occur as they are consumed for print in two-component developer [3]. These changes occur by stress on the developer. The electrostatic and powder properties of developer vary according to those changes of toner and carrier, and they could harm the condition of a magnetic brush and development on the photo conductor. It is necessary to reduce these harmful influences for the stability of image density.

In SD-development system, the stress from the development roller that the developer is acted on was reduced by 40% to control the change of those properties. For the reduction of the stress, we optimized the magnet of the development roller according to the simulation of developer behavior around the roller.

Figure 6 shows the deterioration of charging ability of developer. Charging ability of developer in SD-development system drops little with the number of prints, while the one of the usual type drops to a lower value.

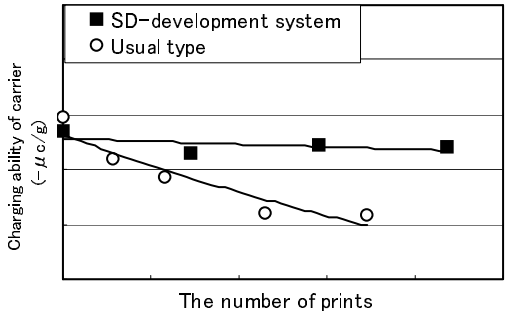

Fig. 6 Deterioration of charge ability

4-3-4. Restraining deterioration of the developer by pre-mix system

Pre-mix development system is the system to replace old developer in the development unit to fresh developer gradually during printing, to restrain deterioration of the developer keeping the high quality printout images, and extend the developer lifetime longer.

Supply toner of the pre-mix system contains a few percent of carrier. So, by supplying the toner to the developer, the new carrier is also added to the developer. The development unit of the pre-mix system has an outlet to exhaust the old developer from the development unit. Therefore, pre-mix system can replace the old developer to the new developer.

The simulation result of the deterioration of charge ability is shown in Figure 7. Each integral curve shows simulation result of different carrier concentration in supply toner. The lifetime of the developer expressed as the number of prints is when the integral curve drops and touches to the straight line. This figure shows if one increases carrier compound ratio than the integral curve which attains the target lifetime, one can prolong the lifetime of the developer.

From this simulation result, we decided to the carrier compound ratio to the supply toner. Figure 8 shows the experimental result of the deterioration of charge ability, under condition on table 1. The result of the new type in figure 8 used the carrier compound supply toner with the determined carrier compound ratio.

By reducing stress and using the pre-mix system, the deterioration of charge ability becomes very stable. In consequence, the developer lifetime of new type is three times longer than the usual type.

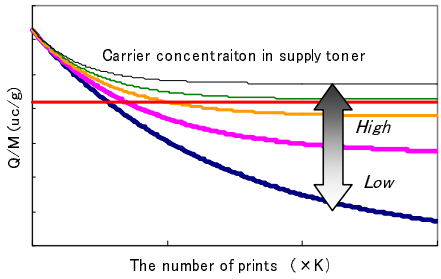

Fig. 7 Deterioration of charge ability (simulation)

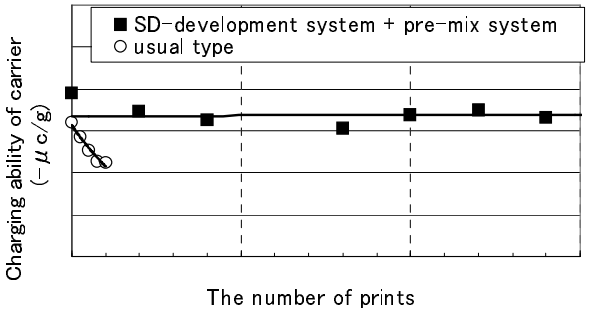

Fig. 8 Deterioration of charge ability (experiment)

4-4. Stabilizing the developer circulation of SD-development system by pre-mix system

The developer circulation in SD-development system is shown on figure 2 and 3. As this circulation, if the volume of the developer is less than a certain amount, the developer on the development roller will be exhausted. Also, if the volume of the developer is too much, the developer at the recovery screw will be packed and overflowed to the development roller. Therefore SD-development system needs high-precision volume control of the developer.

On the other hand, two opposite functions given bellow are required to the developer exhausting of pre-mix system, depending on the volume of the developer.

<Function. 1> High response and high speed exhaustion of the developer, if volume of the developer is over a certain amount of volume. Then the developer inside the development unit will not be excess

<Function. 2> No exhaustion of the developer, if the developer is under a certain amount of volume. So the developer inside the development unit will not decrease.

To do the high-precision volume control of the developer of SD-development system, we used these functions of the developer exhausting of pre-mix system.

On the following, we explain the performance of the developer exhaustion of the pre-mix system and how we achieved the performance.

To adopt pre-mix system to SD-development system, SD-development system has a spot, which the height of the developer in the development unit increases rapidly when the volume of the developer in the development unit exceeded a certain volume. By placing the outlet of the developer around the spot, high response and high speed exhaustion of developer was achieved.

To achieve no exhaustion of the developer, if the developer is under a certain amount of volume, we used 'quality engineering method' to get the optimum condition.

Figure 9-1 shows the experimental result of exhausting speed of developer with developer volume in the development unit before getting the optimum condition. The horizontal axis shows the amount volume of the developer inside the development unit. The vertical axis shows the exhausting speed of the developer from the development unit.

If the volume of the developer in the development unit is below volume B, the volume of the developer is too low, the developer on the development roller will be exhausted. If the developer volume in the development unit is within volume B, no problem occurs and SD-development system is very stable at this volume. If the developer volume in the development unit is over volume B, volume of the developer is too large, the developer at the recovery screw will be packed and overflowed to the development roller. Therefore, before the developer in the development unit decreases into volume A from volume B, exhaustion speed of the developer must be low enough, so as not to decrease anymore. On the other hand, before the developer in the development unit increases into volume C from volume B, exhausting speed of the developer must be high enough, so as not to increase anymore. Thus, the developer volume in the development unit will be stably held at volume B.

Figure 9-1 has a rapidly increasing point of exhaustion speed at volume C, the developer volume increases to the volume C and the developer at the recovery screw will be packed and overflowed to the development roller. It also has some exhaustion speed at volume A, the developer on the development roller will be exhausted.

Figure 9-2 shows the experimental result of exhaustion speed of developer with the developer volume in the development unit after getting the optimum condition shape for outlet. As you see in figure 9-2, rapidly increasing point of exhaustion speed is at volume B, and also exhaustion speed at volume A is approximately zero. Which means the developer volume is stably held at volume B.

As described above, the optimum condition of the pre-mix system in SD-development system made the behavior of the new full-color development unit very stable.

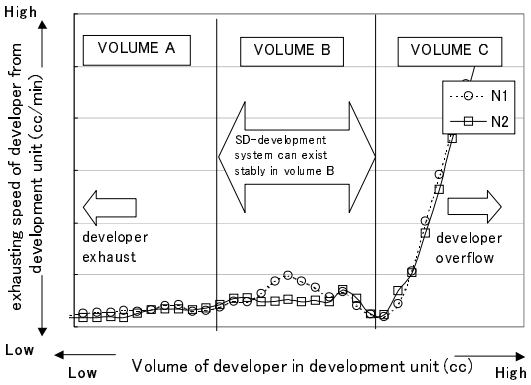

Fig. 9-1 Exhausting speed of developer (before)

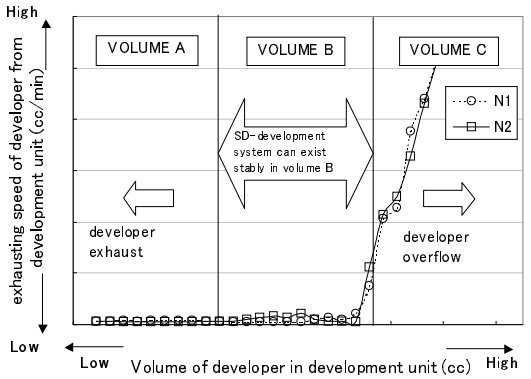

Fig. 9-2 Exhausting speed of developer (after)

5.Conclusion

In this report, we developed the new full-color development unit, which SD-development system merged with pre-mix system. By the synergy of each system, both system show great ability in the new full-color development system, and its stability of image density remarkably improved from usual type.

References

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Author Biography

Yuki Oshikawa received his M.E. degree in mechanical engineering from Keio University, Japan in 2004. He joined Ricoh Co., Ltd., in 2004, where he has been working on research and development of printing technologies. His work has primarily focused on the developing of development systems.