Toner Sticking on Doctor Blade in Non-Magnetic Mono-Component Development System

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Abstract

We investigated toner sticking on the doctor blade which regulates the toner layer thickness. We carried out experiments using a nitrite rubber developing roller, a stainless steel doctor blade, and a toner with an average diameter of 8 μm. From observation of the stuck toner with SEM, we saw that it was due to the accumulation of small-sized toner with diameters of less than 2 μm. We also found that the toner collecting on the doctor blade contained up to 9.9% more small-sized toner. Based on these results, we assume that the decrease in the amount of small-sized toner collecting on the doctor blade resulted in much less toner sticking on the doctor blade. Experiments confirmed this assumption. By decreasing the amount of small-sized toner with diameter of less than 2 μm from 3.5 to 1.7%, the doctor blade life became 8 times longer. By increasing the toner charging capability of the development apparatus, the amount of small-sized toner collecting on the doctor blade decreased from 9.9 to 4.5%, and the doctor blade life was extended by 2.5 times.

Introduction

In a non-magnetic mono-component development system, a uniform toner layer on the development roller is mechanically formed by the doctor blade. Therefore, sometimes the toner is metamorphosed and sticks to the doctor blade. It was found that toner sticking can be reduced by increasing the rate of the high molecular weight toner.[1] But its use resulted in a higher fusing temperature than before. We studied the toner sticking on the doctor blade without changing the molecular weight of the toner.

Observation of Toner Stuck on the Doctor Blade

Experimental Setup

Figure 1 shows the non-magnetic mono-component development apparatus used for this investigation. The developer consists of a development roller, reset roller, and doctor blade. The development roller is made of conductive nitrile rubber. The reset roller is a conductive polyurethane sponge. The doctor blade is made of stainless steel with a rounded working edge. The edge is pressed against the development roller with a force of 3.55 g/mm.

The developer was operated with 50 g of toner having an average diameter of 8 μm and a glass temperature point of 60°C. The development roller rotated at a surface speed of 175 mm/s and the reset roller rotated against it at 260 mm/s. The developer was operated without toner consumption. Under this condition, toner is most likely to stick on doctor blade.

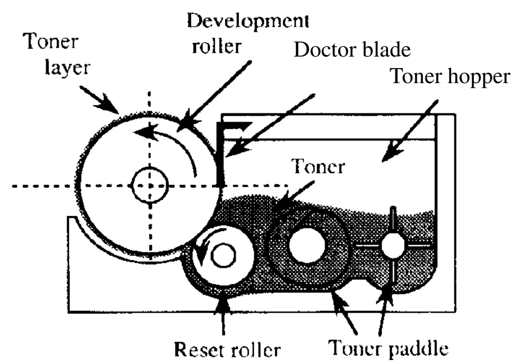

Figure 1. Development apparatus

Results of Observation

Figure 2 shows the results of our observations. After two hours of operation, the width of the stuck toner was about 0.3 mm, and toner particles collected at the generating point on the doctor blade. Thereafter, the stuck toner expanded to the edge of the doctor blade. After 16 hours, the stuck toner expanded beyond the edge of the doctor blade. At this point, the stuck toner has a negative impact on the print sample, and we define the doctor blade life as T_{th}.

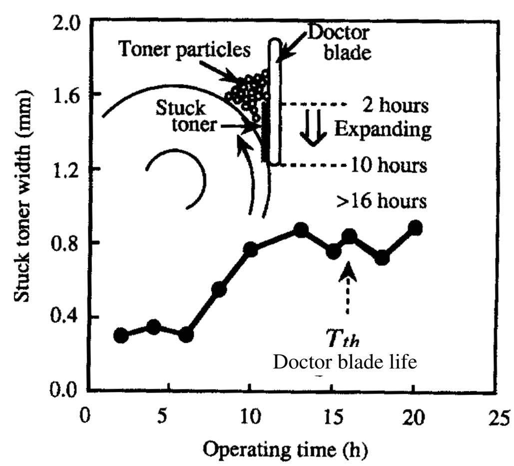

Figure 2. Results of observation

The SEM Image for Stuck Toner

Figure 3 shows the SEM image of the stuck toner. It shows the accumulation of flat shaped toner with a diameter of less than 2 μm. This shows that the stuck toner was selectively made of small-sized toner.

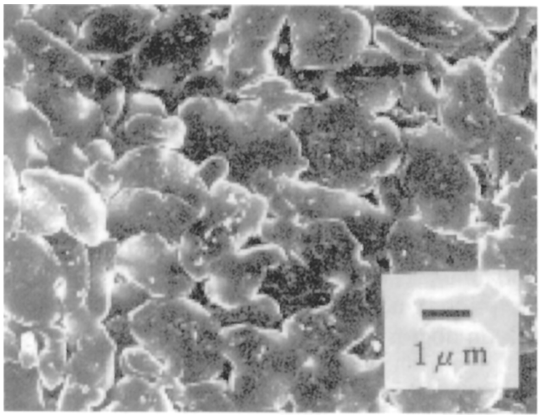

Figure 3. SEM image of stuck toner

Model of Toner Sticking on Doctor Blade

According to our observation, the process of the toner sticking occurs in three steps. First, toner particles collect on the doctor blade. Second, the collecting toner particles melt and stick together on the doctor blade. Then, the stuck toner accumulates.

Toner Melting

Figure 4 shows the schematic model for toner melting. We consider the toner melts on the doctor blade because of the frictional heat between toner and doctor blade. The model shows one toner particle existing between the development roller and the doctor blade. The thermal energy which accumulates in a toner particle is considered. The friction time for each unit of time is $v/2r_t$, where v is the surface speed of the development roller and r_t is a toner particle radius. The thermal energy, q_0, is generated at one friction and the thermal energy, q_x, accumulates in a toner particle. Then, the thermal energy which accumulates in a toner particle for each unit of time is given by $q_0av/2rt$, where a is q_x/q_0.

According to Fulier's law of heat conduction[2], the heat conduction to a toner particle is investigated as follows. The simple thermal equivalent circuit is shown in Fig. 5. The thermal energy Q, flows in the parallel circuit with the thermal capacitance C_h, and the thermal resistance R. The equations for R, C_h, and the thermal circuit equation are as follows.

$$\left.\begin{aligned} C_h &= S\rho\frac{4}{3}\pi r_t^3\left(\frac{\upsilon}{2r_t}\right) \\ R &= \frac{2}{\lambda}\int_0^{r_t}\frac{dr}{\pi(r_t^2-r^2)}\left(\frac{2r_t}{\upsilon}\right) \end{aligned}\right\} \quad (1)$$

$$C_h = \frac{d\theta}{dt} + \frac{\theta-\theta a}{R} = Q \quad (2)$$

$S\rho$: Volume specific heat
λ: Conductivity
θa: Initial toner surface temperature
t: Operating time

Solving equation (2), we get

$$\theta = RQ\{1-\exp(-t/C_hR)\} + \theta_a, \quad (3)$$

where θ is the temperature of the toner particle surface. Then, for infinite t,

$$\theta_\infty = RQ + \theta_a = \frac{q_0 a}{2\lambda\pi r_t} + \theta_a, \quad (4)$$

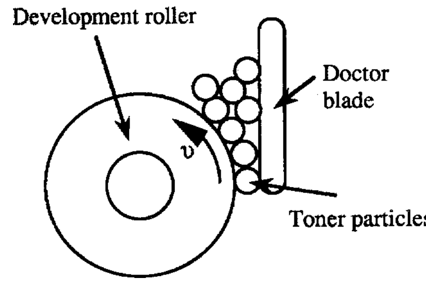

Figure 4. Schematic model of toner melting

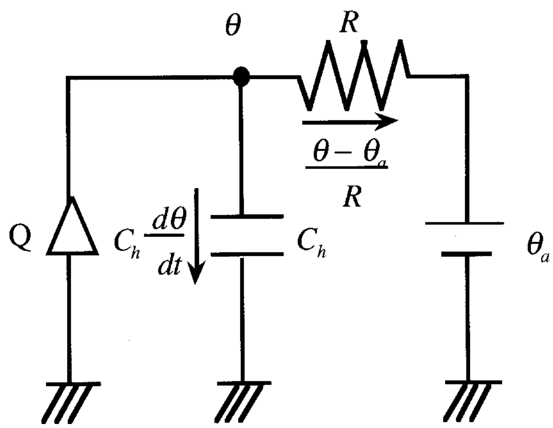

Figure 5. Thermal equivalent circuit of toner melting

The temperature of the toner particle surface is inversely proportional to the toner particle diameter, r_t. The smaller the toner particle size, the higher the temperature of the toner particle surface rises, and the easier the toner sticks to the doctor blade.

Expansion of Stuck Toner

According to this obsevation, the amount of stuck toner must be proportional to the friction time, and to the rate of small-sized toner collecting on the doctor blade, b, since the small-sized toner sticks on the doctor blade selectively. Then, the amount of stuck toner for time, t, is given by,

$$M = l\frac{\upsilon bt}{2r_t} \quad (5)$$

If the amount of stuck toner becomes the constant M_{th} during doctor blade life T_{th}, equation (5) can be transformed to equation (6). Equation (6) shows that the higher the rate of small-sized toner collecting on the doctor blade the shorter the duration of doctor blade life.

$$T_{th} = \left(\frac{2r_t M_{th}}{l\upsilon}\right)\frac{1}{b} \quad (6)$$

Inspection

We carried out two experiments. One, using an improved toner containing less small-sized toner, and another using improved development apparatus with increased toner charging capability.

Table 1. Comparison of standard and improved toner for doctor blade life.

	Toner	
	Standard	Improved
C: % of small-sized toner (< 2μm)	3.5%	1.7%
T_{th}: doctor blade life	16h	128h

The development unit was operatd with the improved toner. Table 1 shows a comparison between the standard and the improved toner for doctor blade life. The small-sized toner with a diameter of less than 2 μm decreases from 3.5% to 1.7%. By using this improved toner, we reduced toner sticking, and doctor blade life was extended by 8 times.

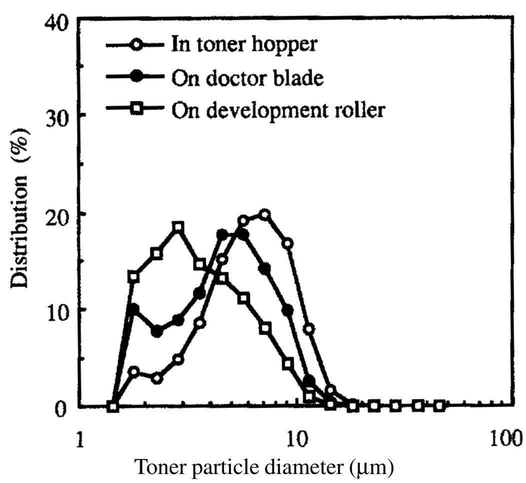

Figure 6. Toner particle diameter distribution.

We investigated the relation between doctor blade life and the rate of small-sized toner collecting on the doctor blade. Figure 6 shows the diameter distribution of the toner particles during development. Table 2 shows a horizontal axis in Fig. 6 and 9 in detail.* We sampled the toner in three areas, at the surface of the development roller, the surface of the doctor blade, and inside the toner hopper. The percent of small-sized toner on the development roller and the doctor blade and in the toner hopper are 13.4%, 9.9% and 3.5%, respectively.

The reason for this difference could be related to the process of toner charging. Figure 7 describes a comparison between small-sized and large-sized toner for the charging process. The standard toner in the toner hopper has no charge. The toner is carried between the reset roller and the development roller, and is charged. The small-sized toner has a higher charge than large-sized toner. The development roller receives higher charged toner selectively. The small-sized toner is easy to put on the development roller and is carried under the doctor blade, but large-sized toner isn't and returns to the toner hopper.

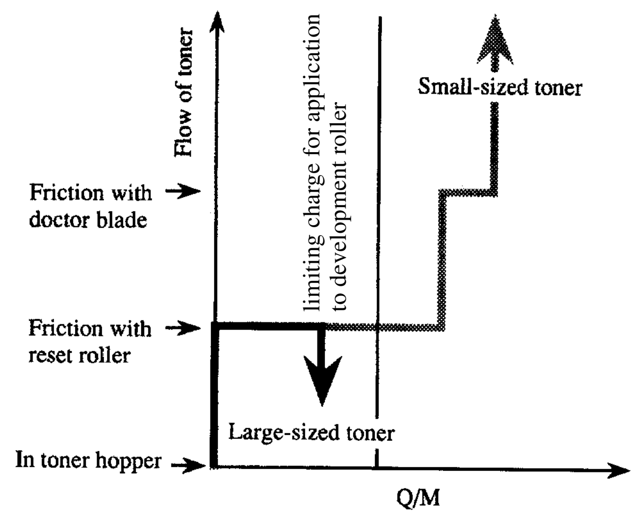

Figure 7. Comparison of small-sized and large-sized toner for charging process

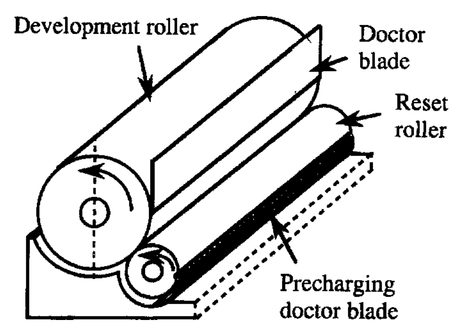

Figure 8. Improved development apparatus

Table 2. Toner particle diameter ranges in Figures 6 and 9.†

Running	Toner particle	Running	Toner particle
1	1.26 ~ 1.59	9	8.00 ~ 10.1
2	1.59 ~ 2.00	10	10.1 ~ 12.7
3	2.00 ~ 2.52	11	12.7 ~ 16.0
4	2.52 ~ 3.17	12	16.0 ~ 20.2
5	3.17 ~ 4.00	13	20.2 ~ 25.4
6	4.00 ~ 5.04	14	25.4 ~ 32.0
7	5.04 ~ 6.35	15	32.0 ~ 40.3
8	6.35 ~ 8.00	16	40.3 ~ 50.8

We created a new development apparatus which does not require increasing the amount of small-sized toner. Figure 8 shows the improved development apparatus. It has a precharging doctor blade which charges the toner uniformly before supplying it to the development roller. The

* author errata now disregards this sentence.

† author errata now disregards this table.

large-sized toner is charged by the precharging doctor blade.

Figure 9 shows the toner particle diameter distribution in the improved development apparatus. The precharging doctor blade can prevent the accumulation of small-sized toner. The percent of small-sized toner on the doctor blade was decreased from 9.9% to 4.5% (Table 3), and the doctor blade life was extended by 2.5 times. The product of doctor blade life and the rate of accumulation of small-sized toner, $T_{th}b$, is constant with and without the precharging doctor blade. This experiment shows doctor blade life is inversely proportional to the rate of small-sized toner collecting on the doctor blade.

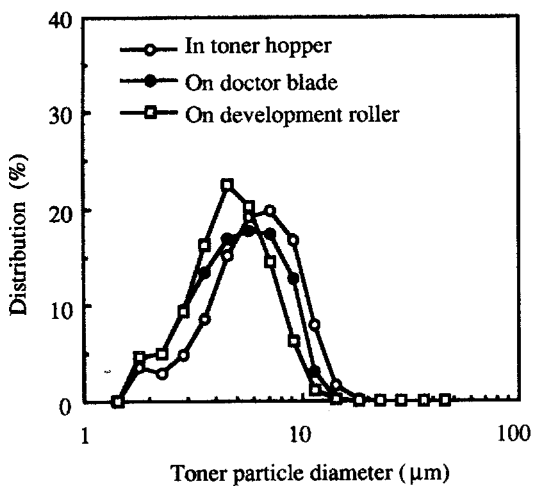

Figure 9. Improved toner particle diameter distribution

Table 3. Comparison of standard and improved development system for doctor blade life.

	Development appartus	
	Standard	Improved
Percemt of small-sized toner collecting on doctor blade	9.9%	4.5%
Doctor blade life	16h	40h

Summary

The mechanism of toner sticking on the doctor blade was shown by model and by experiment. Toner which collects on the doctor blade has high fines content. Small-sized toner selectively melts and sticks on the doctor blade by frictional heat. Stuck toner accumulates in proportion to the rate of small-sized toner collecting on the doctor blade. Finally, a longer doctor blade life was obtained by decreasing the amount of small-sized toner and by using a precharging doctor blade.

References

1. Y. Nakamura, S. Takezawa, Y. Katagiri, N. Sawatari, "Polymerization Toner Techniques in Mono-Component Nonmagnetic Development", *Proc. 7th NIP,* **1**, pp. 222-225 (1991).
2. I. Tanasawa, S. Nishio, T. Maekawa, "2. Heat Conduction", *Heat Transfer Engineering* (in Japanese), 1st ed., Japan, Asakura Syoten Ltd., 1989, pp. 18-24.