Effect of different rounding surface treatment process on particle characteristic of RST toner

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Abstract

The effect on the particle characteristic of pulverized rounding surface treated toner (RST Toner) by various mixing and rounding processes had been researched in this study. Two surface additives with different BET value and surface treatments are used as the spacer between toner particles during rounding surface treatment process. Based on different post-blending conditions of rounding surface treatment, the relationships between circularity, mixing condition, static charge property, BET and flowabilty are presented. In this study, surface fusion system is used to prepare the RST toner.

Introduction

The toner shape is an important factor in image quality to meet the requirements when printing technology is toward faster, higher resolution and color trend. The regular and round shape toner can obtain narrower in tribo-charge distribution [1] and higher transfer efficiency than the toner with irregular shape.

By using the surface fusion system, the rounding surface treated toner (RST toner) [2] can be produced without environmental issue such as like waste water problem in making CPT toner. Also, for preventing toner aggregation in the surface fusion system, the surface additives are added as the spacer between toner particles before the rounding process. In this process, toner particles are mixed with surface additives by a given mixing speed and time.

The present study relates to a RST toner to be used in electrophotographic method. In this method, tribo-charge of toner is highly related to the printing performance. How the surface treatment process affects the toner tribo-charge will be discussed.

Experimental

Material and Instrument

In the present study, polyester resin A and B are selected as the binder resins of the toner.

Polyester A: The glass transition temperature (Tg) is about 60°C, and the softening temperature is about 145°C, produced by Sanyo Chemical Industries.

Polyester B: The glass transition temperature (Tg) is about 65°C, and the softening temperature is about 97°C, produced by Sanyo Chemical Industries.

The colorant used in this study is pigment Red-269.

Two waxes are used in this study, wax A is ethylene-propylene copolymer type. The melting point is about 140~170°C.

Wax B is natural wax. The melting point is about 90~105°C.

Two different types of silica were used in this study as the surface additives. The charge characteristics of these silica are negative.

Silica A: The hydrophobic treatment is HMDS, the BET value is 200m^2/g, the carbon content is about 2.0~5.0%, made by Cabot.

Silica B: The hydrophobic treatment is OTES, the BET value is 50m^2/g, the carbon content is about 2.0~10.0%, made by Cabot.

The particle size distribution of toner in the present study is measured by Multisizer II which is made by Beckman Coulter.

The circularity of toner is measured by FPIA-3000. This particle characterization system is made by Sysmex.

The cohesion which represents flowability of toner is measured by powder tester made by Hosokawa micron corporation.

The tribo-charge of toner is measured by field-Projection method tribo-charge measurement system manufactured by DIT .

The BET value of toner is measured by surface area analyzer made by Mountech co., Ltd.

Preparation of toner

The conventional processes for toner manufacturing including the steps of premixing, extrusion, pulverizing and classification are used to produce the base toner.

The toner consists of resin A around 40~85wt%, resin B around 15~60wt%, the colorant of 5~15wt% and the wax of 1~5wt%. The individual components are premixed in mixer and then kneaded by twin screw extruder for the purpose to disperse the materials consistently into binder resin. After extrusion, the extrusion chips were ground to be the particles with the size around 150~250μm by the pre-grinding equipment. The jet-mill is used for the pulverizing and classification steps. After pulverizing and classification, the D50 of the base toner in the present study is about 7.3μm.

Afterwards, post-blending and rounding processes will be applied to the base toner. In post-blending step, base toner and specific additive, 2wt% to base toner, are mixed by Henschel mixer before the rounding process. The mixing time is 300sec and mixing speeds are varied with experiments. Two kinds of surface additive are used respectively. Then rounding process can be proceeded with this mixed toner.

During the rounding process, feeding rate is fixed to 1±0.2kg/hr. In this study, two circularities of toner were evaluated which are 0.950±0.002 and 0.980±0.002. To reach the target circularity the heat flow of surface fusion system will be adjusted and other operation parameters are fixed. The instrument for surface fusion system is MR-10 made by NPK.

Evaluation

The evaluation indices of the present study are the heat flow temperature, the toner particle size distribution, tribo-charge, BET, and cohesion.

Heat flow temperature
The lower heat flow temperature indicates easier in achieving the circularity requirement. The circularity of toner particle is measured by Sysmex FPIA-3000, and the circularity definition is listed below,

Circularity = (circumferential length of a circle with the same area as particle projected area)/(circumferential length of particle projected image) (1)

Particle size distribution
The variation of particle size distribution before and after the rounding process is used to indicate the aggregated situation of toner particles after rounding process. The lower increment ratio of D50 and lower volume percentage of particle larger than 12.7μm indicate the less toner aggregation.
The increment ratios of D50 is calculated by below equation,

Increment Ratio (%) = (the D50 value after rounding process – the value before rounding process)/(the D50 value before rounding process) × 100% (2)

Tribo-charge
The charge to mass, q/m, represents the tribo-charge of toner. Tribo-charge is a very important characteristic of toner which functions in xerographic process. Tribo-charge must reach and be stable at an appropriate range which is varied with different machines. Field-Projection method tribo-charge measurement system is used to measure q/m which is calculated by below equation,

q/m = total electric charge detected during measuring (micro coulomb) / toner weight (g) (3)

BET
BET is specific surface area of particle which measured by Mountech surface area analyzer. Exclude porosity from definition, larger the BET value means smaller the particle size and larger surface area.

Cohesion
In this study, cohesion is measured by Hosokawa powder tester to evaluate the agglomeration and flowability of toner. Lower the cohesion means lower the toner agglomeration and higher the flowability.

Results and Discussions

Particle size distribution
First part of experiment is mixing toner with Silica A before rounding process, and the results of heat flow temperature and particle size distribution are summarized. In Table 1, when the target circularity of toner is set at 0.950(A1, B1), the effect of mixing speed on heat flow temperature is minor. And the increment of D50 is less than 1.22%. When the target circularity of toner is set at a higher level, 0.980(A2, B2), higher heat flow temperature is needed. By increasing the heat flow temperature, toner particles will be turned into a melting-state and stick with others easily and result in higher D50 increment. With high mixing speed, more silica A will be embedded into toner surface than lower mixing speed. In this situation, there is not enough silica to keep toner particles separated during rounding process. Particles aggregation increases the D50 increment and also makes toner irregularity, so toner needs 30℃ more of heat flow temperature to achieve circularity 0.980. High mixing speed and high temperature result in 18.48% of D50 increment.

Table 2 shows heat flow temperature and particle size distribution when the toner particles achieved the circularity target with Silica B. From the results, when silica B is mixed with toner, the effect of mixing speed on heat flow temperature is minor. Even at high toner circularity (0.980), the D50 increment of toner still under 6.11%. From this point of view, silica B can provide more stable particle size distribution than silica A.

In addition, comparing Table1 and Table2 shows that toner mixed with silica B is easier to achieve circularity target than silica A. At same circularity, the heat flow temperature which is needed to apply on toner with silica B is 5℃ ~ 30℃ lower than toner with silica A. It is in accordance with the result from previous study[3].

Table 1. Toner Circularity, Heat Flow Temp. and Particle Size Distribution －Different Mixing Speed with Silica A

Sample	Mixing Speed (RPM)	Heat Flow (°C)	Circul -arity	Particle Size Distribution		D50 Increment Ratio(%)
				D50 (μm)	>12.7 μm (%)	
Base Toner	---	---	0.933	7.36	2.60	---
A1	2000	190	0.949	7.27	1.39	-1.22
A2		330	0.980	7.72	2.61	4.89
B1	4000	200	0.950	7.45	1.99	1.22
B2		360	0.980	8.72	3.98	18.48

Table 2. Toner Circularity, Heat Flow Temp. and Particle Size Distribution －Different Mixing Speed with Silica B

Sample	Mixing Speed (RPM)	Heat Flow (°C)	Circul -arity	Particle Size Distribution		D50 Increment Ratio(%)
				D50 (μm)	>12.7 μm (%)	
Base Toner	---	---	0.933	7.36	2.60	---
C1	2000	190	0.950	7.54	2.21	2.45
C2		325	0.981	7.81	3.82	6.11
D1	4000	190	0.950	7.54	2.04	2.45
D2		330	0.980	7.72	3.36	4.89

Tribo-charge

In Figure 1, the relationship between circularity and tribo-charge is shown. Silica A was used in these toner samples. At toner circularity 0.950, the tribo-charge of toner makes no big difference between before and after rounding process. But tribo-charge increases dramatically when toner circularity rise to 0.980 after rounding process. Moreover, the mixing process also affects the toner tribo-charge. The tribo-charge is reduced by higher mixing speed.

In Figure 2, it indicated that the tribo-charge is more stable after rounding process mixed with silica B. The variation is no more than 5.3 μC/g.

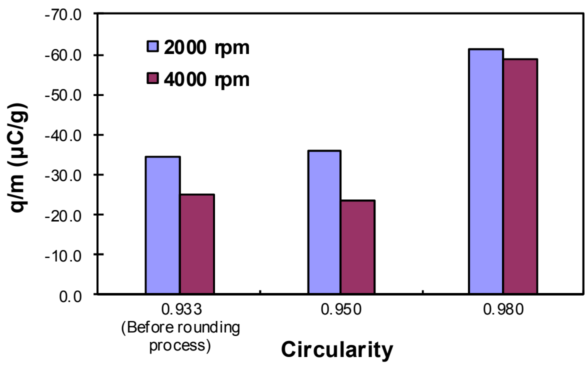

Figure 1. *The relationship between toner circularity and tribo charge at different mixing speed with silica A.*

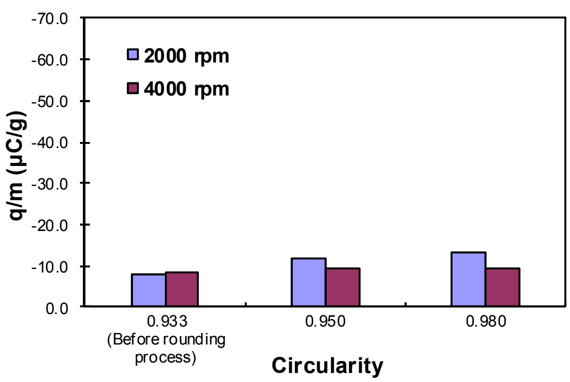

Figure 2. *The relationship between toner circularity and tribo charge at different mixing speed with silica B.*

To know how the mixing and rounding process affects the toner tribo-charge, the BET analysis is proceeded.

Table 3 shows the results of BET and tribo-charge of toner before and after rounding process. A0, B0, C0 and D0 are pulverized toner samples which mixed with surface additive but didn't go through rounding process. The specific condition is listed in Table 3.

Table 3. Toner Circularity, Tribo-charge and BET - Different Mixing Speed and Surface Additive

Sample	Surface Additive	Mixing Speed (RPM)	Circularity	Q/m (μC/g)	BET
A0	Silica A	2000	0.933	-34.3	4.645
A1			0.949	-35.7	1.759
A2			0.980	-61.1	1.251
B0		4000	0.933	-24.8	3.849
B1			0.950	-23.6	1.330
B2			0.980	-59.0	0.896
C0	Silica B	2000	0.933	-7.8	1.749
C1			0.950	-11.6	0.883
C2			0.981	-13.1	0.733
D0		4000	0.933	-8.2	1.692
D1			0.950	-9.1	0.841
D2			0.980	-9.5	0.720

As a whole from the result, the BET value drops after rounding process. The reason is that the mechanism of rounding process is utilizing heat flow to melt the toner surface then the circularity will be increased as a result of surface tension. During the process, binder resin at surface would cover some surface additives which attach on toner particles and smooth some irregular part which results in reducing the BET value.

From another point of view, different mixing speeds also make different BET values. Higher mixing speed gives larger impact force on silica and toner that might embed the silica into the toner, so toner sample gets lower BET value. In this situation, toner particles have less charging site for tribo-charge which results in lower charge than which with lower mixing speed.

Comparing to silica A, the fluctuation of BET value between high and low mixing speed is relatively small with silica B. And it results in stable tribo-charge. The reason is that Silica B is much bigger than silica A which means it has better spacer effect, so silica B will not be embedded easily when mixed at the same mixing speed.

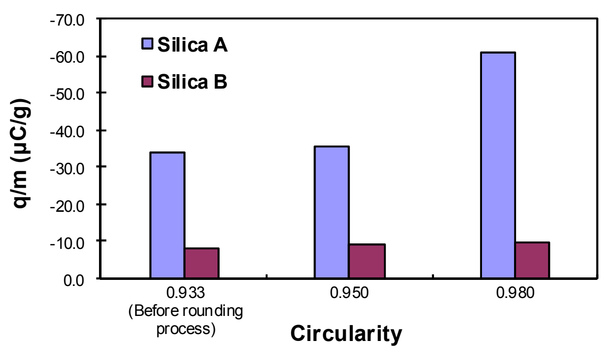

Figure 3. *The relationship between toner circularity and tribo charge with different surface additives at 2000rpm mixing speed.*

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Figure 3 indicates that toner mixed with silica A has higher tribo-charge than silica B in all conditions. The reason is silica A essentially has higher charge than silica B. From this result, tribo-charge of toner could be modified by adjusting surface additives.

Cohesion

Table 4 shows the results of cohesion of toner before and after rounding process. From the results, the cohesion value is no more than 14.4 with silica A at all condition and cohesion of toner with silica B is no less than 26.2. It means surface additive is the key factor to determine the flowability of toner.

Table 4. Toner Circularity and Cohesion - Different Mixing Speed and Surface Additive

Sample	Surface Additive	Mixing Speed (RPM)	Circularity	Cohesion
A0	Silica A	2000	0.933	9.6
A1			0.949	14.4
A2			0.980	11.9
B0		4000	0.933	10.5
B1			0.950	9.6
B2			0.980	10.0
C0	Silica B	2000	0.933	34.3
C1			0.950	45.0
C2			0.981	34.1
D0		4000	0.933	26.2
D1			0.950	47.7
D2			0.980	35.4

Conclusion

By adjusting the surface additive and mixing speed before rounding process, the toner with required characteristics can be produced. Mixing with small silica, toner obtains high tribo-charge and better flowability. On the other hand, mixing with big silica will ease the difficulty of rounding and stabilize the D50 increment by stronger spacer effect.

From the viewpoint of tribo-charge, higher mixing speed will make tribo-charge lower because of embedding silica into toner surface and lack of friction area. It is noticeable that toner with small silica rounding at higher circularity level will increase tribo-charge substantially.

References

[1] K. K. Chamili Kumara, et al., Effect of Charging Method on Charging Characteristics of Mono-component Toner, Proceedings IS&T NIP23: International Conference on Digital Printing Technologies and Digital Fabrication 2007, pg. 61-64.

[2] Shyi-Shyang (Robert) Li, et al., Performance Analysis of Pulverized "Rounding" Surface Treated Toner (RST-toner) vs. Chemically Prepared Toner (CP-toner), Proceedings IS&T NIP23: International Conference on Digital Printing Technologies and Digital Fabrication 2007, pg. 274-277.

[3] Johnny Wang, et al., The Research of Process and Characteristic of Pulverized Rounding Surface Treated Toner, Proceedings IS&T NIP27: International Conference on Digital Printing Technologies and Digital Fabrication 2011, pg. 395-398.

Author Biography

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