The Research of Process and Characteristic of Pulverized Rounding Surface Treated Toner

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Abstract

The purpose of this study is to research into the relationships between the characteristics of the pulverized rounding surface treated toner (RST Toner) and various surface treatments, BET values and quantities of surface additives. The surface additives with different surface treatments including DDS, HMDS and PDMS are used in this study as the spacer between toner particles before the rounding surface treatment process. In this study, the surface fusion system is used to prepare the RST toner with the circularity about 0.970.

Introduction

The toner shape is an important effect on image quality to meet the requirements when the trend of printing technology is toward faster, higher resolution and colorful. The regular and round shape toner could be narrower in tribo-charge distribution [1] and higher transfer efficiency than the toner with irregular shape. The polymerization method for toner manufacturing could control the particle shape easier than the conventional method like pulverization, but the environmental issue like water consumption in chemical process is still the problem should be concerned.

The surface fusion system is used in different industries for the surface modification and would be used in this study to produce the rounding surface treated toner (RST toner) [2]. The basic principle of this surface fusion system is utilizing the high temperature energy for surface modification and increasing the circularity of pulverized toner by the surface tension of toner particle. The challenge of this surface modification (rounding) process is toner particles aggregate easily before or after passing through the high temperature zone and results in decreasing the toner circularity and shifting the particle size distribution. For the purpose of preventing toner aggregation, the surface additives are added to be the spacer between toner particles before this rounding process. How the conditions include different surface treatment additives, different additives BET and different additives quantities affect the rounding treatment process will be discussed in this study.

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 made by DIC Corporation. Blue 15 and Green 7 are comprised in this colorant.

The wax is ethylene-propylene copolymer type. The melting point is about 140~170°C, made by Coschem.

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

Silica A: The hydrophobic treatment is DDS, the BET value is 200m^2/g, the primary particle size is 12nm, the carbon content is about 0.7~1.3%, and the methanol wettability is 35%, made by Evonik Degussa.

Silica B: The hydrophobic treatment is HMDS, the BET value is 200m^2/g, the carbon content is about 4.0~5.0%, and the methanol wettability is 70%, made by Cabot.

Silica C: The hydrophobic treatment is PDMS, the BET value is 200m^2/g, the carbon content is about 3.0~5.5%, and the methanol wettability is 60~70%, made by Evonik Degussa.

Silica D: No hydrophobic treatment and the BET value is 200m^2/g, made by Cabot.

Silica E: The hydrophobic treatment is DDS, the BET value is 130m^2/g, and the primary particle size is 16nm, made by Evonik Degussa.

Silica F: The hydrophobic treatment is DDS, the BET value is 300m^2/g, and the primary particle size is 7nm, made by Evonik Degussa.

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.

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 in this study.

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 are mixed by Henschel mixer before the rounding process. The mixing condition is 4000rpm with 300sec. The kinds and amounts of additives vary with different experiments. Then rounding process can be proceeded with this mixed toner.

In the rounding process, feeding rate is fixed to 2±0.5kg/hr and the target of toner circularity is 0.970±0.002. The surface fusion system for rounding process is MR-10 made by NPK. The operation parameters are fixed and the temperature of heat flow is the only varying parameter in present study.

Evaluation

The evaluation indices of the present study are the toner particle size distribution and the heat flow temperature.

The lower heat flow temperature of surface rounding process when toner circularity achieved the target 0.970±0.002 is better. The lower operating 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)

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 which large than 12.7μm indicate the less toner aggregation.

The increment ratios of D50 and circularity are calculated by below equation,

Increment Ratio (%) = (the value after rounding process - the value before rounding process)/(the value before rounding process) × 100%

Results and Discussions

Different Surface Treatment Additives

Table 1 shows the circularity of toner particles and the heat flow temperatures which the toner particles achieved the circularity target. From the results, the heat flow temperatures when toner with different silica achieved circularity target 0.970±0.002 are 305°C/silica A, 330°C/silica B, 305°C/silica C and 330°C/silica D respectively. The circularity increment ratio of toner particles with silica A at 305°C is 4.18% and silica C is 3.75%, it indicates the toner with silica A could be easier to meet the circularity target than the others, so the difficulty sequence of achieving circularity is silica A< silica C< silica B< silica D.

Table 2 shows the toner particle size distributions before and after the rounding process. From the results, the D50 increment ratios at 305°C are 2.47%/silica A, -0.55%/silica B, 4.95%/silica D respectively, and the D50 of toner particles with silica C is no difference before and after the rounding process. It means the particles aggregation level is silica B< silica C< silica A< silica D. The volume percentages of >12.7μm are with the same tendency. The toner particles with silica D are easier aggregated than others because the silica D is hydrophilic. The carbon content and methanol wettability of silica A are both less than silica B and silica C, it indicates the hydrophobic level of silica A is less than silica B and C, and results in easier particles aggregation.

Figure 1 shows the D50 of toner with different silica are increasing with the temperature. It indicates the toner particles are easier aggregated when heat flow temperature of the rounding process is getting higher. Therefore, the lowest circularity achieving temperature is better because the less in toner aggregation.

Table 1. Toner Circularity and Heat Flow Temp. – Different Surface Treatment Silica

Rounding Process	Silica (Surface Treatment)	Heat Flow (°C)	Circularity	Increment Ratio (%)
Before	---	---	0.933	---
After	A (DDS)	305	0.972	4.18
	B (HMDS)	305	0.966	3.54
		330	0.970	3.97
	C (PDMS)	305	0.968	3.75
	D (---)	305	0.963	3.22
		330	0.969	3.86

Table 2. Toner Particle Size Distribution and Heat Flow Temp. – Different Surface Treatment Silica

Rounding Process	Silica	Heat Flow (°C)	Particle Size Distribution D50 (μm)	Particle Size Distribution >12.7μm (%)	D50 Increment Ratio (%)
Before	---	---	7.28	0.89	---
After	A	305	7.46	2.16	2.47
		340	7.82	3.53	7.42
	B	305	7.24	0.90	-0.55
		330	7.33	0.97	0.69
	C	305	7.28	1.11	0.00
		315	7.37	0.75	1.24
	D	305	7.64	2.39	4.95
		330	7.91	3.97	8.65

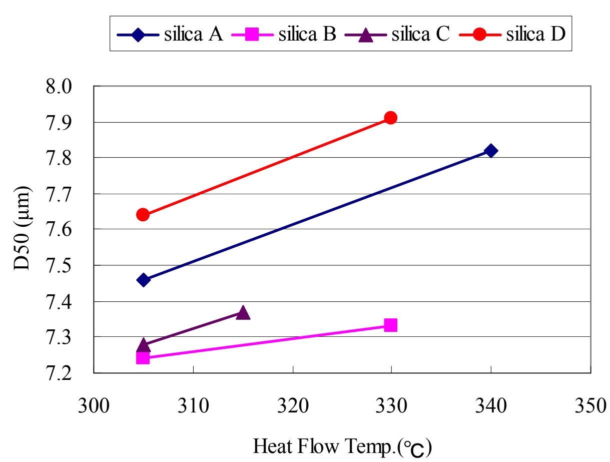

Figure 1. *Toner D50 is increasing with the heat flow temperature*

Different Additives BET

The silica A, E and F are the same hydrophobic treated silica but different in the BET values and primary particle sizes.

Table 3 shows the circularity of toner particles and the heat flow temperatures which the toner particles achieved the circularity target. From the results, the heat flow temperatures when toner with different silica achieved circularity target 0.970±0.002 are 290°C/silica E, 305°C/silica A, and 305°C/silica F respectively. The toner with silica E could achieve the circularity target at the lowest temperature in rounding process, it indicates the toner with silica E could meet circularity target easier than toner with silica A or silica F. The difficulty sequence of achieving circularity is silica E< silica A< silica F from the results of circularity increment ratios.

Table 3. Toner Circularity and Heat Flow Temp. ─ Different Additives BET

Rounding Process	Silica	BET	Heat Flow (°C)	Circular -ity	Increment Ratio (%)
Before	---		---	0.933	---
After	E	130	290	0.969	3.86
			305	0.974	4.39
	A	200	305	0.972	4.18
	F	300	305	0.968	3.75
			315	0.970	3.97

Table 4 is the results of toner particle size distributions before and after the rounding process. The D50 increment ratios of toner with silica E and A at 305°C are 1.92% and 2.47%, and the volume percentages of particles large than 12.7μm are 1.28% and 2.16% respectively. It indicates the toner with silica A is easier aggregated than toner with silica E in the rounding process. From the comparison of toner with silica A and silica F, the D50 increment ratio does not increase with BET, but the toner with silica F should be easier aggregated than toner with silica A from the results of >12.7μm percentages. The function of silica in this study is to be the spacer between toner particles for preventing the toner aggregated and the lower BET or larger silica primary size could have the strong spacer effect.

Different Additives Quantities

The silica E is chosen to use in this part of study because the toner with silica E is less aggregated than others and easier in achieving circularity target. Table 5 shows the results of toner circularity and heat flow temperatures which the toner particles achieved the circularity target. From the results, the toner with 0.5% or 2.0% silica meet the circularity requirement at the same heat flow temperature 290°C and the increment ratios of circularity are the same. It indicates the toner with silica E is easier in achieving the circularity no matter the decreasing in silica quantity.

Table 6 shows the results of toner particle size distributions before and after the rounding process. From the results, the D50 increment ratio and >12.7μm percentages of toner with 0.5% silica E are both obviously higher than the toner with 2.0% silica at 290°C. The D50 increment ratios of toner with 0.5% and 2.0% silica E are 4.95% and 0.69%, the >12.7μm percentages are 3.32% and 1.22% respectively. It indicates the toner particles are easier aggregated in rounding process if the silica quantity is too less to have spacer effect.

Table 4. Toner Particle Size Distribution and Heat Flow Temp. ─ Different Additives BET

Rounding Process	Silica (BET)	BET	Heat Flow (°C)	Particle Size Distribution		D50 Increment Ratio (%)
				D50 (μm)	>12.7μm (%)	
Before	---	---		7.28	0.89	---
After	E	130	290	7.33	1.22	0.69
			305	7.42	1.28	1.92
	A	200	305	7.46	2.16	2.47
	F	300	305	7.42	2.98	1.92
			315	7.42	5.32	1.92

Table 5. Toner Circularity and Heat Flow Temp. ─ Different Additives Quantities

Rounding Process	Silica	Quantity (Wt. %)	Heat Flow (°C)	Circularity	Increment Ratio (%)
Before	---		---	0.933	---
After	E	0.5	290	0.969	3.86
		2.0	290	0.969	3.86

Table 6. Toner Particle Size Distribution and Heat Flow Temp. ─ Different Additives Quantities

Round-ing Process	Silica	Quantity (Wt. %)	Heat Flow (°C)	Particle Size Distribution		D50 Increment Ratio (%)
				D50 (μm)	>12.7 μm (%)	
Before	---	---	---	7.28	0.89	---
After	E	0.5	290	7.64	3.32	4.95
		2.0	290	7.33	1.22	0.69

Conclusions

For the purpose of preventing the toner from aggregation in rounding process, the silica could be used as the spacer between toner particles. In this study, the results indicate the toner with DDS treated silica could easier achieve the circularity target than the silica is hydrophilic or treated with HMDS or PDMS. Containing silica of lower BET value, toner could easily meet the circularity target and be free from aggregation as a result of stronger spacer effect. There is no difference in the difficulty to achieve the circularity when decreasing the amount of DDS silica, but the toner particles aggregate easily when toner with less amount of silica.

References

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