Influence of Properties of Magnetite on Tribocharging Characteristics of Mono-component Magnetic Toners

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Abstract

It is important to know the triboelectric charging characteristics of a toner to control the mono-component magnetic toner development system. In this paper, we studied the relationship between the triboelectric charge to mass ratio (Q/M) of a mono-component magnetic toner and several parameters of magnetite incorporated in the toner. In order to remove the influence of different magnetic force on magnetic toner charging behavior, we measured the triboelectric charge of the mono-component magnetic toner against an iron oxide powder carrier. The concentration of magnetite in the toner was changed from approximately 5 to 55 wt%. We used several kinds of magnetite differing in their particles size and shape. We found that the Q/M decreased proportionally with an increase in magnetite concentration. We assumed this Q/M decrease was related to the magnetite on a toner surface. We calculated the number of magnetite particle on a toner surface, and total cross-sectional area of magnetite particle on a toner surface. The result suggests that total cross-sectional area of magnetite on a toner surface has no effective triboelectric charge. In conclusion, we can describe a relational expression between Q and the parameters of the magnetite as $Q=Q0\times(1-Sm/S)$, where, Q is toner charge, Q0 is charge for the magnetite-free toner, S is surface area of a toner, and Sm is the total cross-sectional area of magnetite on a toner surface.

Introduction

The mono-component magnetic toner development system has been put to practical use as a widely applicable method for low-end to high-end electrophotographic systems.[1] The mono-component magnetic toner is mainly composed of polymer resin and magnetite, together with other ingredients which give the toner magnetic and triboelectric properties required for development, transferring, and fixing onto paper during the electrophotographic processes. It is the most important point to stabilize the triboelectric charge of toner to control the mono-component magnetic toner development system.[2] Although there are many studies about the triboelectric charging characteristics of a two-component toner, there are not enough for the mono-component magnetic toner.[3-9] It is the reason that the triboelectric charging behavior of the mono-component development system is complicate. The same toner indicates occasionally different Q/M value with different development system. Therefore, it is important to know the triboelectric charging characteristics of a toner to design the mono-component magnetic toner development system.

In this study, we tried to make a clear distinction between the roles of magnetic and triboelectric properties of magnetite in the magnetic toner.

Experimental

Toners and Magnetite

To analyze the influence of magnetite on the triboelectric property of the magnetic mono-component toner, we prepared six groups of toners, which are shown in Table 1. All the toners are of negative type, irregular shape, and made of polystyrene-acrylic resin. To clarify the relationship between the triboelectric property of the toner and magnetite property, we used magnetites with different shape and size. Additionally, we changed the magnetite concentration of the toners.

Measurement Procedure of Q/M

To remove the influence of development system dependence on toner charging, we used the triboelectric charging between toner and carrier. The carrier is an irregularly shaped oxidized iron powder, whose mean diameter is approximately 70 μm (Powder Tech Co., Ltd.: EFV 200/300). For the measurement of Q/M with a shaker (Yayoi Co., Ltd.: Model-YS-8D), all the toner powders were combined with the carrier at 2.0% of T/C, and shaken at 200 rpm for 3 minutes. The Q/M of the toner was measured with suction type blow-off equipment. [10-11]

Table 1. Toners used in this study

Toner		Magnetite		
Gr.	D_T (μm)	Shape	Dmag (μm)	WT% (%)
D5S25	5	spherical	0.25	16.7, 37.5, 44.4, 50.0, 54.5
D5S15	5	spherical	0.15	9.1, 16.7, 28.6, 37.5
D5S05	5	spherical	0.05	37.5
D5S03	5	spherical	0.03	37.5
D5AC	5	acicular	0.42/0.06	4.8, 9.1, 16.7, 28.6
D8S25	8	spherical	0.25	16.7, 37.5, 44.4

Results and Discussions

The Relationship Between Magnetite Concentration and Q/M

Figure 1 shows the relationship between magnetite concentration of toner and Q/M for D5S25 group and D8S25 group toners. The difference between D5S25 and D8S25 group toners is the toner diameter (mean volume diameter). As shown in Figure 1, triboelectric charge to mass ratio (Q/M) decreased with increasing magnetite concentration of toner.

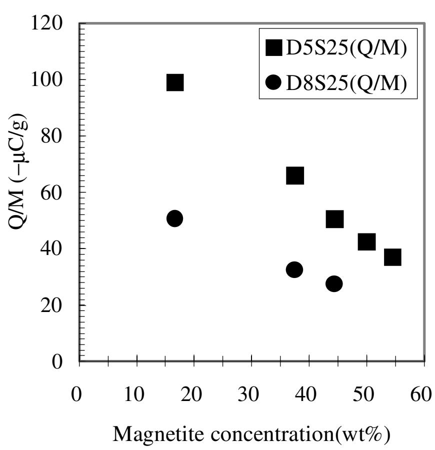

Figure 1.The influence of magnetite concentration on Q/M.

There are two factors in this decrease in triboelectric charge. One is a decrease in charge (Q) and the other is an increase in mass (M). Therefore, in order to remove the influence of increase in toner mass with an increase in magnetite concentration, we converted Q/M to Q/V values by using the following equations, ρ_r=1 g/cm^3, and ρ_{mag} =5 g/cm^3.

$$Q/M = Q/(\rho_t V) \quad (1)$$

$$\rho_t = M/(M_r/\rho_r + M_{mag}/\rho_{mag}) \quad (2)$$

ρ_t, ρ_r, ρ_{mag} : toner, resin , magnetite density
M_r, M_{mag} : resin, magnetite mass
V: toner volume

Figure 2 shows the relationship between triboelectric charge to volume ratio (Q/V) and magnetite concentration of toner. The charge to volume ratio (Q/V) decreased with increasing magnetite concentration as well as Q/M. This result indicates that a magnetite property is related to the triboelectric property of the magnetic mono-component toner.

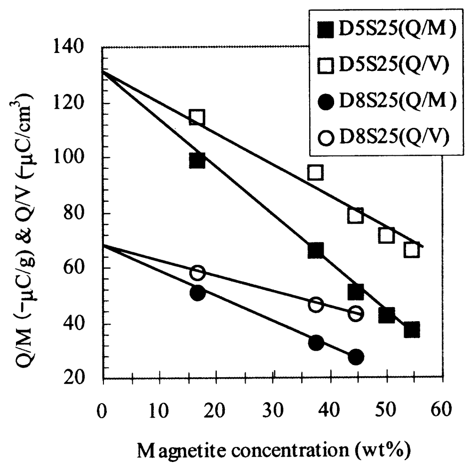

Figure 2.The influence of toner weight increase on Q/M.

The Relationship Between Q/M and Different Size and Shape of Magnetite

To investigate the magnetite property dependence of Q/M, we measured Q/M of several toner groups, additionally, which were D5S15, D5S05 and D5AC. Each group toner has the same diameter, but contained different type magnetite. To make comparison between the magnetite property and Q/M for all toner groups easily, we chose toners with same diameter.

Figure 3 shows the relationship between Q/M and magnetite concentration for each toner group. Similarly to Figure 2, we converted Q/M to Q/V as shown in Figure 4. Both the Q/M and Q/V decreased linearly with increasing magnetite concentration for all the toners of all groups. In Figure 4, the following results were confirmed; (1) Q decreases linearly with an increase in magnetite concentration for the same kind of magnetite, (2) decreasing rate of Q is large in the toner contained acicular shaped magnetite, and (3) decreasing rate of Q is larger in the toner with small size spherical magnetite than with large size spherical magnetite.

In general, triboelectric phenomenon depends on toner surface property. Therefore, the decrease in Q with an increase in magnetite concentration is considered to be related with the magnetite on toner surface.

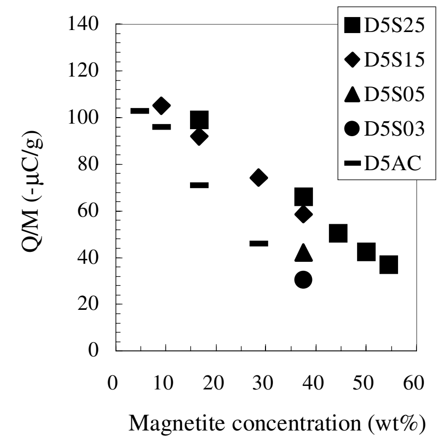

Figure 3. The relationship between Q/M and magnetite concentration with various sizes and shapes.

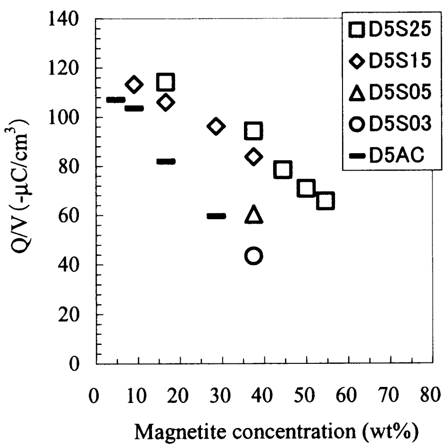

Figure 4. The relationship between Q/V and magnetite concentration with various sizes and shapes.

The Influence of the Number of Magnetite Particle on a Toner Surface

To analyze the influence of magnetite property at the toner surface on decrease in Q, first, we studied the influence of the particle density of magnetite at the toner surface. If the magnetite at the toner surface works as decay sites for Q, the decrease in Q can be considered to be proportional to particle density of magnetite on a toner surface.

We assume that the toner shape is spherical and the magnetite particles are dispersed uniformly in the toner.

In that case, the particle density of magnetite on a toner surface is supposed to the particle density of magnetite in a toner surface layer of a magnetite diameter depth, which model is illustrated in Figure 5 and Figure 6.

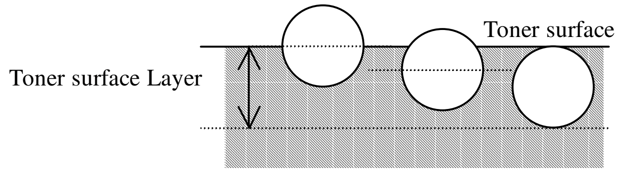

Figure 5. The model of magnetite on toner surface (spherical type).

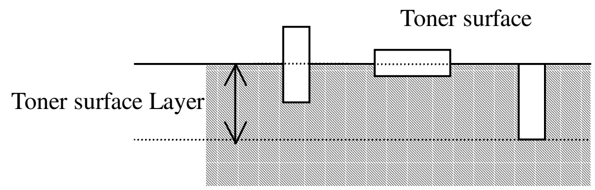

Figure 6. The model of magnetite on toner surface (acicular type).

According to this model, the number of magnetite particle in a unit area on toner surface is calculated by the following equation.

$$N=\{(M_{mag}/ \rho_{mag}\, v_{mag})/V\}D_{mag} \quad (3)$$

N : number of magnetite particle in a unit area
v_{mag}: volume of magnetite particle

Figure 7 shows the relationship between Q/V and the number of magnetite particle in a unit area on a toner surface. As shown in Figure 7, Q/V is not correlative with the number of magnetite particle on a toner surface. Therefore the number of magnetite particle on a toner surface is not directly the cause of the decrease in Q.

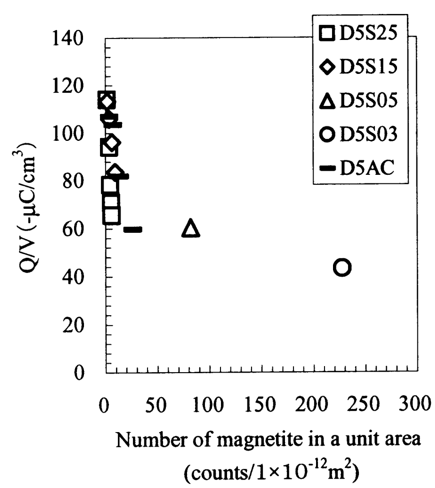

Figure 7. The relationship between Q/V and number of magnetite particle in a unit area on a toner surface.

The Influence of the Magnetite Cross-Sectional Area on a Toner Surface

Second, we studied the influence of the cross-sectional area of magnetite at the toner surface on the decrease in Q.

To estimate the magnetite cross-sectional area, we assume that the cross-sectional area of a magnetite particle is a projective figure area of a magnetite particle on a toner surface. According to this model, the fraction of cross-sectional area of magnetite particle in a unit area on a toner surface is calculated by the following equations.

$$S_{mag}=\{(M_{mag}/\rho_{mag}v_{mag})/V\}D_{mag}s_{mag}=Sm/S \tag{4}$$

S_{mag}: fraction of the cross-sectional area of magnetite particle in a unit area on a toner surface
Sm: total cross-sectional area of magnetite in toner surface
S : toner surface area
s_{mag}: projective cross-sectional area of a magnetite particle

If the shape of magnetite particle is sphere,

$$s_{mag}=\pi(D_{mag}/2)^{\wedge 2} \tag{5}$$

If the magnetite particle is acicular,

$$s_{mag}=\pi(D_{magS}/2)^{\wedge 2}/3+(D_{magL}D_{magS})\,2/3 \tag{6}$$

D_{magS}: Short axis
D_{magL}: Long axis

Figure 8 shows the relationship between Q/V and the fraction of cross-sectional area of magnetite particle in a unit area on a toner surface. It can be confirmed that Q/V is correlative well with the fraction of cross-sectional area of magnetite particle in a unit area on a toner surface. This result suggests that Q decreases linearly with an increase in fraction of cross-sectional area.

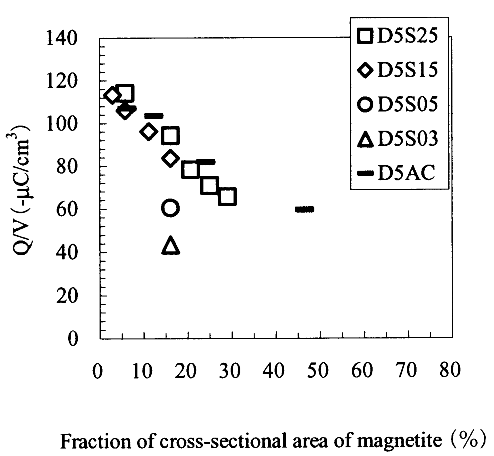

Figure 8. The relationship between Q/V and fraction of cross-sectional area of magnetite on a toner surface in a unit area.

The Compensation of the Cross-Sectional Area of Magnetite Particle With Smaller Size Magnetite

As shown in Figure 9, the slope of the plot of Q/V vs. fraction of cross-sectional area of magnetite particle is steeper for smaller size spherical magnetite. To clarify this phenomenon, we reconsider the assumption of the toner surface depth and the cross-sectional area of magnetite particle. The Q/V value of the magnetite free toner of all toner groups is same (Q=Q0). If the cross-sectional area of magnetite particle has no charge, the Q/V value should be 0 at S_{mag}=1. Therefore, we can draw an ideal line from Q0/V at S_{mag}=0 to 0 at S_{mag}=0 as shown in Figure 9. If Q/V value is located under this ideal line, we underestimated the cross-sectional area of magnetite particle on toner surface or the cross-sectional area of magnetite particle has positive charge.

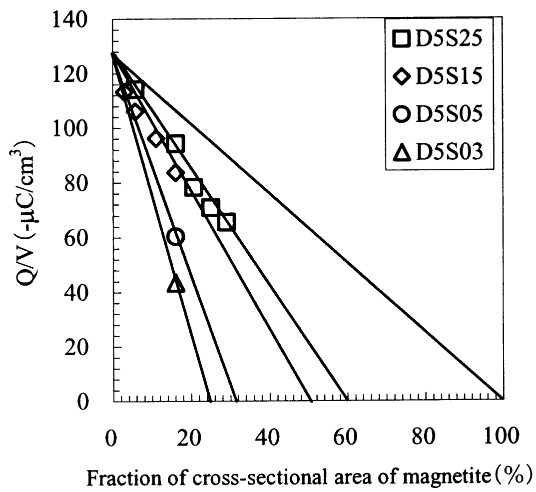

Figure 9. The relationship between Q/V and fraction of cross-sectional area of small size magnetite in toner surface.

To distinguish these two factors, we consider two compensation model of the cross-sectional area of magnetite particle.

One is shown in Figure 10, in which the effective magnetite particles are in the effective toner surface layer of the same constant depth, and the other is shown in Figure 11, in which the effective cross-sectional area of magnetite particle is larger than real one, which means effective magnetite diameter is lager than real one. We define a Deff as a effective magnetite diameter and K as an enlargement distance of magnetite diameter in Figure 11.

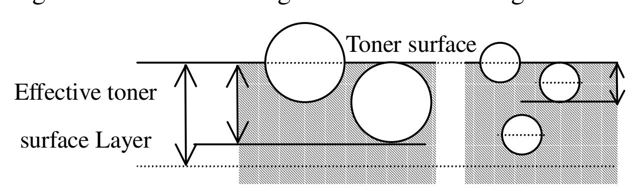

Figure 10. The cross-sectional area model of magnetite on toner surface (constant depth type).

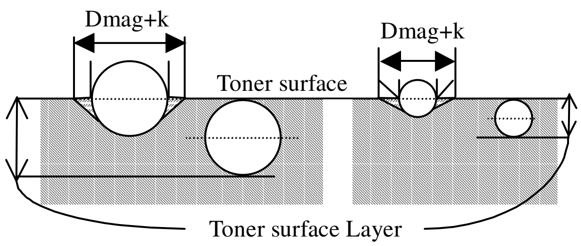

Figure 11. The cross-sectional area model of magnetite on toner surface (effective diameter type)

$$Deff = D_{mag} + K \quad (7)$$

We calculated compensation values of each model by fitting the Q/V line to the ideal line.

Figure 12 shows the relationship between effective toner surface depth and diameter of magnetite. This result shows effective toner surface depth varies depending on the magnetite particle size. Therefore this model is not adequate to the compensation.

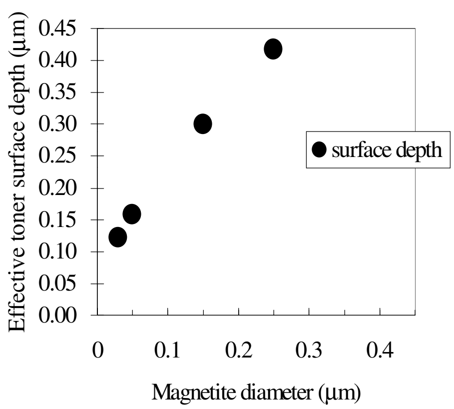

Figure 12. Effective toner surface depth.

Next, Figure 13 shows the relationship between effective diameter of magnetite particle and real one.

Figure 13 shows an enlargement distance (K) of magnetite diameter in this model is nearly constant at different size magnetite. If the area around of magnetite particle affects the decrease in Q as well as cross-sectional area of magnetite particle, the influence of magnetite property to resin is supposed to depend on the distance from a surface of magnetite and not strongly depend on magnetite size. An enlargement distance (K) in this model is nearly constant at different size magnetite.

Therefore this result shows the area around of magnetite particle affects the decrease in Q as well as cross-sectional area of magnetite particle. Additionally, this result suggests that effective cross-sectional area of magnetite particle has no charge, because material of extension area is resin which tribocharges negatively, so that, negative charge of extensional resin area was decayed. Therefore we think effective diameter model is reasonable.

Figure 14 shows the relationship between Q/V and the fraction of cross-sectional area of magnetite particle in a unit area on a toner surface with effective diameter of magnetite particle. All Q/V are nearly on a line.

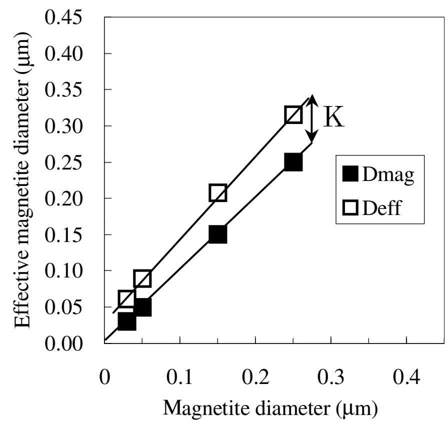

Figure 13. Effective magnetite diameter.

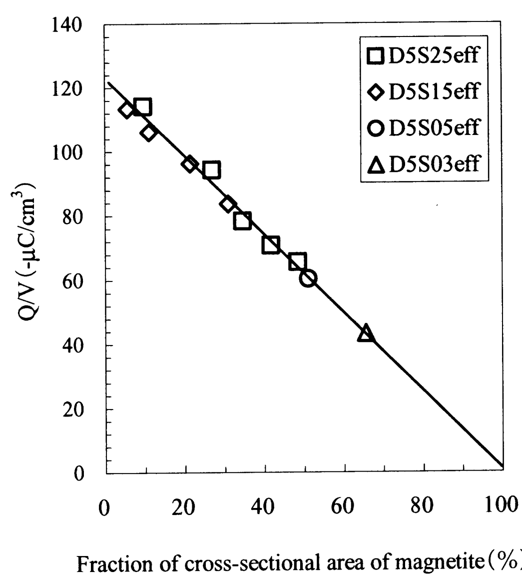

Figure 14. The relationship between Q/V and fraction of effective cross-sectional area of magnetite on toner surface

The Comparison of the Influence of the Magnetite Cross-Sectional Area Between Different Size Toner

If the decrease in Q is proportional to increase in fraction of cross-sectional area of magnetite in a unit area on toner surface, Q reaches 0 at the same fraction of cross-sectional area of magnetite between different size toners. We can confirm this conclusion in Figure 15. Each line of the plot of Q/V and magnetite concentration reaches 0 at the same point on the abscissa.

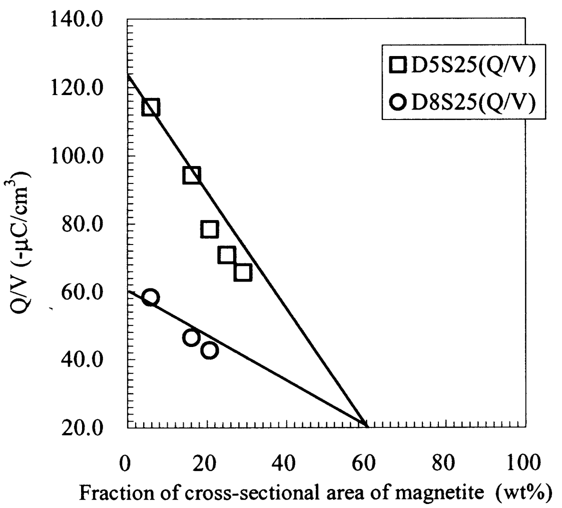

Figure 15. The relationship between Q/V and fraction of effective cross-sectional area of magnetite on a toner surface.

Conclusion

We studied the relationship between the triboelectric property of the magnetic mono-component toner and magnetite property by changing magnetite concentration and type of magnetite used. By examining Q/M behavior between several magnetic toners and carrier, the following conclusions were obtained.

1. The decrease in Q with an increase in magnetite concentration is related to the magnetite on a toner surface.
2. The decrease in Q is proportional to total cross-sectional area of magnetite on a toner surface.
3. The cross-sectional area of magnetite on a toner surface has no effective triboelectric charge.
4. A relational expression between Q and the parameters of the magnetite can be written as $Q=Q0\times(1-Sm/S)$, where, Q is toner charge, Q0 is charge for the magnetite-free toner, S is surface area of a toner, and Sm is the total cross-sectional area of magnetite on a toner surface.

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Biography

Tatsuya Tada received the B. Eng. and M. Eng. degrees from Tohoku University Japan in 1982, 1984, respectively. In 1984 he joined Canon Inc. and is working for the R&D division. He is now a part-time student in the Ph. D. course at Ibaraki University.