A New Blow-off Apparatus for Measuring Intrinsic Toner-Carrier Charges

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Abstract

A blow-off apparatus employing a unique Faraday cage, on which blowing and sucking attachments were mounted, has been fabricated. The apparatus realized a high speed toner-carrier separation and complete removal of the separated toner without agitation in the Faraday cage, thus reducing the tribocharge due to gas blowing to a minimum value. Therefore, the charging amount was regarded as the intrinsic charge of a particular toner-carrier combination. The apparatus construction, the Faraday cage structure, and the optimization of blow-off conditions will be described.

Introduction

In the two-component developer, the charging amount generated between the toner and carrier has been measured by the blow-off method.[1~4] In the blow-off measurement, a toner-carrier mixture is placed into a Faraday cage, which consists of a metal cylinder with meshes provided on both ends of the cylinder. The compressed gas is spurted from the nozzle attached to one or both ends of the cylinder, and toner particles separated from the carrier surface are blown out through the mesh. The generated charge, which is of the same amount but opposite polarity to that of the blown off toner, remains on the carrier particles in the Faraday-cage and measured by an electrometer.

Toner-carrier separation can also be achieved by sucking air through the mesh from one end of the cylinder.[5] Mesh-less blow-off measurements were also attempted.[6] In this case, iron or ferrite beads were used as carrier particles. The toner-carrier mixture was deposited on a rotating magnet rod and compressed gas was spurted directly to the deposited mixture on the rod. The separated charge remained on the carrier particles are measured by an electrometer connected to the rod.

In the mesh-less blow-off measurement, gas blow has to be made weak to prevent the removal of the carrier particles from the magnet rod, this sometimes brings difficulties in the complete removal of toner particles from the rod. On the other hand, the toner separation by strong gas blow or air sucking in other blow-off measurements give a large deviation from the intrinsic charge, because the charging amount in this case always contains a contribution of tribocharging caused by the separated toner and carrier agitation during the measuring operation.

Consequently, the charging amount the conventional blow-off measurement yields should be regarded as a relative value rather than an intrinsic one. The blowing conditions such as the nozzle orifice, the flow rate and the pressure of blowing gas, the structure of the Faraday cage and mesh opening affects the charging amount.

Therefore, a new type of Faraday cage that satisfies the following requirements is needed.

1. The toner particles in the sample are rapidly and perfectly blown off from the carrier surface,
2. agitation of the sample particles caused by the blowing and sucking operation in the cage is maintained to the minimum level,
3. the blown-off toner particles are completely removed from the cage.

In this paper, the principle and the structure of the Faraday cage for the blow-off measurement that enable high speed toner-carrier separation and simultaneous removal of the separated toner are described. The amount of the measured charge is compared with that obtained from the conventional Faraday cage, and the factors that affect the blow-off charging amount are discussed. Also studied are the physical meaning of the obtained charge and the limits of the measurement using the new type Faraday cage.

Principle and Fabrication of the Faraday Cage

Figure 1 shows the structures of the conventional and new type Faraday cages, both developed by us. To obtain a high speed toner-carrier separation, the inner walls of the cylinders for the both types of the cages were tapered, and a nozzle was attached to the top (the narrower end). Toner-carrier mixture samples were set onto the stainless steel (SUS) mesh attached to the bottom (the wider end) of the cylinder. The nozzle orifice of the new type cage is 3 mm Φ while that of the conventional one is 1 mm Φ. A steam regulating disk was attached to the tip of the new type nozzle to make the compressed gas flow along the inner wall of the cylinder.

Figure 2 shows the bottom end structures of the Faraday cages. Here, the bottom ends mean the bottom surfaces of the mesh holders. At the bottom end of the new type Faraday cage, plural grooves (1 mm deep) which aligned tangential direction to the inner wall were engraved. Figure 3 shows the measuring operation. The upper surface of the sucking attachment was brought into contact with the bottom surface of the Faraday cage. At the start of the measurement, gas blowing and air sucking was started simultaneously. Toner particles separated from the carrier surface were blown off through the mesh and instantly removed by the vortex air layer which was generated by air sucking through the grooves.

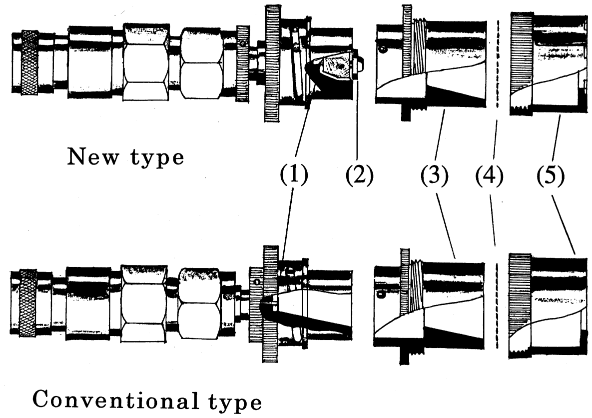

Figure 1. Faraday-cage structure.
(1) Nozzle
(2) Regulating disk
(3) Cylinder
(4) SUS mesh
(5) Mesh holder

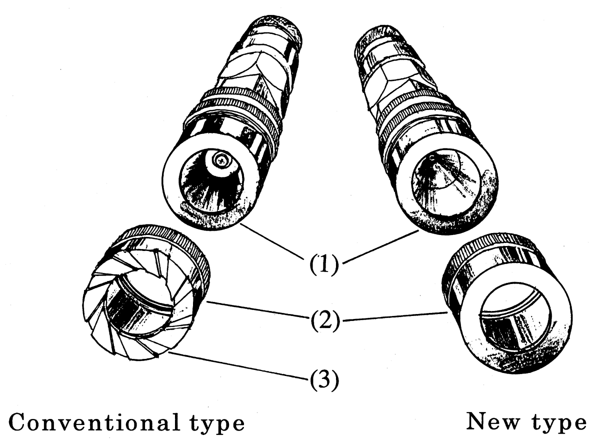

Figure 2. Faraday-cage structures.
(1) Cylinder
(2) Mesh holder
(3) Groove
Meshes are set between (1) and (2)

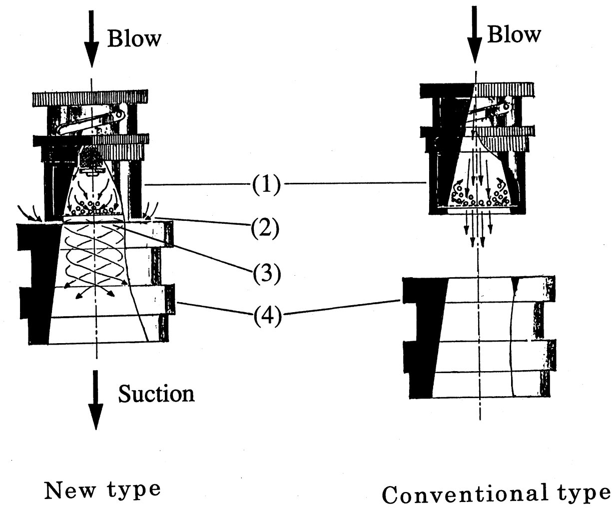

Figure 3. Measuring operation in Faraday-cages.
(1) Cylinder
(2) Sucking air through grooves
(3) Vortex air
(4) Sucking attachment

Results and Discussions

Comparison of the Measurement Results Using Two Types of Faraday Cages

The measurement conditions and results using two types of Faraday cages are compared in Table 1.

In the new type Faraday cage, the orifice of the gas blowing nozzle, gas blowing pressure and air sucking pressure were different from those of the conventional cage.

The sample weight loss in Table 1 was obtained from the difference of weights of the Faraday cage containing a sample before and after the blow-off measurement. The weight loss in the new type Faraday cage coincided with the toner weight in the sample. In the conventional type Faraday cage, on the other hand, the weight loss was sometimes larger than the toner weight. The large weight loss observed in the developer B is regarded as the weight loss of carrier particles and/or the SUS mesh caused by an abrasion due to the agitation by blowing gas. The agitation by

Table 1. Measurement Conditions and Results

	Nozzle mmΦ	Mesh	Gas blowing pressure kg/cm^2	Air sucking pressure mmAq	Blow-off condition	Blow-off charge μC/g	Sample weight loss%	Toner sticking to the cage tip
Conventional type cage	1.0	SUS 400	1.0	1.0	continuous 30secx1	developer A 21.9	toner weight +2	slightly
						developer B 38.8	toner weight +22	slightly
New type cage	1.0	SUS 400	0.25	800	continuous 2 sec × 5	developer A 21.5	toner weight	none
						developer B 12.0	toner weight	none

blowing gas in the conventional type cage also generates the large tribo-charge which explains the large blow-off charge on developer B.

The sticking of the blown off toner to the bottom surface of the cage was observed in the conventional type Faraday cage but the reduction of the blow-off charges due to this sticking toner was negligible, because the charging amount were larger than that obtained by the new type cage on which toner sticking has not been observed.

These result shows that in the case of the new type Faraday cage the three fundamental requirements mentioned in introduction are well satisfied.

Comparison of Blow-off Curves

Figure 4 shows a typical example of measurement results in which the same amount of blow-off charge was obtained for both types of the Faraday cages. In the case of the new type Faraday cage, the charge increased instantly after starting the measuring operation, and attained to the saturation value in a short time. In the case of the conventional cage, the time needed to reach the same saturation value was much longer than that of the new type cage. These results show that by using the new type Faraday cage the measurements are completed within 2~3 seconds; because of the improved cage structure, the toner-carrier separation and the removal of the blown off toner were conducted rapidly and simultaneously.

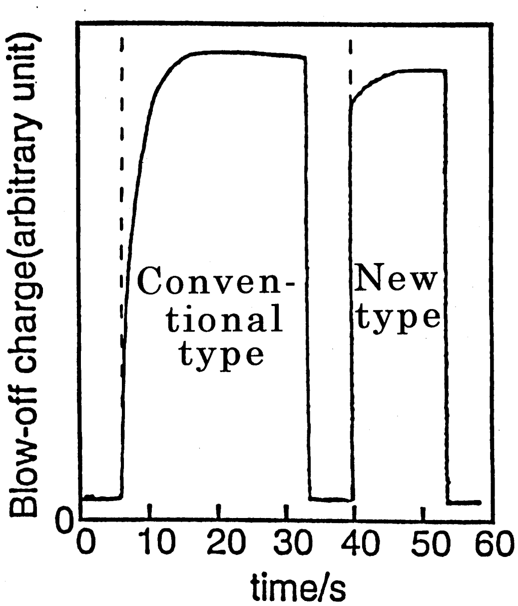

Figure 4. A typical example of blow-off curves. Developer: positively charging toner was used.

Figure 5 shows a typical example of measurement results in which the difference of the obtained blow off curves were very large between the two types of the Faraday cages. In the case of the new type cage, the charging amount after starting the measuring operation increased rapidly, and saturated in a short time. In the case of the conventional type cage, the charge increases but never reaches saturation. The larger charge obtained by the conventional cage is attributed to a tribo-charge between the separated toner particles and carrier particles.

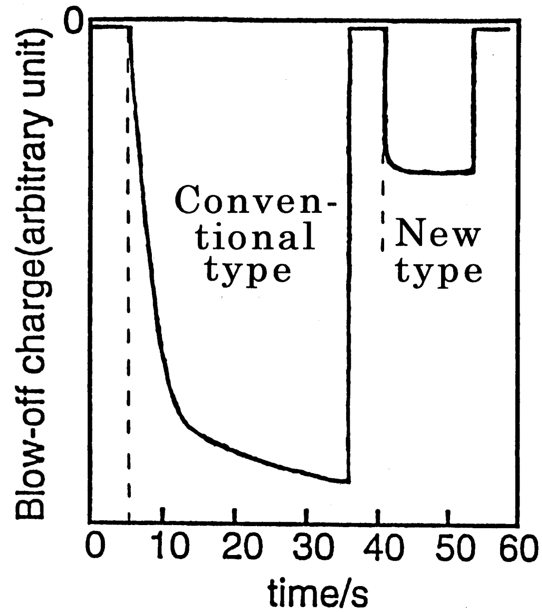

Figure 5. A typical example of blow-off Curves. Developer: Negatively charging toner.

In the case of the conventional cage, a longer time was needed to attain the complete separation of toner particles from the carrier surface. During the measurement operation, the sample particles in the cage repeat contact and detachment by an agitating movement caused by the blowing gas. During that movement, the surface of the toner and carrier particles on the SUS mesh was worn away to generate finer particles. Ultra fine particles added on to the toner surface sometimes gives the very large charge.

In the new type Faraday cage the effect of tribo-charging and the wearing action caused by the blowing gas mentioned above was very small. The separated toner particles were rapidly and completely removed in a short time. These features gave the sharp measurement curve in Figure 4.

The Effects of Blowing and Sucking Operation

Figure 6 shows blow-off curves using the new type Faraday cage. Curve (a) was obtained with gas blowing operation only. The curve is similar to curve (c) which was obtained by gas blowing and air sucking operation in the sense that saturation is quickly reached. The smaller saturation charge in curve (a) is attributed to the sticking of the blown-off toner to the bottom surface of the cage. Curve (b) shows the result with air sucking operation only. The charge gradually increased but did not tend to saturate. This result shows that the air sucking operation is not sufficient to attain the complete separation of the toner particles from the carrier surface. Curves(a) to (c) indicate that both blowing and sucking operation are needed to obtain the intrinsic separate charge between the toner particles and carrier surface. The optimum gas blowing pressure was 0.3~0.5 kg/cm2 and air sucking pressure was 700~1000 mmAq, respectively.

Comparison of Charging Amounts of Several Developers

The relations between the specific toner charge (Q/m) and toner concentration are presented in Figures 7 and 8.

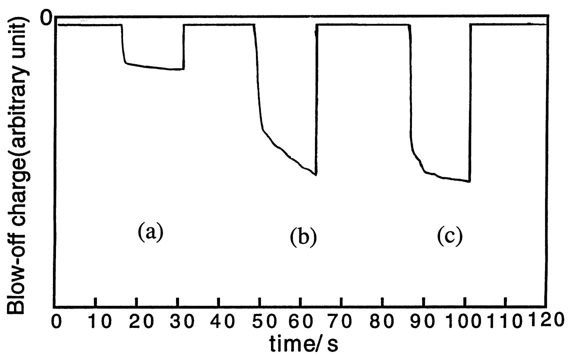

Figure 6. Blow-off Curves using new type Faraday-cage.
(a) Gas blowing only
(b) Air sucking only
(c) Gas blowing and air sucking

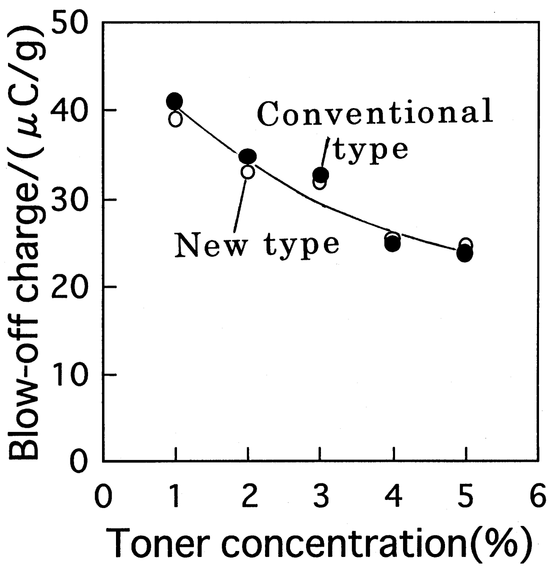

Figure 7. Relation between toner concentration and blow-off charge.

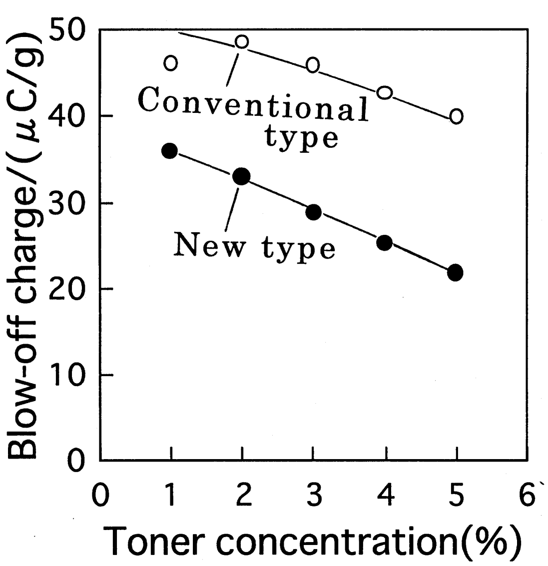

Figure 8. Relation between blow-off charge and toner concentration.

Three types of two component developers were used in these experiments and the amount of the charge obtained by both types of the Faraday cages are compared.

The relations obtained by all developer/Faraday cage combinations showed the same tendency in which the Q/m value decreased with toner concentration.

Figure 7 is a typical example in which the same Q/m values were obtained at the same toner concentration regardless of the Faraday cage type. The toner particles used in these measurements were composed of a tough binder resin having a spherical shape and a smooth surface having no ultra fine particles added to it. The toner seems to realize smooth toner/carrier separation in the measurement process. Therefore, the particles were not generated from wearing of toner and carrier surfaces even in the conventional Faraday cage.

In the case of the developer shown in Figure 8, the Q/M values obtained by the conventional case is larger than those obtained by the new type cage. The toner particles used in these measurements had irregular shapes, and ultra fine particles were added to the toners. Smooth toner-carrier separation was difficult in this case. The particles were easily produced from worn toner and carrier surfaces by the agitating movement caused by the blowing gas. The larger charger amount obtained by the conventional Faraday cage is attributed to the addition of tribo-charge generated on these particles during measurement operation.

Conclusion

A new type of Faraday cage which has gas blowing and air sucking attachments mounted in it has been developed. This new cage realizes high speed toner separation from the carrier surface. Separated toner particles were automatically and completely removed by vortex air generated by air sucking operation. The tribo-charge generated by the blowing gas agitation of separated toner and carrier particles in this Faraday cage was reduced to the minimum value. The cage enables measurement of the intrinsic separate charge between toner and carrier, and is regarded as a useful tool to evaluate the charging characteristics of two component developer.

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