Measurement of accumulation process of electrostatic charge on single particle due to cascade impacts onto metal wall

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***Abstract*—When a particle impacts/contacts on a wall, electrostatic charges are generated, in dry process. To give fundamentals for discussions on electrostatic charging of powder, we have been working to develop experiments to measure the charge generation of single particles due to cascade impact events.**

The apparatus consists of two parallel electrodes connected to independent charge amps each. When a single spherical polymer particle is accelerated and introduced into the two electrodes system with 45-degree angle, it impacts on the electrode alternately and successively, and from the recorded signal the amount of charge carried by the particle before and after each impact event can be determined. We have already reported some preliminary results with PS particles with 200 and 300 micrometer in diameter, and in this work the sensitivity of the charge amp was significantly improved to allow application of 100 micrometer participle. In this presentation we report the results of the 100 micrometer particle, with comparing to these of 200 and 300 micrometer particle cases.

I. INTRODUCTION

In order to give fundamental bases for understandings and discussions of electrostatic charging of powder, we measured the impact charges when single particles impact onto a metal target [1]. In the experiment, the generation of electrostatic charge on a single particle due to a single impact was measured one by one. Afterwards, the basic concept of the measurement of impact charging of single particles was extended to observe or record the charge accumulating process due to cascade impacts by single particles with a metal target. A new apparatus to do so has been developed, and the measurements were performed mainly with spherical and monodispersed polystyrene particles with 200 and 300 μm in diameter. Then the sensitivity of the charge measurement on a single particle was significantly improved. Some results of the experiments will be shown in this report.

II. THE EXPERIMENTAL METHOD

Fig.1 shows the schematic diagram of the experimental apparatus. The apparatus is set in an external acrylic case, which is vacuumed to around 100 Torr. A single particle is thrown into an orifice of the apparatus and accelerated by the pressure difference between the ambient to inside pressure. The main part of the apparatus consists of two parallel electrodes situated in 45 degree, and the thrown particle impacts on the two electrodes repeatedly and alternatively. Each electrode is connected to an oscilloscope via an independent charge amplifier. From the recorded signals, an analysis obtains the charge held by a particle prior to the each impact and the impact charge (which is net charge transfer due to each collision).

The sensitivity of the charge amp was set to around 100 pF (10 mV/pC) for the cases of 200 and 300 μm particles. Later it was significantly improved to about 1 pF (1 V/pC) successfully for smaller particles, which allowed us the measurements with 100μm particles, with a resolution of 10 fC of the charge measurement for a single particle.

Fig.2 shows an example of the signal recorded by an oscilloscope. The horizontal axis is time, and the vertical axis is measured charge. The charge before impacts and the impact charges are determined independently for the every impact from the signal. A signal correspond to the total charge on each electrode, which is the summation of the induced charge and the charge accumulated on the target plate itself. Therefore, $Q_i(k)$, the charge before the k-th impact, can be equated with the following formula.

$$Q_i(k) = Q_{upper}(k) - Q_{upper}(k-1) \text{ (when k is even.)}$$

$$Q_i(k) = Q_{lower}(k) - Q_{lower}(k-1) \text{ (when k is odd.)}$$

Q_{upper} and Q_{lower} mean the charge sensed by the upper electrode and that by the lower electrode respectively. The amount of charge exchange between the particle and the target electrode by each impact can be determined by the difference of charges before and after the impacts.

$$\triangle Q(k) = Q_i(k) - Q_i(k-1)$$

In this way, the initial charge and the impact charge by each impact of the particles were determined one by one and their changes ware observed.

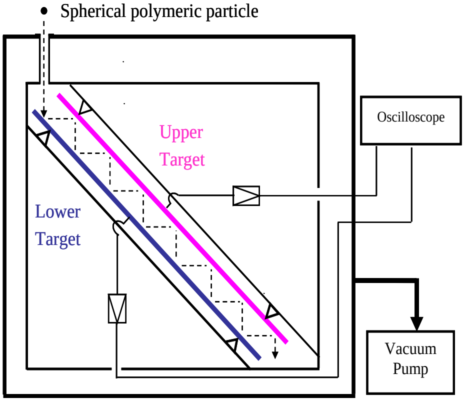

Fig. 1. Schematic diagram of the experimental apparatus.

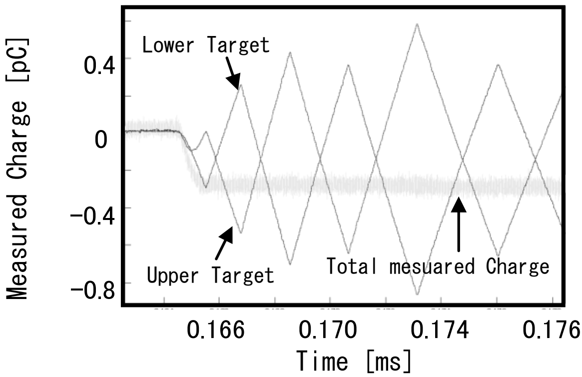

Fig. 2. An example of the signal recorded by oscilloscope

III. EXPERIMENTAL RESULTS

Figs.3-5 show the relationship between the impact charge and charge before impact. The horizontal axis is initial charge, and the vertical axis is impact charge. The larger the size of particles results in the higher the absolute values of the impact and charges before impact, obviously because they are on a single particle. Regardless the difference on the absolute values, the qualitative relationships showed the similar tendency. First, these results show that the particle accumulated negative charge by the impacts on the metal target (stainless steel). Second, for the early steps of the impacts, the impact charge scattered wider and then, the scattering width was reduced in the course of impacts. The absolute value of the impact change was reduced with the higher charge before impact. These results were basically consistent with the argument of the localization of the initial charge on a particle, discussed previously[1]. So-called equilibrium charge is defined as the charge before impact resulting no net charge transfer (zero impact charge). Even with the scattered results of the impact charge as a function of charge before impact, a linear regression yielded the equilibrium charges as shown in these figures as -12.42 pC(300 μm), -2.55 pC(200 μm), -0.873 pC(100 μm).

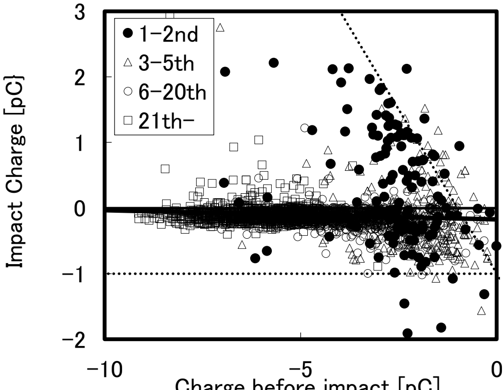

Fig. 3. The relationship between the impact and charge before impact, which integrates the many results of single particles of 300 μm.

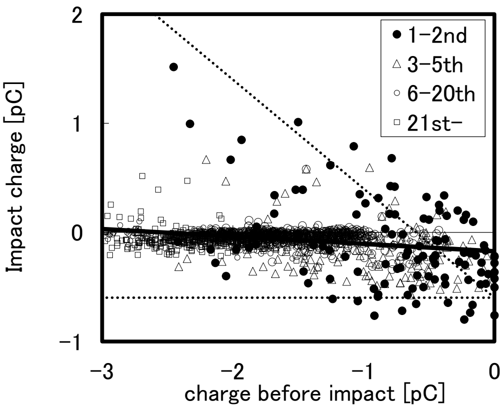

Fig. 4. The relationship between the impact and charge before impact, which integrates the many results of single particles of 200 μm.

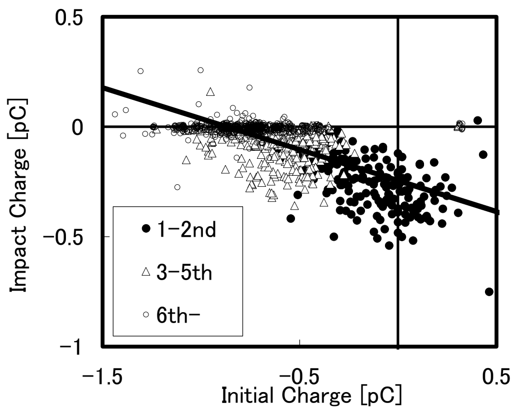

Fig. 5. The relationship between the impact and charge before impact, which integrates the many results of single particles of 100 μm.

IV. Conclusion

We have been working on analyzing mechanism of electrostatic charging of powder. In this purpose, it is important that the experimental results corresponded with the argument of the localization of the charge before impact. In the future works, we will try the experiment using particles made of other materials in order to add more data to our analyses.

References

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