# Tribocharging of Insulating Powders in the Annular Ducts of Pneumatic Devices

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*Abstract*— **The aim the experiments reported in the present work was to evaluate the tribocharging phenomena that might occur in the annular ducts specific to the cyclone-like aspiration unit of a suction-type dilute-phase pneumatic transport system. The experiments were carried out with two types of powders, on two models of ducts, having the same geometrical characteristics but being built of different materials. It was found that the charge acquired by the particles strongly depend on the nature of the material of the annular ducts. This triboelectric effect might be effectively employed for the selective charging and electrostatic separation of granular or pulverulent mixtures of insulating materials.**

***Index Terms*— electrostatic processes, insulating powders, dilute-phase pneumatic transport, tribocharging**

## I. Introduction

THE triboelectric effect [1-3] can be effectively employed for the charging of granular or pulverulent insulating materials in a wide variety of mechanical devices (vibratory feeders, rotating tubes, fluidized beds, …) [4-7]. If differently charged, the constituents of the granular or pulverulent mixtures can be easily separated using the Coulomb forces that act on them when passing through an electrostatic field. The installation that performs the above-described operations is called tribo-electrostatic separator [8]. Such equipment is always part of a complex production line, which includes at least one shredder/grinder that generates the granular or pulverulent material from the in-feed materials (minerals, wastes), and one or several machines that perform the conditioning of the separation products (pure minerals, recycled plastics) in accordance with the customer's requests. Pneumatic transport systems are employed to convey the materials to the separator and to transfer the sorted granulates or powders to the final product conditioning machines [9, 10].

The tribocharging phenomena in pneumatic transport systems has been an active research field for more than 20 years [11-13]. In a previous paper [14], the authors measured the charge of the particles collected at the exit of suction-type dilute-ohase transport system and the charge accumulated on the various sections of the duct; the discrepancy between the two measurements was attributed to the tribocharge imparted to the particles during their transit through the aspirator device, before entering the collector.

The aim of the present work is to evaluate the tribocharging phenomena that might occur in the annular ducts specific to the aspiration unit under investigation. The experiments were carried out with two types of powders, on two models of ducts, having the same geometrical characteristics but being built of different materials.

## II. Experimental Procedure

### A. Materials

The two materials that served in the experiments are commonly used for testing the suction and filtration processes: A. *White corundum*, *F1200*, which is a aluminium oxide ($Al_2O_3$), melting temperature: 2000°C, density: 3.9 g/cm$^3$, specific mass (non-packed density, according to FEPA standard 44-F-1986 ): 1.04-1.02 m.µg/cm$^3$, median diameters (according to FEPA standard 42-F-1984): 3 µm; B. *DMT 8*, which is a test dust, consisting of: mineral powder, i.e., dolomite $CaMg(CO_3)$; cellulose particles (BE 600-30); cotton fibbers (maximum length: 4 mm).

(a) (b)

Fig. 1. Materials used in the experiments: (a): F1200; (b) DMT8.

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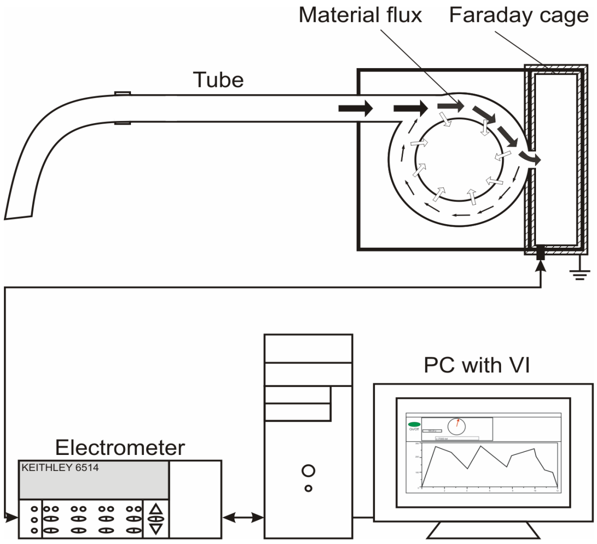
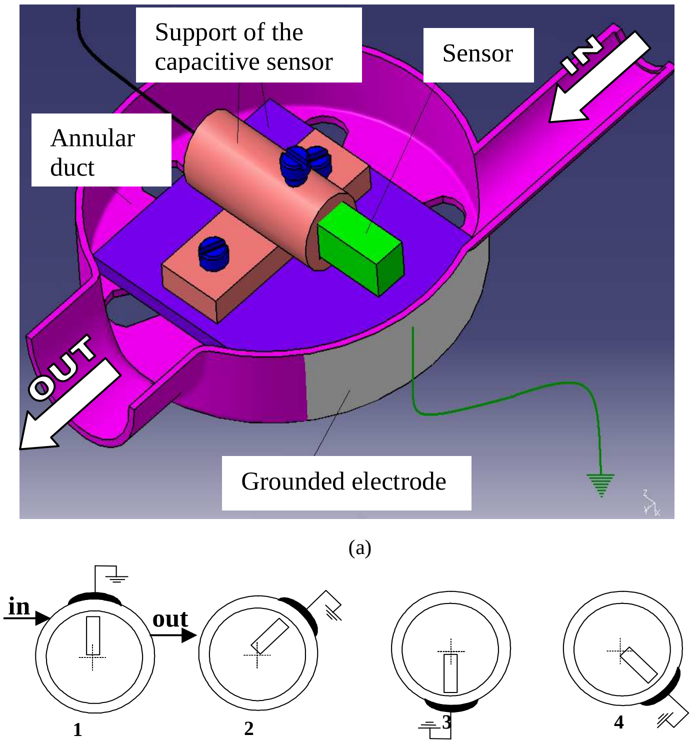



Fig. 2. Experimental set-up for the measurement of the charge carried by the test powders at the exit of the aspiration unit.




(a)

(b)

Fig. 3. Experimental set-up (a) and schematic representation of the four positions of the capacitive probe (b) employed for the measurement of the surface potential decay at the surface of the annular duct of the aspiration unit.

### *B. Experimental set-up*

The experiments were performed on a modified commercial cyclone-type bag-free vacuum cleaner, model R07165, SEB-Rowenta, France. At the rated air-flow of 34 dm$^3$/s, the average air speed in the annular duct of the pipe was higher than 30 m/s.

A quantity of 20 g of test dust (F1200, DMT8) was dispersed evenly over a length of 60 cm and a width of 3 cm. Then the suction tube was moved at a constant speed of 5 cm/s on top of the sample. In this way, the flow of aspiration was kept almost constant in all tests.

Most of the particles were driven by the centrifugal force created by the cyclone-like aspiration unit and accumulated in a collecting box that was modified to be used as a Faraday cage (Fig. 2) [15]. The very fine particles, entrained by the air flow, were captured by the filters situated at the outlet of the aspirating unit.

### *C. Charge measurements*

The charge of the collected particles was measured with an electrometer (model 6514, Keithley Instruments) connected to the Faraday cage (Fig. 2). The electrometer was connected to a personal computer provided with a custom-designed virtual instrument (V.I.), which was developed in a LabVIEW environment (National Instruments) [16]. The V.I. records the charge accumulated every two seconds in the Faraday cage. The total charge was calculated as the sum of the values recorded during the aspiration process.

### *D. Surface potential decay measurements*

After aspiration of 20 g of dust, the lid of the aspiration unit was opened and the probe of an electrostatic voltmeter [17-20] was positioned at a distance of 3 mm from the inner surface of the annular ducts (Fig. 3). The time between the end of the suction and start measuring potential was maintained at 30 seconds in all cases.

Before each new experiment, the annular duct of the aspirator was discharged by connecting it to the ground in several points during a time long-enough for the surface potential to decay at less than 10% of its initial value.

## III. Results and Discussion

### *A. Charge measurements*

In a first set of experiments, the charge of 20 g F1200 and DTM8 samples was measured after aspiration through PA and ABS ducts (Table I). DMT8 charged better in contact with both PA and ABS.

The aim of a second set of experiments was to evaluate the effect of in-feed flow rate on the efficiency of particle charging (Fig. 4). The charge/mass ratio of DMT8 powders progressively decreased with the quantity of material processed per time unit in both PA and ABS ducts. The particles have better chances to get charged when they are more dispersed in the in-feed air. Similar results were obtained with the F1200 powder.

Table I: Charge/Mass Ratios of F1200 and DMT8 Powders

| Duct material | PA | | ABS | |
|---|---|---|---|---|
| Powder type | F1200 | DMT8 | F1200 | DMT8 |
| Charge/mass [μC/g]* | - 0.53 | - 1.12 | - 0.86 | - 2.09 |

* average values of 5 experiments

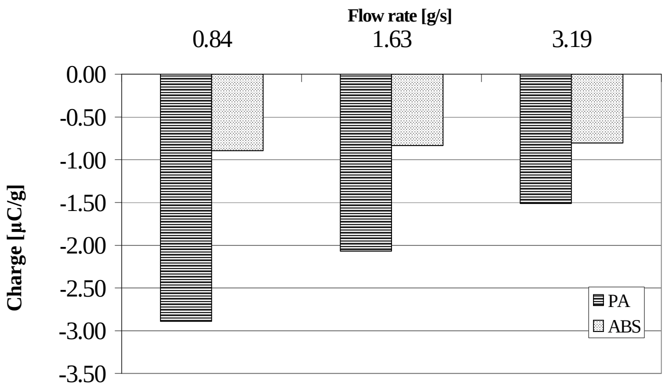



Fig. 4. Charge/mass ratio of DMT8 in PA and ABS ducts, as function of the in-feed flow rate.

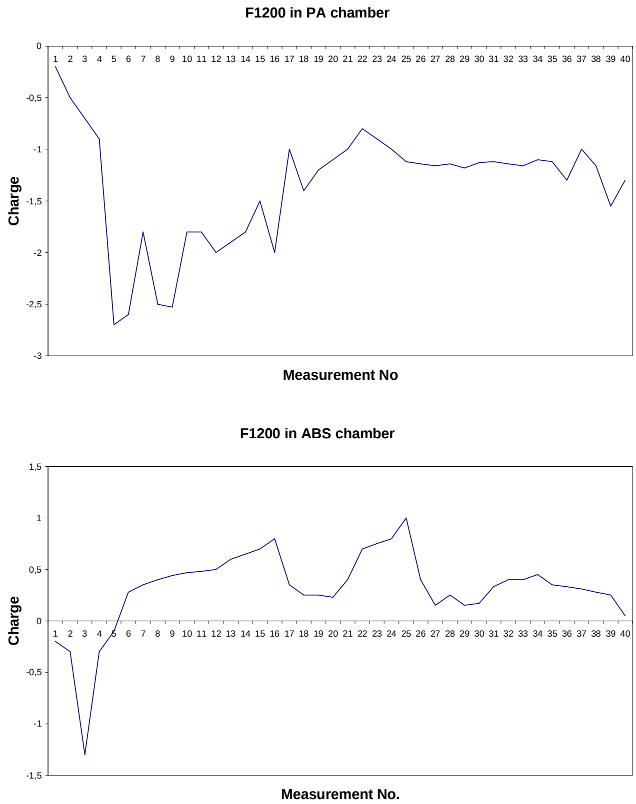



Fig. 5. Charge of F1200 powder aspirated during 80 s through PA (a) and ABS (b) ducts, at a flow rate of 1.63 g/s (one measurement every 2 s).

The third set of experiments was performed at constant feed-rate (1.63 g/s), with a much large quantity (130 g) of F1200 powder. With the PA ducts, the F1200 powders get always negative charges. However, it should be noted that the charge acquired during the first 12 s is always higher than that accumulated in the Faraday cage during seconds 13 to 24, 25 to 36, and so on. It seems that the rather quickly, the charge exchange between the PA and the F1200 stabilizes at a value that is roughly ½ of that measured during the first 12 s of aspiration.

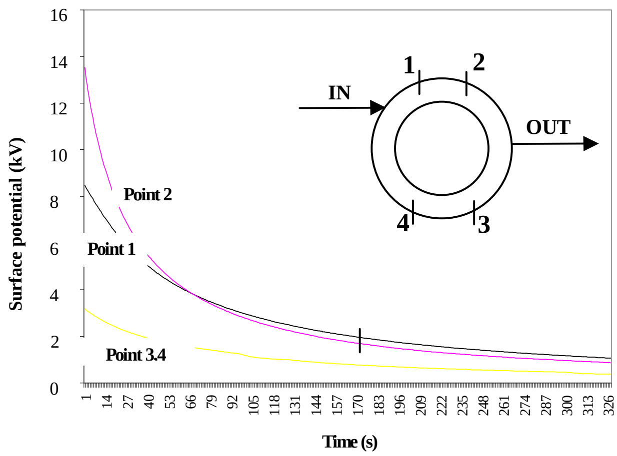



Fig. 6. Surface potential decay curves recorded in points 1 to 4 at the surface of the annular duct in PA, after processing 20 g samples of F1200 powder.

The situation is much more complicated with the ABS ducts. The record of the charge accumulated every 2 s in the Faraday cage shows a strange pattern, which was confirmed by a large number of experiments. At first, the F1200 particles charge negatively, but after less than 10 s, the new material aspirated in the Faraday cage is positively charged. One possible explanation is that ABS is a very good insulator. The walls of the ABS ducts get positively charged during the first 10 s or so, but after that they preferentially accept negative charges from the impacting F1200 particles, a great majority of which having already been negatively charged during their transit through the suction tube of the aspirator unit. This hypothesis needs to be validated by experiments performed on even larger quantities of F1200 powders and/or on other pulverulent materials.

### B. *Surface potential decay measurements*

The potential measured in the four points at the surface of the PA ducts after the aspiration of F1200 powder was positive and its decay with time was rather fast (Fig. 6). These findings are in good agreement with the fact that the charge of the F1200 powder was always negative, when conveyed through the PA duct. The highest potential was recorded in point 2, which is the most exposed to the impact of the aspirated particles. The surface potential measured in 3 and 4 was significantly lower than those in 2 or 1. This can be easily explained by the fact that only a small quantities of the powders pass through zones 3 and 4, most of the particles exiting the annular duct after zone 1. With a much smaller number of particles to impact the duct wall, the charge exchange is less important than in zones 1 and 2.

The polyamide is not a very good insulator: the potential at its surface, which is roughly proportional with the surface charge, decayed to 50% of its initial value in $T_{50\%} \cong 40$ s, in points 1 and 2, and $T_{50\%} \cong 60$ s, in points 3 and 4, for both F1200 and DMT8 experiments (Table II). In less than 8 min, the potential at the surface of the PA duct was less than 10%

TABLE II: SURFACE POTENTIAL DECAY TIME OF PA DUCT TO 50% ($T_{50\,\%}$) AND 10% ($T_{10\,\%}$) OF THE INITIAL VALUE

| Test powder | Measure point | $T_{50\,\%}$ (s) | $T_{10\,\%}$ (s) |
|---|---|---|---|
| DMT8 | 1 | 39 | 292 |
| DMT8 | 2 | 32 | 200 |
| DMT8 | 3 | 57 | 480 |
| DMT8 | 4 | 58 | 396 |
| F1200 | 1 | 43 | 322 |
| F1200 | 2 | 39 | 298 |
| F1200 | 3 | 62 | 487 |
| F1200 | 4 | 59 | 414 |

TABLE III: SURFACE POTENTIAL OF ABS DUCT IN FOUR MEASURE POINTS, AFTER THE ASPIRATION OF DMT8 AND F1200 TEST POWDERS

| Test powder | Measure point | Surface potential (kV) |
|---|---|---|
| DMT8 | 1 | -8,64 |
| DMT8 | 2 | -8,6 |
| DMT8 | 3 | -7,15 |
| DMT8 | 4 | -7,19 |
| F1200 | 1 | -8,49 |
| F1200 | 2 | -8,69 |
| F1200 | 3 | -7,7 |
| F1200 | 4 | -7,37 |

The surface charge decay was faster in points 1 and 3, where the initial potential was higher. This observation is similar to the results of other researchers who studied the potential decay at the surface of insulating materials and described the so-called “cross-over” phenomenon [21-24].

The potential measured in the four points at the surface of the ABS ducts after the aspiration of F1200 powder was negative (Table II) and its absolute value varied very little with time. These findings confirm the good insulating characteristics of ABS and are in good agreement with the F1200 charge measurements performed during the third set of experiments described in section III *A*. Similar results were obtained with the DMT8. With both test powders, the initial potential was higher in points 1 and 2, than in 3 and 4, which are less exposed to the impact of the aspirated particles.

## IV. CONCLUSIONS

1) Insulating powders can be effectively charged in cyclone-like pneumatic devices. The appropriate choice of the duct materials could favour the selective charging of the powders in a mixture. Electrostatic separation techniques could then be employed for the sorting of the differently charged powders.

2) Powder aspiration is accompanied by the accumulation of charge on the annular ducts of these devices. A finer mapping of this charge will not be achieved without a much larger number of tests, to provide a sufficient amount of data to undertake statistical analysis.

3) The electrostatic risks are greatest in the case of the ducts made of good electrical insulators, like ABS. The electric charge densities can reach values close to the threshold disruptive atmospheric air.

4) If the generation of charges is inherent to certain powder processing technologies, including the triboelectrostatic separation of mixed pulverulent materials, it is possible to reduce their accumulation. This would involve the use of less insulating materials for building the ducts of the aspirator unit, and the connexion to the ground of the the components that may generate significant triboelectric charges..

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