Identification of the Granular Product Composition Flowing in a Pneumatic Transport System Using Triboelectric Charge Measurement

I. N. Mahi, A. Tilmatine, R. Messafeur and F. Miloua

Abstract—The triboelectric phenomena resulting from impacts between the particles and the wall are known to affect the efficiency of suction-type dilute-phase transport systems. However this triboelectric charge could be used as an “image” of the granular product passing through the pipe. The aim of this paper is to investigate the feasibility of measuring the triboelectric charge acquired for using as an electrostatic detection sensor for the identification of the product passing through the pipeline. Useful information about the product could be deduced such as the nature (plastic or metal), the composition (simple or binary sample), granulometric size.... The study was conducted with mm-size plastic particles. A Faraday cage sensor connected to an electrometer has been employed for the measurement of the charge, which is equal to the charge transferred to the particles passing through it. A virtual instrument developed in LABVIEW processed the measured data. Under the specific conditions of the experiments described in this paper, the charge of the processed particles was found to give useful information about the flowing material. Obtained results have shown that the measured triboelectric charge reproduced the type of product flowing through the pipe. When passing a binary product, it becomes possible by measuring the triboelectric charge, to determine the nature of the product passing through the pipe and even to know the percentage composition of the granular mixture.

Index Terms—Faraday cage, Labview, Particles, Pneumatic transport, Powders, Triboelectric charge, Virtual instrument.

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1 INTRODUCTION

THE suction-type dilute-phase pneumatic transport systems are typically used for the transportation of powders and granular materials [1]- [2]. Several triboelectric phenomena occur in the ducts through which such materials are conveyed [3], where exchange of electric charge occurs after particle-to-particle or particle-to-wall collisions [4]- [5]. The charge and its polarity acquired by the particle vary depending on the nature of the pipes and the conveyed materials [6]- [7].

The moving particles and the walls of the ducts through which the granular materials are conveyed exchange a triboelectric charge [8]- [9]. This charge is at the origin of triboelectric effects that can affect the efficiency of the pneumatic transportation system. Some papers were published with mm-size particles to refine the understanding of the tribo-electrostatic phenomena that can affect the efficiency of suction-type dilute-phase transport systems [10], and to evaluate the effects of the granular material feed rate and the aspirating air flow rate [11].

The aim of the present paper is to investigate the feasibility of using the triboelectric charge for the identification and the control of the products flowing through the pipe line [12]- [13]. Such charge which is commonly considered as a source of electrostatic discharge is measured in order to deduce some useful information about the granular material. The influence of some factors such as the nature of the product (metal or plastic), the composition (simple or binary) and the particle size have been analyzed.

The experiments were carried out with mm-size plastic particles, using 1.9-meter-long aluminum pipe. They simulated the operating conditions of intermittent suction-type dilute-phase pneumatic transport systems usually employed for feeding a class of industrial processes.

2 MATERIALS AND METHOD

The experimental work was performed using different types of granular products of different sizes: PVC (Polyvinyl chloride), PC (Polycarbonate) and copper granules of millimeter size 1-2 mm (Fig.(1)).The experiments were carried out at constant ambient conditions (temperature $18-20C^{\circ}$; relative humidity 40-50 %) on the laboratory installation represented in Fig. (2), consisting of a straight pipe made of Al (Aluminum) (length: 1.9 m; inner diameter: 40 mm) and an aspirator unit of which the air flow was varied using an electronic speed controller by varying the frequency. At a rated air flow corresponding to a frequency $f = 50\text{Hz}$, the rotation speed of the aspirator motor is $2860 rpm$.

All the obtained results in this paper represent the average value of two duplicate experiments.

In this way, the Al pipe was kept at a floating potential with respect to the ground. The electrometer (model 6415, Keithley Instruments) connected to the Faraday cage was operated as a Coulomb-meter and controlled by a custom designed virtual instrument (VI), which was developed in a LABVIEW environment (National Instruments) [14].

The aspiration motor is turned on at a determined flow rate corresponding to a defined drive frequency, and then the product is manually introduced at one stroke with a

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little "shady" in plastic. All experiments were performed by using the same mass of product equal to 10 g for each sample in order to maintain the same material feed rate and to simulate the intermittent flowing in industrial process.

Before each experiment, the charge of the product was measured to check that they are not pre-charged.

The tribocharging processes in the pipe were monitored by using a Faraday cage. The Faraday cage was placed between the end of the tube and the inlet of the aspirator unit (Fig. 3), and connected to an electrometer via a BNC cable.

3 RESULTS AND DISCUSSION

3.1 IDENTIFICATION OF THE PRODUCT NATURE

Represented in Fig. 4 are typical examples of charge variation versus time recorded by the Faraday cage as displayed by the VI for PVC and PC particles respectively. Fig.(5) represents the amplitude of the triboelectric charge acquired by the three types of particle samples measured by the Faraday cage as function of the air flow, corresponding to different values of the drive frequency.

Obtained results in Fig. 5 show that the measurement of the triboelectric charge makes it possible to determine the nature of the product flowing through a pneumatic conveying line. The plastic particles flow indicates either a positive or a negative charge Qp depending on their position in the triboelectric series relative to the Al (Fig.5). However, there is no charge recorded by the electrometer when the metal granules flow inside the pipe line. The particles (PVC for example) produce two types of charge on the inner wall of the Faraday cage: a negative induced charge Qi and a positive triboelectric charge Qt. When the particles pass through the Faraday cage, the electrometer indicates a negative charge peak $Q_p = Q_i + Q_t$ (Fig.(6)). Indeed, the charge Q_i (negative) is greater than the charge Qt (positive) because almost all the particles produce a charge Qi by electrostatic induction, whereas the charge Qt is generated only during the impact with the wall. Moreover, when all the granules leave the Faraday cage, then the positive charge Qt only remains on the wall, as indicated by the diagram $(Q_w = Q_t)$. Note that the charge Qw left on the wall is greater than the negative charge indicated by the peak in the diagram Qp, because the peak charge measured by the electrometer is the total charge $Q = Q_i(-) + Q_t(+)$.

For $f = 20Hz$, the experiment with copper granules was not possible due to no sufficient air flow as seen in

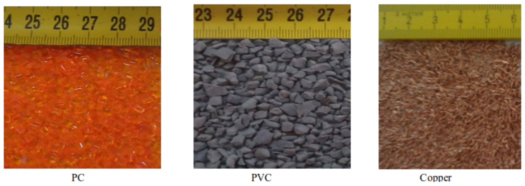

Fig. 1. Samples of the granules.

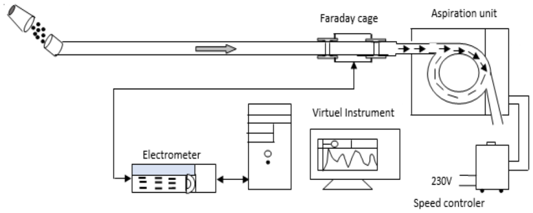

Fig. 2. Descriptive schematic of the experimental device.

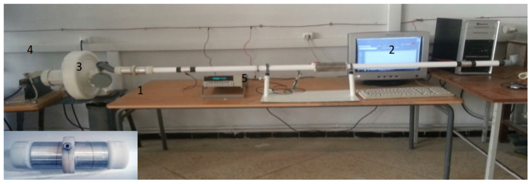

Fig. 3. The experimental setup 1 : faraday cage– 2 : measuring instrument– 3 : Aspiration motor – 4 : speed controller -5: electrometer (model 6415, Keithley Instruments)

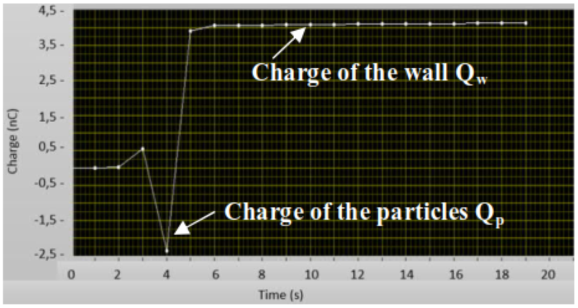

Fig. 4. PVC particles

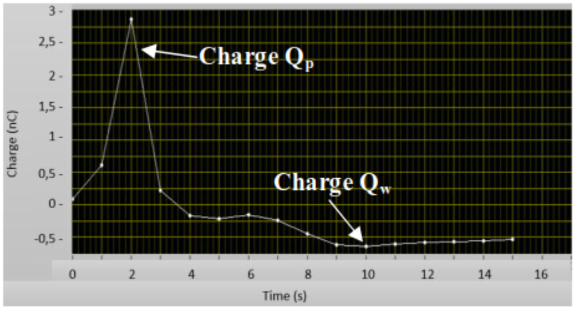

Fig. 5. PC particles

Fig. 6. Triboelectric series of PVC, Al and PC.

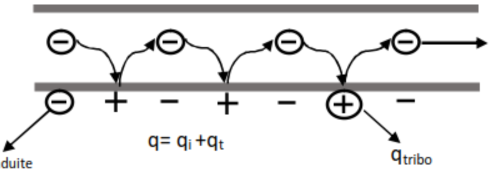

Fig. 7. Charges produced by the particles in the Faraday cage.

Fig.(7), regardless of the effects caused by variation of the air flow which have a complex influence on the triboelectric charging mechanism, PVC and PC particles keep the same sign of charge (positive for PC and negative for PVC) while the copper granules remain uncharged.

3.2 Influence of the product composition

In a second set of experiments, the triboelectric charge was measured when a binary product of a total mass M = 20 g composed of PVC and PC particles flows in the pipeline. Obtained results of the charge variation recorded by the Faraday cage for a “$50\%PVC-50\%PC$” mixture is represented in Fig.(8). Fig.(9) represents the amplitude of the charge Qp acquired by the PVC, PC and “$50\%PVC-50\%PC$” granular products measured by the Faraday cage for different values of the drive frequency.

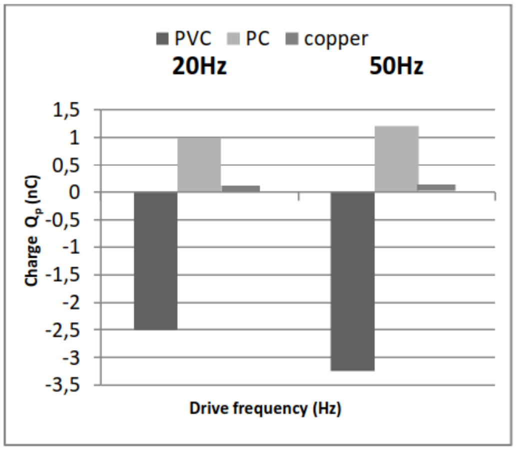

Fig. 8. Variation of the charge amplitude of PVC, PC and copper granules according to the driver frequency (M = 10 g for each product)

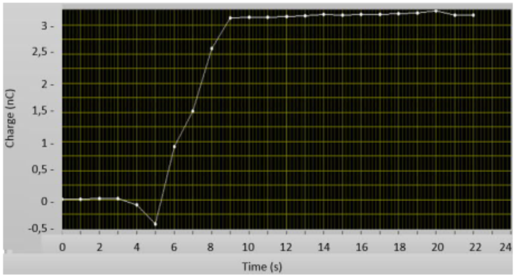

Fig. 9. Charge variation versus time recorded by the Faraday cage for a granular mixture “PVC 50% - PC 50%” of total mass 20 g

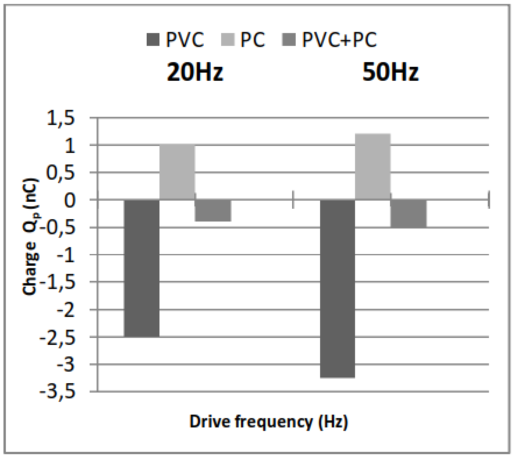

Fig. 10. Variation of the charge amplitude of PVC (10 g), PC (10 g) and “50% PVC-50% PC” of total mass 20 g, according to the drive frequency

Furthermore, a mixture of a total mass $M = 20g$ with 3 different composition values $(20\%PVC-80\%PC, 50\%PVC-50\%PC and 80\%PVC-20\%PC)$, was introduced in the pipe line in order to analyze the effect of the sample composition. Obtained results of the electric charge amplitude acquired by the binary mixture measured by the Faraday cage are shown in Fig. (10). Graph of Fig.8(8) points out the smaller value of the peak charge (Qp= 0.5 nC) as observed in Fig. (4) $(Q_p = 2.5nC)$ and Fig. (4) $(Q_p = 3.0nC)$ for mono-product PVC and PC particles respectively. Furthermore, according to obtained results represented in Fig. (9), the triboelectric charge measured for the granular mixture remains lying between those of PVC and PC products whenever the flow rate varies. In addition, as seen in Fig. (10), the global charge Qp of the binary sample depends on the product composition percentage. This is the consequence of the predominance of the PVC charge, due to the fact that the PVC is situated far from the Al than the PC in the triboelectric series. The charge becomes greater when the mass of PVC increases.

4 CONCLUSION

The experimental analysis carried out in this paper shows the feasibility of measuring the triboelectric charge of the granular product flowing in the pipe line in order to get useful information about the nature of the particles. The amplitude of the charge and its polarity could be used foridentification of the nature of the product (plastic or metal), its composition (mono or binary products).

For example, the charge which is zero when a metal product is flowing becomes positive or negative when some plastic particles are mixed with them. When a binary product of equal composition of two plastics which get opposite charges is flowing, the charge detected is almost zero. If the charge becomes more positive or negative, that means that the composition has changed.

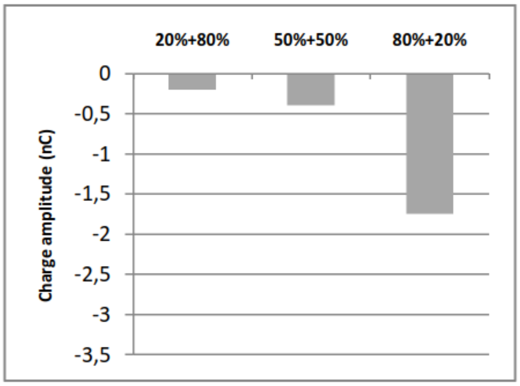

Fig. 11. Variation of the triboelectric charge of the binary product “PVC-PC” depending on its composition

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