CONDUCTION AND CHARGING PHENOMENA IN A FLUIDIZED BED OF SOLID INSULATING PARTICLES

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INTRODUCTION

The mechanism of conduction in insulating material is rather complex and generally does not follow an ohmic law as it is the case for conducting material. In dielectric liquid, conduction is often due to ions of the liquid and dissociated impurities and it is possible to distinguish two kind of phenomena ; the bulk phenomena : migration, convection, dissociation and recombination ; and the electrode phenomena : physicochemical reaction at the electrode, injection... . For solid insulating material a classification also exists between bulk and interfacial phenomena. More, in some polymers as in the case of polyethylene, a slow penetration of charges leads to the presence of space charge density inside the polymer during a large period of time [1].

In the case of powder, the mechanisms are even more complex than for liquids or solids, as this material, specially in a fluidized bed, has sometimes macroscopic behaviour comparable to the liquid but microscopically each grain is a solid material. Thus phenomena occurring in the case of solid or liquid can appear in addition to some specific like for instance electrification by contact or impact.

In this work, we are going first to analyse the mechanical behaviour of a fluidized bed, then to review some models of contact and triboelectrification charging and finally, we analyse the conduction for a vertical fluidized bed corresponding to the experimental study we have undertaken.

MECHANISM OF FLUIDIZATION

When a gas is flowing upward through a layer of divided solid material different mechanical phenomena appear depending on the gas flow rate and on the properties of the granular material. Different configurations exist and it is important to distinguish between aerated bed and fluidized bed. Thus for a very weak flow , air passes through the bed in the interstices without moving the particles (aerated bed), but when the air flow is higher we can see a motion of particles and a rearrangement of them (fluidized beds).

In this last case, as pointed out by Zenz and Othmer [2], the passage of gas upward through a column of powder or granular material is similar to the flow of gas through a column of liquid. This analogy is based on the two kinds of behaviour that are observed with liquids: in the case of low viscosity liquids the air flow goes upwards regularly and a kind of macroscopic homogeneity exists, but for high viscosity liquid the gas moves by large bubbles. These behaviours also exist in the case of fluidized bed. For powders of fine particles ("low viscosity" powders), the air flow produces uniform expansion of the bed allowing an easier passage between the particles, and again a kind of macroscopic homogeneity is observed in that case. For powders with large size particles ("high viscosity" powders), we assist to the formation of bubbles rising through the bed. These two flows have been designated respectively as particulate and aggregative fluidization. More the particulate fluidization exist either in dense bed or in dilute one.

CONTACT CHARGING AND TRIBOELECTRIFICATION PHENOMENON BETWEEN A CONDUCTING WALL AND AN INSULATING PARTICLE

Recent investigations [3], propose a model based on a dual mechanism for metal-polymer electrification. Contact charging and triboelectrification are considered as a non equilibrium two step process consisting of instantaneous bond-forming and bond-breaking. For each successive contact before the equilibrium is reached, new charge is transferred from metal to polymer or vice-versa and this leads to an accumulation of charges on the polymer. The bond-breaking mechanism is due to the breakdown that occurs during the separation, but the bond-forming is not yet well understood and even if the difference in Fermi's levels is a quite important parameter in charge exchange, a physicochemical process based on ion transferred must not be excluded.

Nevertheless it is generally an accepted fact that the charge accumulated shock after shock on a particle goes to a saturation value. When the number of shocks becomes very large the total charge reach an asymptotic value which is call the charge saturation [4].

A large systematic experimental study about impact charge transfer between particles and solid surface has been undertaken previously by our group [5-6]. For micronic particles the experiences have been made in terms of velocity, initial charge, particle diameter and impact angle. Three different electrode materials were tested with glass bead particles : copper, pure polyethylene and polyethylene with carbon.

The following evolutions for the charge transferred (measured in Coulomb/gram) during the impact have been observed :

- a decrease with the impact angle (a normal impact is for a null angle)
- an increase with the particles velocity
- a decrease with the particles diameter
- a decrease with the initial charge (this decrease agrees with Cole's analysis [4]).

CHARGE TRANSFER THROUGH A FLUIDIZED BED

When a vertical column of powder is placed between two horizontal electrodes and a gas flows through it, we can distinguish two bed configurations for the charge exchange.

The first one, is an aerated bed for which the upper electrode is in contact with the bed. In a such configuration the current observed must be the conduction current through the bed.

In the second one, the upper electrode is maintained at a distance from the upper level of the aerated bed, then increasing the flow the bed becomes fluidized and some particles go up and hit the upper electrode, then go down. The transfer of charges between the bed and the upper electrode occurs during this different shocks of particles. Thus even for null applied field between the two electrodes a current exist. If an electric field is now applied it will modify the whole process.

We are going in the following to show experiments we have made to observe this last phenomenon.

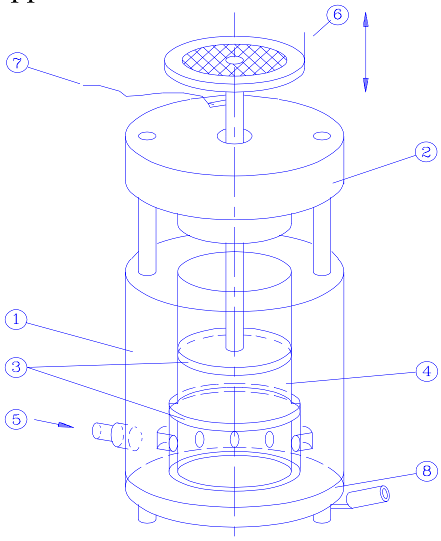
EXPERIMENTAL EQUIPMENT

1) The cell, figure 1 :

It is composed of two parallel electrodes made of porous brass. The bed of granular material is placed between these two electrodes.

The lower one is connected to a metallic pressure chamber. The air flows into this chamber goes through the porous lower electrode, the granular material, the upper electrode and exists the chamber through a grid at the top of the cell.

The upper one is connected to a metallic axis sliding through a ball bearing support. This device allows a sliding motion of this electrode inside the PTFE body of the cell. A compacted polymer foam placed at the electrode circomference prevents from powder leakage during fluidized bed tests. At the top of the axis a disk is used to put weights or to maintain the upper electrode at a fixed distance from the lower one.

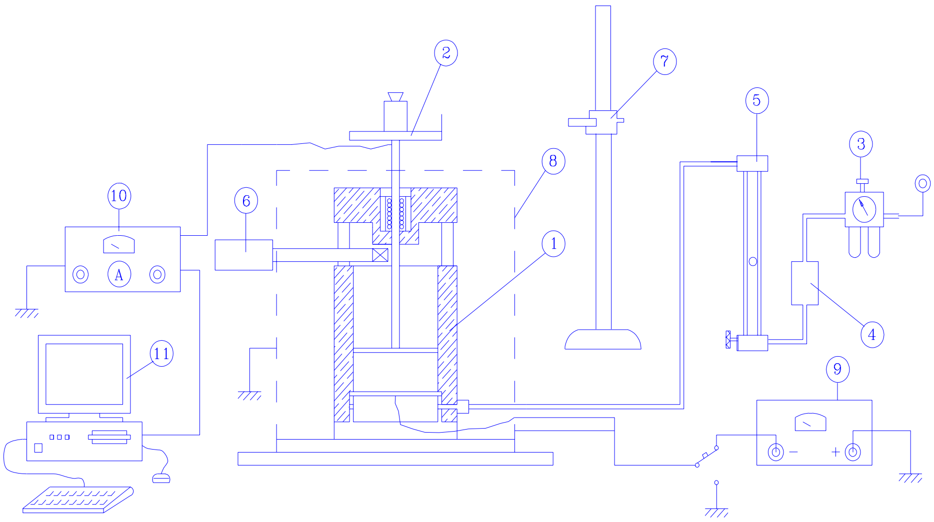


① Body in Teflon, ② Guide with ball bearing, ③ Porous electrode, ④ Powder, ⑤ Inlet of air flow, ⑥ Support for weight application, ⑦ Ammeter connection, ⑧ Voltage supply connector (connected to the pressurisation chamber and to the lower electrode).

Figure 1: **Cell of Measure**

<u>2) The whole equipment, figure 2</u> :

The cell is inside a Faraday cage and an hygrometer put at its top gives the air moisture. The air flows from a pressurised bottle, a dryer, a flowmeter, then through the cell and the hygrometer. The lower electrode is connected to the voltage supply or grounded and the upper one is grounded through a picoammeter Keithley 642, connected to a data acquisition systems.



① Cell of measure, ② Disk to fix electrode spacing, ③ Pressure regulator, ④ Dryer, ⑤ Flowmeter, ⑥Hygrometer, ⑦ Cathetometer, ⑧ Faraday pail, ⑨ Voltage supply, ⑩ Ammeter, 11 Data acquisition system

Figure 2 : **Device to measure charge transfer in a fluidized bed**

EXPERIMENTS

We have made experiments with PTFE powder (as PTFE is the same material than the body of the cell). The particle size is in the interval of 315-400 µm. We considered two kinds of experiments : without an applied electric field and with an applied electric field. The distance between electrodes is fixed at 7.5 mm. The bed before fluidization is around 3.5 mm thick. Different gas flows have been tested in the interval of 1350 l/h-1850 l/h that lead to air mean velocities of 0.19-0.26 m/s.

With the sample at rest in the cell the air flow is imposed suddenly by opening a valve and after 5 seconds when the flow is stabilised, we start our measurements. Precautions about powder humidity and initial charge present in the powder were taken drying the bed by aeration at 800 l/h during half an hour and waiting for the relaxation current flowing through the lower electrode to be lesser than 10^{-14} A.

Figures 3 and 4 show typical results of the current density (negative values) passing through the upper electrode for different air flow rates and different voltages.

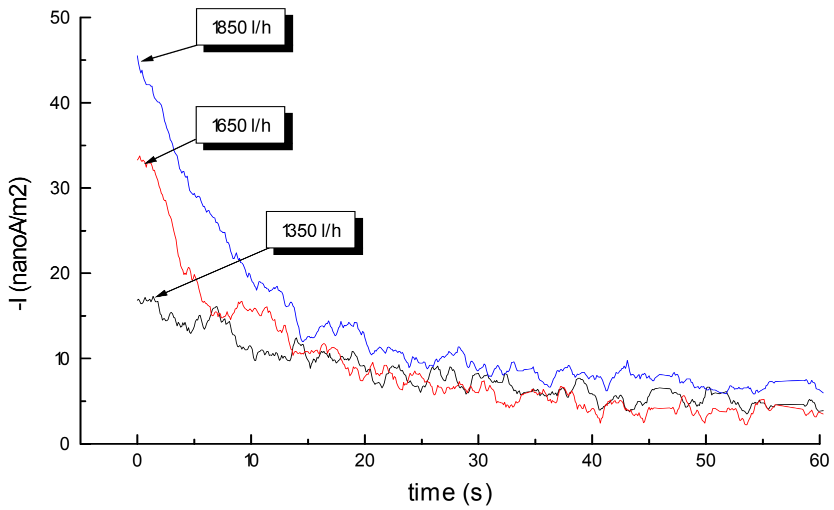


Figure 3 : Current density for different air flow rates. (negative values). 0 Volt

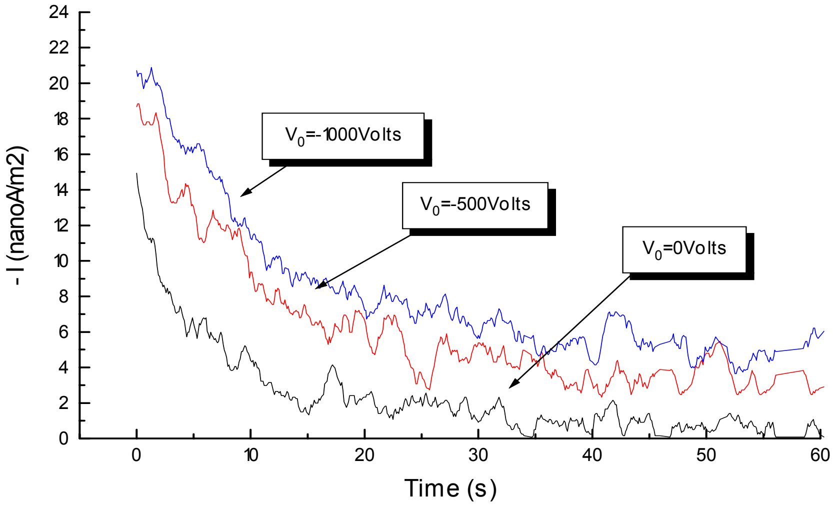


Figure 4 : Current density for different voltages. (negative values). Air flowrate 1500l/h

DISCUSSION

Figure 3 and 4 show that in our experiments the current density decreases asymptotically with time from an initial value to a saturation one.

Our experiences without electric field show that the charging process of the powder by impact onto the upper electrode is characterised by a transfer of negative charges from the powder to the electrode that saturates with time.

In figure 3 we observe that the constant of time of the phenomena strongly depends on the air flow rate. In Cole's model the time that elapses to achieve the saturation depends on the number of shocks. If we consider that with higher air flowrate the impact frequency of powder particles are larger our results agrees with this model.

From figure 4 we observe that the current level linearly grows with the voltage difference applied between electrodes.

The saturation value is not null as a part of the charge accumulated in the powder is continuously neutralised at the lower electrode through the leak resistance of the bed. The higher the voltage applied will be, more charge will be neutralised through it. In this experiment the sign of the lower electrode is negative in order to emphasize this behaviour. The electric field intensity does not seem to modify the time constant in our different experiences.

CONCLUSIONS

This paper shows an experimental study of a vertical column of fluidized Teflon (PTFE) powder placed between two horizontal porous electrodes that may be subjected to a low external electric field.

After some time the process of charge transfer saturates at a constant value. The evolution of the current (initial level and constant of time decrease) depends strongly on the air flow. It is also very sensitive to the applied electric field as a rather low field ($\approx 10^4$ V/m) changes drastically the evolution of the phenomenon.

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