Monitoring of a bag filter by online measurement of the electrical charge of the filter media

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***Abstract*— A new method of monitoring of bag filters that can be used in the field of industrial dust collection has been developed. It makes it possible to follow the evolution of the characteristics of a media (pressure drop and fractional filtration efficiency), during its operation, characterized by clogging and unclogging cycles. The test aerosol consists of white cement particles with an average diameter of less than 40 µm. Unclogging is provided by the injection of compressed air against the current. The proposed electric charge measurement system is similar to a Faraday cage, placed inside a laboratory bag filter, which can detect the presence of cement particles, forming over time a dust cake on the external surface of the media. A change in the sign of the electrical charge (positive to negative) of the fabric is recorded as soon as the dust flow is injected.**

I. Introduction

The bag filter dust collector has been widely used for capturing dust particles from gas streams. Numerous studies have been conducted for determining the performance of the bag filter dust collector using a pilot-scale test bed [1]. In previous tests, the performance was investigated with various bag filters and experimental conditions, including filtration velocity range, material, and inlet concentration of the test particle [2].

The pressure drop, called differential pressure (ΔP) between the clean gas side and the dirty gas side of the baghouse is one of the most important variables that must be considered in baghouse design [3-4]. Pressure drop through a baghouse is caused due to the air flow's resistance when air passes through the filtering bag and the filter cake. Typically, the pressure drop is expressed in inches or centimeters of water. This parameter is important because higher pressure drop means higher energy cost [5]. The energy generally will be consumed by the fans that are used to push or pull the air stream through the baghouse.

The differential pressure is measured by a differential pressure gage gauge) or manometer. However, over time the pressure sensing lines can become clogged with dust or damaged by moisture or corrosion [6-7], and the gauge can become unreadable. Hence, provision for cleaning the pressure taps is required to prevent premature instrument failure due to clogging [8-9].

In this study, a new method will be proposed for monitoring of a bag filter. This technique makes it possible to detect the presence of the dust cake on each filter bag. Indeed, the impact of particles on the bag causes a measurable electrical charge by a sensitive electrometer.

II. MATERIALS AND METHODS

A. Description of the realized baghouse filter

The pilot bag filter consisted of a dust feeder, blower, compartment, and pulse-jet filter cleaning system (Fig.1). The bag filter had a square cross-section and was designed to accommodate two rows of bags with two bags per row. The round type bag filter made of polyester fabric and having a 100 mm diameter and 500 mm length was used as test filter. A blow tube having a 10 mm hole was positioned above the each bag filter for the filter cleaning and compressed air was injected into the bag filter for 0.1 second.

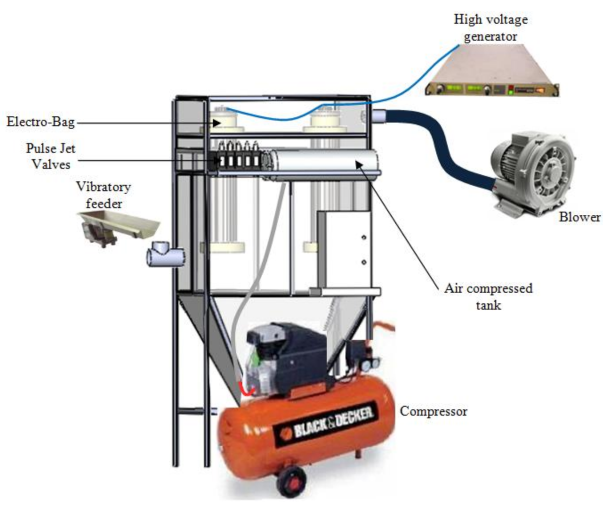

Fig. 1. Schematic of the realized experiment device.

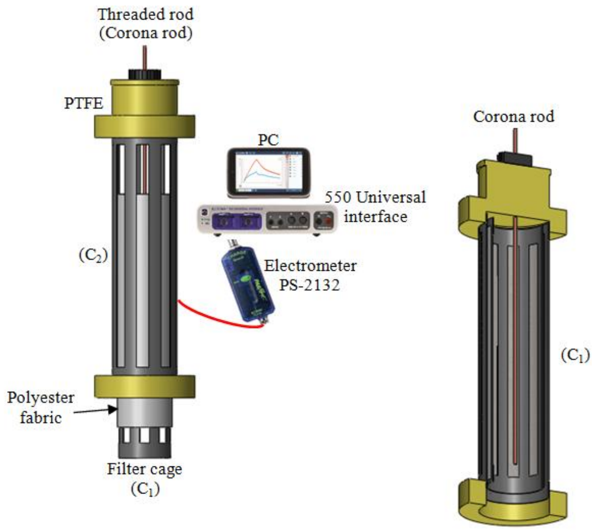

Fig. 2. Schematic of online system monitoring of the electro-bag filter by electrical charge measurement.

The cylinder (C_2) (Fig.2) of the electro-bag has been used as one of the electrodes which form a Faraday cage with an outer carcass connected to the ground [3]. This system allows the on-line measurement of the electrical charge by an electrometer (Pasco-2132) via a 550 universal interface connected to a computer.

B. Experimental procedure

The particles white cement from a cement factory was used as the test dust. The average particle size of cement was 40 µm and their density was about 2900 kg/m^3. Two experiments were conducted. First, the electrical charge for one Electro-bag among four, was measured without presence of particles of cement and without air flow rate.

In this experiment, electrical charging tests of the bag filter were performed for different voltages applied in negative polarity. The neutralization time was estimated and measured by a sensitive electrometer for each voltage level.

Second, the effects of inlet particle concentration on the electrical charge were examined under a constant air flow rate. In this case, the concentration at the inlet varied from 1 to 6 g / s. All experiments were conducted under temperature conditions of 20-25 ° C and 40-60% relative humidity.

The exposure time of the tissue under electrical discharge is a variable parameter, it varies between 3 and 9 s. This time is intermittently performed to allow the charge measurement system to take samples. The bag filter monitoring system is directly connected to the electro-bag (Fig.2).

III. RESULTS AND DISCUSSION

A. Influence of the applied voltage on the electric charge of the bag filter

In this section, we tried to look at the effect of the charge density deposited on the sample on the decline of the surface potential (DPS). The measurements shown in fig. 3 displays the temporary evolution of the DPS for different values of applied voltage and a fixed time (3s) of exposure of the tissue under electric discharge.

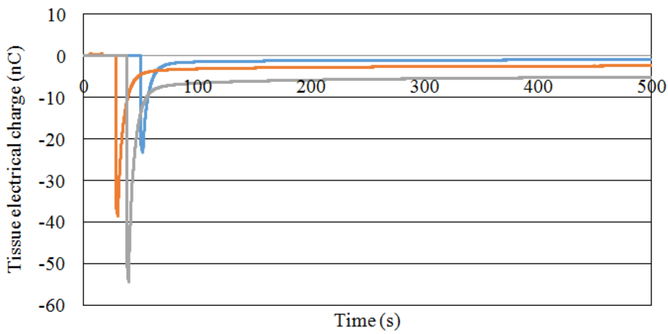

Fig. 3. Variation of the pic of electrical charge as function of applied voltage.

Figure 4 shows the max of electric charge recorded over a period of 3 s. The maximum value corresponds to a voltage of 7 kV obviously.

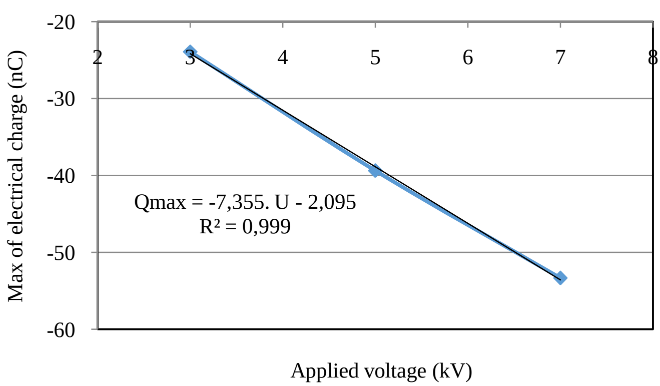

Fig. 4. Variation of the max of electrical charge as function of applied voltage.

The determination of the fabric neutralization time (Fig. 5) is an important parameter in order to determine the charge cycle corresponding to the intermittent start of the high voltage source. This operation increases the performance of the filter capture during operation. In this work we will limit only the effect of the particles on the fabric. The charge recorded in this case is due only to the impact of the powder on the outer surface of the filter bag.

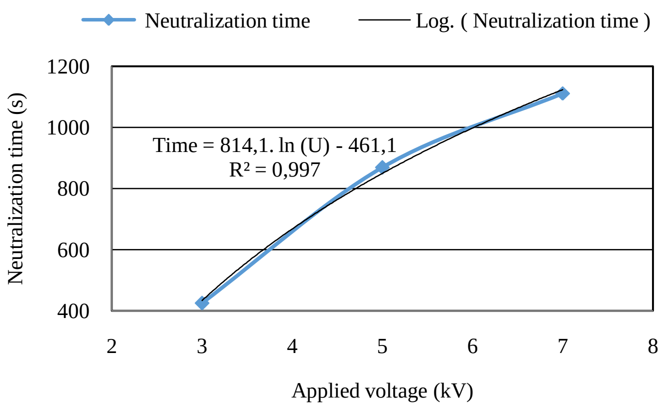

Fig. 5. Neutralization of the bag filter charge as function of applied voltage.

B. Influence of the exposure time of the tissue under electrical discharge

When increasing the load time of the fabric under a fixed voltage (5 kV), a saturation is observed around a time of 7 s. The measured load is around 52 nC (Fig.6).

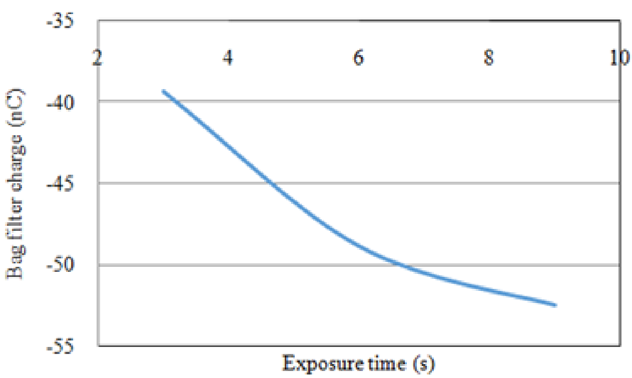

Fig.6. Variation of bag filter charge as function of exposure time for U = 5 kV.

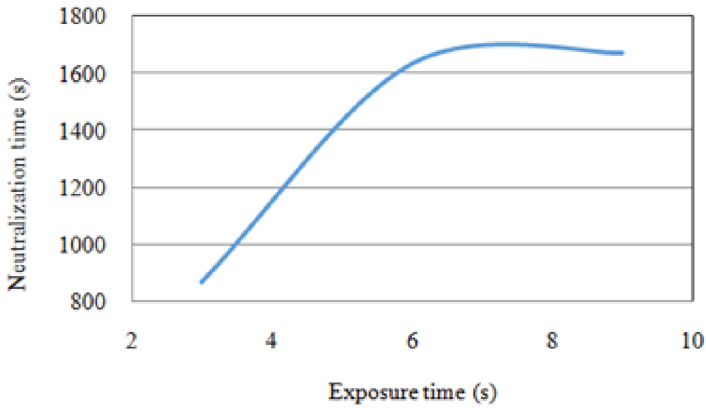

Fig.7. Dust cake deposit control by capacitive measurement.

C. Monitoring of the baghouse by electrical charge measurement

Figure 8 shows the evolution of unclogging of the bag filter using a pulsed jet system. The declogging cycle has been programmed every minute. Each pulse creates a charge drop (ΔQ) at the bag, equivalent to a pressure drop (ΔP), which ensures a continuous operation with greater efficiency. From the variation of the charge obtained, it is possible to quantify the number of pulses of air jets, from the number of charge drops recorded (6 in our case).

During the time interval between 0 and 2000 s, the positive charge recorded is solely due to the impact of airflow with the fabric. Beyond this time and from the moment of injection of the powder, an instantaneous sign change from positive to negative was observed. The charge sign is positive again when the powder flow is stopped.

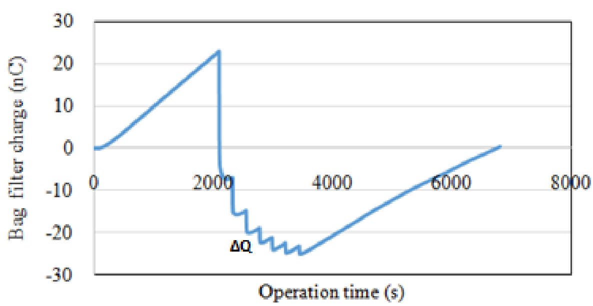

Fig.8. Bag filter charge drop (ΔQ) evolution for 6 clogging/ unclogging cycle.

D.Monitoring of the baghouse by capacitance measurement

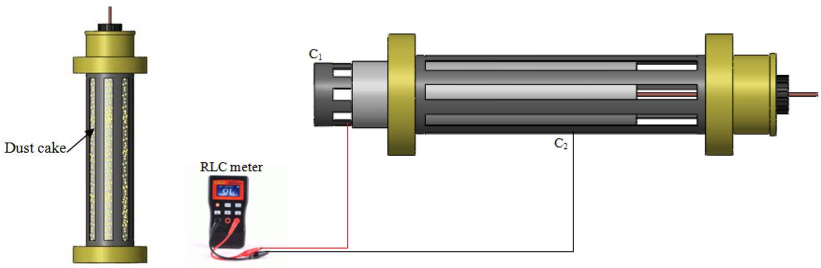

Fig.9. Dust cake deposit control by capacitive measurement.

The objective of this part was to study the feasibility and the implementation of a new technique of monitoring an air filtration device based on the measurement of the electrical capacitance of the electro-bag (Fig. 9). This capacitance consisted of: an internal cage (C_1) or mannequin, whose role was to keep the shape of the bag, despite the depression due to the aspiration of the polluted air. The external cage (C_2), which represents the second electrode of the capacitor, also has an electrical role, once connected to the ground; it ensured the production of an electrical discharge (corona effect), from the threaded rod .

The variation of the capacitance as a function of the operating time of the filter for a constant mass flow rate (3.6 kg/h) is represented by figure 10. The capacitance is measured by a very sensitive RLC meter (0.001 pF–100.00 mF) which allows measurements of capacitance, resistance, or inductance up to a frequency of 500 kHz, for infinitely small values.

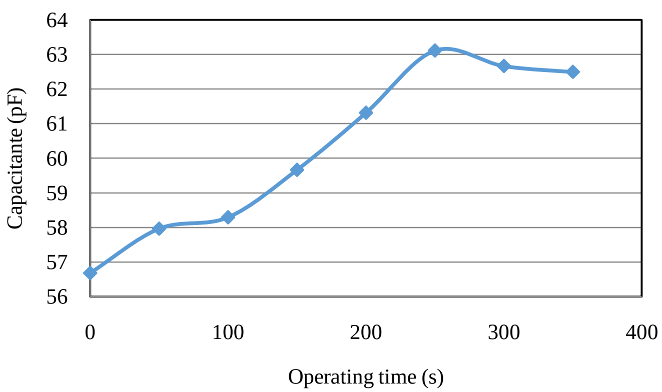

Fig. 10. Variation of the capacitance as a function of operating time.

From the measurements carried out, it can be seen that the capacitance varies almost linearly with the operating time of the filter. It is worth 56.68 pF before injecting the powder. This value is due to the presence of the fabric filter bag, because without it, is equal to 55.3 pF. This is consistent with the following relationship:

$$C = \varepsilon_r.\varepsilon_0.\frac{S}{e} = \varepsilon_r.C_0 \quad (1)$$

ε_r : Relative permittivity of the medium (Channel plus powder);

ε_0 : Permittivity of the vacuum;

S: surface of the filter media equal to 1460 cm^2;

e: Inter-electrode interval equal to 350 mm.

C_0: Capacitance of the Eletro-bag without tissue equal to 55.3 pF.

The change of the capacitance value is mainly due to the variation of the permittivity of the inter-electrode medium. The more the bag filter collects the cement particles, the more of measured capacity becomes important. When the value of the capacitance stagnates around a given value, this corresponds to the saturation of the bag filter. According to fig. 7, the saturation is reached around an operating time equal to 250 s, which corresponds to a mass of 250 g.

IV. CONCLUSION

This experimental study studied the feasibility of monitoring of an industrial pulsed jet bag filter during the filtration of cement particles by electrical charge measurement. The evolution of the charge drop and the efficiency was measured over 6 successive cycles of clogging / unclogging. The results confirmed that the bag filter collects particles. This confirmation was also obtained by capacitance measurements.

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