Experimental Evaluation of the Filtration Efficiency of a Chicane-Type Electrostatic Precipitator

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Abstract— **Reduction of soot emissions of Diesel engines is a crucial issue for the preservation of the environment. The aim of this study is to evaluate the possibility to enhance the performances of standard chicane-type mechanical filters to capture this kind of particles by converting it into an electrostatic precipitator. In such a chicane-type electrostatic precipitator, the plate segments of the collector electrodes are mounted both longitudinal and transverse to the polluted airflow. Incense particles are used to simulate the pollutant and the products collected on the electrodes at various applied high-voltages are characterized using a gas chromatograph/a mass spectrometer, a total organic carbon analyzer and a spectrophotometer. Though these methods do not enable an explicit evaluation of particle collection efficiency, they point out the superiority of the novel combined mechanical-electrostatic precipitator over the common chicane-type filter.**

***Index Terms*— electrostatic precipitator, gas chromatograph, mass spectrophotometer, total carbon analysis**

I. Introduction

Electrostatic precipitation is used to eliminate the solid polluting particles (such as dust and ashes) or liquids (oil mist for example) contained in gases injected into our environment [1-2]. Besides the huge electrostatic filters that purify the flue gases of cement plants, foundries or thermal power stations, smaller-size units have been developed for the treatment of ambient air in workshops, offices, hospitals, and the like, at very low electric energy consumption and high particle retention efficiency (up to 99.9 %) [3-4].

The electrostatic precipitator that is the object of the present paper was inspired by the chicane-type mechanical filters. These apparatus are designed to filter particles of size larger than 10 micrometers in diameter, with collection efficiency up to 85%. It is expected that by combining in a single unit the mechanical filtering and the electrostatic precipitation, higher performances could be attained.

The simplest configuration of such a combined mechanical-electrostatic precipitator consists in two grounded chicanes and one metallic wire connected to a DC high voltage power supply of positive polarity (Fig. 1). The aim of this paper was to evaluate the filtration efficiency of this chicane-type electrostatic precipitator (CTEP) using mass spectrometry in conjunction with total carbon analysis and spectrophotometry.

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II. Experimental Procedure

The grounded electrodes of the CTEP model built for this experimental study (fig. 1) consisted in two polycarbonate plates (dimensions: 60 mm x 40 mm x 5 mm) covered with an aluminium sheet. A positive DC corona discharge was obtained between these plate electrodes and a thin stainless steel wire (diameter: 0.45 mm), connected to a high voltage power supply (U_{max} = 35 kV, I_{max} = 10 mA). The spacing between the plate electrodes and the corona wire was 2 cm.

A small fan propels the air inside the filter, at a very low flow rate (less than 1 dm^3/min). The tests were conducted at stable ambient conditions (21-22°C; RH: 34 -40%).

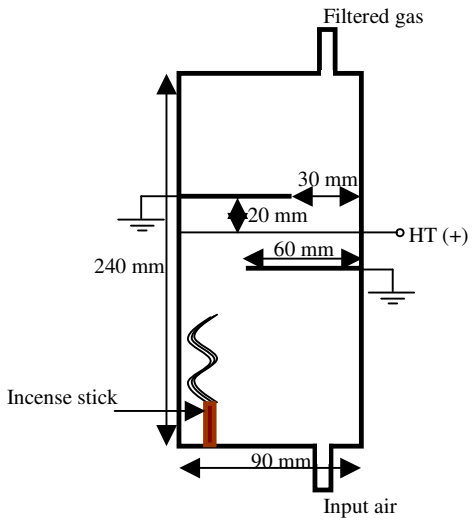

Fig. 1. Schematic representation of the chicane-type electrostatic precipitator.

In each experiment 0.5 grams of incense were burnt inside the enclosure. The time required for the complete burning of the incense stick was 18 min.

After filtration, the products collected on the electrodes are extracted with distilled water using cotton swab and then analyzed by each of the following PC-controlled measuring devices:

- A gas chromatograph/mass spectrometer (Shimadzu, GCMS-QP2010S);
- A total organic carbon (TOC) analyzer (Shimadzu, TOC-V CSN 688);
- A spectrophotometer (UNICAM, UV4-UV/VIS).

III. Results and Discussion

In a first set of experiments, the filtration efficiency of the CTEP was evaluated by comparing the mass spectra of the products collected on the plates with the reference spectrum of the incense stick, for two voltage levels: 12 kV and 14 KV.

The chemical composition of incense consists mainly of organic matter, water and a low percentage (1 to 1.5%) of mineral elements. The principal organic compounds of the incense stick employed for the present study were: Cellulose (40 to 50%) and Lignin (20 to 30%).

The spectrum of the incense stick (Fig. 2) has a main peak at 1892. This peak does not appear in Figs 3 and 4, which give the spectra obtained for the products collected on the plates. It can be concluded that the filtration efficiency is very poor, a result that can be explained by the fact that the CTEP under study consisted of only two plate electrodes and one high voltage wire. By increasing the number of chicanes, higher efficiencies are expected.

Figure 5 shows the results of the measurements performed with the TOC analyser for the reference product and the products collected on the transversal (P_2) and longitudinal (P_1) plates of the filter for two values of the applied voltage: 12 kV and 14 kV. In both situations, the TOC concentrations (expressed in units of CO_2 absorbed naturally) were higher for the products collected on the transversal plate. This can be explained by the dynamic effect of ionic wind on incense particles, which were pushed towards that plate. The particles collected on the longitudinal plate have a finer size and a lower TOC content.

The TOC concentration measured at 14 kV were significantly lower than those recorded at 12 kV, which indicate a marked decrease of the efficiency of the filter, due to the sparks that occur at higher applied voltages.

Absorbance measurement (Fig. 6) is another way to assess the collection efficiency of the particulate filter. The peaks of the spectra obtained by the spectrophotometer for the reference mass as well as for the products collected on the transversal and longitudinal plates, at two values of the applied voltage (12 kV and 14 kV) were similar, but with different levels of absorbance. These results confirm that the efficiency decreases at higher applied voltages.

IV. Conclusion

The characterization of the products collected on the electrodes by the use of coupled gas chromatography / mass spectrometry, in conjunction with total organic carbon analysis and spectrophotometry can provide valuable information for the evaluation of the efficiency of electrostatic precipitators.

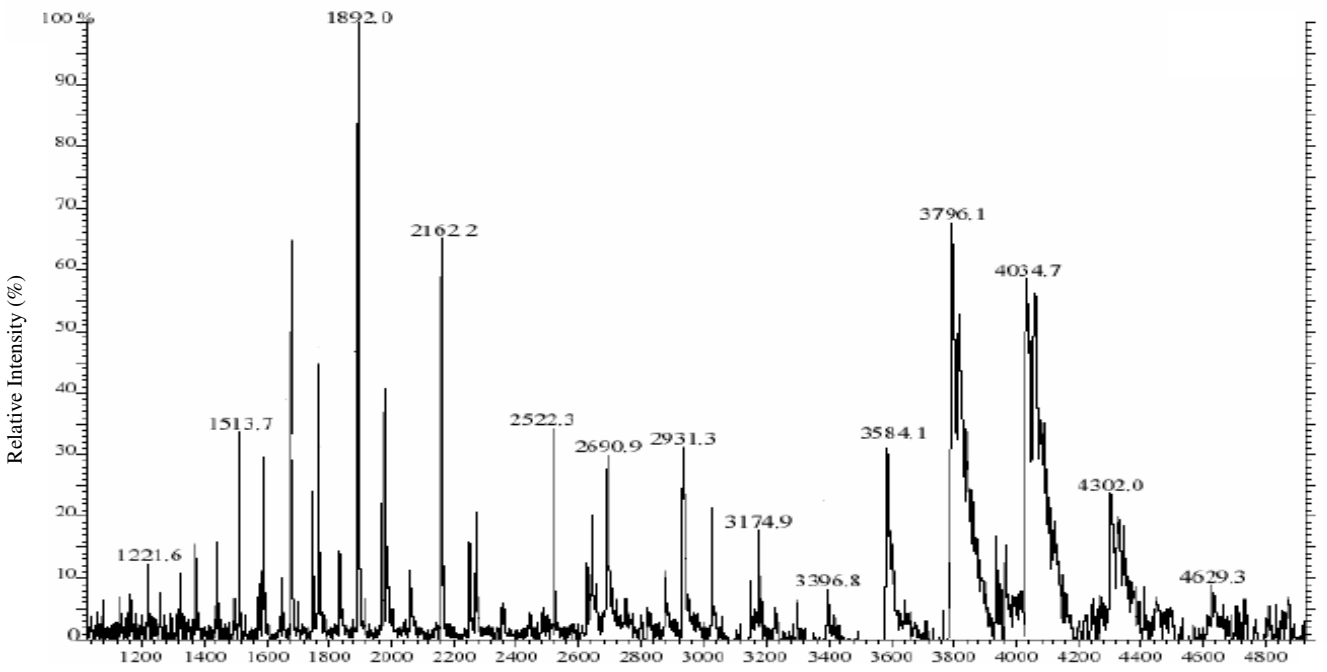

Fig. 2. Reference mass spectrum.

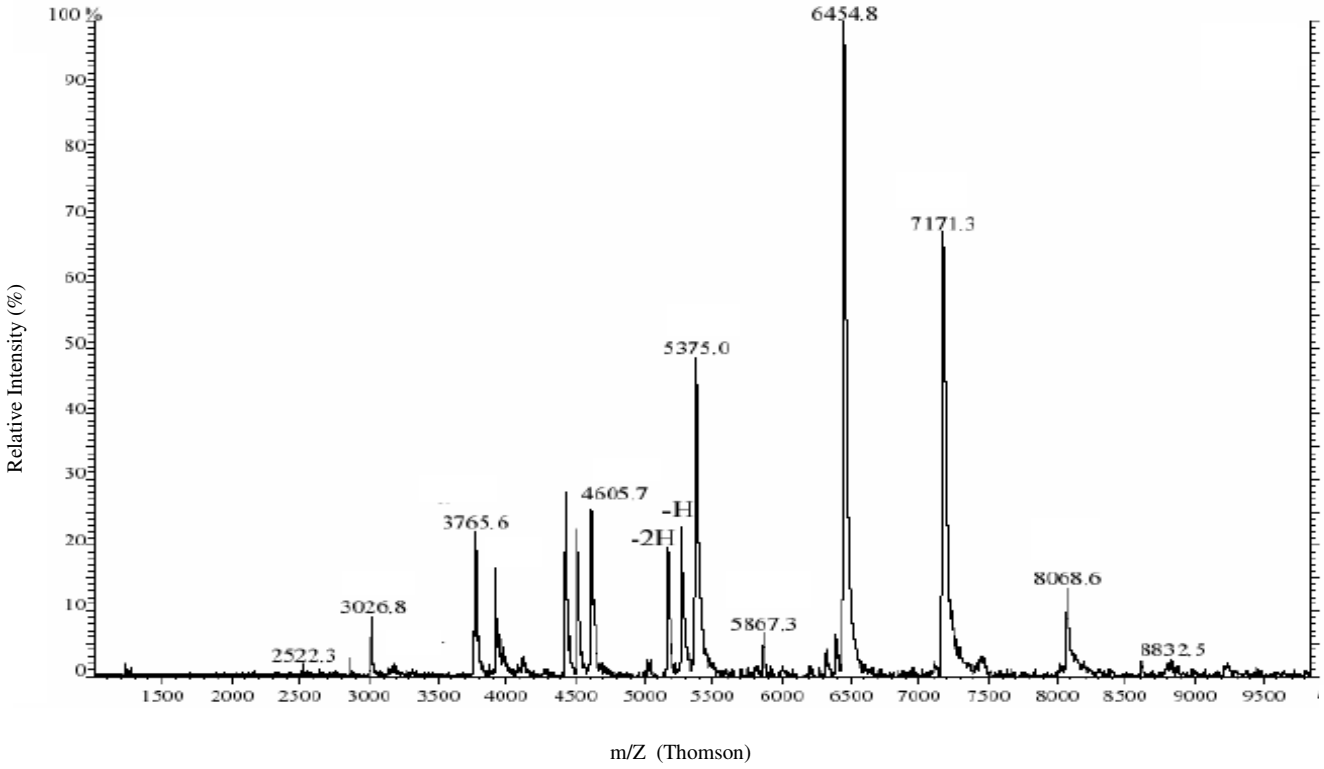

Fig. 3. Mass spectrum of the collected product for a voltage U = 12 kV.

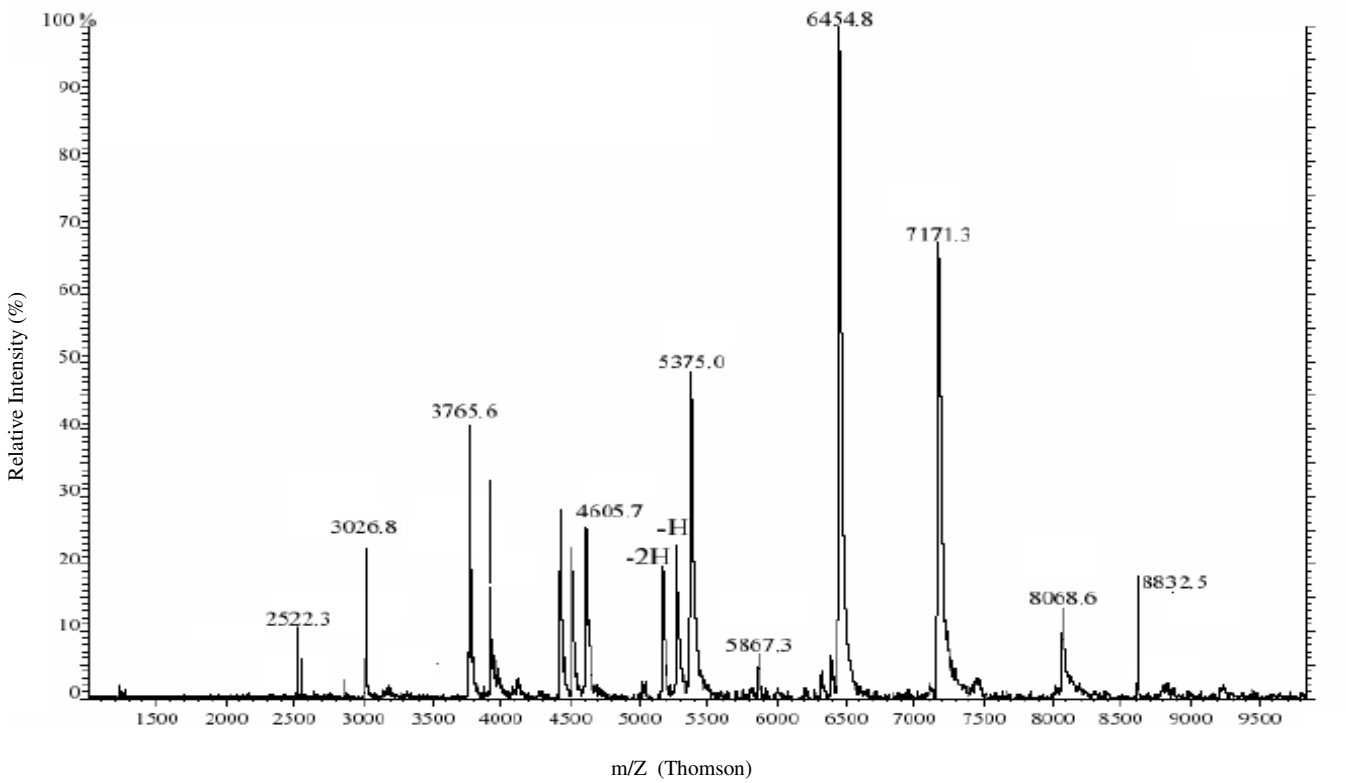

Fig. 4. Mass spectrum of the collected product for a voltage U = 14 kV.

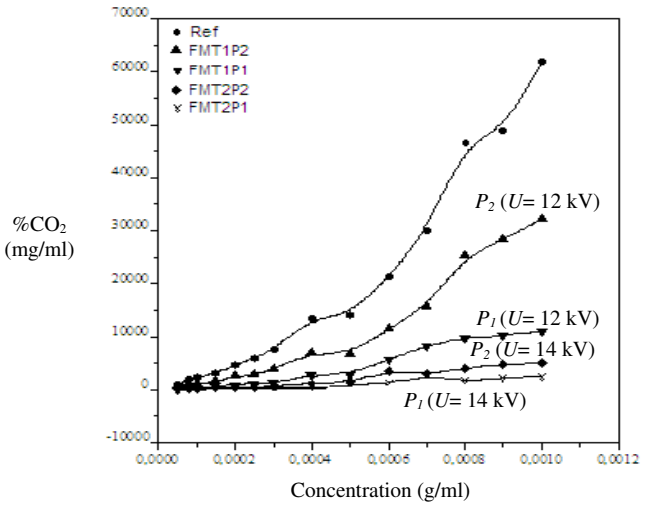

Fig. 5. Variation of % CO_2 as function of the concentration for the mass of incense and the reference mass collected by the longitudinal and transverse plates P_1 and P_2, for U = 12 kV and U = 14 kV.

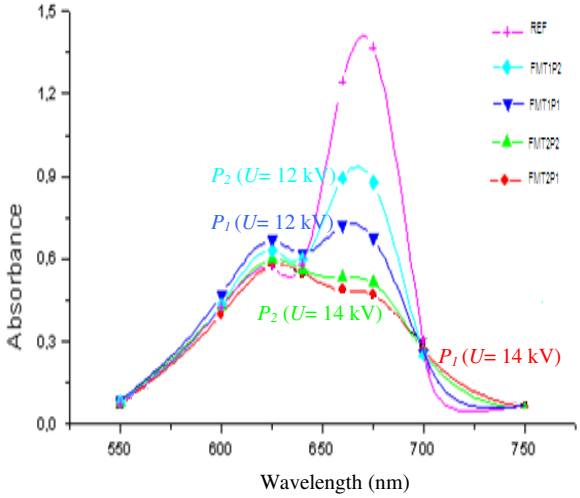

Fig. 6. Variation of the absorbance according to the wavelength for the reference mass of incense and the products collected on the longitudinal and transverse plates P_1 and P_2, for U = 12 kV and U = 14 kV.

Further research is needed in order to improve the performances of the CTEP, by increasing the number of chicanes and their geometry

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