INFLUENCE OF OPERATING CONDITIONS ON BAG FILTER PERFORMANCES FOR INCINERATION FUMES TREATMENT

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ABSTRACT

Filtration performances of a bag filter implemented for the flue gas treatment of waste incineration plant were studied at laboratory scale in order to evaluate the influence of filtration cycles (clogging/unclogging). The filtration performances were evaluated during clogging with a submicronic aerosol with nano-size fraction, at a filtration velocity of 1.9 $cm.s^{-1}$. Investigations of the influence of filter washing and filtration velocity on the filtration performances were performed with the same filtering media in flat configuration. Experimental results showed an influence of filtration velocity on fractional filtration efficiency in particular for particle diameter close to the Most Penetrating Particle Size of the filter. Moreover, results indicated that new filters were significantly less efficient than washed filters at the beginning of the clogging. Finally the influence of clogging/unclogging cycles on bag filter performances was demonstrated both for pressure drop and filtration efficiency evolutions during clogging.

KEYWORDS

Filtration, Bag Filter, Efficiency, Pressure Drop, Clogging/Unclogging Cycle, Incineration

1. Introduction

Nanoparticle research is currently an area of intense scientific interest in order to understand their behavior and transport. ISO (2008) defines a nanoparticle as nano-object with all three external dimensions at the nanoscale which, the size range is approximately from 1 to 100 nanometers (nm). According to toxicology studies, nanoparticles are responsible for health problems (Ostiguy et al., 2006).

There is a huge interest in nanoparticle filtration as one of the simplest methods to reduce efficiently the exposure to such particles. The bag filters have been successfully used for this purpose and allow to reach high performances depending on fibrous media used. So bag filters are usuely used for particulate matter removal in incineration fumes treatment. The pressure drop across the filter and filter efficiency permit to quantify the filtration performances during the operation. But a tradeoff between filter efficiency and pressure drop is often necessary to achieve high filtration efficiency while limiting economical costs due to pressure drop (Brown et al.,1993).

The filtration operation using bag filters is simple. The gas is fed at the bottom of a filter chamber that contains several filter bags. The air is filtered through the various bags (from the outside surface to the inside one) that are usually in vertical position. The filtered air exits through the top of the filtration device. The filter media that retains particles is unclogged periodically by pulse jet method (the injection of compressed air from inlet to the outlet of the bag filter produces a pulse-jet gas flow removing the particles collected on the outside surface of the filter bag) and the particles are recovered at the bottom of the system. During each cycle (clogging/unclogging) the particle collection efficiency increases rapidly due to the formation of a cake formed at the surface of the media until reaching values close to 100%. At the beginning of each cycle, the accumulation of a residual cake on filter surface may influence the filtration time and makes the formation of particles cake faster, while the maximum pressure drop may be reached faster (Park et al., 2012).

This study focused on filtration performances of bag filters used for the flue gas treatment of waste incineration. The study aimed to quantify the filtration performances of a bag filter regarding submicronic particles with nano-size fraction during clogging/unclogging cycles. The influence of filter washing and filtration velocity was also investigated, in particular to assist the development of technical recommendations.

2. Materials and methods

2.1 General Methodology

The filtration performances of bag filter were evaluated at laboratory for 10 cycles of clogging/unclogging. The particles used for the clogging were representative to those found in incineration fumes at the outlet of the boiler. The experiments were conducted at ambient conditions of temperature and humidity and for a filtration velocity of 1.9 $cm.s^{-1}$ representative of that encountered in incineration plants. The results were presented as evolution of filter pressure drop and fractional efficiency (particle collection efficiency versus particle diamter) during the 10 cycles of clogging/unglogging.

The influence of 2 maintenance and operating conditions were also investigated from experiments with the same filtering media but implemented in flat geometry, resepctively bag cleaning and filtration velocity. First, the influence of filter was studied. Indeed, in addition to on-line unclogging, the bag filters are periodically washed off-line to remove remaining pollutants. In order to assess the influence of filter washing, two kinds of flat filters were clogged in the same operating conditions and particle concentration: new (blanck) and washed (used) filters. Note that, in waste incineration plants, in order to benefit from the increase of filtration efficiency of the particulate cake, the bag filters are often pre-coated with sorbent (eg sodium bicarbonate used in flue gas treatment for acid gas absorption) before operation in the system. Regarding the experiments with the bag filter geometry, the media was washed. Secondly, the influence of filtration velocity was also investigated. Flat fabric filters were clogged at two filtration velocities, namely 1.4 and 1.9 $cm.s^{-1}$.

2.2 Experimental set-up

Two laboratory-scale filtration units were used to perform clogging tests of filter in flat and bag configurations. The experimental set-up for single bag filter (reduced height to 0.44 m) was described by Tran et al. (2014). It had been developed in order to operate up to 150°C and in presence of humidity (conditions encountered by the bag filters in flue gas treatment of waste incineration). Laboratory air is previously filtered by an HEPA filter and is fed to filtration device througth a tube with a sufficient length (1 m) to provide an established flow path and comprising the injection of particles. The bag filter module is equipped with upstream and downstream sampling probes for particle counting (SMPS, Grimm) and air is finally exhausted to the atmosphere after filtration of residual particles. The on-line unclogging of bag filter was provided by pulse jet method (compressed air at 6-7 bar). A removable tank allowed dust recovering at the bottom of the bag filter module. The experimental set-up dedicated to flat filters was a simple filtration conduct with the same equipment as the previous set-up (filtration of the ambient air, particle injection, sampling up and downstream of the filter) without on-line unclogging device.

In both experimental set up, the aerosol used for clogging was a condensation aerosol from graphite monoliths (generator DNP 2000, Palas). Filtration efficiency was quantify from isokinetic sampling up- and downstream of the filters and particle counting with a mobility diameter particle counter (SMPS, Grimm) in the range 16-315 nm. Each test with flat filter was repeated three times with different filter samples. For all clogging tests, the maximum pressure drop was set to 120 Pa.

2.3 Filter characteristics

Flat and bag filters, constituted of the same filtering media, were used to perform clogging tests. The flat filters were sampled from a commercial bag filter provided by the company TREDI. Structural properties of the filtering media are presented in Table 1. The media is a non-woven structure composed of Teflon fibers (Polytetrafluoroethylene PTFE). The size distribution of fiber media was determined by Scanning electron microscope and picture analyses. More than 100 fibers were analyzed from 3 different sampling.

Table 1: Main structural parameters of the filtering media

Parameters	**Value**	**Method**
Thickness (µm)	1256 ± 31	Scanning electron microscope
Fiber median diameter (µm)	19.5	Scanning electron microscope
Total porosity (-)	0.64	Mercury porosimetry
Basis weight (g/m^2)	750	NF EN 12 127

3. Results and discussion

3.1 Bag filter performances during clogging/unclogging cycles

Figure 1 shows the increase of pressure drop as a function of time during 10 cycles of bag filter clogging/unclogging. The maximum pressure drop was set to 120 Pa for all filtration cycles, once reached the filter is unclogged thanks to pulse jet. In accordance with literature (Park et al., 2012), the experimental results confirm that the clogging time period of the filtration cycles decreases from the first cycle (1090 min) to the last one (62 min). In terms of minimum pressure drop, the baseline which corresponds to the measured pressure drop ΔP just after cleaning increases with filtration cycles. This increasing (from around 20 to 80 Pa) is due to the residual cake from previous filtration cycles.

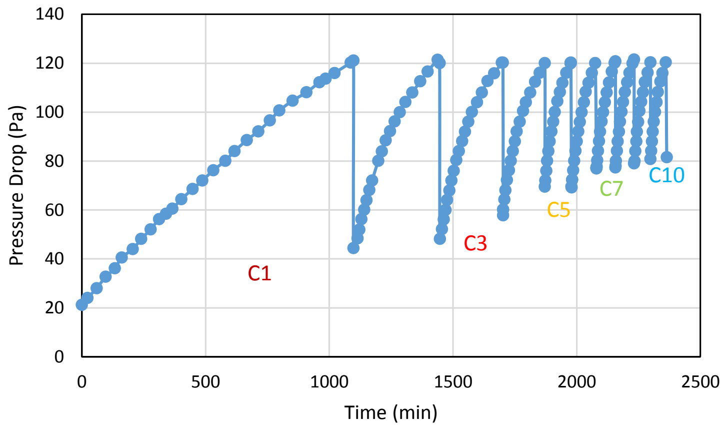

Figure 1: Pressure drop across bag filter versus time for 10 clogging/unclogging cycles

The evolution of bag filter efficiency versus particle diameter for different level of clogging (ratios $\Delta P/\Delta P_0$ with ΔP_0 the initial filter pressure drop of cycle 1) during the first clogging cycle is presented in Figure 2. The results indicate that the minimum particle collection efficiency in size range studied was 91%. The results also reveal, in accordance with filtration theory, an increase in particle collection efficiency with the filter clogging. The Most Penetrating Particle Size (MPPS) value, is not observable for the size range at $\Delta P/\Delta P_0$=2.7, but decreases from 90 nm for $\Delta P/\Delta P_0$=5.6 to 60 nm for $\Delta P/\Delta P_0$=7, for higher level of clogging (ie from $\Delta P/\Delta P_0$=9) particle collection efficiency reaches almost 100% wathever particle diameter is.

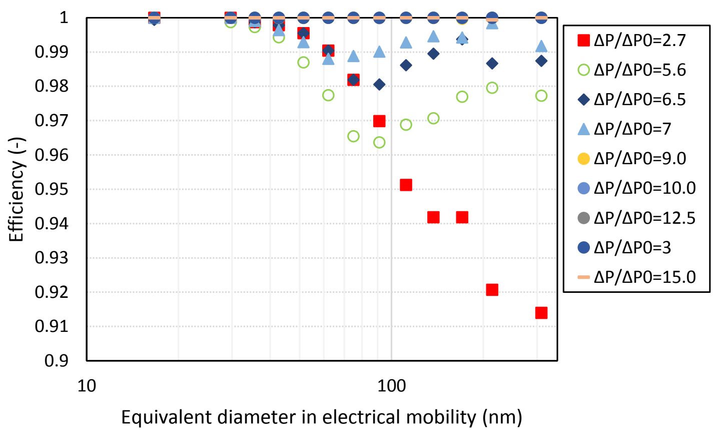

Figure 2: Evolution of fractional efficiency as a function of equivalent diameter in electrical mobility, for the first filtration cycle (C1) at different values of $\Delta P/\Delta P_0$

Figure 3 shows the fractional efficiency evolution at the upper pressure drop (120 Pa) for different clogging cycles. The results indicate that for particle size close to the

MPPS area (around 50-200 nm) the fractional efficiency decreases from the first to the last clogging cycle with a maximum efficiency close to 100% and a minimum of 98.5 %. The fractional efficiency for particles with diameter less than 50 nm and above 200 nm is less influenced by the sequence of clogging/unclogging cycles.

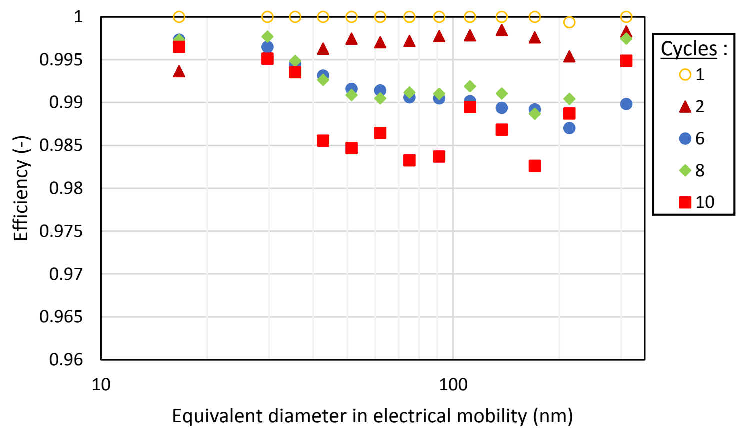

Figure 3: Evolution of fractional efficiency as a function of equivalent diameter in electrical mobility at the upper pressure drop for different filtration cycles

3.2 Influence of filter washing and filtration velocity on filtration performances

In order to investigate the influence of filter washing on the filtration efficiency, washed and new filters implemented in flat geometry were clogged in the same operating conditions. Figure 4 presents the fractional efficiency for 3 levels of clogging (ratios $\Delta P/\Delta P_0$). The results indicate that at lower pressure drop ($\Delta P/\Delta P_0=2$), the washed filter compare to the new filter at the same level of clogging, presents a significantly higher efficiency in the MPPS area. As expected this gap in efficiency decreases with increasing the level of clogging until reaching particle collection efficiency of almost 100% for $\Delta P/\Delta P_0=6$.

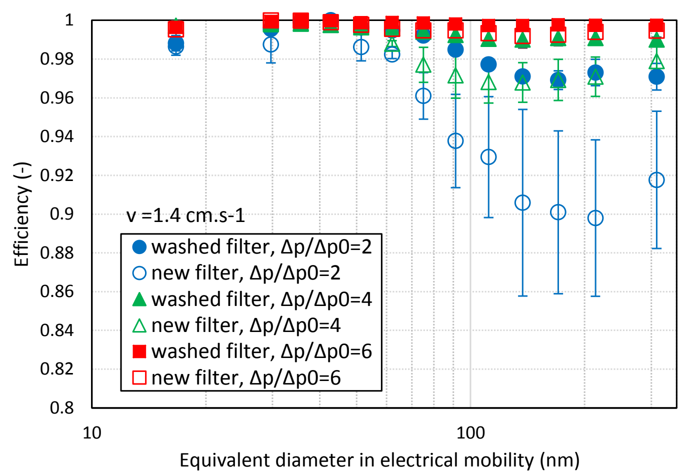

Figure 4: Evolution of fractional efficiency as a function of equivalent diameter in electrical mobility for washed and new flat filters for different values of $\Delta P/\Delta P_0$ at 1.4 $cm.s^{-1}$ filtration velocity

3.2 Influence of filtration velocity on filtration performances

Figure 5 compares the fractional collection efficiency for flat filters clogged at 2 different filtration velocities of 1.4 and 1.9 $cm.s^{-1}$ and for different level of clogging (ratios $\Delta P/\Delta P_0$). As seen previously in Figure 4 and in accordance with filtration theory, there is an increase of efficiency with the increase of pressure drop ratio for the both filtration velocities. For the begining of clogging ($\Delta P/\Delta P_0$=2, Figure 5), the efficiency is significantly higher at filtration velocity of 1.4 $cm.s^{-1}$ than at 1.9 $cm.s^{-1}$ for particle size ranging from 50 to140 nm (ie below the MPPS). This result is consistent with filtration theory: for particle size smaller than the MPPS, the Brownian diffusion is the dominant particle collection mechanism whose efficiency increases with decreasing the filtration velocity. The influence of filtration velocity is not significant for higher level of clogging, when filtration efficiency becomes close to 100% whatever particle size is.

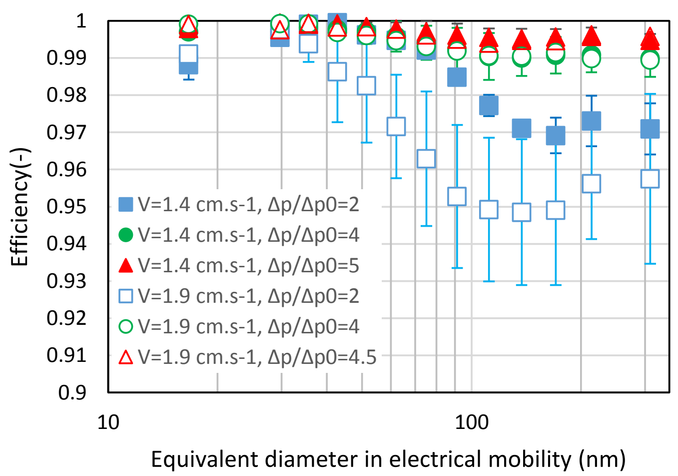

Figure 5: Evolution of fractional efficiency, as a function of equivalent diameter in electrical mobility, of washed and new flat filters at two filtration velocities (1.4 and 1.9 $cm.s^{-1}$) and at different values of $\Delta P/\Delta P_0$

Conclusion

The filtration efficiency and pressure drop of bag and flat filters were evaluated for particle size range of 16-315 nm. The main conclusions obtained experimentally are: (1) the efficiency of bag filter increases with increase of pressure drop during clogging until reaching efficiency of almost 100%. (2) Filtration efficiency decreases with increase of velocity, especialy for particles diameters ranging between 50-140 nm. (3) New filters are significantly less efficient than washed filters in the beginning of clogging at low $\Delta P/\Delta P_0$ ratios.

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