Pressure drop model for nanostructured deposit

F.X Ouf[1], D. Thomas[2, 3], F. Gensdarmes[1], S. Bourrous[1] and L. Bouilloux[1]

[1]Institut de Radioprotection et de Sûreté Nucléaire (IRSN), PSN-RES, SCA, Gif-sur-Yvette, 91192, France
[2]Université de Lorraine, Laboratoire Réactions et Génie des Procédés (LRGP), UMR 7274, F-54000, Nancy, France
[3]CNRS, Laboratoire Réactions et Génie des Procédés (LRGP), UMR 7274, F-54000, Nancy, France
Keywords: pressure drop, nanoparticle, agglomerate, aggregate.
Presenting author email: francois-xavier.ouf@irsn.fr

High Efficiency Particulate Air (HEPA) filters are commonly used to maintain the containment of nanoparticles or radioactive particles in industrial applications. Since the efficiency of such filters for nanoparticles has been largely investigated in the past decades, few works are devoted to the pressure drop of nanostructured deposit. Despite this lack of knowledge on experimental properties of such deposits, several theoretical models have been proposed in the literature but do not take into account the complex morphologies of nanoparticles (NPs), which could be structured as agglomerates (only point contact between NPs) or aggregates (partial fusion between NPs).

The aim of the present communication is to propose a new predictive model of pressure drop of nanostructured deposits composed of agglomerates and aggregates. For this purpose, an experimental test bench has been developed and is presented on figure 1. It is composed of two different sources of nanoparticles; a spark discharge generator (PALAS GFG 1000) with carbon electrodes and a combustion aerosol generator using propane as fuel (miniCAST 5201 Jing.).

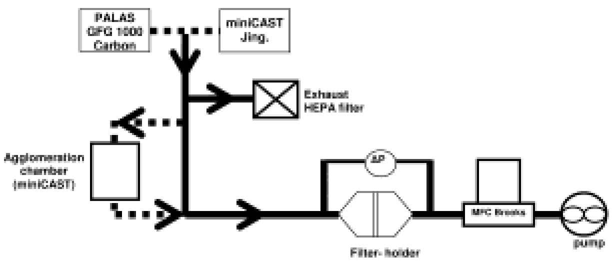

Figure 1. Experimental test bench.

A filter holder is implemented at the outlet of these aerosol generators, the filtration flow-rate is controlled by a mass flow rate controller (MFC Brooks 5850) and the pressure drop is measured with a differential pressure transducer (Wöhler DC2000 Pro). PTFE membranes (Millipore FSLW04700 with 3.0 µm pore size) have been used and the deposited mass M_C of nanoparticles has been measured with a METTLER AE 240 weighing cell with a resolution of 0.01 mg. The filtration surface area A_f has been measured visually and the height H of the cake with a focus-variation surface metrology system (InfiniteFocus ALICONA). The porosity of the cake ε has been computed according to the experimental correlation between height and mass of the cake.

Table 1 presents experimental conditions and corresponding mean porosities. A correlation has been proposed for predictive reason.

Table 1. Experimental conditions and mean porosity

Aerosol generator	miniCAST				GFG 1000			
Configuration	No chambers			Agglomeration chambers	Frequency: 500 u.a.		Frequency: 999 u.a.	
Filtration velocity U_f (m/s)	0.01	0.05	0.09		0.01	0.09	0.01	0.09
Cake porosity	0.973	0.950	0.940	0.946	0.984	0.957	0.980	0.966
Uncertainty	0.002	0.003	0.002	0.020	0.020	0.005	0.004	0.020
Aggregate or agglomerate count median diameter (nm)	91			170	48	49	54	62
Pe	1.1	5.7	10.0	52.9	0.2	1.8	0.3	3.4

The experimental results have been compared to a new pressure drop deposit model (Thomas et al., 2014) based on the Davies relation and including a correction factor taking into account the potential fusion of NPs in the aggregates composing the deposit.

$$\Delta P = \frac{64\,\alpha^{0.5}\,(1+56\,\alpha^3)}{Cc\ d_p^2\ \rho_{PP}} \frac{(1-Co)}{\left[\frac{2}{3} - Co^2\left(1-\frac{Co}{3}\right)\right]}\ \eta\ m_S\ Uf,$$

α is the packing density of the deposit, Cc the slip factor, d_p the diameter of average mass of the NPs, ρ_{pp} the bulk density of the NPs, Co the overlap parameter, η is the gas viscosity, m_s the mass of deposit per surface area and Uf the filtration velocity. Figure 2 presents the good agreement observed between present model and experimental results (95 % of the experimental results are predicted with an uncertainty of +/- 25 %).

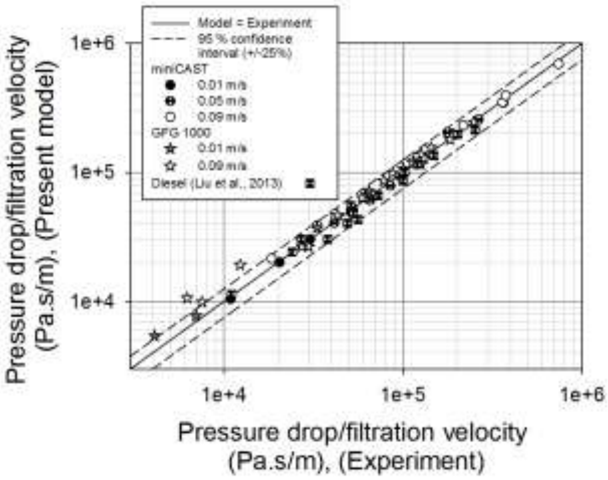

Figure 2. Comparison between model and experiments.

Thomas, D., Ouf, F.X., Gensdarmes, F., Bourrous, S., and Bouilloux L. (2014) *Sep. Purif. Technol.* **138**, 144-152.