Visualization of nanoparticles deposits onto spherical collectors

L. Wingert[1, 2, 3], A. Charvet[2, 3], S. Pacault[2, 3], C. Godoy[2, 3], Q. Ribeyre[2, 3], N. Bardin-Monnier[2, 3], D. Thomas[2, 3]

[1] Institut National de Recherche et de Sécurité (INRS), F-54519, Vandœuvre-lès-Nancy, France
[2] Université de Lorraine, Laboratoire Réactions et Génie des Procédés, UMR 7274, F-54000, Nancy, France
[3] CNRS, Laboratoire Réactions et Génie des Procédés, UMR 7274, F-54000, Nancy, France
Keywords: Deposit morphology, Nanoparticles, Spherical collectors, Pressure drop
Presenting author email: loic.wingert@inrs.fr

In order to develop predictive models dealing with the granular beds clogging by nanoparticles, i.e. to forecast both the collection efficiency and pressure drop evolutions, the deposit morphology on the collectors is a key information.

Some studies concerning the deposition on spherical collectors of micron-sized particles suspended in a liquid solution were carried out (Payatakes et al., 1981, Chang et al., 2010). In the case of airborne particles deposits, one of the main studies was conducted by Kasper et al. (2010). They investigated the structure and the density of deposits formed by micron-sized particles on a single fiber. Nevertheless, there is no study concerning the case of the deposition of nanostructured particles onto spherical collectors.

Therefore, we decided to observe this type of deposit both on a magnetic beads line and a magnetic beads layer mounted on a rotating frame. The use of magnetic beads ensures that the collectors are kept rigidly connected in both cases without using any support that would disrupt the flow and thus the deposit structure. The deposit observations were performed by a set of digital microscopes (X 25, X 250, X470) permitting to follow the growth of the deposit thickness on the collectors line and the closure of the pores of the collectors layer. For this last case, the pressure drop increase during the clogging was also monitored to be correlated with the observed pores closure state. Three types of nanoparticles were used: graphite (line and layer), iron (layer) and titanium (layer). Furthermore, the experiments were conducted at two different superficial velocities: 20 cm/s (line and layer) and 5 cm/s (layer).

The results of the beads line experiments permitted to show, thanks to the rotating frame, that the deposit is homogenous all over the collector surface in the case of Brownian particles deposition. Nonetheless, the deposit layer appeared to be ellipsoidal and almost non-existent at the contact points between two beads. This ellipsoidal shape was attributed to a higher air flow resistance at the contact points inducing a lower particle mass flow rate in these zones.

The tests conducted on the beads layer revealed the same ellipsoidal shape of the deposit between the four contact points of a pore. From the microscope viewings, a pore closure degree could also be measured using a Matlab® code based on the binarization of the pictures. Thus, the pressure drop as a function of the pore closure degree was plotted for all the performed experiments (cf. figure1). On the figure 1, some binarized viewings of the clogged pores are also presented.

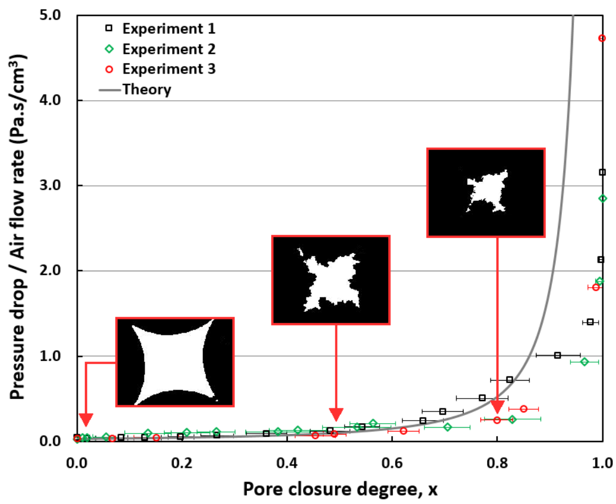

Figure 1. Pressure drop evolution as a function of pore closure degree.

All the pressure drop evolutions appeared very close whatever the operating conditions and in spite of visually different porosities for each kind of agglomerates and of location differences of the deposit in the pores. Indeed, in the case of the iron particles, the deposit was highly affected by the magnetic field created by the collectors. These observations seem to indicate that the whole air flow passes through the unblocked area of the pores. A theoretical approach was conducted in order to confirm this assumption. The pressure drop of a pore of the layer considered as a discretized constricted tube was calculated using the Poiseuille's law. This calculation was repeated for all the pore closure degrees assuming a uniform deposit thickness on the pore wall (cf. figure 1). A good agreement was observed whatever the superficial velocity, the agglomerates size and consequently the deposit porosity. This result tends to prove that the fluid do not flow through the deposit until reaching very high pore closure degrees.

These results, obtained on the beads line and the beads layer, permit to better understand the clogging process and will be useful for the development of predictive deep bed filtration models.

Payatakes, A., Park, H.Y., Petrie, J. (1981). *Chemical Engineering Science*, 36, 1319-1335.

Chang, Y.-I., Rong-Shin, L., Wei-You, C. (2006). *Separation and Purification Technology*, 52, 126-135.

Kasper, G., Schollmeier, S., Meyer, J. (2010). *Journal of Aerosol Science*, 41, 1167-1182.