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Short Communication

Service life of circular pleated filters vs. that of their flat counterpart

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ABSTRACT

In this note, an easy-to-use two-dimensional model is developed to predict the instantaneous pressure drop and collection efficiency of circular pleated filters as a function of time in both the surface and depth filtration regimes. Our model uses average velocity profiles that represent the flow field inside a circular pleated filter to circumvent the need for conducting CPU-intensive CFD calculations to predict the service life of a circular filter. This is accomplished by considering a reasonable dust-cake profile inside the pleat channels as a function of the flow and particles properties, and allowing the cake to grow as the filter continues to collect particles over time. Despite the approximate nature of its predictions, the speed at which a large parameter study can be completed makes the present model very valuable for design and development of circular pleated filters. Using this model for instance, it can be shown quantitatively that circular filters with high inlet-to-outlet diameter ratios outperform their flat counterparts.

1. Introduction

Aerosol filters are often pleated into triangular or rectangular patterns and the resulting geometries are often rolled up into a circular shape to accommodate as much filtration media as possible in a confined space (see Fig. 1a). Obviously, the inlet and outlet diameters of the pleats depend on the dimensions of the casing in which the circular cartridge will be placed. Despite the widespread use of pleated filters, the effects of dust deposition and cake formation on the performance of such filters have only been reported in a very few studies (e.g., the computational studies in [1–5] or the experimental work in [6–11]). As such, no study has yet been reported to establish a link between the radial geometry of a circular pleated filter and its filtration performance (collection efficiency and pressure drop) when loaded with dust particles. This paper is therefore devised to study the effects of geometric parameters on the filtration performance of circular pleated filters over time. From the basic principles of fluid dynamics, one expects the flow field inside a circular pleat to be different from that of a flat pleat (flow into a sink versus a uniform flow). Therefore, the current work is particularly focused on the differences between the performance of a circular pleated filter and its flat counterpart (see Fig. 1a and b), as pleated fibrous media are often tested in a flat configuration. The present study builds on the in-depth knowledge obtained from our previous computational fluid dynamics (CFD) simulations of dust-cake growth inside pleated filter media in a flat configuration [2–4]. However, in contrast to such CFD simulations, the approximate model presented in this paper allows one to simulate the entire lifecycle of a filter in a few minutes.

In the remainder of this paper, we first present our formulations for predicting the pressure drop and collection efficiency of circular pleated filters with and without dust-cake (Section 2). In Section 3, we compare the predictions of our model to those obtained from more accurate CFD simulations. Our results and discussion are given in Section 4 followed by our conclusions in Section 5.

2. Modeling circular pleated filters

2.1. Clean fitters

Assuming filter media to be the sole source of pressure drop in a pleated filter, the face velocity (air velocity normal to the media) can be obtained using Darcy's law:

$$v_w = \frac{\Delta p}{t_m} \frac{k}{\mu} \tag{1}$$

where Δp is the pressure drop across the media, k is the permeability of the media, t_m is the thickness of the fibrous media, and μ is the air viscosity. Considering a control volume inside the pleat channel,

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