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Short communication

On the pressure drop prediction of filter media composed of fibers with bimodal diameter distributions

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Abstract

In addition to collection efficiency, pressure drop is the most important characteristic of a filter medium. While there are numerous analytical expressions available for predicting the pressure drop of the filters made up of fibers with a unimodal fiber diameter distribution, there are not enough studies dedicated to filters composed of fibers with a bimodal (or multimodal) fiber diameter distribution. In this work, the pressure drop per unit thickness of filters made of bimodal fiber diameters is calculated by solving the Navier–Stokes equations in a series of 2-D geometries. These results are used to find the unimodal equivalent diameters of each bimodal filter that could be used in the existing expressions for calculating pressure drop. In agreement with the work of Brown and Thorpe [Brown, R.C., Thorpe, A., Glass-fiber filters with bimodal fiber size distributions. Powder Technology 118 (2001) 3–9.], it was found that the area-weighted averaging of the fiber diameters in a bimodal filter provides a relatively good estimation of its equivalent unimodal fiber diameter. We, however, noticed that in such an averaging the error percentage in the pressure drop prediction is sensitive to the fiber diameter ratios as well as the fraction of each fiber diameter in the bimodal filter. We, therefore, obtained a correction factor for the estimation of the unimodal equivalent diameters as a function of fiber diameter ratio and their number fractions.

Keywords: Fibrous filter; Pressure drop; Bimodal; CFD

1. Introduction

The pressure drop caused by fibrous filters has been studied for many years and numerous analytical, numerical and empirical correlations are available for such media. In almost all these models, a filter is assumed to be made up of fibers with a unimodal fiber diameter distribution. Ignoring the width of the fiber diameter distribution, it is still possible to conveniently calculate the filter's pressure drop using a single average fiber diameter. A great portion of the fibrous filters however, are made up of blends of coarse and fine fibers with widely different average diameters. This is often the case where mechanical strength and filtration efficiency are both important. The fine fibers contribute to the high filtration efficiency (high collection efficiency for a given pressure drop) while the coarser fibers contribute to the medium's rigidity. The fibers may be intimately blended in the case of short fibers like in carded, air-laid, or wet-laid fiber-webs or layered in the case of melt-spun media such as melt-blown and/or spun-bonded webs. Despite their importance, not enough work has been dedicated to calculating the pressure drop of filters with bimodal (or multimodal) fiber diameter distribution. This is probably because of the presence of too many independent but coupled variables which contribute greatly to the complexity of such calculations. The current study is aimed at improving our understanding of the influence of different variables on the permeability of filters with bimodal fiber diameters.

To estimate the pressure drop of unimodal filters, air flow through the media was modeled by solving the flow governing equations over a structured array of fibers in two or three dimensional geometries. Various authors have proposed well-known models for predicting the pressure drop of unimodal filters [1–10]. All these models present the pressure drop per unit thickness of a unimodal filter as:

$$\frac{\Delta p}{t} = f(\phi)\frac{\eta V}{r^2} \quad (1)$$

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