



Predicting Initial Pressure Drop of Fibrous Filter Media – Typical Models and Recent Improvements

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ABSTRACT

Initial pressure drop, along with efficiency and capacity, is one of the important performance parameters of a fibrous filter. In moving towards “Analysis-Led Design” of filtration products, a realistic prediction of initial pressure drop based on media physical parameters is a necessary first step.

We will present existing models, such as the 2D Kuwabara and the 3D cellular approach, and discuss their limitations in predicting initial pressure drop of fibrous filter media, which have pushed us towards a numerical modeling (CFD) approach. In order to optimize the inner fiber structure for a specific application, simple and rapid simulations are required. Therefore a 2D approach, which can run on a standard PC workstation, is favored over sophisticated 3D fiber models, running on parallel computers.

As the fiber structure is not truly random, a literature survey of various 2D approaches to model disarrangement or random fiber structures will be presented. However, fully random structures still over-predict the pressure drop by 120 % to 200 %, compared to measurements on some of our important filter media grades. Therefore we will present some of the results of a Technology Development for Six Sigma (TDFSS) project, and our approach of modeling fibrous filters by creating “partial-random” structures. We will illustrate our rapid and highly automated method combining MATLAB and the CFD program FLUENT/GAMBIT to predict realistic initial pressure drop values. The much-improved agreement between CFD predictions and measurements for a wide variety of different filter media will be shown and discussed.

Keywords: Filtration, CFD, 2D Kuwabara, 3D cellular approach

Introduction

Usually the pressure drop Δp of a fibrous filter media is predicted based on the flow resistance of single fibers. In the simplest case of a homogeneous media consisting of

fibers monodisperse in diameter, the initial pressure drop is calculated by

$$\frac{\Delta p}{z} = \frac{rv^2}{2} c_D \frac{a}{\frac{p}{4} D_F} \quad (\text{Eq. 1})$$