

The effect of porosity on deposition on fibrous filters.

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INTRODUCTION

Fibrous filters generally consist of many threadlike fibres oriented more or less normal to the fluid flow which passes through them. Particles carried by the fluid flow may impact upon the fibres and become removed from the flow. The collected particles accumulate forming complex structures which influence the fluid flow and further deposition. Understanding the process of particle deposition and its effects upon further deposition are crucial in understanding the performances of fibrous filters. We have been developing a numerical model of fibrous filtration aimed at investigating deposition due to various mechanisms and the effect filter properties and particle characteristics have upon it, Dunnett and Clement 2006, 2009. We have shown that deposit porosity does not influence further deposition for small particles where diffusion is dominant, Dunnett and Clement 2009. However, in this work, we show that deposition by interception can be strongly affected by porosity to produce deposit shapes observed previously Kanaoka et al (1986).

NUMERICAL MODEL

In earlier work, Dunnett and Clement (2009), a numerical model has been developed which determines the flow field, and particle motion, around a single fibre which has a porous deposit made up of collected particles on its surface. Neighbouring fibres are taken into account by the application of boundary conditions on the computational domain. The deposition of particles onto the porous surface can be determined and hence the growth of the deposit modelled. The shape of the deposit is affected by the size of the particles considered. For small particles diffusion is the main mechanism by which they deposit on the surface and in this case deposit is collected around the majority of the fibre. The main non-dimensional parameters to consider when solving for the particle concentration, n , in this case are the Peclet number, Pe , given by $Pe=U_0d/D$, and κ the ratio of the particle to fibre diameters. U_0 is the mean flow velocity, d the fibre diameter and D the coefficient of diffusion of the particles. The effects of particle interception with the surface are accounted for when solving for n by the application of boundary conditions. Interception becomes more important as the size of the particle increases and dominates

when $s = \frac{\kappa}{\delta} \geq 1$. In this expression $\delta=(4k/Pe)^{1/3}$,

where k is the hydrodynamic factor, is the non-dimensional thickness of the diffusion layer.

For still larger particles inertial impaction is the dominant mechanism of capture.

An example of a deposit formed, where interception is the method of deposition, is shown in Figure 1. In the figure the fibre initially has a layer of deposit on it. The value of s is approximately unity hence we are in the region where interception has just become the dominant deposition mechanism. The surface formed by particles depositing due to interception is shown for the cases when the initial deposit is assumed to be solid and when it is porous with a porosity of $\phi=0.92$, where ϕ is the fraction of the porous media that is occupied by void space. The value of κ is 0.025.

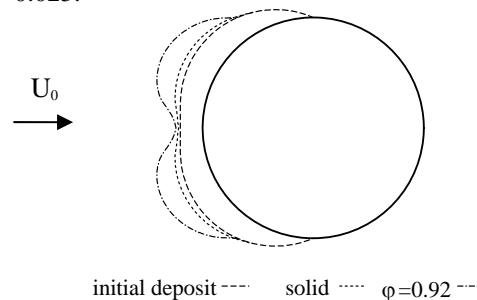


Figure 1. Surface formed by interception.

It is found here that for deposition due to interception the porosity of the initial deposit does not become significant until $\phi>0.8$. After this value the deposit surface grows rapidly as the flow moves through the deposit already formed. The resulting formation of “ears” on the deposit is a characteristic feature of some of the deposits observed by Kanaoka et al (1986).

We have already shown that the porosity of the deposit does not affect the deposition pattern when diffusion is dominant, but its value is clearly important in the interception region.

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