

Calculation of deposition on fibrous filters as a function of time

S. J. Dunnett¹ and C. F. Clement²

¹Department of Aeronautical and Automotive Engineering, Loughborough University, Loughborough, Leics. LE11 3TU, U.K.

²15 Witan Way, Wantage, Oxon, OX12 9EU, U.K.

Keywords: fibrous filter, filtration, numerical simulation, particle deposition

Presenting author email: s.j.dunnett@lboro.ac.uk

Introduction

Fibrous filters are routinely used to remove particles from the air. The filters consist of numerous fibres arranged in such a way that they are mostly perpendicular to the air flow through it. The packing fraction of such filters is generally small enabling the modelling of filter performance to be undertaken using single fibre theory. When the filters are in use particles collect on the fibres and are removed from the air. The deposit collected on the fibres affects the air flow through the filter and hence the subsequent deposit of particles. To date we have a fairly good understanding of the performance of fibrous filters at the start of their lives when no deposit is collected. The problem of filter efficiency as a deposit builds up has been addressed by Kasper et al (2009) who found empirical fits to experimental data that they have obtained. In the work presented here we will describe a method of calculating the collection efficiency and mass build up on a fibre for the case when interception or impaction are the major deposition mechanisms. The method is based on a previously developed numerical model, Dunnett and Clement (2012) and an efficient mathematical technique for determining critical trajectories Clement and Dunnett (2014).

Numerical model and procedure

The numerical model developed by Dunnett and Clement (2012) applies to deposition on a fibre, radius R_f , in a cell of radius y_c which is related to the packing fraction of the filter, c by the equation $c=R_f^2/y_c^2$. In our two dimensional model the dimension of the cell corresponding to length along the fibre is irrelevant to the deposition process, and the particle mass flux, F , mass in the deposit, M and deposit volume, V , are all in units per unit length of the fibre. The flux, F_c , entering a single cell is given by

$$F_c=2y_cnm_p v \quad (1)$$

where n is the concentration of particles of mass m_p and velocity v . The mass deposition rate on a fibre at time t is

$$\frac{dM}{dt} = F_c E(t) \quad (2)$$

where $E(t)$ is the deposition efficiency which is the fraction of particles entering the cell which are deposited. This corresponds to an increase in volume of

$$\frac{dV}{dt} = \frac{F_c E(t)}{\rho_p (1-P)} \quad (3)$$

where ρ_p is the particle density and P is the deposit porosity. The deposition efficiency depends on the geometry of the existing deposit and it is assumed in our model that $E(t)$ remains constant, $E_L(t)$, during the deposition of a layer L of depth d at the front of the fibre. Therefore, from equation (3), the total volume deposited for a layer is given by

$$V_L = \frac{F_c E_L(t) t_L}{\rho_p (1-P)} \quad (4)$$

where t_L is the time taken to deposit the layer L of width d .

To determine $E_L(t)$ we find the critical trajectory, using the techniques given in Clement and Dunnett(2014), which enters the cell at a height y_L so that $E_L=y_L/y_c$.

We assume that the incident fluxes forming the new deposit in figure 1 remain constant during the layer deposition. This enables us to directly determine t_L for deposition width d at the front, and V_L from integration of the fluxes over the new deposit.

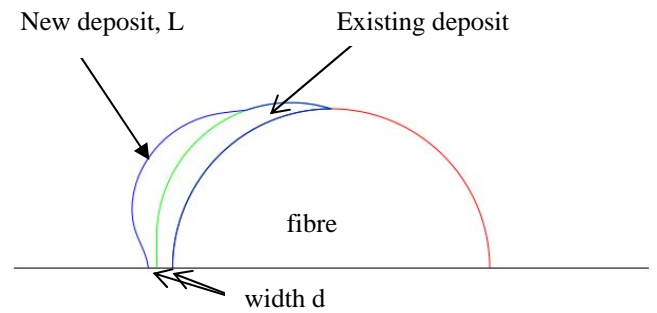


Figure 1. Deposit geometry for a new layer on an existing deposit.

Hence it is possible to investigate the volume and mass deposited as a function of time and results will be presented.

References

- Clement, C.F. and Dunnett, S.J. (2014) *J. Aerosol Sci.*, 69, 98-112.
- Dunnett, S.J. and Clement, C.F. (2012) *J. Aerosol Sci.*, 55, 85-99.
- Kasper, G., Schmollmeier, S., Meyer, J. and Hoferer, J. (2009) *J. Aerosol Sci.*, 40, 993-1009.