1. Introduction

Classical theories of particle filtration via fibrous filters have been developed for clean media. These theories were based on an exact or a numerical solution of the flow field around a perfectly clean fiber placed normal to the flow direction in a two-dimensional configuration [1,2]. Classical filtration theories have resulted in a variety of easy-to-use semi-empirical expressions for predicting the performance (i.e., collection efficiency and pressure drop) of fibrous filters (see [1,2]) for comprehensive reviews). However, filters do not remain clean during the course of their operation. Particles deposit on the fibers and form complicated dendritic structures. The deposited particles affect the flow field around the fibers as the air streamlines change in response to the changes in the filter's morphology, and render the aforementioned expressions inaccurate. Therefore, existing pressure drop and collection efficiency expressions are only valid for the early stages of a filter's life.

Despite its obvious importance, filtration theories have not been sufficiently developed to provide accurate predictions for the performance of particle-loaded filter media. The most computation-ally affordable approach to account for the changes in a filter's internal structure is to assume that the deposited particles form a homogenous porous coating with a given porosity around the fibers, and to allow this coating to grow according to some simple mathematical rules (often in 2-D domains). However, such an approach comes at the expense of neglecting the microstructure of the particle deposits, which can lead to considerable errors in predicting the flow streamlines, and therefore collection efficiency and pressure drop, especially for the particles captured via interception or inertial impaction mechanisms (e.g., [3–5]). As will be discussed later in this paper, a more realistic model of the particle loading process is one that captures the dendrite shape of the deposits and updates the flow field based on such morphological changes.

The geometry of a loaded fiber changes depending on the particle deposition mechanism. If the mechanism is mainly interception, the deposition pattern will be on the fibers' lateral sides. By increasing the Stokes number $Stk = \frac{\rho_p d_l^2 C \nu}{18 \mu d_f}$, the particle deposition mechanism changes to the inertial impaction. In this regime, the particles do not follow the streamlines perfectly, and