CHAPTER I
INTRODUCTION

1.1 Inportance of Air Filtration

Particulate pollutants of micron-order size have been identified as the most hazardous pollutant from a public health point of view. Therefore, there is acute need for complete removal of contaminating particles from the inhaled air. Air cleaning may be achieved with the cyclone, scrubber, fabric filter, electrostatic precipitator, fibrous filter, etc. Most of air filters can remove fine particles smaller than 10 μm diameters. When there is need for efficient, for instance higher than 95%, removal of particles smaller than 1 μm diameters from the flow of air, a good fibrous air filter can be used. The fibrous air filter is an effective method of removing submicron particles with the additional advantage of low energy consumption. But one disadvantage of using the fibrous air filter has been the failure in developing convenient and effective methods for cleaning the filter. Hence, most industrial applications are still confined to some specific cases where high efficiency is demanded and use of disposable filter elements is practical for environmental protection such as clean rooms, emergency filtration system for radioactive aerosols, respiratory mask, etc.

The deposition mechanism of aerosol particles in the fibrous air filter is of interest to many researchers because the filter is used in various industries for dust collection and environmental protection. It is well known that the depostion of aerosol particles on a fiber depends on the combined effects of inertial impaction, Brownian diffusion, gravitational settling, direct interception, static electricity, etc. When the filter is used for a long period of time, the morphology of aerosols collected on the fiber is different from that on a clean fiber. It was found that aerosol particles do not deposit only on the fiber surface but also on formerly depositing particles forming tree-like agglomerates called dendrites (Davies 1973). Each dendrite is rooted at the fiber surface and hinders in the main flow. Therefore, it acts as a collector and keeps growing as additional particels deposit on it.

Many experimental studies have found that these pheonomena lead to an increase in both the aerosol collection efficiency and the pressure drop of the fibrous air filter with filtration time (Kimura et al., 1964; Billing, 1966). The experimental aerosol collection efficiency of the dust loaded fiber normalized by the corresponding collection efficiency of the clean fiber was found to be expressible by the following linear function of the mass of particles accumulating in a unit filter volume, i.e. $\frac{\eta}{\eta_0} = 1 + \lambda\, m$,where λ is the collection efficiency raising factor (Yoshioka et al., 1969).

Over a long period of time, filtration results in the formation and growth of dendrites on the fibers, which increase the filtration efficiency and pressure drop. Many investigators have focussed on mathematical formulation and analysis of particles deposition on the fiber. Payatakes and Tien (1974) and Payatakes (1976a, 1976b, and 1977) have developed deterministic expressions for the dendritic growth process via interception collection mechanism. Wang et al. (1977) have also simulated the dendritic growth process on a sphere and a two dimensional cylinder by assuming that the filtration process is random.

Meanwhile, Kanaoka et al. (1980, 1981, and 1983) have also simulated the growing process of particle dendrites on a dust loaded fiber via Monte-Carlo simulation of the stochastic model respectively for inertial interception and/or convective diffusion collection mechanism. Moreover, they find that the shapes of the dendrites obtained from their simulations agree fairly well with experimental investigations and the ratio of the collection efficiency of single fiber with dust load to that of a clean fiber is expressible as a linear function of the mass of particles depositing in a unit filter volume. In addition, the values of the collection efficiency raising factor λ are in qualitative agreement with some experimental study (Myojo et al., 1984). However, it was found that the stochastic model required a large computer memory and much computational time.

In recent years, a simple population balance model has been developed for predicting the dendritic growth of aerosol particles and the accompanying increase in the collection efficeincy on the single fiber via convective diffusional deposition by requiring only a personal computer without requiring much computational time (Tanthapanichakoon et al., 1993). The simulation results using the new simplified model agree fairly well with those obtained previously by Monte-Carlo simulation of the stochastic model. Moreover, this model has not yet been applied to the inertial impaction mechanism. In the new model, two essential parameters, e_N and e'_N, play an important role in determinising the formation and growth of dendrites on the single fiber. There parameters have been estimated by experience to fit the results of stochastic simulation for convective diffusion mechanism.

1.2 Objectives of the present study

1. To study and apply the simplified model to predict the dendritic growth of aerosol particles and the corresponding aerosol collection efficiency on a dust-loaded fiber for the case of convective diffusion mechanism.
2. To modify the simplified model to predict the dendritic growth of aerosol particles and aerosol collection efficiency on the dust-loaded fiber for the case of inertial impaction mechanism.
3. To estimate the optimal values of the parameters of the simplified model for both the convective diffusional and inertial impaction mechanisms.

1.3 Scope of study

1. The simplified model derived from the populationn balance of dendritic growing on a single fiber was applied to the convective diffusion mechanism and extended to the inertial impaction mechanism.

2. For the sake of flexibility, the C++ programming language was chosen to code the model program and the optimizing program. The resulting computer code will be tested on an IBM compatible personal computer.

3. The simplex non-linear optimization method was used to estimate the parameters of this model. It was used to find the optimal values of these parameters by comparison between the previously obtained results of stochastic model and the results of this model.

4. The corresponding stochastic model was simulated for various filtration conditions estimation to obtain additional stochastic simulation results for comparison with the results of the simplified model.