mgr inż. Mateusz Kamiński
Faculty of Chemical and Process Engineering
Warsaw University of Technology

ABSTRACT OF THE DOCTORAL THESIS

The use of single- and multi-layer nonwoven filters for the purification of gases from suspended solid and liquid particles

In recent years, there has been a substantial increase in the demand for the development and use of methods to remove solid and liquid particles of various origins suspended in the gas stream. One way of cleaning the gas stream is to utilise a filtration process using nonwoven filters. In order to carry out the filtration process effectively, the knowledge of all the components of the system under consideration and the phenomena occurring during the process is required. It is essential to possess knowledge regarding the challenge of the process - aerosol, the utilised solution - filter, and all the additional effects and changes occurring in the system as a result of the process. On the basis of this information, a calculation model can be created to describe the filter performance during the filtration of a given aerosol. The series of publications that form the basis of this dissertation addresses the theoretical and experimental aspects of mixture aerosol filtration using nonwoven filters and presents the development of a calculation model.

The nonwoven filters utilised in this study were made by melt-blown technique, and their internal structure is characterised by an irregular and random distribution of fibres. The utilised filters differed in the average size of the filter-forming fibres, and, as shown in the course of the work, the description of the filter by the average value of the fibre size is not sufficient. A method for determining the actual filter fibre size distribution based on the microscopic images and implementation of a simplified version of this distribution in a calculation model is presented.

Single-component aerosols consisting of graphite particles, oil droplets and water droplets, as well as their multi-component combinations with different concentrations, were utilised during the research, which made it possible to indicate and compare the effects occurring on

the surface and inside the filter due to the deposition of aerosol particles of different types and properties on its fibres.

Experiments with a mixture aerosol containing solid particles and oil droplets resulted in the identification of the characteristic for this aerosol, maximum efficiency observed for filters with high overall efficiency and high efficiency of the fibres building such a filter, accompanied by a minimum observed in the average size of the particle penetrating the filter. The occurrence of this effect was attributed to the existence of a maximum efficiency front moving inside the filter, the existence of which is related to the effects of particle slip on the liquid-wetted fibre, movement of the retained liquid on the fibre surface and into the depth of the filter, as well as its drainage forced by the flow and action of the gravitational force, secondary entrainment of particles deposited from the fibre surface, a change in the effective diameter of the fibre, a change in the local packing density and a change in the local linear velocity of the flow.

The research indicated the need to utilise empirical solutions in the calculation model with suitably adjusted coefficients, a more accurate representation of the filter fibre size distribution, the concept of effective particle density and the resulting changes in filter packing density due to aerosol particle deposition on the fibres, changes in the linear flow velocity through the filter and, in the case of the fibres considered independently, changes in their diameter. The proposed calculation model was utilised to describe the change in filter mass, and based on this, a model was proposed to describe the change in pressure drop across the filter, which was also used to describe the tested filters.

Discrepancies between experimental and model results have been analysed, and their potential explanations have been proposed, and based on them, additional phenomena which may occur in the studied systems have been indicated, and promising directions for further research and considerations have been suggested, which would allow a more accurate description of the process of filtration of solid and liquid particles suspended in the gas stream with the use of nonwoven filters.

Keywords: multi-component aerosols, solid particles, nonwoven filters, liquid droplets calculation model, pressure drop, filtration efficiency