Simultaneous Filtration of Liquid and Solid Aerosols on Fibrous Filters

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Abstract* – The subject area of this work refers to filtration process by using fibrous filters made by modified melt-blown technique during simultaneous exposition to contaminated gas by solid particles and liquid microdroplets. The paper consists a characteristics of deposition of aerosols with different morphology and influence for pressure drops for separation solid, liquid and mixed aerosols on fibres. In this research a filtration test set-up was modified to allow to generate and put into airstream simultaneously both particles and droplets.

Keywords – aerosol deposition; fibrous filter; filtration efficiency; melt-blown technique; mixed aerosols.

I. Introduction

Nowadays gas purification process is one of the most significant step in the processing of various substances and is widely used in many industrial processes for humen and nature protection. Harmful and unwanted particles must be removed from the waste gases before there could be released to the atmosphere. This allows us to minimize a negative impact on the environment. New generation of high efficiency fibrous polymer filters can be used for capture and removal from air pollutants in wide range of size diameter [1, 2].

In the literature of subject, mainly removal of solid [3,4] or liquid particles [5,6] separatly has been reported. Very rare are informations about simultaneous occurrence of these two types of aerosols, they interaction with each others and with the surface of the collector. However, in real conditions of filtration process these two type pollutants often occur in air. It has affected for the actual lifetime of the filter materials. Hence, there is a big need for a better understanding of the simultaneous filtration of mixed aerosols.

In the paper [4], it have been shown phenomena, which occur during the filtration of solid particles. In the first step, the particles settle on the surfaces of the clean fibers. During the filtration process the particles starts to forming a dendritic structures. As a results, they reduce pores of onwoven and we could observe that filtration efficiency and airflow resistance increase.

The separation of aerosols with liquid droplets was investigated in [4]. In the first part of process, the droplets deposited on the surface of the filter fibers and create thin film layer . In this step of process we could observed a slight increase in pressure drop. After some time oil starts fill almost the entire space between the filter fibers forming numerous liquid bridges what results in an exponential increase of airflow resistance. Later on when this resistance reaches a maximal value the pressure drop and particle penetration are nearly constant. This is due to the balance between loading, dripping and redistribution of droplets.

In case of solid particles dendritic structures are formed which are hardly to tear down. As a result of coalescence, droplets create the liquid bridges and oil may flow on the fibres [4]. In the case where the filter contains particles of both types, the nature of the interaction between them and between them and the fibers has changed. It affects directly in the filtration efficiency, nature of the deposition as a result of additional interactions and forces (e.g. capillary forces) [7]. Furthermore, it makes a difference in the pressure resistance characteristics during the filtration process.

The framework of our investigation includes the measurement of pressure drop across the filter and analysis of deposits formed on the surface of the fibers after the filtration process by using scanning electron microscope (SEM).

II. Materials and methods

As a filtration medium, fibrous filters made by means of modified melt-blown technique were used [1]. Non-woven filtrating media contains packed fibres formed into layers with irregular structure and polydisperse diameter distribution of fibres. The filters were made from polypropylene. This polymer has high value of Melt Flow Index that allows to obtain filters with thin average fibres diameter. In this studies the mean fiber diameter was 7.186 μm, porosity of filters was 97.02% and mean thickness of a filter was 5.059 mm.

The tests of filtration process were carried out at the modified MFP 1000 set-up (PALAS® GmbH). This is a set-up specially designed for testing flat filtrating materials. The main components of the test bench are: solid particle generator, nebulizer – liquid particle generator, charge neutralizer, spectrometer particle counter and vacuum pump used to suck the sample into the particles counter probe.

The appropriate equipment and materials were used to generate dispersed phases. In the case of solid particles, it was the RBG 1000 generator and synthetic silica dust the "Arizona fine test dust". To generate the droplets the PLG 1000 generator and DEHS (Di-Ethyl-Hexyl-Sebacat) oil were used.

During the tests, the test bench was modified to allow simultaneously put into filtrating chamber solid and liquid particles. The particles size distributions of generated aerosols are shown in Fig.1.

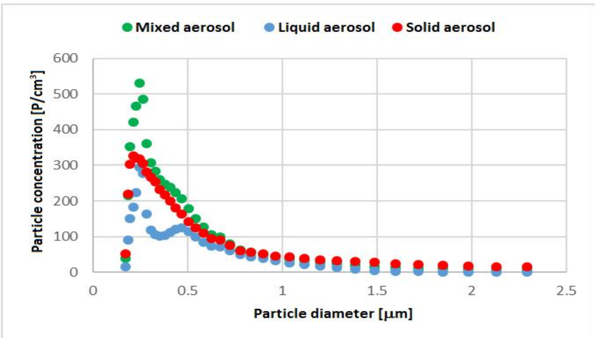

Fig.1 Particle size distribution of generated aerosols.

The total concentration of generated silica dust was 4996 [P/cm^3], for oil droplets it was 2956 [P/cm^3] and for mixed aerosol it was 5810 [P/cm^3]. It can be notice that the total amount of particles for mixed aerosol was less than the sum of solids and liquids (7952 [P/cm^3]) more than 25%. This may be due to collisions of particles in the filtration chamber and particles deposition mixing jets.

III. Results

It was noted that during the simultaneous loading of the filter by mixed aerosol we observed that pressure drop on filter increase much more slower than in the case of solid particles separation and increase only a little bit faster in compared with the oil droplet separation. This is due to the reorganization of dendritic structure deposits, which occur under the influence of a thin layer of liquid formed on fibres and particles. Due to the presence of oil on the fibers, solid particles firstly create dense layer throughout their lengths. On the next step of process particles start to form larger clusters which cause that flow resistance is increasing slowly. This type of structure makes less resistance to the flow of air then solid particles dendrites structure. The changes of pressure drop during 7h filtering process are shown in Fig.2.

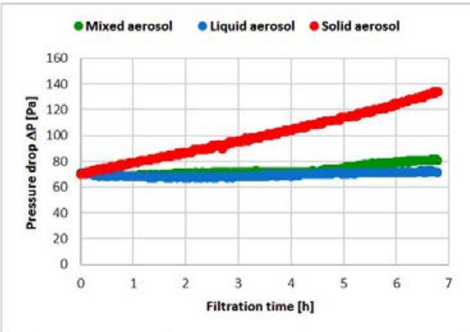

Fig.2 Changes of pressure drop under continuous loading by different types of aerosols.

A series of photos was taken to see the morphology of deposits on fibers (see Fig.3). There is considerable difference between deposits of solid, liquid and mixed aerosol. Dendritic structures are clearly visible for solid particles and liquid bridges for oil droplets. However, the most interesting is the appearance of fibers with both types of particles. It is easy to see how the fibers were loaded by dust and oil. The presence of creates dense compact structures.

Conclusion

During the loading of non-wowen filters there may be observed huge differences between filtration deposits, depending on the form of particles (solid, liquid or mixed). Mixed (solid and liquid) particles form characteristic compact structures. This is caused by the presence of oil, which disturbs to form dendritic structures and spreads dust along the whole length fibers and makes dense structures. Moreover, there were observed changes in the trends of the pressure drop across the filters. During a filtration of mixed aerosol the flow resistance grows only a little more quickly than during the filtration of oil droplets.

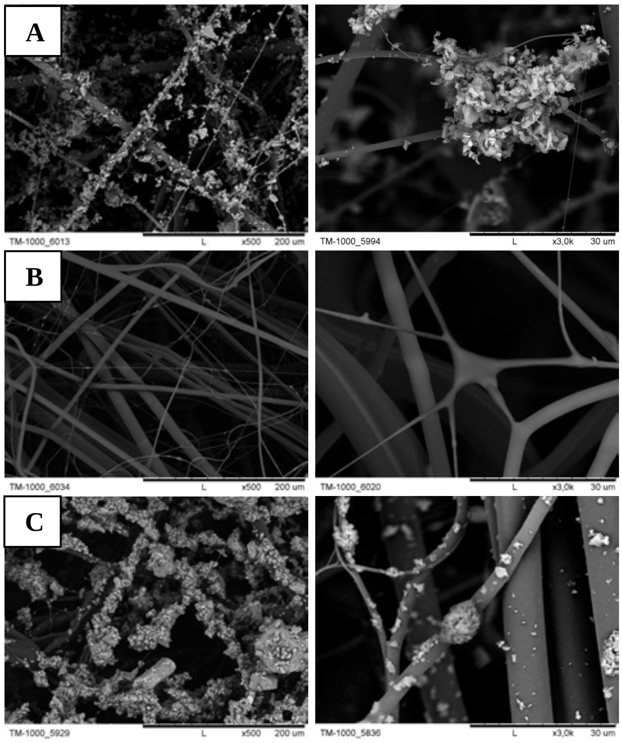

Fig.3 SEM images of filters after filtration of (A) solid particles (B) liquid droplets (C) mixed aerosol.

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