



## Evaluation of the Effect of the Microstructure of Glass Fiber and Polytetrafluoroethylene-Based Filter Fabric on Bag Filter Performance

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### ABSTRACT

This paper examines the microstructural parameters of filter fabric manufactured from a combination of glass fibers and polytetrafluoroethylene (PTFE) fibers and evaluates their effect on the performance of a bag filter unit. In the course of the study, filter fabric samples with thicknesses of 1.0 mm, 1.5 mm, and 2.0 mm were investigated by microscopic analysis at 100× magnification. For each sample, original micrographs, segmented images, and contour images were generated, and these were used to determine the values of the open area, closed area, and specific contact surface area. The analysis revealed that, as fabric thickness increased, porosity decreased, the fiber arrangement became denser, and the fraction of open channels was reduced. At the same time, the proportion of closed areas increased. The calculated values of the specific contact surface area showed a decreasing trend with increasing fabric thickness. The obtained results indicate that the microstructure of glass fiber-PTFE-based filter fabric is a significant factor governing the aerodynamic and filtration characteristics of a bag filter. According to the findings, the 1.5 mm-thick fabric may be regarded as the most favorable option, since it ensures a relatively optimal balance among the open area, closed area, and contact surface area.

### Keywords:

filter fabric, glass fiber, polytetrafluoroethylene, PTFE, microstructure, open area, closed area, specific contact surface area, bag filter, porosity

### Introduction.

As a result of technological processes in industrial enterprises, fine-dispersed dust-laden gases are released into the atmosphere. Such emissions are widely encountered in the building materials industry, the chemical industry, asphalt-concrete production, mineral fertilizer manufacturing, and other sectors. The solid particles contained in dust-laden gas emissions discharged into the atmosphere worsen environmental conditions, reduce

workplace air quality, and adversely affect human health. For this reason, the efficient purification of industrial dust-laden gases is a matter of considerable scientific and practical importance.

Among the technologies used for dust-laden gas purification, bag filter units are distinguished from other devices by their high efficiency, structural simplicity, and ability to capture fine particles. However, the performance of such units depends not only on

external hydrodynamic operating conditions, but also closely on the internal structure of the filter fabric. In particular, the void system within the filter fabric, the mutual arrangement of fibers, the ratio of open and closed areas, and the volumetric density of surfaces directly interacting with the gas flow have a significant influence on the filtration process.

In recent years, interest in composite filter materials suitable for operation under high-temperature and aggressive environmental conditions has been increasing. In particular, composite woven fabrics formed from glass fibers and polytetrafluoroethylene (PTFE) fibers are regarded as especially promising because they combine such important advantages as high thermal resistance, chemical stability, mechanical strength, and the ability to retain fine particles. Glass fibers form the strong structural framework of the filter medium, whereas PTFE fibers improve surface inertness, reduce adhesion, and enhance regeneration capability. However, in order to substantiate the practical effectiveness of such materials, a detailed analysis of their microstructural parameters is required.

In evaluating the microstructure of filter fabric, the principal indicators are the open area, closed area, and specific contact surface area. The open area determines the pathways through which the gas flow passes within the fabric, whereas the closed area represents the portion where fibers are interconnected and involved in particle retention. The specific contact surface area, in turn, characterizes the active interaction surface per unit volume and is therefore of particular importance in the analysis of filtration efficiency.

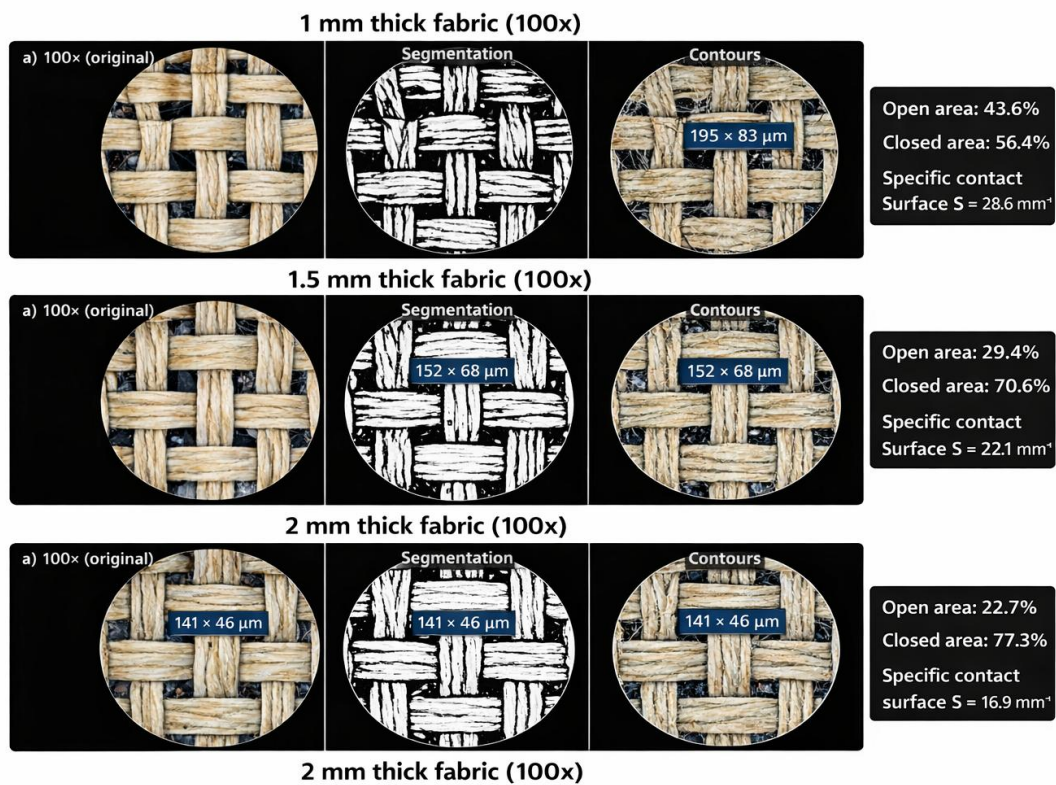
In this context, the present study carried out a microscopic analysis at 100× magnification for filter fabrics woven from a combination of glass

fibers and PTFE fibers with thicknesses of 1.0 mm, 1.5 mm, and 2.0 mm. The aim of the study was to determine the patterns of variation in the open area, closed area, and specific contact surface area with changes in fabric thickness, and to assess their influence on the performance of a bag filter.

### **Research Methodology.**

A digital microscopic analysis method was adopted to evaluate the microstructural parameters of the filter fabric. The investigated material was assumed to consist of yarn formed from a combination of glass fibers and polytetrafluoroethylene (PTFE) fibers, from which the filtering woven fabric was subsequently produced. In the microstructural analysis, PTFE fibers were identified as cream-colored, whereas glass fibers were considered light brown in appearance. This approach made it possible to distinguish the two fiber components in the micrographs and to model their distribution within the fabric structure.

Three filter fabric variants with thicknesses of 1.0 mm, 1.5 mm, and 2.0 mm were selected for the study. For each variant, a microstructural image at 100× magnification was obtained using an SM001-SYANS digital optical microscope. The analysis was performed in three stages. In the first stage, the original microscopic image of the fabric was obtained. In the second stage, the image was segmented in order to separate the fibers from the void regions. In the third stage, contour analysis was applied to define the boundaries of the open and closed areas. Accordingly, for each thickness, the microstructural analysis was conducted on the basis of three image types: the original image, the segmented image, and the contour image. These stages of microstructural analysis are presented in Figure



**Figure 1. Stages of 100× microstructural analysis of the filter fabric: original image, segmented image, and contour analysis**

As shown in Figure 1, the original image represents the natural arrangement of the fibers, while the segmentation stage enables the separation of the fibers from the void regions. In the contour analysis stage, the boundaries of the open and closed areas were defined, making it possible to determine their geometric parameters.

The open area of the fabric, i.e., the fraction of void spaces available for gas passage, was determined by the following equation, %;

$$\varepsilon = \frac{A_{och}}{A_{um}} \cdot 100\% \tag{1}$$

where  $\varepsilon$  denotes the open area (porosity) of the fabric, %;  $A_{op}$  is the area of voids through which gas can pass,  $m^2$ ; and  $A_t$  is the total analyzed area,  $m^2$ .

Correspondingly, the fraction of the closed area was determined using the following equation:

$$\varphi = 100 - \varepsilon \tag{2}$$

where  $\varphi$  denotes the fraction of the closed region formed by the fibers and their contact zones, %.

For the evaluation of the specific contact surface area of the filter fabric, an equation representing the amount of active surface per unit volume was used:

$$S_v = \frac{A_{kon}}{V} \tag{3}$$

For the purpose of simplified engineering evaluation, the fibers were assumed to be cylindrical elements, and the specific contact surface area was additionally expressed in the following form:

$$S_v = \frac{4(1 - \varepsilon)}{d_f} \tag{4}$$

where  $d_f$  denotes the equivalent fiber diameter,  $\mu m$ . In this study, for the purpose of approximate calculation,  $d_f \approx 10 \mu m$  was adopted.

To relate the microstructural analysis to the actual geometric dimensions of the filter, the external parameters of the filter sleeve were also considered. The sleeve diameter was taken as  $D = 150$  mm, and the sleeve length as  $L = 1200$  mm. Under these assumptions, the total filtration area was determined by the following equation:

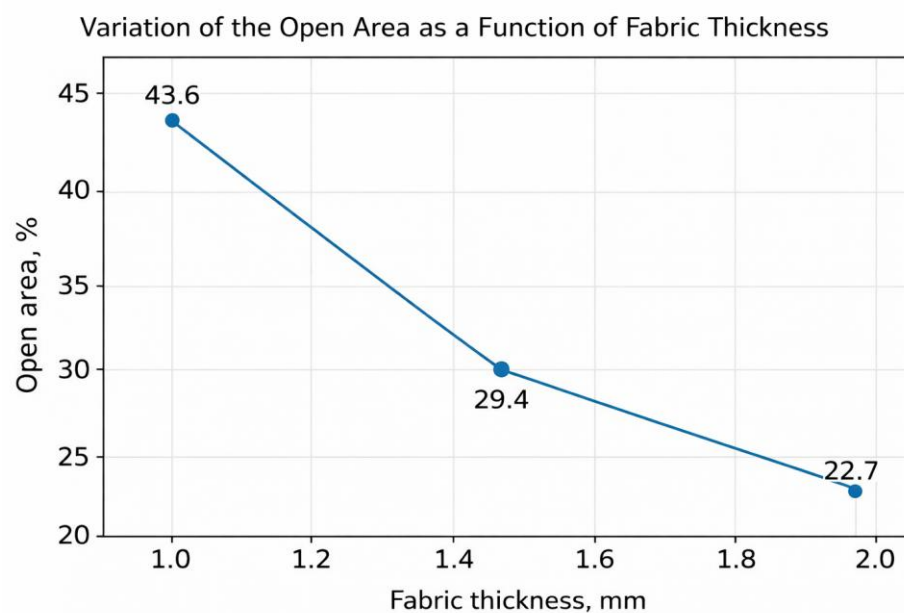
$$F = \pi DL \quad (5)$$

The calculation showed that the total filtration area for a single sleeve is  $F = 0.565$  m<sup>2</sup>. This parameter served as a basis for

evaluating the practical application range of the filter fabric and the total interaction surface within a single sleeve.

## Results.

The microscopic analysis results demonstrated that increasing filter fabric thickness leads to significant changes in its internal structure. In particular, the fraction of the open area was found to decrease consistently with increasing fabric thickness. This relationship is illustrated in Figure 2



**Figure 2. Dependence of the Open Area on Fabric Thickness**

For the 1 mm-thick fabric, the voids between the fibers were found to be relatively large and to form interconnected channels. This structure provides favorable conditions for comparatively free gas flow through the fabric. Based on segmentation and contour analysis, the open area in this case was determined to be 43.6%, while the corresponding closed area was 56.4%. The specific contact surface area was estimated at 28.6 mm<sup>-1</sup>. These values indicate that the 1 mm-thick fabric possesses relatively high porosity and forms a structure favorable for gas permeability.

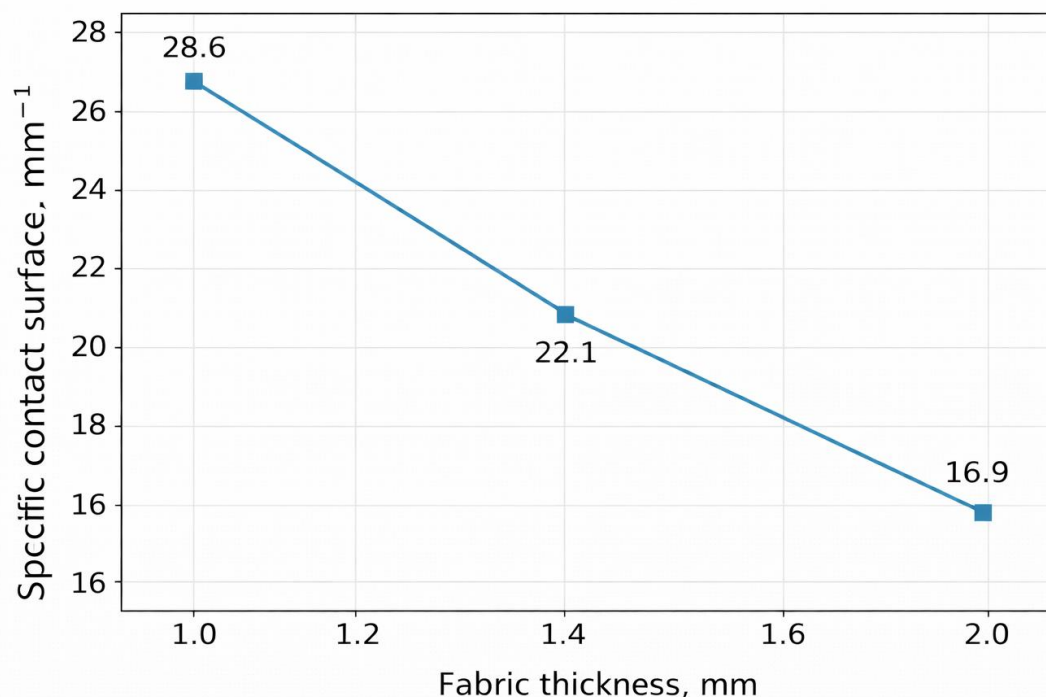
In the case of the 1.5 mm-thick fabric, the microstructure was observed to be relatively denser. Under these conditions, the voids between the fibers became partially narrower, while the internal channels acquired a more complex geometry. The analysis showed that the open area amounted to 29.4%, whereas the closed area reached 70.6%. The specific contact surface area was determined to be 22.1 mm<sup>-1</sup>. These results suggest that this fabric variant retains sufficient void space for gas passage, while simultaneously providing a favorable environment for particle-fiber interaction.

The 2 mm-thick fabric exhibited the densest microstructure. In this case, the fiber bundles were arranged much more compactly, and the voids became smaller and more localized in nature. This led to a reduction in the open area to 22.7% and an increase in the closed area to 77.3%. The specific contact surface area was calculated to be  $16.9 \text{ mm}^{-1}$ . These findings indicate that, in the structure of the fabric of this thickness, the free gas passage channels are substantially reduced, the flow

path becomes more tortuous, and the filter medium becomes considerably denser.

In summary, the obtained values show that, as the fabric thickness increased from 1 mm to 2 mm, the open area decreased from 43.6% to 22.7%, while the closed area increased from 56.4% to 77.3%. At the same time, the specific contact surface area was also found to vary with fabric thickness. The calculated results of this variation are presented in Figure 3.

Variation of the Specific Contact Surface Area as a Function of Fabric Thickness



**Figure 3. Variation of the Specific Contact Surface Area as a Function of Fabric Thickness**

As shown by the analysis of Figure 3, the specific contact surface area decreases with increasing fabric thickness. This trend can be attributed to the increase in fabric volume and the corresponding redistribution of the active surface on a unit-volume basis.

#### Discussion.

The obtained results confirm that the microstructural parameters of the filter fabric constitute one of the principal factors governing the performance of a bag filter. In the filtration process, the gas flow passes mainly through the open zones, whereas solid particles are retained on the fiber surfaces, at

fiber contact points, and along the walls of the internal flow channels. Accordingly, any modification of the microstructure directly affects both the aerodynamic resistance and the cleaning efficiency of the filter.

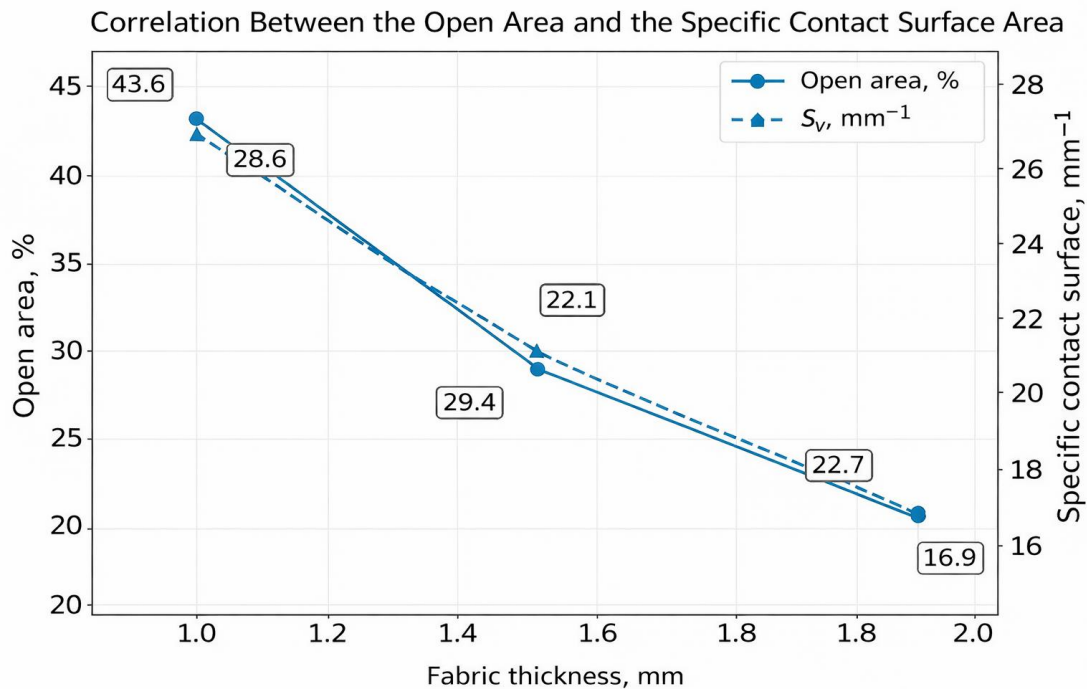
In the case of the 1 mm-thick fabric, the relatively high porosity implies lower resistance to gas flow; however, the probability of particle collision with and retention by the fibers may be comparatively limited. Such a structure may be particularly effective under conditions of high gas flow rates and relatively low dust loading. However, high porosity alone

is insufficient to ensure efficient capture of fine dispersed particles.

In contrast, for the 2 mm-thick fabric, structural densification results in narrower gas passage channels. This increases the likelihood of particle-fiber interactions and may enhance filtration efficiency. At the same time, the increase in aerodynamic resistance also intensifies the risk of more rapid filter saturation and greater difficulty in the regeneration process. Therefore, a very thick

fabric cannot always be considered the most rational solution.

The 1.5 mm-thick fabric demonstrated the most favorable balance from an engineering perspective. It retained a sufficient open area to maintain gas permeability, while simultaneously forming the necessary closed zones and contact environment required for effective particle retention. The interdependent variation of the open area and the specific contact surface area is shown in Figure 4.



**Figure 4. Correlation between the Open Area and the Specific Contact Surface Area**

As illustrated in Figure 4, both the open area and the specific contact surface area show a decreasing tendency with increasing fabric thickness. However, the rates of change of these parameters are different, and at a thickness of approximately 1.5 mm, a relatively favorable balance between them is achieved.

The specific contact surface area values obtained in the study also proved to be significant for assessing the performance of the filter fabric. At first glance, it might be assumed that an increase in the closed area would also result in an increase in the active surface area. However, because the specific contact surface area is evaluated on a unit-volume basis, the overall volume increases more rapidly as the fabric becomes thicker, whereas the relative

fraction of active surfaces fully accessible to the gas flow may decrease. This effect was particularly evident in the results obtained for the 2 mm-thick fabric.

Therefore, in selecting a filter fabric, attention should be paid not only to its overall density, but also to the optimal ratio among such microstructural parameters as open area, closed area, and specific contact surface area. This is of substantial importance for the scientifically grounded design of bag filter units.

### Conclusion.

The results of the conducted study demonstrated that the microstructural parameters of a filter fabric woven from glass

fiber and polytetrafluoroethylene (PTFE) fibers exert a direct and significant influence on the performance of a bag filter unit. Based on microscopic analysis, it was established that variations in fabric thickness lead to regular changes in its internal structure, particularly in such parameters as the open area, closed area, and specific contact surface area. It was found that, as the fabric thickness increases, the proportion of voids between the fibers decreases, while the fraction of closed areas rises due to structural densification. At the same time, the increasing complexity of the volumetric structure of the filter layer results in a tendency toward a decrease in the specific contact surface area per unit volume.

The findings also showed that filter fabrics of different thicknesses possess distinct advantages and limitations from the standpoint of the filtration process. In particular, the 1 mm-thick fabric was characterized by high gas permeability and relatively low aerodynamic resistance owing to its larger open area. In contrast, the 2 mm-thick fabric exhibited a denser microstructure and, consequently, a higher potential for particle retention. However, such a structure is also naturally associated with greater resistance to gas flow. The 1.5 mm-thick fabric, on the other hand, was evaluated as the most optimal alternative, since it provides a relatively favorable balance among the open area, closed area, and specific contact surface area.

Thus, it was substantiated that the preliminary evaluation of the microstructural characteristics of filter fabrics is of considerable scientific and practical importance for the design of bag filters, the selection of their optimal structural parameters, and the determination of the most rational balance between cleaning efficiency and aerodynamic resistance.

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