Investigation of filter materials for gas cleaning from sulfuric acid

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Abstract. In the production of sulfuric acid, the final step is to clean the exhaust gases from the sulfuric acid mist. Currently, many industrial enterprises have abandoned the use of electrostatic precipitators to catch acid droplets in favor of the use of bag filters. The authors conducted an experimental study of the effectiveness of various filter materials and their combination in the form of a bag for catching sulfuric acid fog. A filter package was proposed from layers of fiberglass and fluoroplastic materials for industrial use, which showed a 98% efficiency for cleaning exhaust gases from a sulfuric acid mist.

1. Introduction
The production of sulfuric acid consists of the following successive stages [1]: the formation of sulfur dioxide during the combustion of sulfur, the catalytic oxidation of sulfur dioxide to sulfur trioxide, and the absorption of sulfur trioxide by concentrated sulfuric acid. Each of these operations is carried out in a separate apparatus and is fraught with a number of difficulties [2]. This article solves the urgent problem of cleaning exhaust gases from a sulfuric acid mist. The increased formation of a sulfuric acid fog may be due to non-observance of the technological regulations, but in any case, its formation and accumulation cannot be completely eliminated - it is not possible [3].

Currently, two methods are used for cleaning exhaust gases from a sulfuric acid mist [4,5]. The first method involves the use of electric filters, which have several advantages over other cleaning methods, namely, they are characterized by high gas cleaning efficiency, the ability to work in a wide range of particle sizes and low resistance to air flow [6]. Despite all these advantages, the key disadvantage of using electrostatic precipitators is the high cost of this process. The second method is based on the use of cheap and easy-to-use high-performance bag filters [7]. Before cleaning the exhaust gases from the mist of sulfuric acid, it is cleaned of large drops and splashes. For this, horizontally arranged metal grids can be used [8]. Large droplets linger on them and then, under the action of gravity, flow down.

When choosing filter materials for cleaning exhaust gases from a sulfuric acid mist, it is necessary to take into account the high acidic aggressiveness of the medium and elevated temperatures [9]. Therefore, at present, the following types of materials are widely used: polypropylene, fiberglass, fluoroplastic, carbon-graphite.

The aim of the work is an experimental study of the effectiveness of various filter materials and their combination in the form of a bag for catching sulfuric acid fog.

2. Research methods
Common research filters were selected as objects of study (table 1).
Table 1. Characteristics of the studied materials.

| Type of needle-punched filter material | Thickness, mm | Mass per unit area, g/m² | Air permeability, m³/(m²·min) |
|---------------------------------------|---------------|--------------------------|------------------------------|
| Polypropylene filter                  | 5.0           | 500                      | 40.50                        |
| Fluorine filter “Fluorine” (TU 8391-259-0020663-99) | 6.4           | 1780                     | 62.60                        |
| Carbon filter                         | 3.0           | 1400                     | 6.00                         |
| Fiberglass filter IPFA-850-7A (TU 6-19-330-86) | 6.0           | 850                      | 44.58                        |

The studies were conducted on the experimental setup shown in figure 1.

Figure 1. An experimental setup for determining the efficiency of catching sulfuric acid fog with fiber filters: 1 - round-bottom flask; 2 - an absorber; 3 - fog diluent; 4 - a cartridge from fluoroplast; 5 - filter material; 6 - inlet rheometer; 7 - output rheometer; 8; 9 - cartridges for AFA filters; 10; eleven; 13 - cranes; 12 - gas meter; 14 - flask with calcium chloride; 15 - air blower; 16 - laboratory autotransformer; 17 - a thermometer; 18 - containers for sampling; 19 - Drexel; 20 - differential pressure gauge.

3. Results and discussion

Figure 2 shows the dependence of the hydraulic resistance of various filters on the gas flow filtration rate. It is shown that carbon-graphite material has the greatest hydraulic resistance, and PTFE is the least.

As a filter for catching sulfuric acid mist in industry, a combination of layers of various materials performing certain functions is used [10]. So the filter layers are used to capture particles of fog and enlarge droplets of liquid. Their number is selected from 2 to 5. Glass fiber or carbon graphite can be used as a filter material. The resistance of carbon-graphite material is much higher than fiberglass, so it is practically not used for mass purification of exhaust gases in large-capacity industry. A carbon-graphite filter can be used to clean a small volume of gas emissions with a low inlet concentration in the case where increased requirements are imposed on the purity of the exhaust gases. Moreover, the cost of fiberglass filter material is significantly lower than carbon-graphite.

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To date, there are no design formulas for the selection of an effective package of filter materials depending on specific conditions. Only practical research allows us to draw a conclusion about the effective use of a package consisting of several layers of materials. In addition to the effectiveness of the package, it is necessary to take into account parameters such as its cost and hydraulic resistance. And only in the totality of these values can we justify the use of the filter in each case.

To identify the most effective package, experimental studies were conducted on 11 types of combination of filter materials. Based on the results of industrial tests, the following package was proposed: 4 layers of fiberglass, 2 layers of fluorine, 3 layers of fiberglass, 2 layers of fluorine, 4 layers of fiberglass. Dividing the filtering process into 2 stages improves the efficiency of the catch.

For the developed package, we plotted the dependences of the hydraulic resistance on the filtration rate (Figure 3) and efficiency on the input concentration (figure 4). The package efficiency is 98–99% with a resistance of 2.3 kPa, a filtration rate of 0.15 m/s and an input concentration of about 1 g/m$^3$.

![Figure 2. The dependence of the hydraulic resistance of filter materials P on the gas filtration rate W at an irrigation density of 0.0132 m$^3$/(m$^2$·h): 1 - fluorine; 2 - polypropylene; 3 - fiberglass; 4 - carbon graphite.](image)

![Figure 3. The dependence of the hydraulic resistance P of the proposed filter package on the gas filtration rate W.](image)
Figure 4. The dependence of the filter efficiency \( n \) on the input concentration of sulfuric acid mist \( C \).

Prevention of secondary spraying from the outer surface of the filter bag is of great practical importance. At high gas flow rates, coarse droplets of sulfuric acid do not flow down under the action of gravity, but are pressed through all layers of the filter bag and carried into the environment with exhaust air. This leads to environmental degradation, corrosion of pipelines, loss of acid, etc. In order to avoid this negative effect, it is necessary to strictly adhere to the technological regulations in compliance with the filtration rate in the range from 0.1 to 0.4 m/s.

4. Conclusion
Based on the research results, the following conclusions were made:

1. The greatest hydraulic resistance, depending on the filtration rate of the gas stream at an irrigation density of 0.0132 m\(^3\)/ (m\(^2\)·h), has carbon graphite filter material, the lowest is fluoroplastic.
2. The developed filter package, including 4 layers of fiberglass, 2 layers of fluorine, 3 layers of fiberglass, 2 layers of fluorine, 4 layers of fiberglass, has shown high efficiency for cleaning exhaust gases from sulfuric acid mist (98–99%) at a resistance of 2.3 kPa, filtration rate 0.15 m/s and an input concentration of the order of 1 g/m\(^3\).
3. To prevent secondary splashing from the outer surface of the filter bag, the gas filtration rate must be in the range from 0.1 to 0.4 m/s.

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