Technique and device for filter elements regeneration based on powder filter material

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Abstract. The design of a device for filter elements regeneration is presented without disassembling the filters in which they are installed. A distinctive feature of the device is the use of a preliminarily vacuumed chamber designed to discharge contaminants from the surface of the filter element. This makes it possible to increase the operation time of the filters before they are disassembled in order to clean the filters on special stands or replace them. The efficiency of the device in production conditions is shown by the example of cleaning an aqueous solution of peat hydrohumate by powder filter elements.

1. Introduction

Multiple regeneration of filter products becomes important when using expensive porous materials based on metal powders, i.e. powder filter materials (PFMs), which have a number of advantages compared to analogues [1, 2]. PFMs can be subjected to mechanical, chemical and thermal regeneration techniques [3, 4], as a rule, with the disassembly of the filter device. In turn, extending the service life of the device between regenerations with disassembly is also an important task, especially when a process shutdown is associated with an interruption in the process cycle. Most often, the regeneration of filter elements without disassembly is carried out by one of the mechanical methods – back-wash [5, 6]. However, these techniques are characterized by low-speed performance [7], process complexity or high cost [8, 9]. Increasing the speed and efficiency of the process due to the energy of the explosion, electrical impulses or the accumulation of compressed air by them significantly complicate and cost the process, or make it inappropriate. This paper provides data on the counter flow regeneration process and the device for its implementation, based on preliminary vacuum pumping of the contaminant discharge chamber, overlapping the input channel of the suspension to be cleaned into the inlet cavity of the filter device, and the sharp opening of the channel connecting the
inlet cavity to the contaminant discharge chamber. The technique is simple, does not require special equipment and ensures high-speed performance of the process.

2. Results of experiments and their discussion

For research, an aqueous solution of peat hydrohumate was used as a model medium in the development of the device [10], where peat hydrohumate was used as a plant growth regulator. The necessity of filtering this medium is caused by the clogging of the nozzle holes by particles from the suspension during the spraying of the growth regulator onto the treated crop plants, leading to a frequent stop of agricultural vehicles and, accordingly, to a sharp slowdown in production. On the other hand, during the filtering process in the production of a plant growth regulator, the formation of sediment on the surface of the filter elements makes it necessary to carry out the regeneration of the latter without disassembling the filter, otherwise the productivity of the production process of the hydrohumate solution decreases sharply.

Based on the condition that the particles which are present in the hydrohumate solution should not clog the nozzle hole that sprays the growth regulator suspension onto plants, and its minimum size is 200 μm. A value of 65 ± 5 μm (about one third of the nozzle hole size ensuring unobstructed passage of a particle through the nozzle) was adopted as a given precision of cleaning. This made it possible to define filter material for laboratory and full-scale tests, i.e. PFMs based on BrO10F1 tin-phosphorous bronze powder with particle size (minus 0.315+0.2) mm. Later on, for laboratory tests, experimental samples were used in the form of a disk with a diameter of 30 and a thickness of 3 mm, made of BrO10F1 bronze powder with a particle size of (minus 0.315+0.2) mm, for full-scale tests in production conditions – experimental samples of tubular filter elements with dimensions a diameter of 60 a thickness of 3 mm and a length 200 mm were used. Porosity, coefficient of permeability, pore size of experimental samples of filter material in the form of a disk made of bronze powder and their retention ability are shown in tables 1 and 2.

| Table 1. Characteristics of the experimental sample of powder filter material for laboratory and full-scale tests. |
|---------------------------------------------------------------|
| Porosity | Coefficient of permeability, $m^2 \times 10^{13}$ | Pore size, μm |
|----------|---------------------------------|---------------|
| 0.34     | 109.6                           | 58.0          |
|          |                                 | 72.0          |

| Table 2. Particle size distribution in the initial aqueous hydrogumate solution and in the filtrate after filtration through the experimental sample of PFM. |
|---------------------------------------------------------------|
| Particle size range | Filtrate filtered through sample |
|---------------------|---------------------------------|
| 0.1-1.0             | 22.38                           |
| 1.0-10.0            | 41.45                           |
| 10.0-30.0           | 31.35                           |
| 30.0-50.0           | 3.57                            |
| 50.0-100.0          | 1.25$^a$                        |
| 100.0-200.0         | –                               |
| 200.0-400.0         | –                               |

$^a$ Actually, particles of 50.0–70.0 μm are present on the distribution curve;

$^b$ Particle sizes were studied both in the initial suspension and in the filtrate using a Malvern Mastersizer laser diffraction analyzer of particle size distribution with an automatic dispersion and supply unit of HydroS sample company (England).

To provide rationale for the possibility of using the proposed regeneration technique, laboratory tests of PFM were carried out. The experimental sample in the form of a disk, after determining the
coefficient of permeability, was installed in the holder and a model suspension (peat hydrohumate) was filtered through it at a constant pressure up to reduction of the throughput by a factor of 2. Then, the process of inter-regenerative cleaning was carried out by blocking the channel of the suspension to be cleaned into the inlet cavity of the holder with the sample and opening the channel connecting the inlet cavity of the filter with a preliminary vacuumed tank for collection of contaminants. After that, the sample was removed from the holder, the permeability coefficient was determined, and the process (of filtration, regeneration, and measurements) was repeated until the coefficient of permeability of the sample after regeneration was reduced by two or more times compared to the initial one. The research results are shown in Table 3.

Table 3. Values of permeability coefficient of experimental PFM sample before and after regeneration

| Initial | After the next regeneration |
|---------|-----------------------------|
|         | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 |
| 109.6   | 104.5 | 99.4 | 94.7 | 90.0 | 85.2 | 80.4 | 74.0 | 69.1 | 64.4 | 60.0 | 54.6 |

Analysis of the data in Table 3 made it possible to find out that the sample withstood 11 regenerations. The device ensured a recovery in throughput of at least 90% in all cases of sample regeneration, i.e. positive test results can be observed.

Full-scale tests of prototypes of tubular filter elements made of BrO10F1 bronze powder with particle size (minus 0.315+0.2) mm and with the same throughput characteristics, as experimental PFM samples in the form of a disk, were carried out under production conditions of Private Unitary Enterprise "Cherven Agro". The test results also gave positive results.

The tests were carried out using the device [11], schematically shown in Figure 1.

Figure 1. A device for filtering suspensions: 1 – pump; 2, 4, 6, 9, 10, 12 – crane; 3 – filter; 5 – storage capacity; 7 – vacuum pump; 8 – safety filter; 11 – fine cleaning filter

Figure 2 shows the assembly stage of the tubular powder filter element of the prototype device.
Figure 3 shows the filtering device during testing.

Figure 2. Assembly of the filter element from the PFM prototype device

Figure 3. Testing a prototype device for cleaning a suspension of peat hydrohumate

The tests showed that the powder filter material based on BrO10F1 bronze powder used for the manufacture of the filter element installed in the device provides high cleaning efficiency, as well as the efficiency of the proposed regeneration method was confirmed. At the same time, the production performance of the device is relatively low – 1 m³/h. It is explained by a large-scale factor.

Preliminary laboratory tests made it possible to determine promising areas for further research to improve the efficiency of the developed device. So, its efficiency can be improved by using two-layer materials with a small thickness of the filtering layer, as well as by impregnating the filter layer with materials with low adhesive activity. In the first case, the increase is caused by an increase in PFM production performance, in the second – by the simplification of the regeneration process.

3. Summary and conclusion

The technique and design of the device for the regeneration of filter elements based on PFM without disassembling the filter device is proposed, based on preliminary vacuum pumping of the contaminant discharge chamber, blocking the input channel of the suspension to be cleaned into the inlet cavity of the filter device and the sharp opening of the channel connecting the inlet cavity to the contaminant discharge chamber. On the example of filtering an aqueous suspension of peat hydrohumate during laboratory tests, the efficiency of their regeneration by the proposed method is
substantiated. Full-scale tests of the developed device were carried out under production conditions of Private Unitary Enterprise "Cherven Agro", which gave positive results.

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Acknowledgments

The work was carried out with the financial support of the State Research Program “Physical materials science, new materials and technologies” of subprogram “Composite materials”, Republic of Belarus.