Aerodynamic Characteristics and Fractional Composition of the Flask Dust

V N Azarova, A A Sakharova
Institute of Architecture and Construction Volgograd State Technical University, 400074, Akademicheskaya st., 1, Volgograd, Russia

E-mail: aazarovpubl@mail.ru, sax.nastyayandex.ru

Abstract. Flask is a siliceous microporous sedimentary rock. Recently, it is increasingly used as a sorbent and as an additive to building materials. An important process for obtaining a product is crushing, sifting, roasting, and so on. All of them are accompanied by dust. This dust may be a pollutant of the air, waste, etc. The article presents the results of experimental and field studies of the fractional composition and aerodynamic characteristics (sedimentation rate) of the dust of the flask of various deposits. An experiment was carried out, the installation was described, as well as the data processing technique. The integral functions of the mass distribution of the dust particles of the flask across the diameters in the probabilistic-logarithmic coordinate system are constructed, both for the whole ensemble of particles and for particles of different ranges of sedimentation rates.

1. Introduction

To date, the construction market is replete with various additives for the production of concrete composites with directional performance characteristics. The problem lies in the fact that these compounds are usually imported, the composition of the additive is the property of the manufacturer and is often classified. The use of imported raw materials in domestic technologies is not always justified, because until the end of the composition is not clear can manifest itself as an antagonist in prolonged use [1].

Flasks - environmental safe materials, natural aluminosilicates, have a unique set of properties that, in a detailed study, will solve various problems that arise during the operation of construction objects.

They are common in the Middle and Lower Volga (Samara, Saratov, Volgograd, Astrakhan, Penza region), in the Central regions (Moscow, Kaluga, Bryansk region), in the Leningrad region (Kingissepskoe field), in the Donbass, on the eastern slope of the Ural ridge (in the strip from Irbit in the north to Troitsk in the south), in the Caucasus (Kisatibskoye deposit in the Akhalsikhe region of Georgia), in Transcaucasia (the Nurnusskoye deposit in Armenia), in Moldova (along the Dniester), in Kamchatka, the North Sakhalin and other [2].

Flask, as well as diatomite and tripilla, are used as:
- adsorbents for the purification of syrups, juices, oils, gases, petroleum products, etc. (high porosity determines the ability to absorb various colloidal substances from solutions);
- serve as a hydraulic additive to Portland cement, ensuring the durability of underwater concrete and concrete structures and dams;
- additive in the manufacture of lightweight concrete, ceramic and thermal insulation products in a mixture with vermiculite, asbestos, mineral wool, which provides sound and thermal insulation properties of the material;
- filler in the production of plastics, some types of rubber, sealing wax, matches, napkin paper, paints;
- as a multi-purpose additive in the production of wall ceramics [3].
- in the form of opal-soil mixtures of different composition for the device design layers of road pavement on highways IV and V categories in IV and V road-climatic zones [4].

For example, the flask of the Kamennoyarskoye field of the Chernoyarsk district of the Astrakhan region has found application:

1. In industry: for the purification of petroleum products; for the regeneration of oils and autolov; as carriers of catalysts and catalysts; as filter powders, various rubber fillers, plastics, etc.; as a raw material for the production of liquid glass; for air and oil gas drying.

2. In the food industry: for the purification of oils, beer, wine, sugar syrups, etc.; for storage of fruits and vegetables; pest control;

3. In environmental protection: for the purification of natural and industrial gases from harmful substances (oxides of sulfur, nitrogen, carbon, etc.); for purification of drinking, waste and industrial waters; for ecological rehabilitation of ponds and reservoirs; ecological rehabilitation of soils contaminated with radionuclides;

4. In the production of mineral fertilizers: for the conditioning of mineral fertilizers; as carriers of insecticides, micronutrients;

5. In plant growing: agriculture; for land reclamation and recultivation; for receiving hydroponic materials;

6. In animal husbandry: as biostimulating feed additives; sanitary litter for livestock; wastewater cleaners, dezodorization of rooms, etc.;

7. As pet products: biostimulating feed additives; sanitary litter for toilets; sand for bathing fur animals [5].

The flaks of this deposit have the following physicochemical characteristics: specific gravity 2.98 g/cm³; specific surface area - 730 m²/g; porosity of 9.86%; pore volume - 0.88 cm³/g; natural humidity of 0.2-0.5%; mechanical strength 590 kg/cm²; hardness 2.5; shredability 19%; abrasion 0.77%; bulk density of 2.6 g/cm³; the pore radius is 55 nm [6–8]. The chemical composition is given in table 1.

Table 1. The chemical composition of the flasks of the Astrakhan region

| Component | SiO₂ | Al₂O₃ | Fe₂O₃ | H₂O | CaSO₄ | CaCO₃ |
|-----------|------|-------|-------|-----|-------|-------|
| Content, % | 75-80 | 18-22 | 0.5-1.0 | 0.2-0.5 | 0.3-0.5 | 0.12-0.80 |

Figure 1 shows the samples of the mineral flask.

![Figure 1. The studied samples of the mineral flask](image-url)
2. Results

The analysis of the technological schemes for the production of sorbents and additives from the flask allowed us to propose an optimal scheme and select the nodes of dust formation, as a rule, with a particle size of up to 0.1 μm (fig. 2).

As follows from the diagram (fig. 2), dust extraction, aspiration and vibrating screens are the nodes for dust extraction.

The dust of the flask is an air-dispersed system in which the dispersed medium is gaseous, and the dispersed phase is solid. In most cases, dust particles are characterized by an irregular geometric shape, and in size, as a rule, they range from 0.001 to 100 μm [9].

![Figure 2. Scheme for obtaining the sorbent from the flask](image)

Aspiration systems

- Kamennoyarskogo field Chernoyarsk district of Astrakhan region
- Field of the Volgograd region

![Figure 3. Disperse composition of the dust of the flask](image)
For dispersion analysis, a microscopic analysis method was used using PK [10-14] and a computer program for dispersion analysis DUST 1 [15].

At the same time, the fractional composition of the flask dust was studied by the methods described in [16] using a monocular microscope MICROMED 1 var. 1-20 and a handheld particle counter - HANDHELD 3016 IAQ.

There are various theoretical and experimental relationships for describing the fractional composition of dust [16]. A.N. Kolmogorov established [16] that, under natural assumptions, the logarithmic normal law can be applied to the dispersed composition of most comminuted materials. However, in a number of works, it was shown that this rule is fulfilled only on certain intervals of equivalent particle ranges and, as a rule, the distribution of dust in real technological processes is described by a truncated logarithmic normal distribution [16, 18].

For example, figure 4 shows the integral distribution functions of the mass of dust particles of the flask, obtained by research, over equivalent diameters for two fields.

![Figure 4. Integral mass distribution functions of dust particles of the flask, in equivalent diameters for two fields: 1 – Kamennoyarskogo field Chernoyarsk district of Astrakhan region; 2 - field of the Volgograd region.](image)

As follows from the curves obtained, the law of A.N. Kolmogorov is performed only on the following intervals of change of equivalent diameter δ: [1,5; 7] for the fields of the Astrakhan region and [2,3; 10]
for the Volgograd region. That is, where the integral distribution function in the probabilistic-logarithmic coordinate system is represented by a straight line.

These properties are important from the technical side - the fractional composition of dust is crucial for the development and improvement of dust collection devices and systems, as well as for taking measures to prevent the release of dust, the calculation of the patterns of its distribution in the environment.

3. Experiment

The purpose of the experimental study is to determine the aerodynamic properties of dust particles of the flask, using the method of fractional sedimentation, followed by analysis of their dispersion composition and plotting dependencies of the sedimentation rate on the equivalent diameter of dust particles in the probabilistic-logarithmic grid. In this case, the regularities of dust emission from the process equipment were observed, namely, “portionality” and dust concentration.

In case of fractional sedimentation, sometimes called fractional sedimentation, the analyzed dust sample collected in emissions into the atmosphere and into the working area in the process of obtaining sorbent and additives to building materials [13,19].

An air sedimentometer was used as a device to determine the rate of settling of the flask dust by sedimentometry in the air [13]. A portion of the studied dust weighing about 2.5 mg evenly (without lumps) is placed on a sheet of filter paper. The powder is sprayed by a sharp air push in a special spray device, from which a cloud of dust gets into the upper part of the sedimentation cylinder, where particles under the action of gravity settle in still air. Particles with different speeds of fall are deposited on a sticky tape (scotch), laid on a belt conveyor. The conveyor belt jerk moves by the size of the diameter of the sedimentation cylinder at equal intervals of time, the range of sedimentation is 1 sec. The ranges of change in the sedimentation rate of the particles were equal (m/s):

1) V > 1.8 m/s; 2) 1.8 > V > 0.96 m/s; 3) 0.96 > V > 0.65 m/s; 4) 0.65 > V > 0.51 m/s.

After the experimental part, the optical method was used to analyze the dispersed composition of the flask dust deposited on the tape by microscopic method using a personal computer (PC) [18,20]. The method of determining the dispersed composition of dust is based on photographing magnified under a microscope 200-1000 times the selected samples of dust particles fixed on the slide, followed by processing photos using a graphics editor. Further calculation involves counting the number of particles in each image and the construction of integral curves in the probabilistic-logarithmic coordinate system. These actions are performed in the program "SPOTEXPLORE V1.0".

During the experiment, it was found that the particle diameters in each of the ranges of sedimentation rates on average decrease with decreasing average velocity. Figure 5 shows the integral mass distribution functions of dust particles in flasks for various ranges of sedimentation rates.
Figure 5. Integral mass distribution functions of flask dust particles for various ranges of sedimentation rates

1 - V > 1.8 m/s; 2 - 1.8 > V > 0.96 m/s; 3 - 0.96 > V > 0.65 m/s; 4 - 0.65 > V > 0.51 m/s.

а - Kamennoyarsko field Chernoyarsk district of Astrakhan region
b - field of the Volgograd region

The median and maximum diameter of the flask dust are presented in table 2.

Table 2. Ranges of change of speeds of subsidence of dust flask

| Settling speed, m/s | Kamennoyarsko field Chernoyarsk district of Astrakhan region | field of the Volgograd region |
|---------------------|-------------------------------------------------------------|--------------------------------|
| V > 1.8             | δ50, μm: 4.8; δmax, μm: 12                                | δ50, μm: 4.0; δmax, μm: 11.5    |
| 1.8 > V > 0.96      | δ50, μm: 4.3; δmax, μm: 9.7                              | δ50, μm: 3.5; δmax, μm: 9.1     |
| 0.96 > V > 0.65     | δ50, μm: 3.2; δmax, μm: 6.8                              | δ50, μm: 3.1; δmax, μm: 6.8     |
| 0.65 > V > 0.51     | δ50, μm: 2.7; δmax, μm: 5.9                              | δ50, μm: 2.6; δmax, μm: 5.9     |

Conclusions
Thus, the data obtained allow us to determine the devices that can provide the necessary efficiency of dust collection for flask dust with such fractional and aerodynamic properties.

References
[1] Kozhevnikova Yu.G., Plotnikova D.A, Bashmachnikov V.D. Development of the composition of a mortar modified by the introduction of a mineral supplement from local materials - flasks of the Kamennoyarsk field in the Chernoyarsk region of the Astrakhan region // Internet magazine "SCIENCE" Vol. 7, No 5 (2015) http://naukovedenie.ru/PDF/77TVN515.pdf (free access). The title from the screen. Yazy rus DOI: 10.15862 / 77TVN515
[2] http://www.ecosystema.ru/08nature/min/2_5_2_11.htm
[3] Kotlyar V.D., Talpa B.V. Flasks - a promising raw material for wall ceramics // Construction materials. 2007. № 2. S. 31–35.

[4] http://stroi-archive.ru/dorozhnuye-materialy/104-osobennosti-konstruirovaniya-dorozhnih-odezhd-iz-opochnyh-materialov.html

[5] http://xn--80aaag3blasi.xn--p1ai/company

[6] Bodnya M.S. The influence of flasks of the Astrakhan region on the ionic composition of the soil // Proceedings of the Samara Scientific Center of the Russian Academy of Sciences. 2011. Vol. 13, No. 5 (2) – 2011.

[7] Flasks Astrakhan region / N.N. Alykov, T.V. Alykova, N.M. Alykov and others; by ed. N. M. Alykova. Astrakhan: ASU, 2005. 138 p.

[8] Distanov U. G., Konyukhova T.P. Mineral raw materials. Natural sorbents: right. M. : Geoinformmark, 1999. 42 p.

[9] Strelyaeva, A. B. Analysis of sources of atmospheric air pollution with fine dust / A. B. Strelyaeva , N. S. Barikaeva, E. A. Kalyuzhina // VolgGASU Internet Bulletin. –2014.–№3 (34). –C.1. – Access mode: www.vestnik.vgasu.ru.

[10] Gradus, L. Ya. A guide to analysis of variance by microscopy [Text] / L. Ya. Gradus. – Moscow: Chemistry, 1979. – 232 p.,

[11] Johnson, N. Statistics and planning an experiment in engineering and science [Text] / N. Johnson, F. Lyon. - Moscow: World, 1981. – 250 p.

[12] Ermakov, S. M. Mathematical theory of optimal experiment: study guide [Text] / S. M. Ermakov, A. A. Zhiglyavsky. - Moscow: Science, 1987. – 320 p.

[13] Kouzov, P. A. Fundamentals of analysis of the dispersed composition of industrial dusts and crushed materials [Text] / P. A. Kouzov. - 3rd ed. reclaiming - Leningrad: Chemistry, 1987. – 264 p.

[14] Romashov G.I. The main processes and methods for determining the dispersion composition of industrial dusts [Text]. - L. : LIOT, 1938. – 176 p.

[15] Testimonial about state for registration of computer program No. 2014618468 of August 21, 2014, of the Russian Federation DUST 1 / V.N. Azarov, D.A. Bykadorov, O.A. Bykadorov, D.V. Azarov, A.V. Azarov, D.A. Nikolenko, M.A. Nikolenko. – 2012.

[16] Azarov, V.N. Research of Dust Content in the Earthworks Working Area / V.N Azarov, M.V. Trokhimchuk, O.P. Sidelnikova // Procedia Engineering. Vol. 150: 2nd International Conference on Industrial Engineering (ICIE-2016) / ed. by A.A. Radionov. - [Elsevier publishing], 2016. – P. 2008–2012.

[17] Kolmogorov, A. N. On the logarithmically normal distribution law of particles during crushing [Text] / A. N. Kolmogorov // DAN SSSR. – 1941. – T.31. –№2. – pp. 1030–1039.

[18] Aerodynamic Characteristics of Dust in the Emissions Into the Atmosphere and Working Zone of Construction Enterprises / V.N. Azarov, A.I. Evtushenko, V.P. Batmanov, A. B. Streblaeva, V.V. Lupinogin // International Review of Civil Engineering. – 2016 – Vol. 7, No. 5 – c. 132-136.

[19] Kouzov, P.A. Methods for determining the physicochemical properties of industrial dusts / P. A. Kouzov, L. Ya. Seriabina. – L.: Chemistry, Leningr. department, 1983.

[20] Artyukhin, A.S. Experimental studies of aerodynamic characteristics and efficiency of dust collection of VZP devices [Text] /A.S. Artyukhin, N. S. Ponomareva // Problems of Industrial Ecology: Collection of Materials 130 and Scientific. tr. young environmental engineers. – Volgograd: VolgGASU, 2006. p. 133-138.