AERODYNAMIC RESISTANCE OF BIOFILTER WITH PACKING FROM PINE CONES

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Abstract. In the paper, the aerodynamics (pressure drop) of the existing packings for biofilters is considered. Experiments on practical suitability of a packing from a natural origin for the biofilter – pine cones are made. Results of the research of the aerodynamic resistance of packings from artificial materials (foam rubber cubes, silicagel) and natural materials (lump wood, cone, bark) are given. These packings are widely used in the heat-mass transfer devices. The experiments were carried out on the experimental column. The diameter of the column is 200 mm. The height of the column is 1000 mm. The results of the experiments are generalized using similarity criteria – Reynolds. The geometrical characteristics of this random packing (pine cone) are received and compared with other packings from artificial (Raschig ring, Pall ring, Berl saddle, Flexirings) and natural (wood chips, bark) materials. The aerodynamic tests of a packing are carried out and compared with the data of other packings. Some recommendations about improvement of the performance data of the packing are made.

Keywords: biofilter, aerodynamic resistance, random packing, pine cone.

Introduction

At the present stage of technical development of humanity there is more and more sharp a question of preservation of the vital elements one of which is the air. Despite obvious understanding of it, the industries reluctantly go on installation of the effective gas-cleaning system. Therefore, one more demand is made to such sort to installations - low cost. One of the effective and inexpensive methods is biological purification of air [1; 2]. The volatile organic compounds (VOC), such as methanol, phenol, formaldehyde, butanol, toluene, benzene and other get to the atmosphere from the enterprises of food, chemical industry, woodworking, transport, agricultural and etc. [3]. Use in such establishments of standard purification techniques, such as absorption, adsorption or incineration, is expensive compared with the biological treatment method [2]. The advantage of the method of biological purification of gas is the technological essence of the carrying out process. The process takes place without formation of secondary waste. Biological purification of gas is oxidation of organic compounds to carbon dioxide and water vapors by means of microorganisms, in which the organic compounds contained in the air are a source of energy [4].

However, the complexity in the operation of the biofilter is that the efficiency of the biofilter is more dependent on the "comfortable" conditions created to the microorganisms by person. Water, nutrients and power sources (carbon) are necessary for microorganisms for their normal activity.

Not always that amount of the organic compounds which are in cleared air can suffice for maintenance of microbiological life in the biofilter, so using the packing from the natural materials, which include carbon, solves this issue.

The following requirements are imposed to the packings for biofilters: high specific surface, porosity and low aerodynamic resistance.

In the Moscow State University of Mechanical Engineering as a random packing for mass exchange processes in biofilters the pine cone was offered.

Materials and methods

The experiments were carried out on the stand, the scheme of which is presented in Fig.1. The installation general view is represented in Fig. 2.

The experiments and the statistical methods were conducted according to GOST.

- Environment protection. Atmosphere. Methods for determination of pressure and temperature of gas-and-dust streams from stationary sources of pollution (GOST 17.2.4.07-90).
- Nature protection. Atmosphere methods for de-termination of velocity and flow rate of gas-and-dust streams from stationary sources of pollution (GOST 17.2.4.06-90).

Equipment used during the experiments:

- manometer type MCM-2400 (5) -1.0 on technical standards of accuracy class 1.0;
- liquid manometers, U-shaped in accordance with GOST 9933;
- gauges showing GOST 2405, accuracy class 1.5;
- pressure tube design NIIOGAZ GOST 17.2.4.06;
- ethyl alcohol in accordance with GOST 17299;
- technical glass thermometer according to GOST 28498;
- barometer accuracy class 1.0.

The installation consists of the packed column (1) with random packing (2), air blower (3), rate-of-flow meter (4), rotameter (8), systems of air gates (a, б), differential pressure gage (5a, 5б) and serving computer (6). In the COMPUTER this information will be transformed and stands out in a digital and graphic kind of dependence of hydraulic resistance of a packing from speed of air in a column. Air through the mist eliminator (7) leaves in the atmosphere.

The gas through the rate-of-flow meter moves in the column. The gate regulates air giving. At the column irrigation through rotameter certain expense of water moves. Differential manometers measure accordingly the pressure difference in the column and the expense of the submitted air.

The diameter of the column is 200 mm, height of the column is 1000 mm, height of packing is 800 mm. Air flow amounted to 200 $m^3 \cdot h^{-1}$, which corresponds to the velocity flow W_0 = 0-1 $m \cdot s^{-1}$ in the calculation of the total cross section empty apparatus. The air temperature was 20 ºC, the barometric pressure is 101.3 kPa.

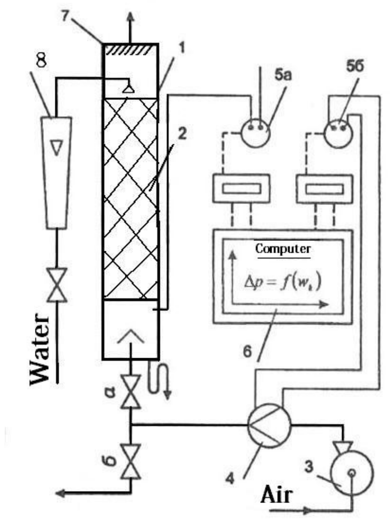

Fig.1. **Circuit of the experimental device:**
1 – column; 2 – pine cones; 3 – ventilator; 4 – rate-of-flow meter; 5 – differential pressure gage; 6 – computer; 7 – mist eliminator; 8 – rotameter

Fig. 2. **Installation general view**

Results and discussion

Often in biofilters as loading the random packing of an organic origin is used. Natural media are peat, brushwood and peat mix, compost, wood bark, straw, sawdust, soil, etc. [5; 2].

Compost is rich with nutrients and microorganisms fertilizer. It is valuable that for its production special additives as various organic waste are not necessary. Besides, use of compost will help get rid of accumulating waste. The ability of compost in the biofilter effectively to clear pollutants of a wide range allows applying this loading in many options.

However, use as loading of this material leads to increase in a design of the biofilter, biofilters of an open design belong to such types. These biofilters are deprived of any mobility and cannot be established and used directly in shops for technical reasons.

Other types of loading are bark, chips. Such loading differs with good porosity and ability to hold moisture, delivers enough of nutrients for growth of microbes, creates conditions for continuous intake of air, and does not dry quickly. This natural material applied as loading of the biofilter, differs with durability. Depending on the extent of application it can be used within 1-3 years [1]. However, this loading is not convenient from the point of view of operation. The loading has high hydraulic resistance and the loading over time is pressed, which negatively affects the efficiency of the apparatus. In our university as a packing of this kind pine cones were offered. In comparison with the above stated packing materials the cone possesses a more developed specific surface, smaller aerodynamic resistance that is confirmed by the skilled data presented in Fig. 3.

The share of free volume of a packing or porosity was defined by a method of the filling of volume of a packing to water. The relation of the volume of water to the volume occupied by a packing gives the size (ε) or *Vfree* [6]. One more defined characteristic is the free section, *Sfree*, $m^2 \cdot m^{-2}$. The free section of a packing is equal in size with its free volume, so *Vfree* = *Sfree*.

The specific surface area was calculated by the geometric method, taking a pine cone in a cone with a subsequent amendment to the selected approach. The calculated data were refined by means of representation in the work [6] on regularities for random packing.

Fig. 3 shows the dependence of the head loss on the flow velocity obtained empirically by the apparatus shown in Fig. 2. The graph (Fig. 3) shows that the cone hydraulic resistance is one order less than the hydraulic resistance of other packing from natural materials.

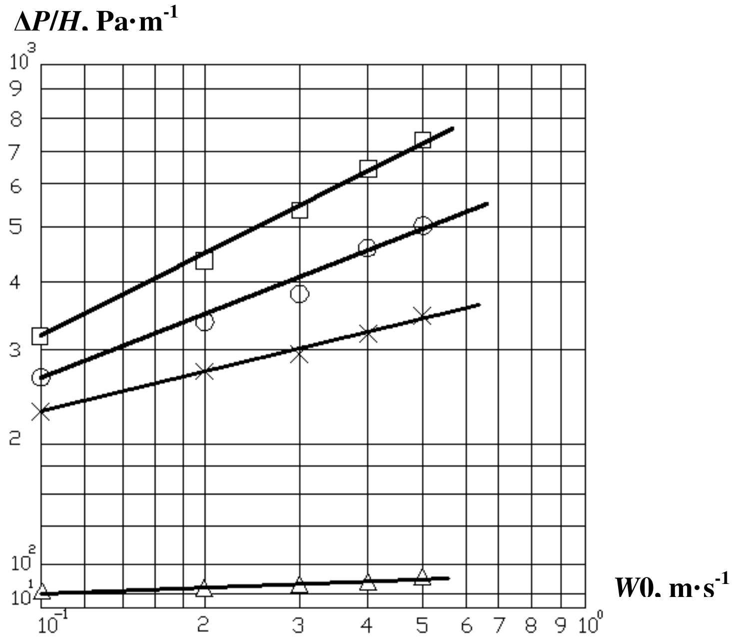

Fig. 3. **Dependence of the head loss $\Delta P/H$ on the flow velocity $W0$ for the tested dry packings:** □ – mix of wood chips, bark and zeolite granules [1]; ○ – mix of wood chips, bark, granules of zeolite and foam rubber cubes [1]; × – mix of wood chips, bark and foam rubber cubes [1]; Δ – pine cones

Apparently from Table 1 pine cones possess a high specific surface. The structure of the material has a very high porosity that positively affects when carrying out the process as the porous structure serves as a convenient rough surface for microorganisms, and also in time the water necessary for activity of microbes is late.

The pine cones absorb liquid and are closed during irrigation because of their natural properties, so for a given work the surface may cover pine cones varnish. Carrying out this procedure will adversely affect the ability of wetting represented element that will lead to difficulty creating a biofilm. The insufficient wettability of a packing will have an adverse effect on the efficiency of the process.

Table 1

Geometrical characteristics of the packing

Type of the packing	Specific surface, $m^2 \cdot m^{-3}$	Void volume fraction (porosity), $m^3 \cdot m^{-3}$	Equivalent diameter, m
Raschig ring (ceramic), 50x50x5, mm	110	0.735	0.027
Pall ring (plastic), 50x50x5, mm	111	0.920	0.010
Berl saddle, 50x50, mm	410	0.680	0.006
Flexirings 1’’	65	0.940	0.058
Pine cones	320	0.800	0.010
Bark	250	0.500	0.008

Conclusions

The random packing of an organic origin – pine cones is offered. A low aerodynamic resistance (about 40 Pa per meter run at a speed up to 1 $m \cdot s^{-1}$) is combined with a high specific surface of 320 $m^{-2} \cdot m^{-3}$. The material of a packing is not only the supporter, but also the substratum for microorganisms, it is well moistened, and this material is available, does not demand production, and also is an environmentally-friendly material.

The packing from pine cones is an additional substrate for microorganisms. In this connection, the pine cones are worse than the inert packing material. The structure collapses and packing pine cone comes into disrepair, but there is no need to make this application packing economically attractive.

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