SORPTION-FILTERING PROPERTIES OF CONTACT ELEMENTS BASED ON HIGHLY POROUS CERAMIC BLOCK-CELLULAR MATERIALS

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ABSTRACT

The influence of the structural and physical characteristics of carriers based on ceramic highly porous block materials of a cellular structure on the sorption-filtering properties of contact elements is considered, and their optimal combination with the performance characteristics of sorbent filters for high-performance gas cleaning systems operating at high temperatures and aggressive environments is shown.

Keywords: ceramic highly porous cellular materials (HPM), contact element carriers, filter-sorbent, gas-dynamic resistance, gas permeability, purification efficiency, sorption capacity.

INTRODUCTION

The special structural and physical characteristics of ceramic highly porous cellular materials (HPM) are due to the geometric shape and material composition of the ceramic frame obtained by duplicating the structure of reticulated polyurethane foam (PUF). The dimensions of the bridges and cell nodes, which are regulated during synthesis, create a high total porosity of up to 95% and an accessible external bulk surface (up to 3500 m^2/m^3 and higher, depending on the

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pore density of the original PUF) [1]. The composition of the ceramic slurry, as a rule, is high-alumina; in the process of solid-phase firing and destruction of the polymer matrix, it gives the material chemical resistance and high compressive strength (over 2.0 MPa), which provides improved performance properties of the obtained carriers and contact elements based on them in sorption processes. filtration of gaseous media, which include low gas-dynamic resistance, high sorption capacity for neutralized harmful components and cleaning efficiency in aggressive gas streams at high temperatures.

The listed physical and operational characteristics are mutually related to the primary structural characteristics of block-cellular contact elements: equivalent cell diameter and total porosity. Reducing the equivalent cell diameter and porosity leads to an increase in the outer surface and mechanical compressive strength. At the same time, mass transfer characteristics and gas-dynamic resistance increase [2]. The mesh-cell structure and freely accessible open pores of the HPCM make them equally permeable to flow in any direction, which is not the case in block honeycomb and granular contact element carriers. A constant change in the direction of flow in macropores turbulizes the flow of reagents and eliminates stagnant zones. The homogeneous open-cell structure of the HPCM provides the possibility of active mass transfer in the entire free volume of the material. The optimal combination of interrelated structural and operational characteristics opens up great prospects for the use of highly porous cellular carriers (HPVCs) in various processes associated with transport phenomena, in particular, in chemisorption.

The efficiency of contact elements based on HPCM is determined by the following characteristics: external volumetric surface of the sorption-active layer deposited on the ceramic frame, gas-dynamic resistance and gas permeability; quantitative assessment of the compactness of the material - the available specific external volumetric surface (or the external surface of the contact elements located in a unit volume).

For its calculation, a number of dependencies based on various structural models of the HPCM cell are proposed. The most common model of HPCM (or ceramic foam) is in the form of a tetrakaidecahedron (TTCD), for which several calculation options have been proposed, for which a comparative analysis and accuracy assessment were carried out in [3].

Due to the lack of reliable calculation methods, gas-dynamic (or hydraulic) resistance is often determined experimentally. The study of the gas-dynamic properties of block carriers with a cellular structure in [4] was carried out taking into account a number of important requirements, the main of which is the observance of the minimum cross-sectional size of the sample perpendicular to the flow of the filtered medium.

The irregular structure of the HPCM ensures the turbulence of gas flows [6].

The specific external volumetric surface of the sorption-filtering layer of a cellular structure has the largest value in comparison with an organized layer (honeycomb structure) and with an unorganized bulk layer of granules (Figure 1). A change in the equivalent diameter of a cell, granule or honeycomb has a great influence on the change in the specific outer surface of the filter layer, especially in the range d_E = 1.0–3.0 mm.

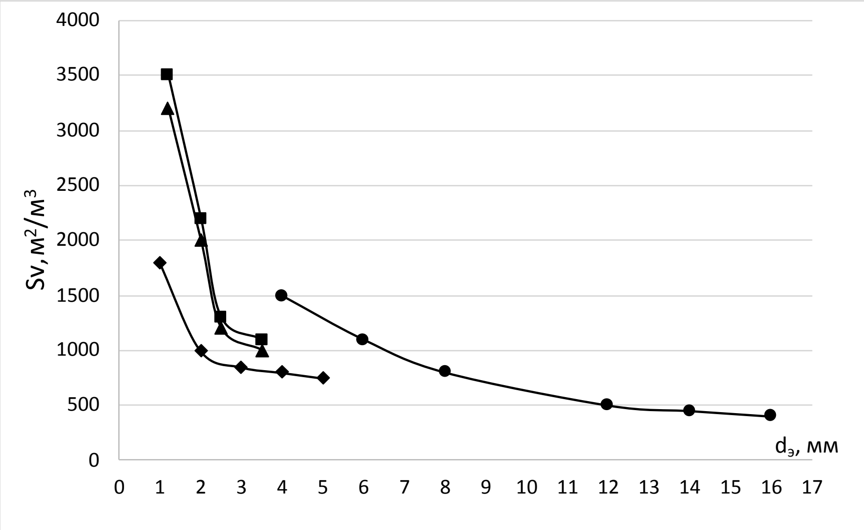

Figure 1 - Dependence of the external specific volume surface on the equivalent diameter for contact elements of various structures:

Table 1 Characteristics of the tested samples of fine-mesh highly porous ceramic carrier d_{mesh}=1–2mm (d_{av}=1.5mm), pore density 45 ppi

№	h, cm	m, g	S, cm²	V, cm³	kg/m³	P_{tosh}, %
1	5	24,75	15,9	79,5	0,31	92,2
2	5	26,71			0,34	91,6
3	5	24,91			0,31	92,1
4	5	27,48			0,35	91,3
5	5	26,88			0,34	91,5
6	5	26,79			0,34	91,6

Taking into account the low speeds of gas flows in these processes (0.05–0.5 m/s), the optimal cell sizes of the ceramic frame of block sorbent filters noted above were chosen: dcell = 0.5–1.3 mm (30 and 45 ppi) . The sorption-active layer up to 135 mm high, organized from contact elements with a diameter of 45 mm, has a minimum gas-dynamic resistance at the level of an unfilled reactor in the specified range of velocities of the purified air [7]. The external specific surface for blocks with a pore density of 30 ppi averages 1500 m^2/m^3, for blocks of 45 ppi - 2100 m^2/m^3.

The use of HPCM with a large cell size (pore density < 30 ppi) is inappropriate due to a significant decrease in the external bulk surface and a greater likelihood of breakthrough of gaseous radionuclides.

An increase in the pore density above 45 ppi leads to a sharp increase in the gas-dynamic resistance.

Sorbent filters based on block HPCMs for trapping volatile iodine compounds with a deposited $AgNO_3$ active layer [8] have advantages over granular silica gel or alumogel impregnated with silver nitrate used in radiochemical production.

In granular sorbents, up to 70% $AgNO_3$ impregnated in an amount of 7–10% wt. from the mass of the carrier, and for block-cellular sorbents, almost the entire active layer applied to the developed outer surface works in an amount of up to 15–20% wt. $AgNO_3$, i.e. the capacity of contact elements increases several times: up to 0.09 g I2/g sorbent and up to 0.068 g CH_3I/g sorbent. The dynamic capacitance is proportional to the amount of deposited $AgNO_3$. At a process temperature of 190°C, the purification efficiency for methyl iodide and molecular iodine reaches 99.20% for samples with a pore density of 30 ppi and 99.97% for samples with a pore density of 45 ppi.

CONCLUSION

The conducted studies have shown that sorption-filtering contact elements based on ceramic block HPCMs have 2–3 times larger accessible external specific surface area, total porosity and contact time with the gas flows being cleaned compared to granular ones, while the apparent density and gas-dynamic resistance of the sorption layer 2-3 times less.
Such indicators of structural and physical characteristics ensure the dynamic capacity of sorbents with almost complete use of the outer surface of their active layer for increased specific loads on the reaction gas flows to the same extent, which leads to a decrease in the structural dimensions of the reactors, a decrease in their metal consumption and capital costs.
The results obtained can be used to develop and design highly efficient gas cleaning systems operating at high temperatures and aggressive environments, using the calculated volume of contact elements based on ceramic HPCMs with a given optimal ratio of gas dynamic and mass transfer characteristics.

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