PERFORMANCE OF SPHERICAL ACTIVATED CARBON IN STRUCTURED FILTER MEDIA

Omar Guerra Gonzalez[1], Ilsebill Eckle[1], Bertram Boehringer[1], Jann M. Giebelhausen[2]

[1] Blücher GmbH, 40699 Erkrath, Germany
[2] AdsorTech GmbH, 14727 Premnitz, Germany

Introduction

Spherical activated carbons (SAC) play an important role in the development and production of adsorptive composite materials for protection against CBRN (Chemical, Biological, Radiological and Nuclear) threats. The choice of a filter media for an application depends e.g. on integration demands, spatial restrictions, challenge levels and air flow management. As a consequence of the ample variety of system requirements, not only the dimensioning of the filter itself but also a structuring of the filter media is necessary.

The presentation shall discuss the relation between adsorbent design (production techniques, selection of suitable synthetic raw materials), filter media structure (SAC alignment, bed configuration) and achievable performance metrics (efficiency, breakthrough curve, flow resistance, protection time) for following media:

1. Fabric filters as 2D-protection systems. (cf. Fig. 1 a, b)
2. Open porous foam filter media with SAC as adsorbent. (cf. Fig. 1 c, d)
3. Cluster structures resulting from agglomeration, molding or extrusion of one or several selective adsorbents and SAC. (cf. Fig. 1 e-g)
4. Self-carrying, freely-moldable SAC-based structures (monoliths) for system integration. (cf. Fig. 1 h, i)

Experimental

The spherical activated carbons studied were polymer based (PBSAC) to ensure both a reproducible carbon quality and a well-defined sphere size. The effect of sphere size and size distribution on the performance of the different structures was analyzed.

The performance of the different media was characterized by one-pass breakthrough tests (cp. Fig. 2). Breakthrough tests on 3D-media were conducted in a by-pass test chamber. The test cell allows for measurements in bulk beds of up to 180 mm diameter with variable bed thicknesses. The tests within this work were carried out in cylindrical beds with diameters of 46 and 50 mm and bed thicknesses between 5 and 40 mm. The test gases comprise Ammonia, Chlorine, Cyclohexane, Dimethyl ether, Isobutane and Toluene. The test gas challenge concentrations were varied between 10 and 2500 ppm. The gas velocity was varied between 6.4 cm/s and 1 m/s. Test temperatures were in the range of 20-23°C. The air humidity was varied between 25 and 70 % r. H.

Tests were carried out on foam filter materials produced under variation of the foam pore size, the thickness and the mass per unit area.

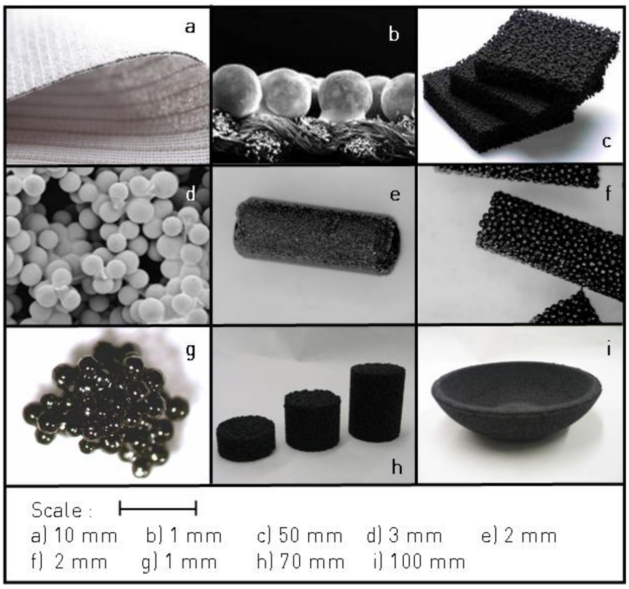

Fig. 1 Examples for structured filter media based on SAC

The agglomerates were produced in a drum agglomeration process and tested in different size ranges with different adsorbents and adsorbent mixtures (composite agglomerates). The PBSAC-based pellets were produced by extrusion and molding. The monoliths studied were produced using the previously mentioned agglomerates as starting material with variable composition. The final molding and shaping was carried out with different compaction degrees to control the monolith density.

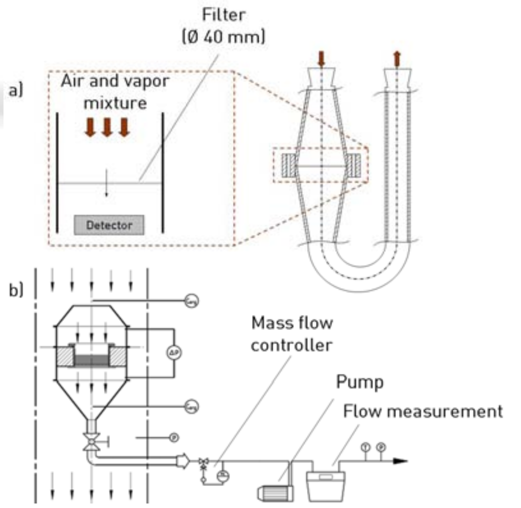

Fig. 2 Schematic description of test rig for breakthrough tests on a) PBSAC-based fabric filters and b) 3D-filter material

Results and Discussion

For a given PBSAC it can be seen that, regarding efficiency, retention time and pressure drop, different operating regions are covered by different structured media.

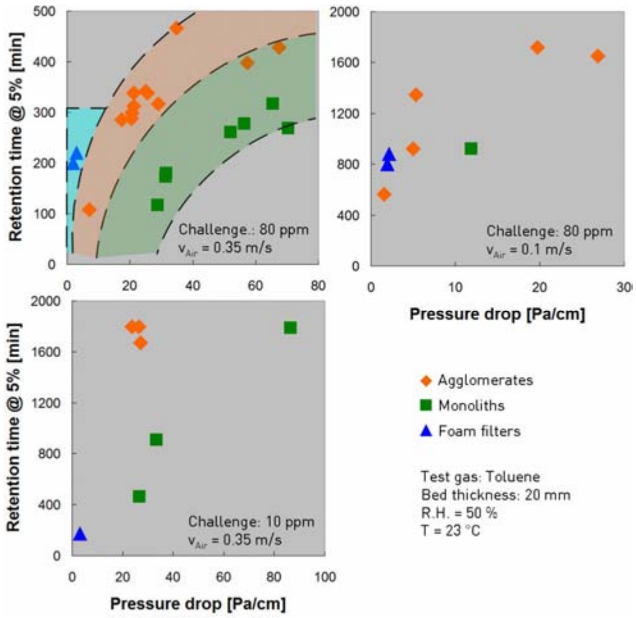

Fig. 3 Comparison of retention time (breakthrough 5%) vs. pressure drop for various filter materials in a constant volume

Within these operating regions it could be seen that production parameters can be used to control the performance criteria. The most relevant differences between the systems are derived from bed porosity and tortuosity. The performance of fabric and foam filters depends strongly on the size of the PBSAC and the spacing between the individual spheres as also predicted by theoretical models as described e. g. in [1].

The granule shape has a strong influence on the breakthrough and the pressure drop (cp. Fig. 4). Irregularly shaped PBSAC-agglomerates show generally a longer retention time in the ranges of low breakthrough and a steeper curve raise afterwards than cylindrical shaped structures for otherwise comparable pressure drop and t_{50} levels.

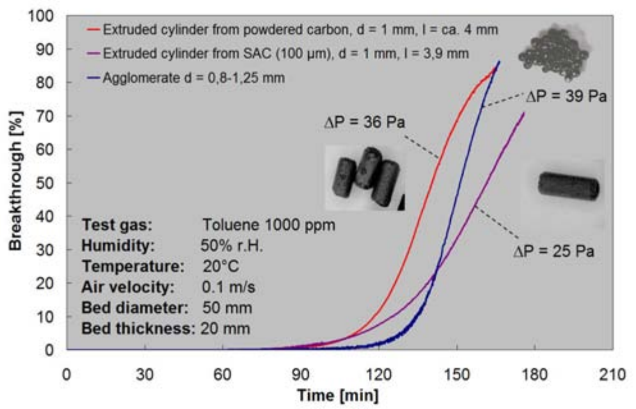

Fig. 4 Comparison of breakthrough curves for bulk filter media materials

In the region of low breakthrough both for PBSAC-agglomerates and PBSAC-pellets it was seen that not only the size and shape of the final granules but also the size of the primary carbon particles have an effect on adsorption and on pressure drop (cp. Table 1).

Table 1. Retention Time* (Breakthrough 1%) and Pressure Drop of Cylindrical Molded Adsorbents.

Primary adsorbent particles	Cylinder shaped adsorbents d_{Cyl} = ca. 1 mm, L_{Cyl} = ca. 4 mm	Cylinder shaped adsorbents d_{Cyl} = ca. 2 mm, L_{Cyl} = ca. 5 mm
Powder	$t_{1\%}$ = 95 min ΔP = 36 Pa	-
PBSAC $d_{Primary}$ = ca. 100 µm	$t_{1\%}$ = 90 min ΔP = 25 Pa	$t_{1\%}$ = 47 min ΔP = 15 Pa
PBSAC $d_{Primary}$ = 350 – 560 µm	-	$t_{1\%}$ = 28 min ΔP = 9 Pa

**Gas: Toluene 1000 ppm, v_{Air} = 0.1 m/s, T = 20°C, 50% r.H., bed diameter: 50 mm, bed height: 20 mm*

In the case of the monoliths, the test samples were produced in the same shape of the test cells.

In addition to the size of the agglomerates used for their production, the final monolith density can be used to control pressure drop and adsorption. An effect of the primary carbon particle size was not seen.

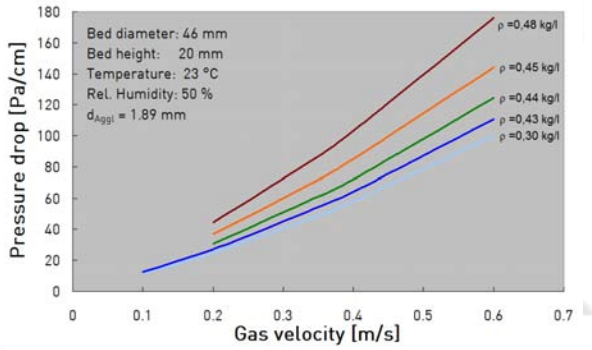

Fig. 5 Effect of compaction degree on the pressure drop for monolithic structures

Conclusions

One-pass breakthrough measurements showed that SAC can cover a broad performance spectrum both in adsorption efficiency and in pressure drop levels. The type of filter media structure plays a key role in the control over these criteria by creating additional degrees of freedom for bed alignment, bed porosity and bed tortuosity.

In addition to the versatile properties of PBSAC, e.g. regarding pore size distribution or surface chemistry [2], the different filter forming technologies allow for a broadening of their application range.

References

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