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Gas flow maldistribution in ceramic honeycomb packing

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Honeycomb packing is a type of structured packing with very good hydrodynamic, heat and mass transfer characteristics. A thorough study on its gas-flow distribution ability is carried out and has also shown very good results. Results are obtained for the maldistribution factor above and below the packing layers of different height and packing elements of different size. Also, results for the maldistribution factor at different flow rates are reported. Basic packing characteristics are determined, for example for packing No 1 the uniformity limit is 0.15 and penetration depth is about 0.4 m. For packing No 2 the uniformity limit is 0.13 and penetration depth is about 0.6 m.

Key words: packed columns, honeycomb packing, gas flow maldistribution, maldistribution factor, uniformity limit, penetration depth.

INTRODUCTION

Honeycomb packing is a structured packing with very good hydrodynamic, heat and mass transfer characteristics [1]. The body of a single packing element contains seven vertical hexagonal channels arranged like in a honey comb. In the column body, the packing is arranged in horizontal rows placed one over the other in a manner that the holes of each layer do not coincide with the holes of the layer below. This structure does not permit significant radial spreading of the gas flow in horizontal direction.

Previous studies on the gas flow velocity profile in such type of packing [2–4] have registered a good distribution. It is observed that in case of thicker layers, the gas flow velocity does not affect the flow maldistribution.

It is interesting to study the flow maldistribution below and above the packing layer, which depends strongly on the type of gas inlet device. Determination of the uniformity limit and penetration depth for this type of packing is another task of this study.

EXPERIMENTAL

The experimental study of gas flow maldistribution in a layer of honey-comb packing has been done in a column 0.47 m in diameter with three types of gas inlet devices (Fig. 1): straight inlet ID1 (Fig. 1a), bevelled inlet ID2 (Fig. 1b) and bent-to-bottom inlet ID3 (Fig. 1c).

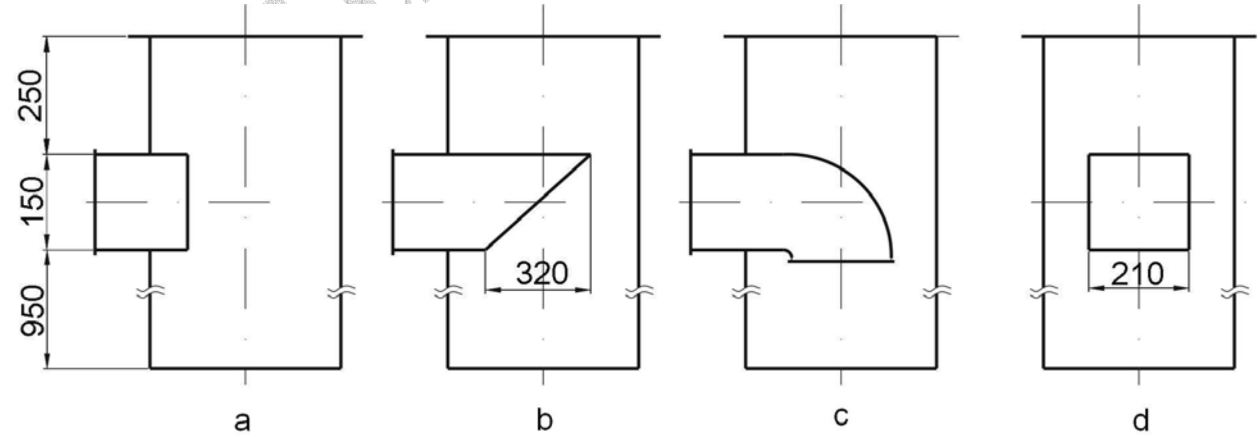

Fig. 1. Types of gas inlet devices (ID): a - straight inlet ID1; b - bevelled inlet ID2; c - bent-to-bottom inlet ID3; d - side look.

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Two packings have been studied. Their geometry parameters are rather similar and are given in previous publications [2, 4]. Packing No 1 has diameter of the circumference, inscribed in the packing hexagonal, equal to 21 mm and the height of the packing element is 66 mm. For packing No 2 these values are respectively 27 and 61 mm.

The packing elements have been arranged in rows over a supporting grid. It is mounted in the column lower part at 250 mm above the gas inlet upper end. The distance between the inlet and column bottom is 950 mm. Fig. 2 illustrates the arrangement of a packing row. The openings of every next row should not coincide with the openings of the row below.

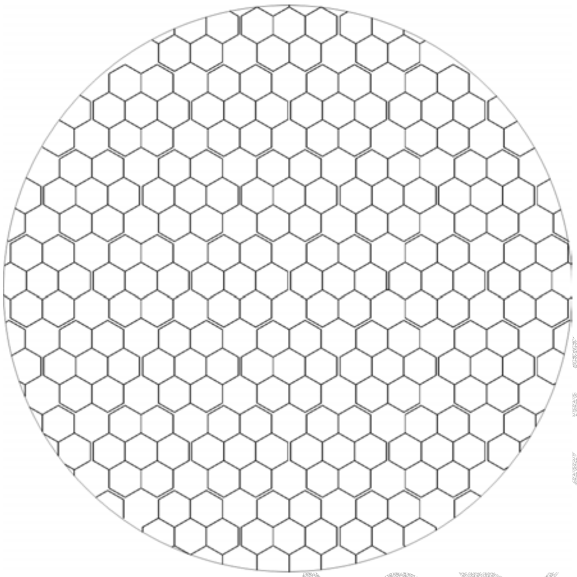

Fig. 2. Packed layer with blocks of ceramic honeycomb packing.

The measurement of gas flow velocity over the layer has been done by two schemes, depending on the height of column section filled with packing. When the section has been entirely filled (packing height 0.8 or 1.6 m), the measuring probe (thermoanemometer) has been placed directly on every packing hole over the cross-section (Fig. 2), and the maximal velocity over the corresponding hole is registered. When the column section has been partially filled, the velocity has been measured along two perpendicular directions – parallel and perpendicular to the axis of the inlet gas device.

The measured velocity profiles have been treated by the following equation in order to obtain the maldistribution factor M_f :

$$M_f = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\frac{W_i - W_0}{W_0}\right)^2} \qquad (2)$$

In case of direct measurement over each hole the measuring probe (thermoanemometer) has been placed in the center of the hole and the registered velocity is the maximum one – $W_i = W_{max,i}$ and $W_0 = W_{max,0}$.

The velocity profile measurements below the packing layer have been made along two perpendicular diameters.

In parallel with velocity measurements, pressure drop of the packing layer has been measured with a sensitive differential manometer (precision 0.1 Pa).

All measurements have been done at varying the mean superficial flow velocity in the range 1.0–2.5 m/s.

RESULTS AND DISCUSSION

Fig. 3 represents the maldistribution factor above and below the layer for packing No 1 as depending on gas flow velocity. Some of the experimental data are given in [3]. The results are for two types of gas inlets (ID2 и ID3) and for packing height 0.26 m. Preliminary tests have shown that the non-uniformity created by inlet devices ID1 and ID2 are rather similar. The inlet device ID3 has demonstrated most favourable qualities. It is seen that the flow distribution in this case is significantly better even with such a small layer. This result is confirmed by our proper studies [2, 4, 5] and by these of other authors [6].

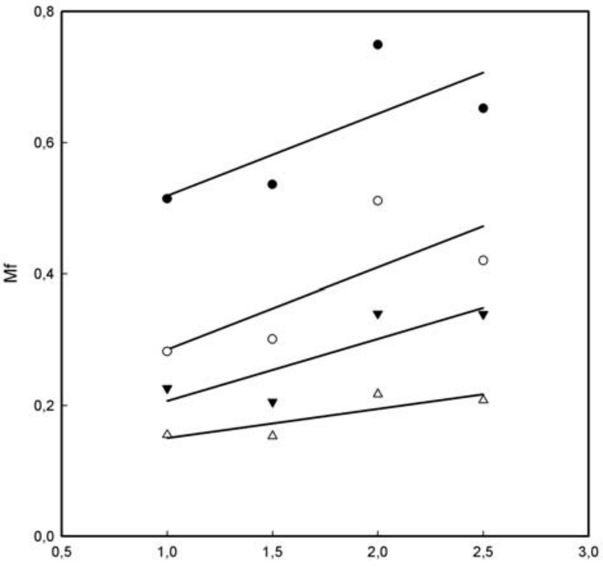

Fig. 3. Dependence of maldistribution factor on gas velocity in column below and over a layer height of 0.26 m for honeycomb No 1 and two types of inlets – ID2 and ID3; ● - below the packing and ID2; ○ - over the packing and ID2; ▼ - below the packing and ID3; Δ - over the packing and ID3.

An interesting result is obtained with much higher layer of the same packing (Fig. 4). Two facts can be seen: The maldistribution factor at great layer height (1.6 m) is independent on gas flow velocity. Also, there is not significant difference in the maldistribution before and after the layer.

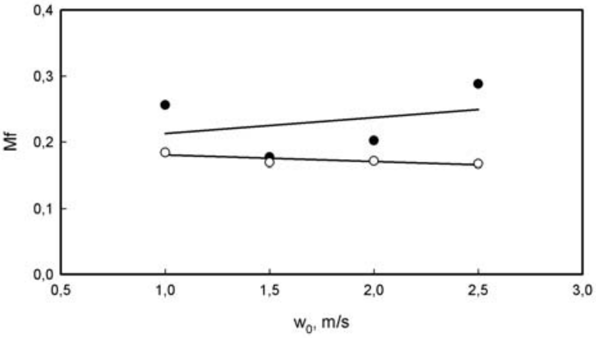

Fig. 4. Dependence of maldistribution factor on gas velocity in column below and under a layer height of 1.6 m for honeycomb No 1 and inlet ID3:
● - below the packing; ○ - over the packing.

Comparative studies on the maldistribution factor before and after the packing layer cannot be found in the literature. In all cases better flow distribution is observed above the layer. More detailed studies should be done, but one can say in advance that a better performance is related to packing structure, to its distribution ability, and probably to its pressure drop. The latter has been measured and the results are given on Fig. 5. Generally, it is not high and rather similar for both packings (Honeycomb No 1 and honeycomb No 2).

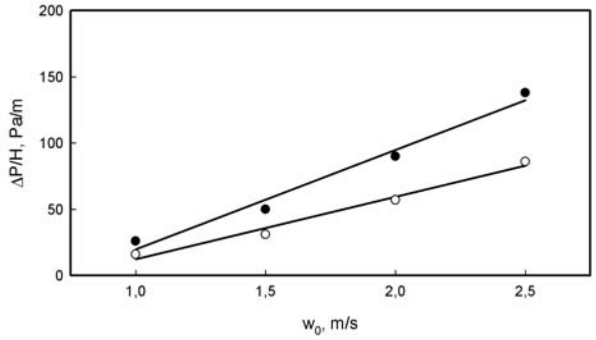

Fig. 5. Pressure drop as depending of gas velocity for honeycomb No 1 and honeycomb No 2: ● - honeycomb No 1 packing; ○ - honeycomb No 2 packing.

Analogous study on the maldistribution factor at different flow velocity has been carried out with packing honeycomb No 2 with gas inlet of type ID3 (Fig. 1c) and packing height 0.8 m. The results are reported on Fig. 6.

The evolution of maldistribution factor with the layer height is an important characteristic of the packing [5, 7]. Fig. 7 illustrates this dependence for packing Honey-comb No 1 at four different flow velocities (w_o = 1.0, 1.5, 2.0 and 2.5 m/s). As it is seen, at lower packing height (H = 0.26 and 0.8 m), the maldistribution factor varies in some range, while at larger packing height (H = 1.2 and 1.6 m) the values of M_f are very similar. This result confirms a previous estimation [3] that for thicker layers the maldistribution factor does not depend on gas flow velocity.

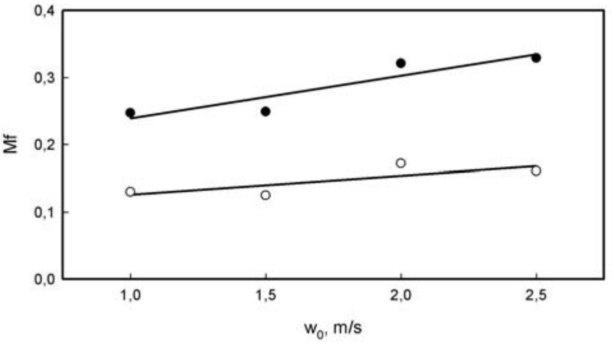

Fig. 6. Dependence of maldistribution factor on gas velocity in column below and under a layer height of 0.8 m for Honey-comb No 2 and inlet ID3:
● - below the packing; ○ - over the packing.

From Fig. 7 one can take information for penetration depth and uniformity limit [4, 7] of the ceramic honey-comb packing. For packing No 1 it is 0.4 and 0.15 correspondingly. Close to these values are the results for packing No 2 with uniformity limit 0.13 and penetration depth about 0.6 m.

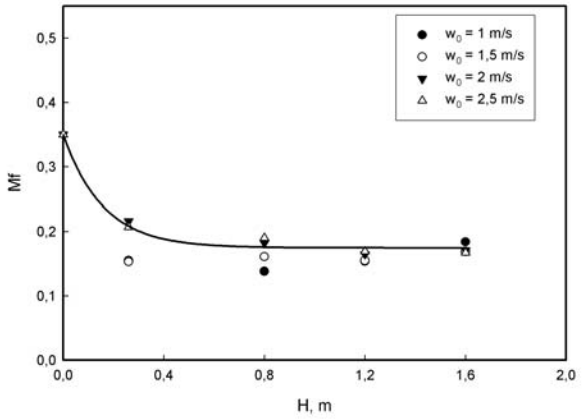

Fig. 7. Dependence of maldistribution factor on layer height of honeycomb No 1 packing ID3 gas inlet.

CONCLUSION

The structured ceramic packing honeycomb, besides its great hydrodynamic, heat and mass transfer characteristics, possess a very good distribution for the gas flow. Although the packing structure (packing made of ceramic blocks with hexagonal vertical holes) does not permit a radial gas spreading, the maldistribution factor M_f is sufficiently low. For example, for packing No 1, uniformity limit equal to 0.15 and penetration depth about 0.4 m have been experimentally determined. Close to these values are the parameters of packing No 2, for which the uniformity limit is equal to 0.13 and penetration depth is about 0.6 m.

Symbols

ID	inlet device;
H	height of a packing, m;
M_f	maldistribution factor;
n	number of measuring point;
W_i	gas velocity in point *i,* m/s;
W_o	gas flow superficial velocity, m/s;
W_{maxi}	maximum gas flow velocity in point *i*, m/s;
W_{maxo}	mean maximum velocity in given cross-section, m/s.

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НЕРАВНОМЕРНОСТ НА ГАЗОВОТО ТЕЧЕНИЕ В БЛОКОВ КЕРАМИЧЕН ПЪЛНЕЖ „ПЧЕЛНА ПИТА“

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(Резюме)

Блоковият керамичен пълнеж “Пчелна пита” е подреден тип пълнеж с много добри хидродинамични и топло- и масообменни характеристики. Подробното изследване на разпределителната му способност на газовото течение също показва много добри резултати. Показани са резултатите от изследване на фактора на неравномерност под и над пълнежния слой за пълнежи с различни размери на блока пълнеж и с различни височини на слоя пълнеж. Интересни са резултатите за фактора на неравномерност при различни скорости на течението и за измервания под и над слоя пълнеж. Установени са основни характеристики на пълнежа, като лимит на равномерност, който за пълнеж № 1 е 0.15 и дълбочина на проникване, която е около 0.4 m. За пълнеж “Пчелна пита” № 2 лимитът на неравномерност е 0.13, а дълбочината на проникване е около 0.6 m.