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Gas flow maldistribution in columns packed with HOLPACK packing

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HOLPACK packing is the type of horizontal structured packing and is already widely used in the industry. It has good heat and mass transfer characteristics, and good ability to distribute uniformly the flows over the column cross-section. This work reports on the examination of the gas distribution using the so called maldistribution factor, Mf. The uniformity limit and the depth of penetration are determined for the various packing types, differing by dimensions of the packing sheets as well as by distances between the sheets. In arrangement where sheets are distant from each other within the range between 10 and 50 mm, the uniformity limit is at Mf = 0.19 and Mf = 0.18, and if no distance Mf = 0.23.

Key words: packed-bed columns, HOLPACK packing, gas flow maldistribution, maldistribution factor, penetration depth, uniformity limit

INTRODUCTION

The HOLPACK packing consists of expanded metal sheets, placed horizontally inside the column at a given distance [1, 2] (Fig. 1). To improve the uniform gas and liquid distribution over the column cross-section it is only necessary to alternate the direction of the slits from sheet to sheet, each sheet rotated in the same direction as the previous, to 90^o. The packing has shown by far very good efficiency and low pressure drop, and thus it has found industrial application [3–5].

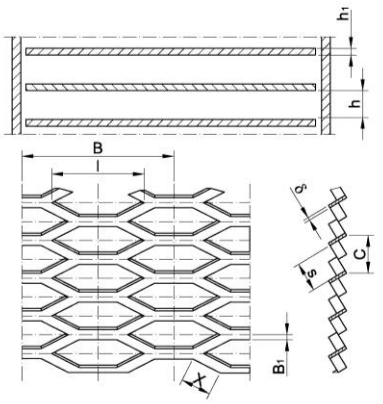

Fig.1. Scheme of the HOLPACK packing arrangement

It is known that a basic problem for the packed columns is the non-uniform flow distribution over the column cross section. This changes the flow velocity and the mass transfer intensity which results in variable concentrations of the radial direction and reduction of the efficiency. There is a method for determination of the influence of the vapor phase radial maldistribution on the column efficiency in the rectification process [6, 7]. This method is based on data for the maldistribution factor which is an integral indicator that takes into account both the velocity value at a point of the column cross section and the area of the section it occupies. In order to apply this method in columns, using the HOLPACK packing, it is necessary to determine the maldistribution factor for the different heights of the packed layer, and to find its lower value – the so called uniformity limit.

EXPERIMENTAL

The first studies on gas distribution in HOLPACK packed columns are from 1984 [8], and they show the velocity profiles at different heights along the column. The examinations were made with two types of packings that differ by their dimensions and distances between the sheets. The geometric characteristics of the examined packings are given in Table 1, lines 1 to 4. Line 5 shows the characteristics of a packing, examined later.

The present experiments are carried out as gas flow velocity is measured above a packed layer with a given height at two mutually perpendicular diameters, along the axis of the gas inlet device and perpendicularly to it [8]. The velocity was measured by electrical anemometer without a counter current liquid flow. Gas was fed into the

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column with two types of gas inlet devices. Table 1 shows initial distribution data for both types of inlet

Table 1. Geometric characteristics of the studied types of the HOLPACK packings.

Packing No	Hydraulic diameter of the orifices, d_h, mm	Distance between the sheets, h, mm	Thickness of the metal sheet, δ, mm	Thickness of the packing sheet, h_1, mm	Free volume, ε
1	6.5	10	0.8	3.0	0.87
2	6.5	50	0.8	3.0	0.87
3	20.8	10	4.0	17.5	0.85
4	20.8	50	4.0	17.5	0.85
5	20.8	0	4.0	17.5	0.85

devices along with the velocity profiles above the packing layers [8]. This gives an idea about the distribution ability of the HOLPACK packing layers. The data [8] show that the packing layers 'smooth down' the velocity profile to a uniformity of less than 25 %, having a very high value of the initial maldistribution.

Using the results of these experiments, data was collected to find the dependence of the maldistribution factor from the layer height. These data were processed in order to determine the value of the uniformity limit and the penetration depth.

More recently experiments were carried out with HOLPACK packing but having no distance between the metal sheets, i.e. at h = 0 (see line 5 in Table 1). However, measurements were done while changing the packing height.

RESULTS AND DISCUSSION

The packing layer heights at which a uniform distribution of the gas flow is achieved, or the so called penetration depth, are defined based on these experiments [8, 9].

The correlation between the maldistribution factor, *Mf* and the packing layer height, *H*, is a very important characteristic in practical terms [9]. Figure 2 shows this correlation for packing No 1 (see Table 1). We see a sharp improvement of the uniformity to a certain value, and then with increase of the layer height, it remains constant. This value of the *Mf* is called the uniformity limit, and the layer height at which it is obtained is the penetration depth. Thus, the uniformity limit is 0.19 and the penetration depth is 0.6 m for HOLPACK packing No 1.

The maldistribution factor, *Mf,* is defined as follows [10]:

$$M_f = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\frac{w_i - w_0}{w_0}\right)^2}\,, \qquad (1)$$

where w is the local gas flow velocity, w_o – the mean velocity over the column cross section, and n is the number of the experimental points.

The maldistribution is generally divided into two types: large-scale and small-scale [11]. Large-scale maldistribution is due to the initial phase distribution and the formation of local flows such as wall flow or bypass gas flows. Small-scale maldistribution is due to the packing discrete structure and cannot be eliminated. These two types of maldistribution can be easily distinguished on Fig. 2. The section of the curve from H = 0 to the depth of penetration is the maldistribution, caused by the gas inlet device, i.e. this is the large-scale maldistribution, and the uniformity limit characterizes the small-scale maldistribution.

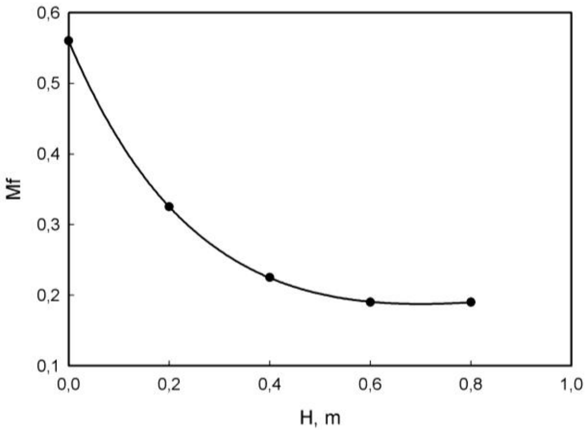

Fig.2. Dependence of the maldistribution factor *Mf* from the layer height for HOLPACK No 1 at gas velocity w = 1.8 m/s.

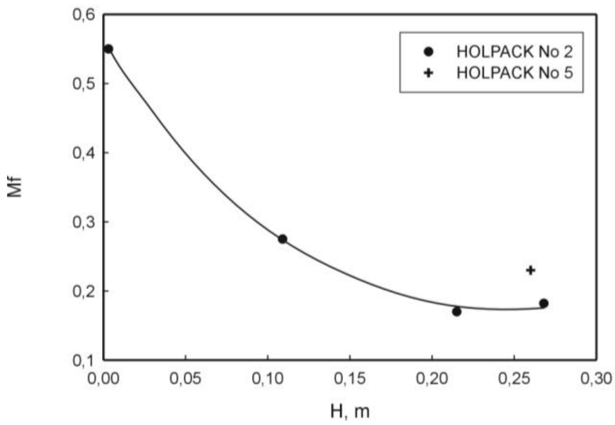

Fig.3. Dependence of the maldistribution factor, *Mf,* from the layer height for HOLPACK No 2 at gas velocity w = 1.8 m/s.

Fig. 3 shows the dependence of the maldistribution factor from the packing height, *H*, for HOLPACK packing No 2. A value at which the uniformity remains constant also can be seen. This happens at *Mf* = 0.18, and the height at which it is reached, i.e. the penetration depth, is 0.25 m. The same figure shows as well the value of the maldistribution factor for packing No 5, i.e. with no distance between the sheets. It is *Mf* = 0.23 at *H* = 0.26 m, and it remains the same at *H* = 0.63 m. This gives us grounds to assume that this value remains constant. Obviously, the lack of distance between the sheets does not allow radial distribution as gas passes through the sheets.

As we said above, the minimal values of the maldistribution factor that can be reached are the uniformity limit [9, 12, 13]. They are limited by the small-scale maldistribution which is characterized by the discrete structure of each type of packing

The maldistribution factor values below and above the packing layer at different gas flow velocities [12] are interesting. Such data for packing No 5 are given on Fig. 4. We see the big difference in the *Mf* value below and above the packing layer. This is probably due to the aerodynamic resistance, spreading coefficient, and the packing type. Therefore, data for the pressure drop, Δp, of several types of the HOLPACK packing are given on next Figure 5.

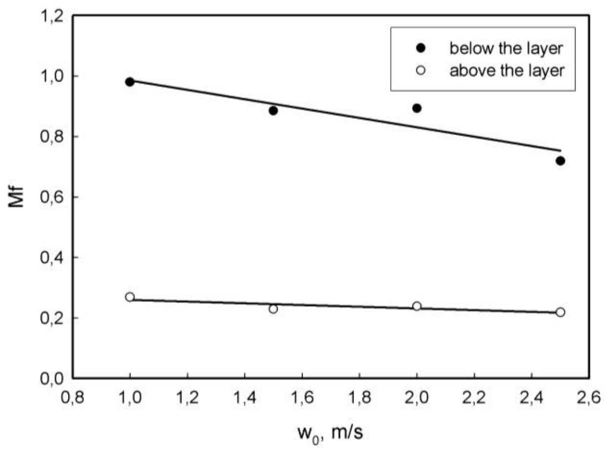

Fig.4. Dependence of the maldistribution factor, *Mf*, from the mean velocity w_0 at column cross section, measured below and above a layer of HOLPACK No 5 with height of 0.63 m.

Uniformity limit of packings No 3 and No 4 can be determined based on the aerodynamic picture of packings No 1 and No 2. They have the same distance between the packing sheets, similar geometry and similar pressure drop (Fig. 5). Therefore, we can assume that the uniformity limit of packings HOLPACK No 3 and No 4 is also 0.19 and 0.18, respectively.

For HOLPACK packing with distance between the sheets of 20 mm, which is often used in practice, the uniformity limit can be assumed at *Mf* = 0.185.

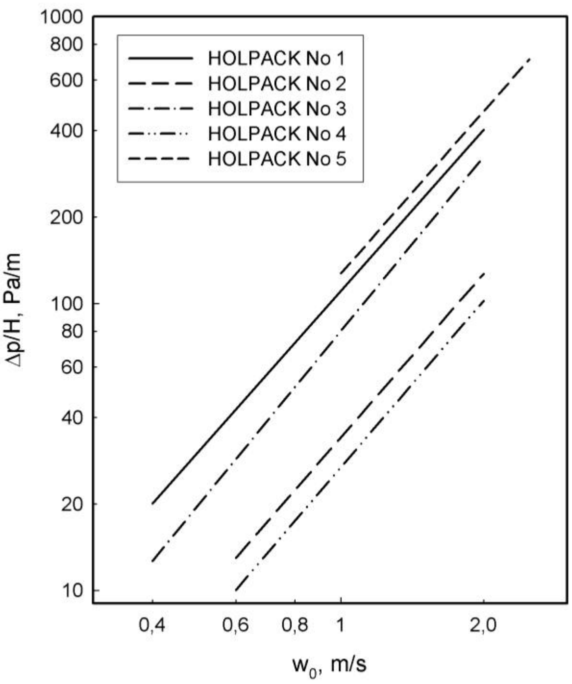

Fig.5. Dependence of the pressure drop at 1 m height of the HOLPACK layer from the gas velocity w_0.

To determine the value of the *Mf* for an uniformity limit is not a goal of this paper in itself. It gives a possibility to determine the impact of the gas flow maldistribution on the mass transfer efficiency in a packed column. This can be done using the recently found stochastic model for quantitative evaluation of the influence of vapor phase small-scale maldistribution on the packing efficiency in rectification packed columns based on data for maldistribution factor [6, 7]. The obtained here data for the maldistribution factor at reaching the penetration depth does not change with the increase of the layer height. Therefore, it can be assumed that this lowest value of the *Mf* characterizes specifically the small-scale maldistribution, caused by the discrete packing structure. In the rectification of ethanol-water system in the range of high ethanol concentrations, the efficiency reduction of the HOLPACK packing is found to be 10 – 12 %. It should be noticed that under the same conditions the efficiency reduction of some modern random packings is between 14 and 38 %, although in general, they show higher mass transfer efficiency. Therefore, non-uniform distribution in gas (vapor) phase is significant in some cases and has to be taken into consideration. The above should be considered when choosing a packing for a given particular process. The lesser efficiency reduction due to gas maldistribution is another important feature of the HOLPACK packing.

CONCLUSION

In conclusion we can say that the HOLPACK packing, apart from its good heat and mass transfer characteristics, has very good ability to equalize gas flow in packed columns. The packings with distance between the expanded metal sheets make it possible by equalization of velocity profile in radial direction in the space between the sheets. The packings with no distance between the sheets give less opportunity to the gas to spread in all directions. The uniformity limit is found to be 0.19 for packings No 1 and 3 (Table 1), and 0.18 for packings No 2 and No 4. A uniformity limit at *Mf* = 0.185 can be assumed for the HOLPACK packing with distance between the sheets of 20 mm (often used in practice). A uniformity limit is determined at *Mf* = 0.23 (for packing No 5 (Table 1). These values lead to a comparatively small deterioration of the mass transfer processes, occurred in the columns, packed with HOLPACK packing, because of the gas flow maldistribution.

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НЕРАВНОМЕРНОСТ НА ГАЗОВОТО ТЕЧЕНИЕ В КОЛОНИ С ПЪЛНЕЖ HOLPACK

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(Резюме)

Пълнежът HOLPACK е от типа на хоризонталните структурирани пълнежи и е намерил вече широко приложение в промишлеността. Той притежава добри топло- и масообменни характеристики както и добра способност да разпределя равномерно потоците по напречното сечение на колоната. В настоящата работа е изследвано разпределението на газа с помощта на фактора на неравномерност. Установени са лимита на равномерност и дълбочината на проникване на различните видове пълнежи, различаващи се както по размери на пълнежните листа, така също и по разстоянията между тях. За пълнежите с разстояние между листата 10 и 50 mm, лимита на равномерност е при *Mf* = 0,19 и *Mf* = 0,18, а при липса на разстояние *Mf* = 0,23.

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