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Vertical plates with inclined capillary grooves for redistribution of the liquid phase over the cross-section of packed columns I. Equations for calculating the liquid flow-rates in the capillary grooves

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Abstract

The uniform distribution of the liquid phase over the cross-section of a packed column is a major prerequisite for its effective operation. Regarding various distributor designs, the best uniformity has been obtained with devices which distribute the liquid into jets with equal flow-rates, distributed uniformly across the column cross-section. The final liquid redistribution, to obtain uniformity over cross-sections of the range of a packing element, takes place in the packing itself or in a specially designed redistribution layer. For this purpose, a packing with inclined capillary grooves, especially suitable for low liquid superficial velocity, is developed. It consists of parallel vertical plates with inclined crossing small-size grooves stamped in them. On the bases of the data obtained from the experimental study of the liquid flow in these grooves, dimensionless equations are obtained which are necessary for calculating the height of the new redistribution layer.

Keywords: Packed columns; Liquid distribution; Redistribution layer; Capillary grooves; Dimensioning

1. Introduction

The regular distribution of the gas and liquid phases over the cross-section of the packed columns is very important for their efficient operation [1–3; 4, p.173–176; 5]. That is why in the last years there are many publications investigating the distribution of the phases [3–12]. The problems connected with the liquid phase, which needs special distributing devices, are more important. Of all known distributors, the best uniformity has been obtained with those dividing the liquid flow into streams with equal flow-rates uniformly distributed over the column cross-section. Further redistribution, depending on the shape of the packing elements, takes place in the packing. The packings with vertical walls and especially the Honeycomb packing [13–15] in comparison with other packings are with lowest pressure drop for a mass transfer unit, respectively with highest mass transfer coefficient for a given pressure drop. Another advantage is that they do not spread the liquid to the column wall, and that is why the initial uniform distribution of the liquid phase is preserved along the whole packing height. The Honeycomb packings produced of thin sheets of very wettable material are especially effective [18]. It is because among all packings, the Honeycomb packing pressure drop is particularly sensitive to the reduction of the void fraction. The power at this value in the equations for pressure drop calculation is about 5.13 [16,17]. A disadvantage of these packings is that they have poor distribution properties. In order to obtain good distribution of the liquid (high spreading coefficient) it is necessary to add a horizontal component to the velocity vector of the liquid flowing down over the packing, by inclination of the packing walls. This leads to strong increasing of the wall effect and of the packing pressure drop. That is why the best solution is to create a special packing for redistribution of the liquid phase over the column cross-section which is mounted over the main packing with vertical walls. Specially structured packings with inclined walls, already implemented in the industry, are designed for that purpose [19–21]. They have high spreading coefficient along with high gas and liquid flow velocities at the loading and flooding points. This allows optimal operation of the main packing with vertical walls. Although this principle leads to significant increasing of the column efficiency,

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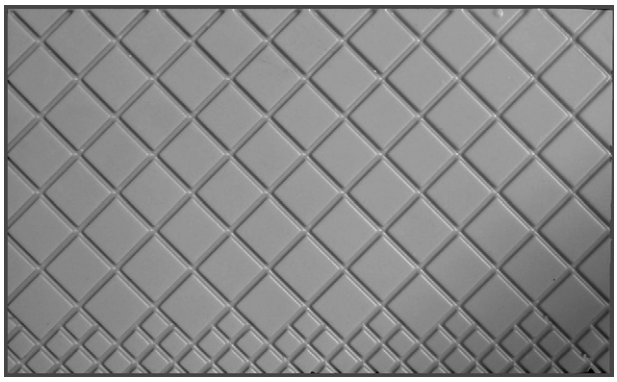

Fig. 1. Photograph of a plate of the investigated packing with stamped inclined capillary grooves.

it is not accepted by the researchers and packing producers, that is why the only investigations in this area up to now are the investigations of the author and his team.

An essential disadvantage of the existing packings for redistribution layers is that their inclined walls change not only the direction of the liquid streams, which is necessary, but also the gas flow direction which is undesirable because of the increase of the packing pressure drop. In order to avoid this disadvantage, packings made of vertical plates with crossing inclined capillary grooves stamped on their surface are proposed [22,23] (Fig. 1). Fig. 2 presents schematically the cross-section of a rectangular groove cut on an experimental plate of polystyrene. The plates can operate as a part of the liquid distributor and also as a distribution layer between the distributor and the main packing. Schemes of such devices are given in Figs. 3 and 4. The liquid phase in Fig. 3 leaves the trough (pipe) 1 of the distributor through orifices perforated in them and goes over plates 2. Here it is regularly distributed by the inclined crossing capillary grooves. From plates 2 the liquid flows over plates 3 and is regularly distributed along their length too. The uniform distribution after plates 2 and 3 ensures regular distribution over the whole apparatus cross-section.

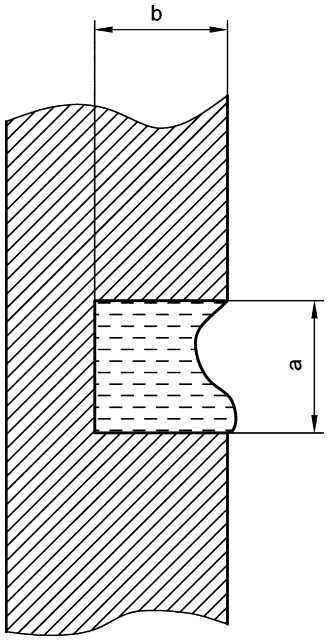

Fig. 2. Shape of the liquid phase surface in an open capillary groove.

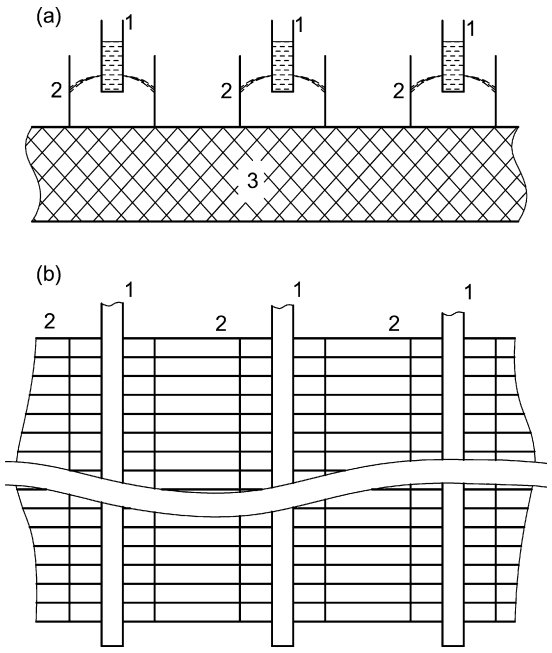

Fig. 3. Scheme of a liquid distributor using plates with stamped inclined capillary grooves. (a) Cross-section view; (b) above view. (1) Distributing troughs; (2) plates parallel to the distributing troughs; (3) plates perpendicular to the distributing troughs.

In Fig. 4 the liquid phase distributor consists of connected pipes or troughs 1. The liquid is leaving them through the irrigation orifices 2 and falls on the inclined part 4 of the plate 3 with inclined grooves 5. The liquid is uniformly distributed along the whole plate length.

For implementation of the new device in the industry, it is necessary to have a method for calculation of the height of the plate under which the distribution of the liquid phase will be uniform with a preliminary given precision. For creating such a method, equations for determination of the flow-rates in the channels of the plate are needed.

The aim of this paper is to obtain these equations.

2. Description of the approach

Fig. 5 shows how the capillary grooves can be placed on a vertical plate. Each groove is schematically presented by a line.

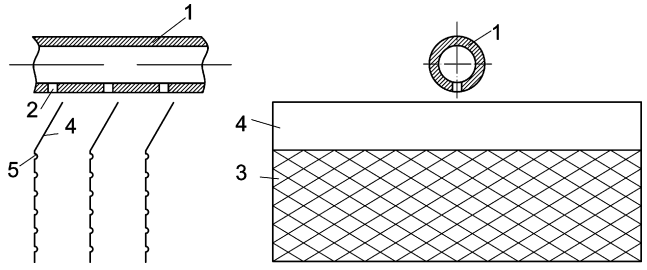

Fig. 4. Scheme of a liquid phase distributor consisting of connected pipes or troughs. (1) Irrigation pipe; (2) irrigation orifices; (3) vertical plates; (4) inclined part of plate 3; (5) inclined grooves.