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Cascade bowl-type heat and mass exchange packing with dripping irrigation mode

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Abstract. Data of experimental study of hydrodynamics, heat and mass transfer of cascade bowl-type heat and mass exchange packing with dripping spray mode and some comparative characteristics of the packed device with packing, which have wide industrial application, are given in the article.

Introduction

A large quantity of industrial packingsis known and a lot of packingsare offered to be used industrially, and the work aimed at the creation of new packings is still going on. Creation of new highly efficient packings is a difficult and time-consuming process that sometimes requires providing for necessary but colliding structural solutions [1].

Requirements set for the packings of industrial apparatuses are low flow resistance, a wide range of liquid and gas (vapour) load, ability to form a uniform velocity profile in the cross-section of the apparatus, good wettability of the packing (and in some cases hydrophobic behaviour, when it is necessary to reach dripping water flow mode), high retaining capacity for liquid, resistance to aggressive media, sufficient mechanical strength and low cost. The variety of packings used industrially is reasoned by the necessity to ensure high efficiency of the process equipment operation.

The selection of known and creation of new packings for industrial equipment is always accompanied by the necessity to assess their efficiency with regard to the specific process. Due to the specific character of the processes implemented in two-phase filtration flow it is impossible to clearly identify the most efficient type of packings for it.

The aim of the offered structure of the packing element for heat and mass exchange apparatus is to create an aerodynamically streamline configuration of the packing with the creation of good dripping liquid flow mode.

This ensures reduction of flow resistance to the ascending gas flow, decrease of energy efficiency and increase of heat and mass transfer intensity.

The result is reached by the structure where the packing element of the heat and mass exchange apparatus has a set of parallel bars on which plates with holes are placed in cascade. At that the plates are of cusp form with shaped edges and are placed with their apex down with locks placed above each plate. The cusp form of the plates of the mass exchange packing element and their installation with apex down, towards the gas flow, creates an aerodynamically streamline configuration that significantly decreases flow resistance to the ascending gas flow and energy spent on mass exchange process. The orientation of the plates in the heat and mass exchange packing elements towards the liquid flow ensures sufficient retaining capacity for liquid. This packing is universal, because depending on its orientation in space it can be applied in the process of fractionation in a splitter column and in the process of evaporation cooling. The packing type is shown in Figure 1.

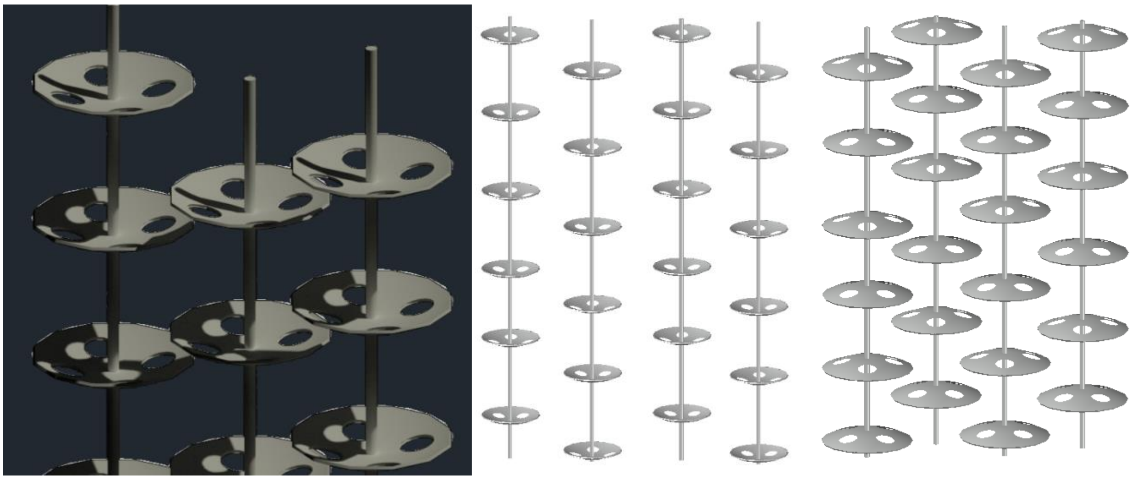

Figure 1. Structured cascade packing [2]

This packing includes parallel metal bars on which stainless steel round-shaped "cup" elements are fixed. Cups have several holes. Bars, on which the elements are fixed, pass through the middle part of the element. The elements are located concentrically with respect to each other with a certain distance from each other on the bar. The bars are attached to the frame which provides rigidity; this frame makes the assembly of the packing in the apparatuses easier, because it can be assembled by units having round or rectangular section. The plates are located in such away that drops fall down from the plate, pass the unit and hit the next plate where they break, thus, renewing their heat and mass transfer surface. These cycles repeat continuously in the whole height of the packing.

To confirm the efficiency of the designed packing we have performed a series of experiments. The aim was to receive the data on basic flow characteristics of the designed cascade packing. The packings chosen for comparison were a range of industrial packings [1-6].

Experimental part

In order to perform a full range of experimental studies and compare packings having different configurations, we have designed an experimental stand (Figure 2) which is based on the modular study principle and has a cartridge system of replacement packings that provides for a quick and precise study of heat and mass exchange and flow characteristics of the packings [1, 3].

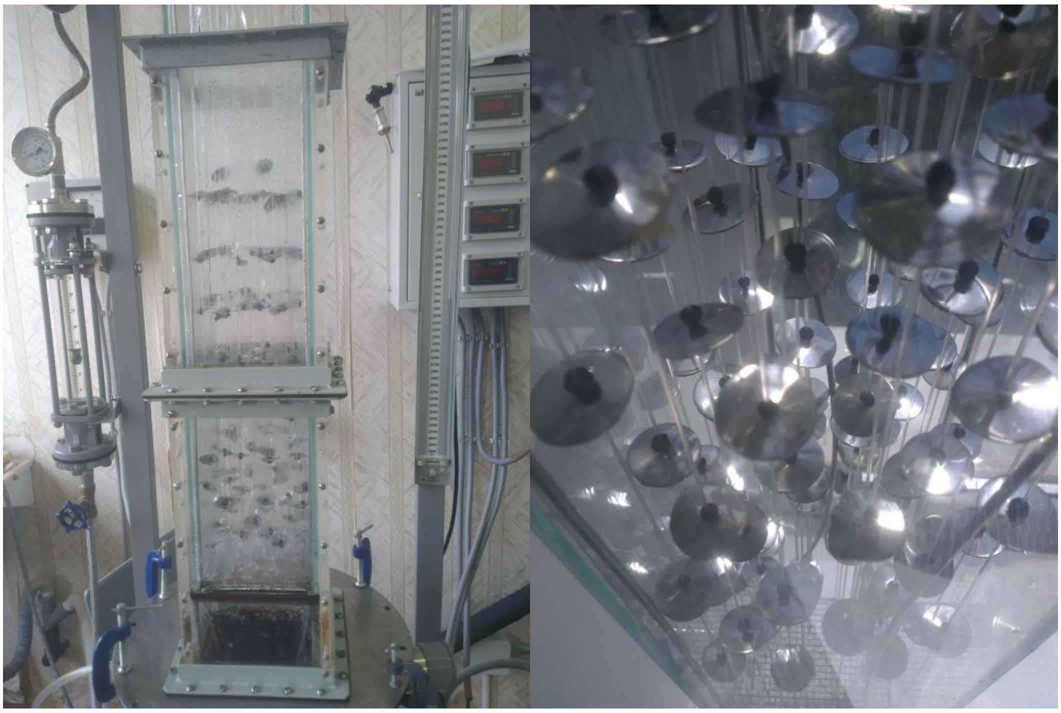

Figure 2. Experimental stand for studying characteristics of packings

Results and Discussion

Experimental data on flow resistance of dry and spray heat and mass exchange packings are given in Figure 3.

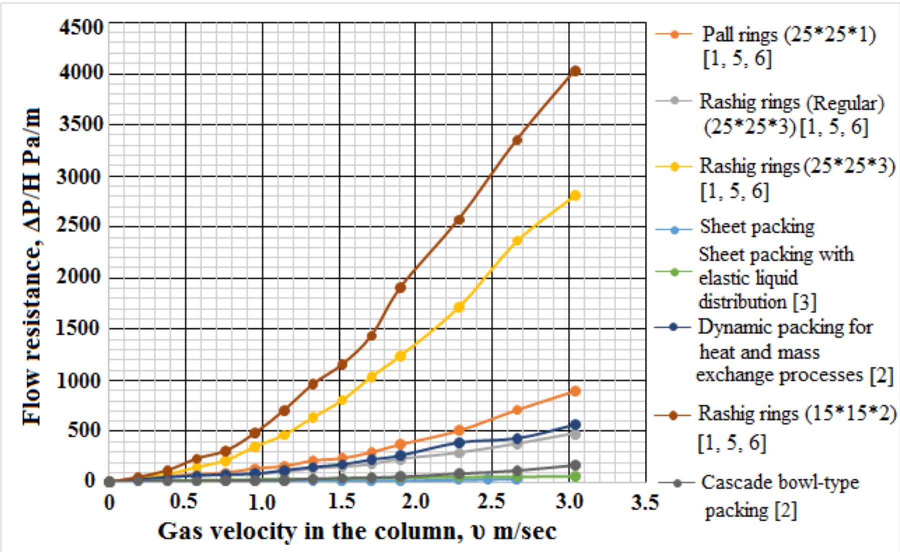

Figure 3. Flow resistance of dry packings vs. gas velocity in the column

In order to summarize the experimental data and prepare the comparison of the tested heat and mass exchange packing and packings that are widely spread in the industry, it is offered to use generalized equation $\lambda = f(Re_m)$ as per the method described in papers [5, 6]. Using this generalized equation we can compare their energy efficiency and describe the use of any packings having very

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complex configurations.

Based on the filtration curves obtained during experiments (Figure 3) for the described heat and mass packing [5, 6] we determined linear dimensions l_1 and l_2, α and β values which are viscous and inertial factors in the Dupuit-Forchheimer equation, respectively, modified Reynolds numbers Re_m, and corresponding flow resistance factors $\boldsymbol{\lambda}$, given in Table 1. This analysis was performed according to the method described in papers [5, 6]. This method helps to identify the industrial application and analyse the energy requirements for the industrial processes for any packings of any configuration. They can be summarized and are within the mode range of filtration curve $\lambda=f(Re_m)$, shown in Figure 4.

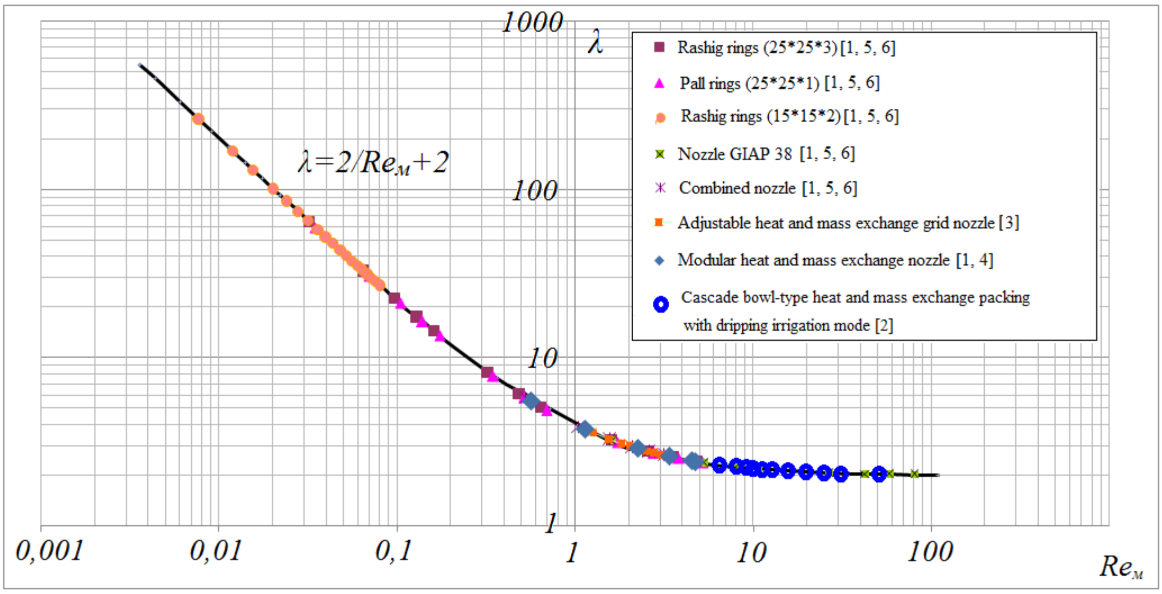

Figure 4. $\lambda=f(Re_m)$ diagram for packings with different structures [5, 6]

The analysis of the obtained experimental data on the flow dynamics of the designed cascade heat and mass exchange packing with dripping flow mode suggests that it is especially promising for evaporation cooling of water in cooling towers and in wet gas cleaning plants.

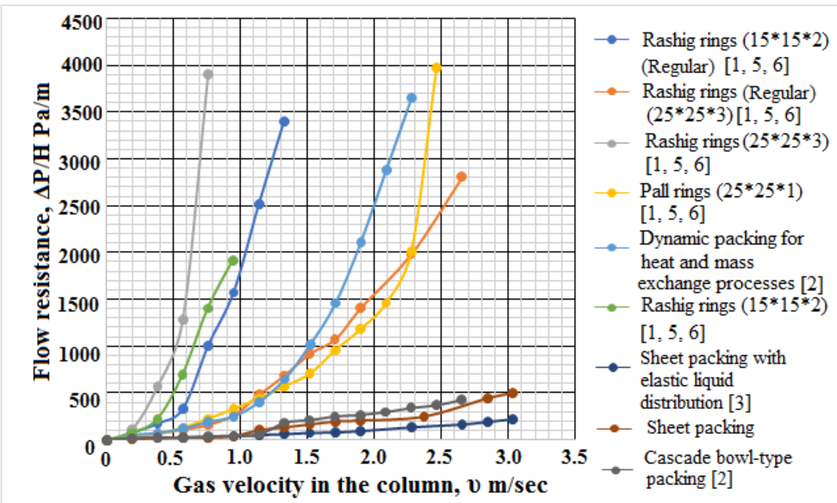

Figure 5. Relation between flow resistance of irrigation packings and gas velocity in the column

The main experimentally confirmed specific feature of the cascade bowl-type packing is the effect of oscillation of flexible cables which fix the elements. These oscillations occur even at smallest air speeds and intensify when the air flow increases. This effect occurs because the air rounds the elements in space that are fixed at a distance on flexible cables which easily lose balance position. The oscillation effect tears films on the surfaces of the packing elements, and a stable dripping flow mode is maintained in the whole height of the packing. Besides, the triggered oscillations result in heat and mass exchange processes intensification.

For packings with dripping liquid flow mode we have developed calculation methods [7, 8] where apart from heat and mass transfer coefficients there is another key parameter of the packings – retaining capacity, i. e. the ability of the packing to accumulates certain amount of liquid depending on the operation mode. This characteristic shows the total time of water retaining and mass transfer surface for packings with dripping flow mode [7, 8]. Figure 5 shows diagrams depicting retaining capacity determined experimentally for different packings depending on gas velocity in the column. Besides, retaining capacity is critical for the application of this packing in specific processes as well as the suggested method $\lambda=f(Re_m)$ [5, 6].

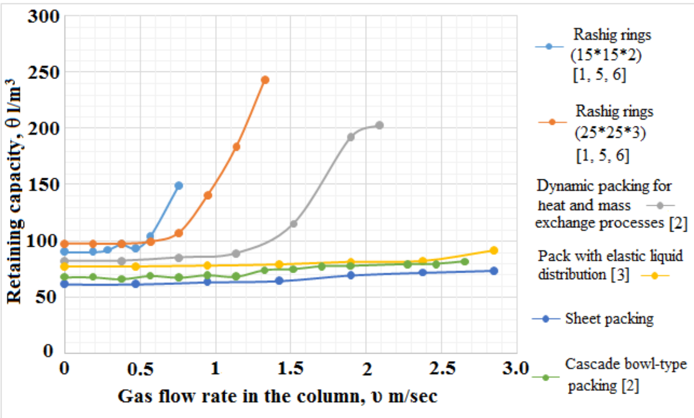

Figure 6. Retaining capacity of the irrigation packing vs. gas velocity in the column

Conclusions

Compared with a range of packings which have been studied experimentally, the designed cascade heat and mass exchange packing has a very low flow resistance that proves its energy efficiency and has satisfactory retaining capacity that corresponds to the packings suitable for evaporation cooling of circulating water in cooling towers. The main experimentally proven effect is oscillation of the elements in almost whole range of gas operation velocities that intensifies dripping flow mode and can be easily implemented in small cooling towers for local recycling water supply systems.

It is noteworthy that the designed cascade heat and mass exchange packing is very promising as a module for decontamination of circulating water in electrical field [1, 4]. This packing is very simple and can be finely adjusted for the requirements of specific heat and mass exchange process and apparatus though it may seem complex, because the structure and configuration of the packing elements as well as distances between them can be different and easily adjusted.

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