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Heat and mass exchange packing with adjustable parameters for absorption and evaporation cooling

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Abstract. Data of experimental study of hydrodynamics, heat and mass transfer of packing with adjustable parameters and some comparative characteristics of the packed device with packing, which have wide industrial application, are given in the article.

Introduction

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 specific process. Specific character of different heat and mass exchange processes complicates the selection of an efficient packing for their implementation. We are trying to find a systematic approach to process the experimental data.

The aim of the work is designing and study of available heat and mass exchange packings with adjustable parameters and changeable flow modes for absorption process during selective gas cleaning and evaporation cooling of circulating water in local water supply systems at industrial enterprises.

The main task at this stage of heat and mass exchange packings study is the creation of packings providing the possibility for adjustment of their key parameters, porosity and specific surface, that consequently results in the possibility to manage flow processes. Such packings should be structured with the possibility to change their structure, or if they are non-regular, they should have elastic properties and be compressible. This idea implemented in an original engineering solution [2] to use wastes from metal treatment plants (shavings) as heat and mass exchange packings. Depending on the cutting mode shavings can have absolutely different configurations. The studied samples of shavings packing elements were obtained during lathe turning of stainless steel 12H18N10T and 08H17N14M2T (Aisi316Ti) widely used in industry.

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Figure 1. Designed adjustable packing for heat and mass exchange processes with changeable packing density (Modification 1 and 2) [2]

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.



Figure 2. Experimental stand for studying characteristics of packings

Results and Discussion

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

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 complex configurations.

Based on the filtration curves obtained during experiments (Figure. 3) for the described heat and mass packing [2] 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 λ, 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 5.

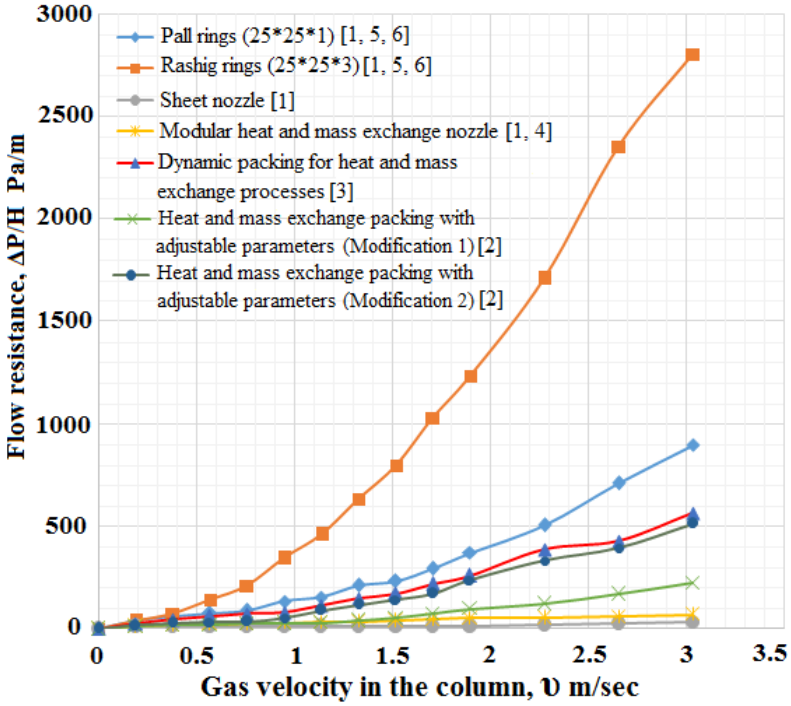


Figure 3. Relation between flow resistance of dry packings and gas velocity in the column

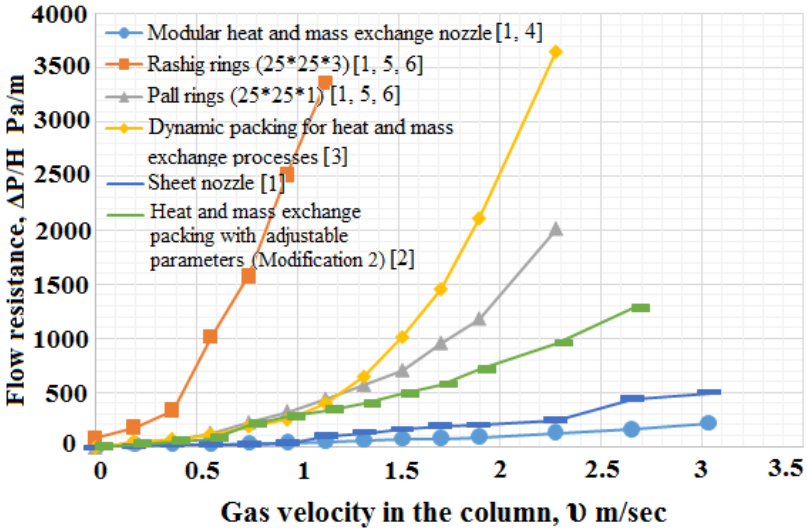


Figure 4. Relation between flow resistance of spray packings and gas velocity in the column

The result of the comparison of the packings is given in Figure 5.

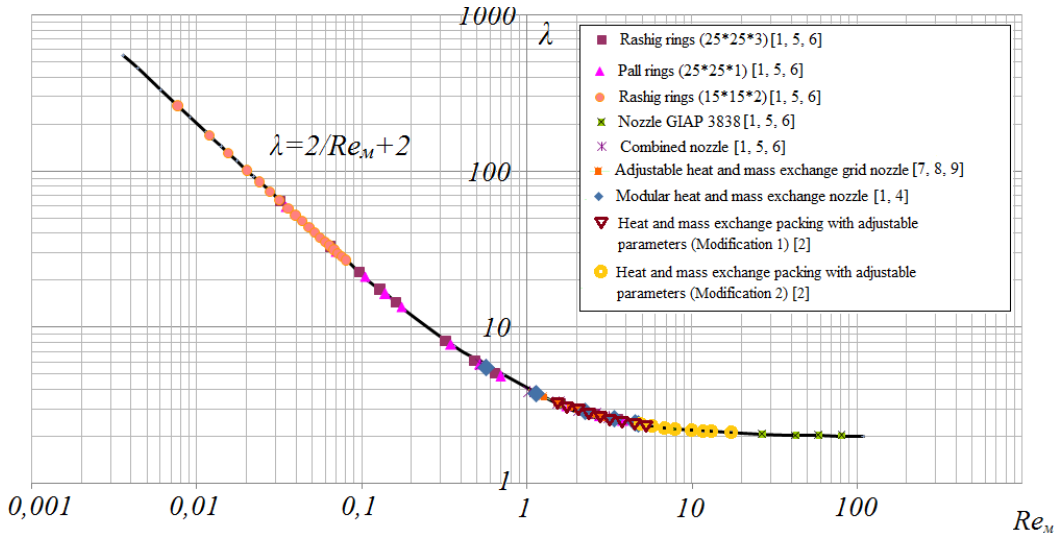


Figure 5. $\lambda=f(Re_m)$ diagram for packings with different structures [5, 6]

It is clear that wire heat and mass packings with adjustable parameters, porosity and specific surface, can have a very wide mode range because of packing density and possibility to change. The results suggest that dense adjustable packings (Modification 1) can be used for absorption, because such packings can ensure developed flow operation modes, even emulsification, though it provides a high flow resistance. While adjustable packing (Modification 2) has a very low flow resistance and implements a dripping-film liquid flow mode.

We are studying the retaining capacity of the packings with adjustable properties and we will prepare a comparative classification based on the experimental data. Retaining capacity means the capacity of the packing to accumulate a certain amount of liquid depending on the operation mode; it shows the total time of water retaining and mass transfer surface for a range of packings [7, 8]. Figure 6 shows diagrams depicting the retaining capacity determined experimentally for different packings depending on gas velocity in the column.

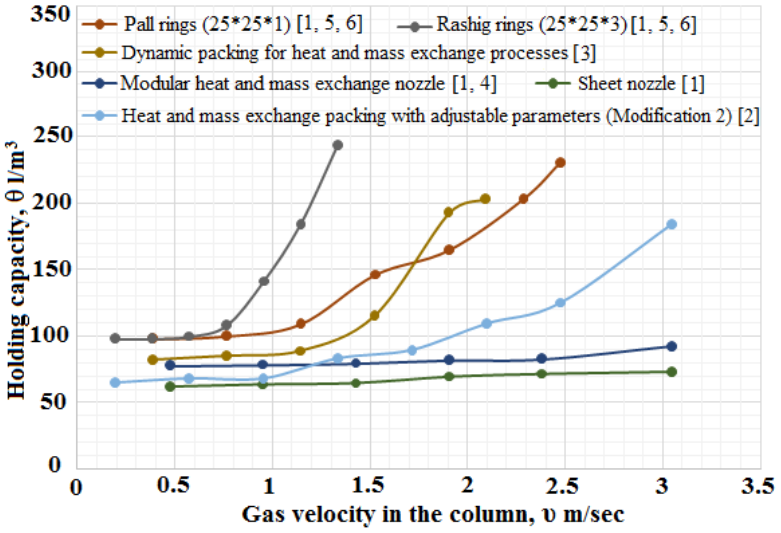


Figure 6. Retaining capacity of packing devices vs. gas velocity in the column

Correlation coefficient in all three experiments equalled 0.99 that means that the dependence $Y=A+BX+CX^2$ is direct and high. We obtained the dependence equations which are as follows:

$Y=6{,}50072+0{,}1015X+0{,}003903659X^2$ for a dry packing;
$Y=1{,}6906+1{,}0795X+0{,}018150219X^2$ for irrigation packing;
$Y=410{,}736+2{,}21032X+0{,}038150271X^2$ for retaining capacity (Figure 7).

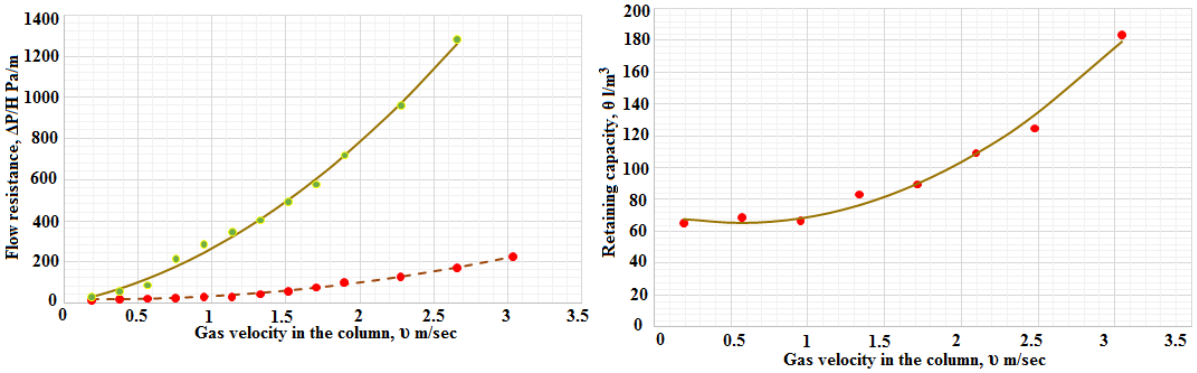


Figure 7. Deviation of experimental data from theoretical flow resistance of a dry (dashed line) and spray (solid line) studied packing and deviation of experimental data from theoretical retaining capacity of the studied packing (Modification 2) [2]

Conclusions

The obtained experimental data for the packings with adjustable porosity and specific surface and, consequently, changeable flow modes suggest that such packings are very promising for study and application, even though their analysis is complicated by conditions of creation, specific modes of cutting of metal working machines. It should be remembered that the material of such packings is waste material, though of very high quality from the point of view of material properties. Only stainless steel that is resistant to aggressive media and atmospheric wear are suitable. This is very important according to the specific character of the processes for which the packings are applicable. From our point of view ecologically and environmentally the application of such packings is an incredible process solution. The general idea and our aim is to create absolutely controllable heat and mass exchange packings that can automatically adjust to the operating flow modes; this adjustment can occur mechanically by compression and expansion, but with account of required parameters, such as heat and mass transfer coefficients, retaining capacity, response function, flow resistances.

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