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

1Persidkiy A.V., 2Merentsov N.A., 3Lebedev V.N., 2Golovanchikov A.B.

1JSC Federal Scientific and Production Centre «Titan - Barricady» 400071, Russia, Volgograd, Prospect Lenin, b/n
2Volgograd State Technical University, 400131, Russia, Volgograd, Prospect Lenin, 28
3«LUKOIL-Engineering VolgogradNIPImorneft» branch in Volgograd 400078, Russia, Volgograd, Prospect Lenin, 96

steeple@mail.ru

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.
**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 $l_2$, $\alpha$ and $\beta$ values which are viscous and inertial factors in the Dupuit-Forchheimer equation, respectively, modified Reynolds numbers $Re_m$, and corresponding flow resistance factors $\lambda$, 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 5.
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]](image)

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](image)
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.

**References**

[1] Merentsov NA, Lebedev VN, Golovanchikov AB, Balashov VA, Nefed'eva EE 2018 IOP Conference Series: Earth and Environmental Science (115) 9

[2] Golovanchikov AB, Vorotneva SB, Merentsov NA, Du'kina NA, Zalipayeva OA, Sham'yanova AP 2012 Patent 117317 RU, IPC B 01 J 19/32 VSTU

[3] Golovanchikov AB, Vasil'ev PS, Ljapkov AV, Chjorikova KV, Topilin MV, Tishhenko PO 2016 Patent 160198 RU, IPC B 01 J 19/00 VSTU

[4] Golovanchikov AB, Sivolobova NO, Merentsov NA, Du'kina NA, Shishljannikov VV, Dorofeeva NI 2012 Patent 129450 RU, IPC F 28 S 25/08 VSTU

[5] Golovanchikov AB, Balashov VA, Merentsov NA 2017 Chemical and Petroleum Engineering 53(1-2)10-13

[6] Merentsov NA, Balashov VA, Orljankina JaA 2013 Izvestija Volgogradskogo gosudarstvennogo tehnicheskogo universiteta, Ser. Reologija, processy i apparaty himicheskoi tehnologii (The news of Volgograd state technical University, Ser. Rheology,
processes and devices of chemical technology) 1 (104) 112-114
[7] Golovanchikov AB, Merentsov NA, Balashov VA 2013 Chemical and Petroleum Engineering 48(9-10) 595-601
[8] Golovanchikov AB, Merentsov NA, Balashov VA, Orljankina JaA 2012 Izvestija Volgogradskogo gosudarstvennogo tehnicheskogo universiteta, Ser. Aktual'nye problemy upravlenija, vychislitel'noj tehniki i informatiki v tehnicheskikh sistemah (The news of Volgograd state technical University, Ser. Actual problems of management, computer science and Informatics in technical systems) 10 (97) 22-28
[9] Kagan AM, Yudina LA, Pushnov AS 2012 Theoretical Foundations of Chemical Engineering 46(2) 165-171
[10] Gorodilov AA, Berengarten MG, Pushnov AS 2016 Theoretical Foundations of Chemical Engineering 50(3) 325-334
[11] Gorodilov AA, Berengarten MG, Pushnov AS 2016 Theoretical Foundations of Chemical Engineering 50(4) 422-429.
[12] Mitin AK, Nikolaikina NE, Pushnov AS, Zagustina NA 2016 Chemical and Petroleum Engineering 52(1) 47-52
[13] Klyushenkova MI, Kuznetsova NA, Pushnov AS, Berengarten MG, Mokrousova EA 2014 Chemical and Petroleum Engineering 50(7-8) 508-512
[14] Gorodilov AA, Pushnov AS, Berengarten MG 2014 Chemical and Petroleum Engineering 50(1-2) 84-90
[15] Pushnov AS, Sokolov AS, Sidel’nikov II, Kurbatova EA, Mitrofanova EG 2014 Chemical and Petroleum Engineering 50(5-6) 330-334
[16] Chizh, KV, Pushnov, AS, Berengarten MG 2014 Chemical and Petroleum Engineering 50(3-4) 244-250
[17] Berengarten MG, Nevelson AO, Pushnov AS 2013 Chemical and Petroleum Engineering 48(11-12) 723-729
[18] Shilin MV, Berengarten MG, Pushnov AS, Klyushenkova MI 2013 Chemical and Petroleum Engineering 48(9-10) 608-614
[19] Mitin AK, Valdberg AY, Pushnov AS 2012 Chemical and Petroleum Engineering 48(1-2) 50-53
[20] Tsurikova NP, Pushnov AS, Lagutkin MG, Shishov VI 2012 Chemical and Petroleum Engineering 48(1-2) 3-8
[21] Kagan AM, Pushnov AS 2012 Russian Journal of Applied Chemistry 85(3) 523-526