COMPARISON OF THE EFFECTIVE SURFACE AREA OF SOME HIGHLY EFFECTIVE RANDOM PACKINGS THIRD AND FORTH GENERATION

Nikolai Kolev, Svetoslav Nakov, Ljutzkan Ljutzkanov, Dimitar Kolev
Institute of Chemical Engineering, Bulgarian Academy of Sciences, Acad. G. Bonchev St., Bl.103, 1113 Sofia, Bulgaria, Phone: (359-2)870-40-19, Fax: (359-2)870-75-23,
E-mail: kolev@bas.bg

The effective surface area ae of 14 variants of three highly effective types of packings (IMTP, Raschig Super-Ring (RSR) and Ralu-Flow) made of stainless steel or plastic is investigated as a function of the liquid superficial velocity. The packing size varied from 20 to 70 mm, and the liquid superficial velocity from 5 and 200 $m^3/(m^2h)$. The comparison of the obtained data shows the following:

Among all investigated packings at comparable values of the specific area and the liquid superficial velocities, the metal Raschig Super Rings have the highest effective area. They have also the lowest pressure drop at the same effective surface area and gas velocity.

At comparable values of the specific area and the liquid superficial velocities the effective surface areas of plastic Ralu-Flow and plastic RSR are practically the same, but the first of them have lower pressure drop at the same gas velocity and effective surface area.

KEYWORDS: packed bed column, effective surface area, pressure drop, comparison, different packings, RSR, IMTP, Ralu-Flow

INTRODUCTION

It follows from the theory of mass transfer processes, the models of Hiegbe[1], Danckwerts [2], Kishinevski [3,4] and Levich [5], that the decrease of the length of the liquid films flowing downwards over the elements of the packings leads to an increase of the mass transfer coefficient in the gas and in the liquid phase. As the length of the films is connected with the length of the packing elements, or more precisely with the width of the lamellas of which these elements consist, the decrease of this width leads to an increase of the mass transfer coefficient [6]. The investigation of the effect of the height of the ring-form elements and of standard Raschig rings on the liquid and gas side controlled mass transfer coefficient [7,8] confirms this theoretically obtained result. Moreover the reduction of the length of the packing elements leads to reduction of the pressure drop too. For this reason practically all novel types of random packings, consist of small width lamellas. Among them the Raschig Super-Rings, IMTP and Ralu-Flow are especially appropriate for packed bed columns because of their high mass transfer coefficients and low pressure drop [9–16].

A very important performance characteristic of each packing is its effective surface area. Up to now there are no data and no comparison of the effective surface areas of these packings. The aim of the present paper is to fill up this gap.

INVESTIGATED PACKINGS

Because of the significant influence of the packing material on the effective surface area, packings made of stainless steel and plastic, the most largely used materials for this purpose, are studded. In Figures 1–3 photographs of the investigated packings are presented.

The type, the material and the geometrical characteristics of the investigated packings are given in Table 1.

Figure 1. RSR metal packing

Figure 2. IMTP metal packing

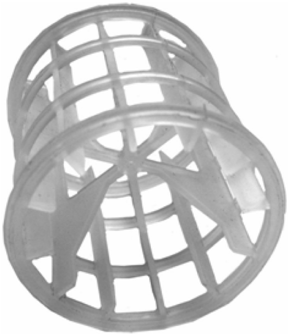

Figure 3. Plastic Ralu-Flow

EXPERIMENTS

The investigations are carried out using the method of Danckwerts [17–19], with absorption of CO_2 in water solution of NaOH. In detail it is considered in [20], at gas (air) velocity, equal to 1 m/s. Parallel to the measurements of the effective surface area, the pressure drop of the packing is also investigated by using a differential manometer, with accuracy 0.1 Pa. The experimental installation is described in [20]. The column diameter was 470 mm. The height of the packing in all experiments was 2400 mm.

Table 1

Name	Material	Surface area m^2/m^3	free Vol %	Nom. diam. mm
Raschig Super-Ring No. 0.5	metal	236.2	96	20
Raschig Super-Ring No. 0.7	metal	175.9	97	25
Raschig Super-Ring No. 1	metal	155.5	98	30
Raschig Super-Ring No. 1.5	metal	105.8	98	38
Raschig Super-Ring No. 2	metal	100.6	98	50
Raschig Super-Ring No. 3	metal	74.9	98	70
IMTP 25	Metal	242.8	97	25
IMTP 40	Metal	171.6	97	40
IMTP 50	Metal	107.1	98	50
IMTP 70	Metal	69.1	98	70
Ralu-Flow No.1 PP	Plastic	177	95	25
Ralu-Flow No.2 PP	Plastic	98.4	95	50
Raschig Super-Ring No. 0.6	Plastic	206.3	96	25
Raschig Super-Ring No. 2	Plastic	117.2	96	50

A special liquid phase distributor ensuring liquid superficial velocity in the packing from 5 to 200 $m^3/(m^2h)$, distributed in 923 drip points per m^2, was used. The concentration of the NaOH in the liquid phase was kept constant by feeding of concentrated NaOH from a Mariott vessel.

DATA FOR THE EFFECTIVE SURFACE AREA

The data for the effective surface area a_e for all investigated packings versus liquid superficial velocity L are represented in Figures 4–7. The comparison of the data for a_e

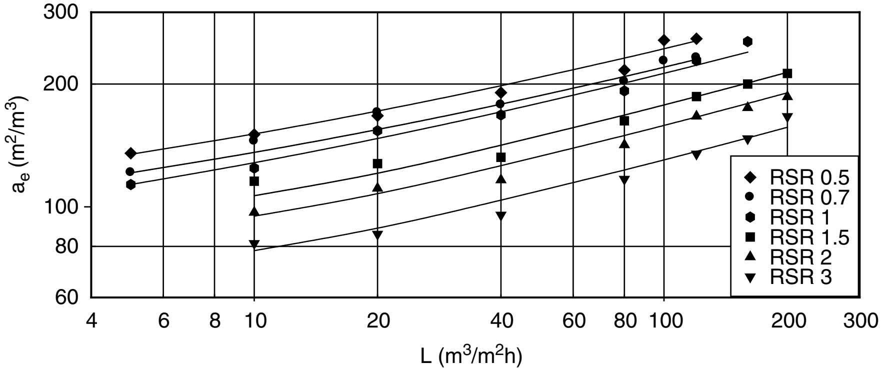

Figure 4. Effective surface area of the investigated metal RSR versus the liquid superficial velocity

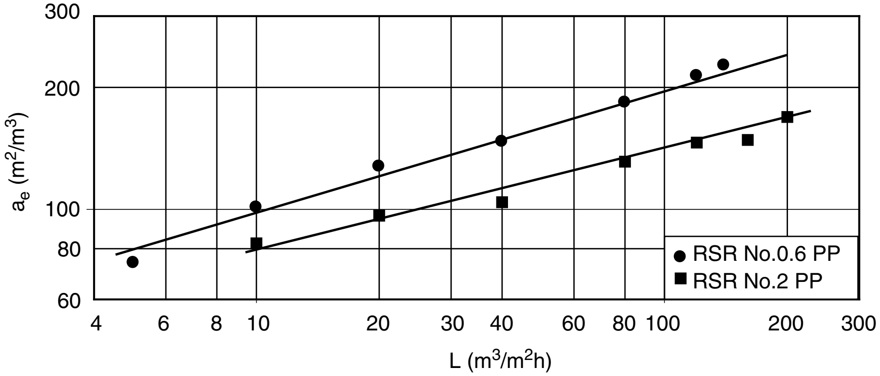

Figure 5. Effective surface area of the investigated plastic RSR versus the liquid superficial velocity

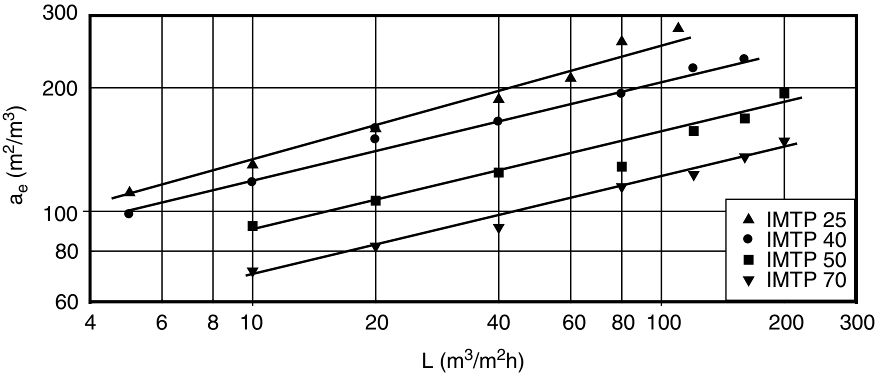

Figure 6. Effective surface area of the investigated metal IMTP versus the liquid superficial velocity

with the specific surface area a of the corresponding packings shows, that at the maximal investigated liquid superficial velocity used for each of them a_e is greater. That is the ratio a_e/a at sufficiently high liquid superficial velocity reaches values greater than 1. That means that the effective surface of the drops and jets trickling in the free volume of the packing is significant.

The data for metal RSR No. 3, Figure 4, shows that even at $L = 10\ m^3/(m^2h)$ the effective surface of this packing is some higher than its specific surface area. At $L = 200\ m^3/(m^2h)$ its effective surface is more than two times higher than its specific

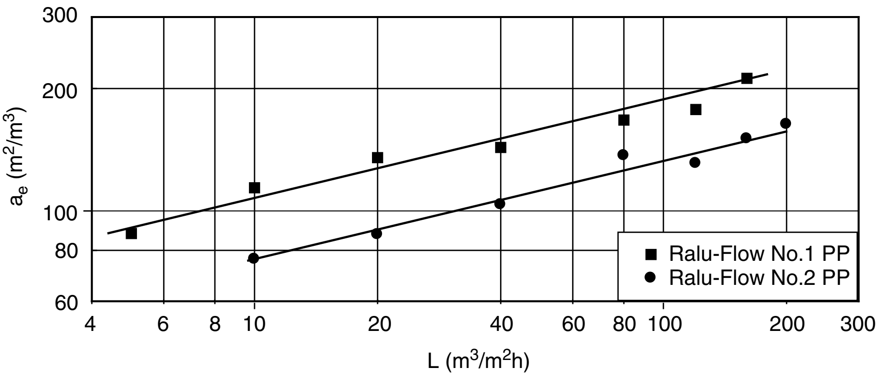

Figure 7. Effective surface area of the investigated plastic Ralu-Flow versus the liquid superficial velocity

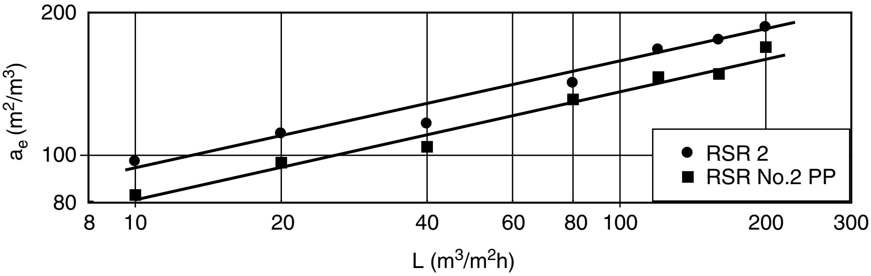

Figure 8. Comparison of the effective surface of RSR No. 2 of metal and of plastic

one. It must be mentioned that for the most of the packing types, Figures 5, 6 and 8 for the smallest packing elements the line in coordinates $a_e = f(L)$ has greater angle of inclination. Probably it is connected with different increasing of the area of jets and drops trickling in the packing void fraction, as well as of the wetted surface area, with increasing of the liquid superficial velocity. For the Ralu-Flow packing such a difference in the angle of inclination is not observed.

COMPARISON OF THE DATA FOR DIFFERENT PACKINGS

The influence of the packing material can be seen in Figures 9–11, where a comparison between the effective surface of metal and plastic RSR with one and the same dimensions for each of the materials is presented.

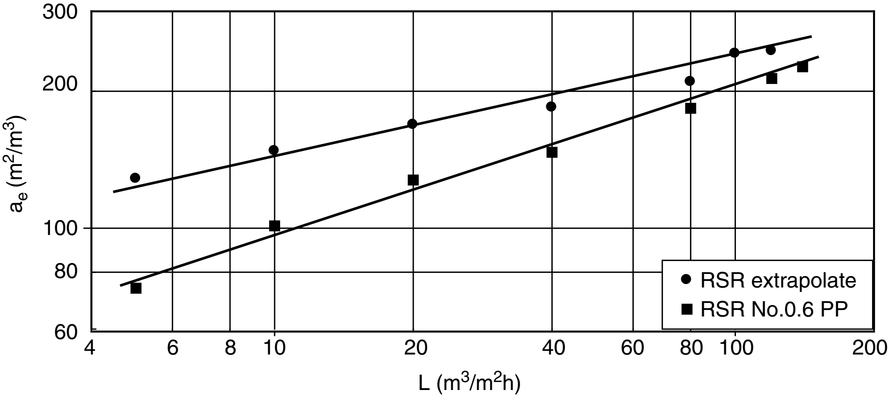

Figure 9. Comparison of the effective surface of RSR No. 0.6 of plastic with extrapolated data for the same packing of metal

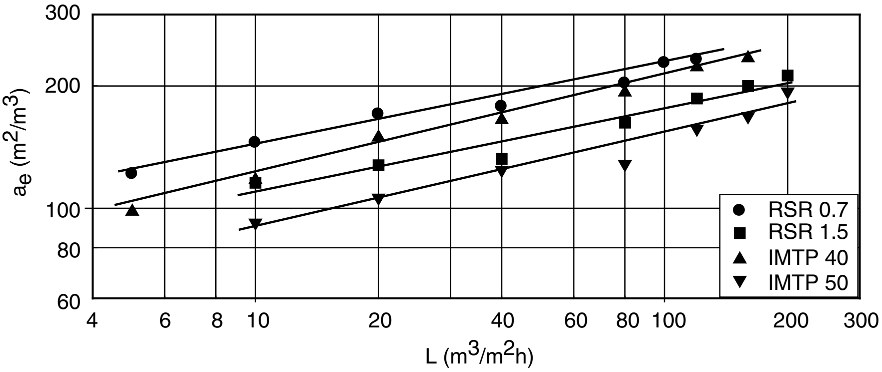

Figure 10. Comparison of metal RSR and metal IMTP

The comparison in Figure 8 shows that the effective surface of the plastic packing is only with about 15% lower.

Because the effective surface area of the drops and jets trickling in the packing free volume is practically not dependent on the packing material and because the effect of this surface is greater in case of greater packing elements, it is expected that the influence of the wettability of the material is greater in case of smaller elements. In Figure 9 a comparison of the effective surface for metal and plastic RSR No. 6 is made. Since there are no data for metal RSR No. 6, the data used in Figure 9 are extrapolated from the data for metal RSR No. 0.5 and No. 0.7.

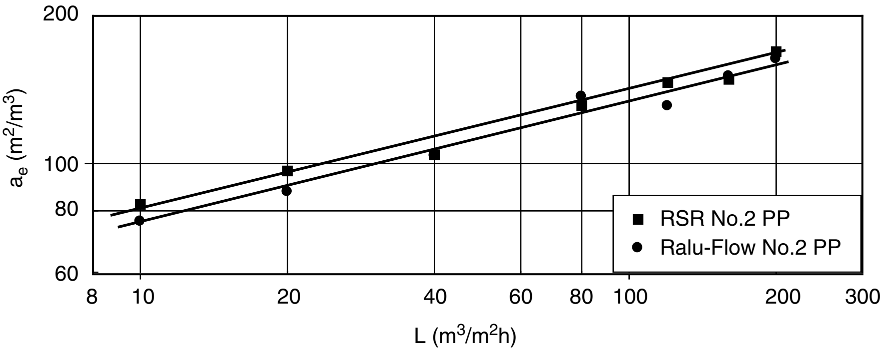

Figure 11. Comparison of the effective surface of plastic RSR. No. 2 and Ralu-Flow No. 2 PP versus liquid superficial velocity

The comparison shows that the effective surface area of metal RSR is between 12% and 43% higher. The lower % is at higher liquid superficial velocity.

In Figure 10 a comparison of the metal RSR and IMTP with practically one and the same specific surface area is presented. The first pair is RSR No. 0.7 and IMTP 40, with specific surfaces 175 and 171 m^2/m^3 respectively. The second one is RSR No. 1.5 and IMTP 50, with specific surfaces 105.8 and 107.7 m^2/m^3. The comparison shows, that the effective surface of the RSR is about 15% higher. This difference is connected with the different form of the two packings and mostly with the special forming of the end lamellas of the IMTP so that each of these lamellas consists practically of two perpendicular lamellas. The surface of these complicated end lamellas is about 28.8 to 49% of the whole surface of the packing depending on the size of the packing elements. In case of RSR all lamellas are simple. The flowing of the liquid in the two cases is different. To explain easier this difference, let us consider the results of investigations [21] carried out for modeling the leakage of the liquid phase in packings. It was found that on the bottom part of an irrigated well wettable vertical plate a long liquid drop is formed. Its height is about 5 mm in case of irrigation with water. That means that the bottom part of the vertical plate is fully wetted, because of capillary forces. Simple experiments show also, that narrow, well wettable lamellas, on which the liquid is flowing, are completely wetted from both sizes with moving liquid. The reason is that because of capillary forces the liquid can not break off the lamellas. If a given lamella is replaced by a profile consisting of two perpendicular lamellas with a common long side, the vertical one is not wetted. That is why packings with such complicated forms, as for example IMTP are less wetted.

The comparison between the effective surface of plastic RSR and Ralu-Flow, packings with close specific areas, is presented in Figure 11 (for RSR No 2PP and Ralu-Flow No. 2 PP) and Figure 12 (for RSR No. 0.6 and Ralu-Flow No. 1 PP). The specific surface areas for the first two packings are 117.2 m^2/m^3 for RSR and 98.4 m^2/m^3 for the Ralu-Flow. For the second two packings there are 206.3 and 177 m^2/m^3 respectively. In the first case the effective surface area of RSR is about 8% higher for all liquid superficial velocities. In the second, at low liquid superficial velocities it is about 11% higher, and at high values of L up to 11% lower. Because the comparable packings have not exactly the same values of the specific surface, it is difficult to tell which packing form is more proper to obtain higher effective surface.

The comparisons of the investigated packings show also that the pressure drop of IMTP 40 is higher with 35% and more than this of RSR No. 0.7 and RSR No. 1. The specific surface area of IMTP 40 is between these of the two RSR packings used for comparison. Similar results are obtained by the comparison between the packings IMTP 50 and RSR 1.5.

The comparison of the pressure drop of the plastic packings Ralu-Flow No.2 PP and RSR No.2 PP, which have close specific surfaces, shows that the pressure drop of the Ralu-Flow is between 23 and 40% lower (under the loading point) than this of the corresponding RSR. Over the loading point the difference is bigger.

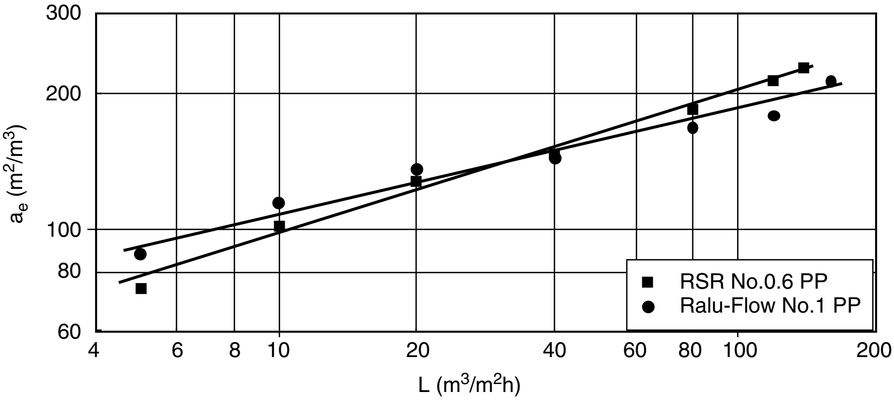

Figure 12. Comparison of the effective surface of plastic RSR No. 0.6 and Ralu-Flow No. 1 PP versus liquid superficial velocity

A comparison of all investigated metal packings with all plastic ones shows, as expected, that at the same specific surface and liquid superficial velocity, the metal packing has greater effective surface area and lower pressure drop.

NOMENCLATURE

a_e	effective surface area of the packing, m^2/m^3;
K_G	mass transfer coefficient, m/s;
K_Ga	volumetric mass transfer coefficient, 1/s;

GREEK SYMBOLS

ΔP	pressure drop per 1 m height of packing per, Pa/m;

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