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Contribution to Heat Transfer Study in Reactors with Fixed Particles Bed

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Abstract

The heat transfer between effluent and walls of fixed particles beds reactors is influenced by many factory which depend on the characteristics of particles beds and fluid conditions.
In many industrial types of equipment in the chemical and petrochemical industry for heat transfer there are used spherical particles beds.
This paper presents an experimental study for the determination of heat transfer coefficient between the interior of the reactor and reactor wall.

Key words: *heat transfer, spherical particles beds, catalytic reactors*

Introduction

The paper presents an experimental study to calculate the partial convective heat transfer coefficients in a tube in a tube heat exchanger. Also, the paper aims to put in evidence, based on experimental data the validation of this experimental results and than, application of the various relationships for calculating specific criteria number recommended by the literature.

Experimental work

Determinations were made for spherical particles that are made of ceramics and glass. The experimental lab unit comprising: a furnace, a tube in a tube heat exchanger, spherical particles as packing and two rotameters. For each circuit (cold and hot circuit) are used was suitable rotameters and for hot water network is included an hot oven.

Experimental calculations have been lead in three main directions:
A - determinations for transmission of the heat in a tube in tube apparatus, without packing;
B - experimental work, using ceramic packing in the interior of the tube;
C - experimental determinations, using glass as packing into tube in tube exchanger.

For all these cases, there are two flows moving in opposite directions (the countercurrent exchange system): the flow of cold stream (cold water circulating in the ring space) and flow of hot stream (hot water, which circulates through the inner tube).
To calculate the partial heat transfer coefficients have been considered three relationships.
All these relationships are applicable to the laminar flow, checked by experimental determinations.
The calculating relationships used are following [1-5]:

$$Nu = 0.475(\mathrm{Re}\cdot \mathrm{Pr})^{1/3}\left(\frac{\mu}{\mu_p}\right)^{0.14} \tag{1}$$

$$Nu = 1.86(\mathrm{Re}\cdot \mathrm{Pr}\cdot d/L)^{1/3}\left(\frac{\mu}{\mu_p}\right)^{0.14} \tag{2}$$

$$Nu = 0.74\cdot f\cdot \mathrm{Re}^{0.2}\cdot \mathrm{Pr}^{0.3}\cdot Gr^{0.1} \tag{3}$$

Relationships 1 and 2, Sieder – Tate equations and take account of the sizes of exchanger, meaning the length L = 1 m and the interior diameter of the tube small d = 0,026 m, and to simplify the calculations this simplex $\left(\frac{\mu}{\mu_p}\right)^{0.14}$ was approximated with 1 [$\left(\frac{\mu}{\mu_p}\right)^{0.14}$ = 1].

Relationship (3) uses the relatively stable Aladiev, and the Grashof term appears and it is specific to free convective heat transfer. This relationship is applied to the $\mathrm{Re}\cdot\mathrm{Pr} > 1800$, and f term is called correction factor that characterizes the current stabilization of fluid, which depends on the ratio

L / d. In this work for the length of heat exchanger equal to 1 m, from literature data, f chosen was 1,026 [1].

Flow measurements and stream temperatures have made for each case study (A, B and C), and the temperatures were measured to the entry and the exit of the heat exchanger.

Results

The following ten tables presents the results obtained in applying the three relationships described previously. Table 1 presents the results for the first case considered, when the tube is empty. The values of the flows are constant for the three relationships calculating. In Table 2 are given the partial heat transfer coefficients produced for the relationships (1) and (2).

Table 1. The results obtained in the empty tube case

No. det.	**V_c, l/h**	**V_r, l/h**	**tc_1, ^0C**	**tc_2, ^0C**	**tr_1, ^0C**	**tr_2, ^0C**	**Q lost, W**	**Q receive, W**	**w, m/s**	**Re**	**Pr**
A1	62	18	69	55	17	61	992	909	0.032	1672	3.16
A2	63	11	69	58	17.5	61	791	549	0.033	1699	3.15
A3	60	32	71	50	16	49	1441	1216	0.031	1613	3.18

Table 2. Heat transfer coefficients option A for Sieder-Tate realationships

No.det.	**Relationship 1**			**Relationship 2**		
	Nu 1	**α_i, W/m$^2\cdot{}^0$C**	**tp_i, ^0C**	**Nu 2**	**α_i, W/m$^2\cdot{}^0$C**	**tp_i, ^0C**
A1	8.27	209	4	9.59	242	12
A2	8.31	210	18	9.64	244	23
A3	8.19	206	-25	9.50	240	-13

Relationship (3), where Grashof criteria is involved, is developed with the assumption of a temperature inside of the tube, value that has to be checked. The following tables show only the amount of temperature that has been verified for all three variants (A1, A2, A3). Literature recommends the fluid flows through a tube vertically, as the coefficient obtained for the partial transfer of heat to be multiplied by 0.85 when fluid flows from top to bottom and are cooled, as in the case reviewed.

Table 3. Heat transfer coefficients option A for the Aladiev relationship

No.det.	**tp_i supposed, ^0C**	**Δt, ^0C**	**Gr**	**Nu 3**	**α_i corrected, W/m$^2\cdot{}^0$C**	**tp_i calculated ^0C**	**tp_e, ^0C**
A1	53	9	$2.16\cdot10^{11}$	63.44	1372	53.15	52
A2	56	7.5	$1.95\cdot10^{11}$	63.00	1365	56.44	55
A3	48	12.5	$2.86\cdot10^{11}$	65.21	1408	48.03	47

In tables 4-9 are presented the results obtained for other work directions, B and C. The values of the heat transfer coefficients calculated are too small and values for the temperature inside the wall does not have physical significance.

Table 4. The results obtained for ceramics packing

Det. number	V_c, l/h	V_r, l/h	tc_1, ^{0}C	tc_2, ^{0}C	tr_1, ^{0}C	tr_2, ^{0}C	Q Losted heat, W	Q Received heat, W	w, m/s	Re	Pr
B1	57	19.5	49	39	19.6	44	665	548	0.029	1288	3.92
B2	49	19	56	42	19.8	51	787	682	0.026	1195	3.59
B3	59	18	50	41	19.7	47	610	566	0.031	1366	3.81

Table 5. Heat transfer coefficients - option B for Sieder-Tate relations

Determination number	Relations 1			Relations 2		
	Nu 1	α_i, W/m^2·^{0}C	tp_i, ^{0}C	Nu 2	α_i, W/m^2·^{0}C	tp_i, ^{0}C
B1	8.15	199	3.9	9.45	231	9.4
B2	7.72	191	-1.4	8.95	221	5.6
B3	8.23	202	8.7	9.55	234	13.7

Table 6. Heat transfer coefficients option B for Aladiev relation

Det. number	tp_i supposed, ^{0}C	Δt, ^{0}C	Gr	Nu 3	α_i corrected W/m^2·^{0}C	tp_i calculated ^{0}C	tp_e, ^{0}C
B1	37	7	$7.91 \cdot 10^{11}$	58.91	1225	37.5	36.8
B2	41	8	$1.17 \cdot 10^{11}$	58.76	1234	41	40.4
B3	39.5	6	$0.74 \cdot 10^{11}$	58.67	1224	39.5	38.8

Table 7. The results obtained for glass packing

No. det.	V_c, l/h	V_r, l/h	tc_1, ^{0}C	tc_2, ^{0}C	tr_1, ^{0}C	tr_2, ^{0}C	Q lost, W	Q receive, W	w, m/s	Re	Pr
C1	78	28.5	50	39	13.5	42.5	986	954	0.041	1777	3.88
C2	50	28.5	71	40	13.5	51	1775	1231	0.026	1309	3.29
C3	32	28.5	78	31	13.5	56	1723	1393	0.017	831	3.33

Table 8. Heat transfer coefficients - option C for Sieder-Tate realationship

Det. number	**Relation 1**			**Relation 2**		
	Nu 1	**α_i, W/m$^2\cdot{}^0$C**	**tp$_i$, ^{0}C**	**Nu 2**	**α_i, W/m$^2\cdot{}^0$C**	**tp$_i$, ^{0}C**
C1	9.04	222	-9.81	10.48	257	-2.32
C2	7.73	193	-56.5	8.97	224	-41.1
C3	6.67	166	-71.7	7.74	193	-54.3

Table 9. Coefficients of heat transfer option C for the Aladiev relationship

Det. number	**tp$_i$ suppose, ^{0}C**	**Δt, ^{0}C**	**Gr**	**Nu 3**	**α_i corected, W/m$^2\cdot{}^0$C**	**tp$_i$ calculated ^{0}C**	**tp$_e$, ^{0}C**
C1	35.5	9	$1.04\cdot10^{11}$	64.42	1341	35.53	34.6
C2	39.5	16	$3.03\cdot10^{11}$	64.14	1363	39.62	37.8
C3	37.5	17	$3.12\cdot10^{11}$	58.95	1251	37.69	35.8

The values of the *Nu* number calculated with relationship (3) were compared with the experimentaly *Nu* values for the three variants (A, B, C) are presented in Table 10.

The graphical representation of these values is shown in Figure 1.

Table 10. *Nu* number values calculated and determined experimentally

Variant	**Det. number**	**Nu calculated**	**Experimental Nu**
A	1	63.44	54.32
	2	63.00	53.93
	3	65.21	55.87
B	1	58.91	50.10
	2	58.76	49.94
	3	58.67	49.87
C	1	64.42	54.75
	2	64.14	54.52
	3	58.95	50.10

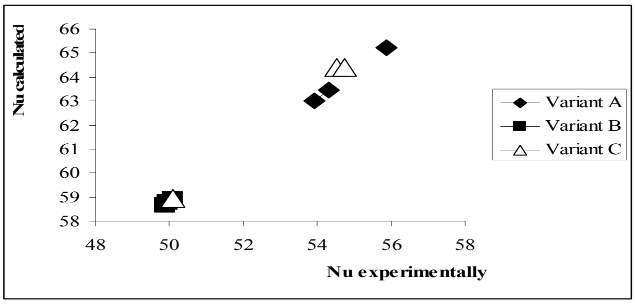

Fig.1. Corelations between Nu number

Conclusions

It notes that the values of heat transfer coefficients calculated on the basis of experimental data are different of those calculated with Sieder-Tate relationships. For Sieder-Tate relationships, the values obtained for the temperature inside the tube are too small to be applied. This is the reason that the temperatures outside of the tube were not calculated. As regarding Aladiev the relationship, relationship (3), is remarked the influence free convective flow**,** the laminar flow through vertical tubes, is modified profile speed of the fluid. Here, speed is no longer maximum spindle, the maximum being seen near the wall. The values of the heat transfer coefficients are greater when using Aladiev relationship. Diagrams in Figures 2 - 4 presents the comparison of the Nu number calculated and experimental Nu values.

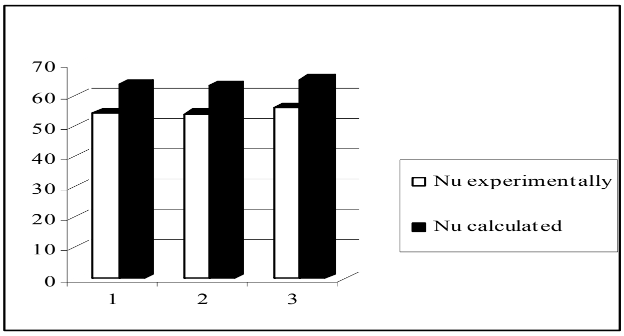

Fig.2 Correlation between Nu calculated and experimental Nu values (variant A)

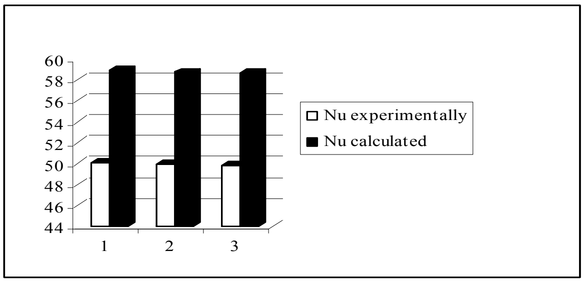

Fig.3 Correlation between Nu calculated and experimental values (variant B)

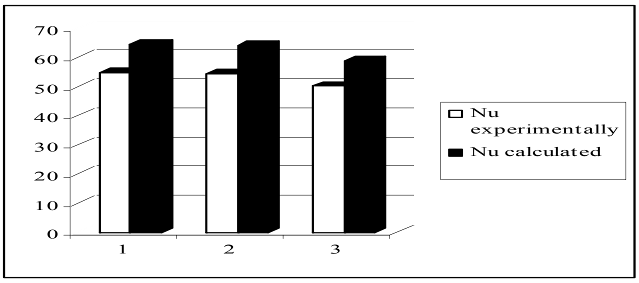

Fig.4 Correlation between Nu calculated and experimental Nu values (variant C)

It notes that the partial heat transfer coefficients in the use of small ceramic packing, compared with values obtained for glass packing. Directions for future research are conducted to use several types of packing: either spherical shapes made from other materials or the other geometrical shapes.

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Contribuţii la studiul transferului de căldură în reactoarele cu strat fix de particule

Rezumat

În reactoarele cu straturi fixe de catalizator, transferul de căldură între efluent şi pereţii rectoarelor este influenţat de mai mulţi factori care depind de caracteristicile straturilor de particule şi condiţiile efluentului.In multe utilaje din industria chimică şi petrochimică pentru îmbunătăţirea transferului de căldură se folosesc particule sferice.Lucrarea prezintă un studiu experimental privind calculul coeficientului de transfer de căldură între interiorul şi peretele reactoarelor.