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STUDY OF HYDRODYNAMIC REGIMES IN INTERNAL PIPE PROFILES IN SHELL-AND-TUBE HEAT EXCHANGERS

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Abstract
In the article, a new design of the inner pipe profile is recommended for shell-and-tube heat exchangers used in heat exchange processes in chemical industries. In the development of the structure, spherical concave and spherical linear pipe profiles were selected, and a systematic analysis of their operating parameters was carried out and intermediate limits were determined. The hydrodynamic regimes of the proposed spherical concave pipe profile are investigated. In the experiments, depending on the change of the spherical concave radius, it was determined that the liquid consumption is Q=0.055-0.297 m3/h and the flow regime is in the range of 46535 ÷ 35089. Empirical formulas were obtained for the experimental results using the method of least squares.

Keywords: flow mode, consumption, speed, model, visual state, systematic analysis, pipe, spherical tube, spherical tube, cooling agent.

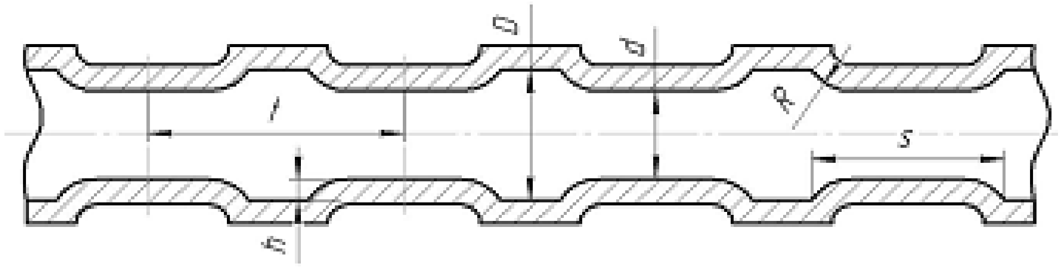
Introduction

The effects of internal pipes and heat exchanger zones on the heat exchange process and the phenomena occurring inside the device in the shell-and-tube heat exchanger used in chemical industry enterprises were analyzed, and the visual status was considered based on the MATLAB program [1]. Spherical protruding and spherical concave profiles of the inner pipe were selected for the ridge analysis [2,3,4]. In the conducted systematic analysis, it was determined that the temperature of the heated and heated products in the zones of the heat exchanger with a countercurrent flow changes over time. As we move from zones to zones, the temperature of the cold liquid increases and the temperature of the hot liquid decreases. Using the results of the analysis, it was proved that it is possible to choose the optimal length of the pipe or the heat exchange surface, and at the same time, the optimal dimensions of the heat exchanger device. As the number of zones increases, the accuracy of the model increases. But it caused an increase in hydraulic resistance. This method of systematic analysis made it possible to accurately calculate the heat exchange system and process [5,6,7]. The results of the systematic analysis of the analyzed pipe profiles and the basis of their parameters showed that at both hierarchical levels, the process of mutual heat exchange between the product and the cooling agent was much better in the spherical concave tube than in the spherical outlet tube. However, the irregularity of the flow regime in the spherical concave pipe caused inconveniences when using the pipe. This, in turn, is related to the construction of the pipe.

Methodology

Based on the results of the linear analysis, an improved structural scheme of the spherical concave pipe profile was developed (Fig. 1).

The advantage of the proposed spherical concave pipe over existing pipes is that, firstly, the spherical concave*S*The length of the cooling agent ensures an increase in the flow regime. Conversely, the inner diameter of the pipe *D* disrupts the flow regime, which in turn causes an increase in the resistance inside the pipe. As a result, the heat exchange process accelerates.



D and d-Pipe internal diameters; S- Spherical concave length: h- Spherical concave height; R-Spherical Concave Radius; t- The distance to the centre of two spherical concavities

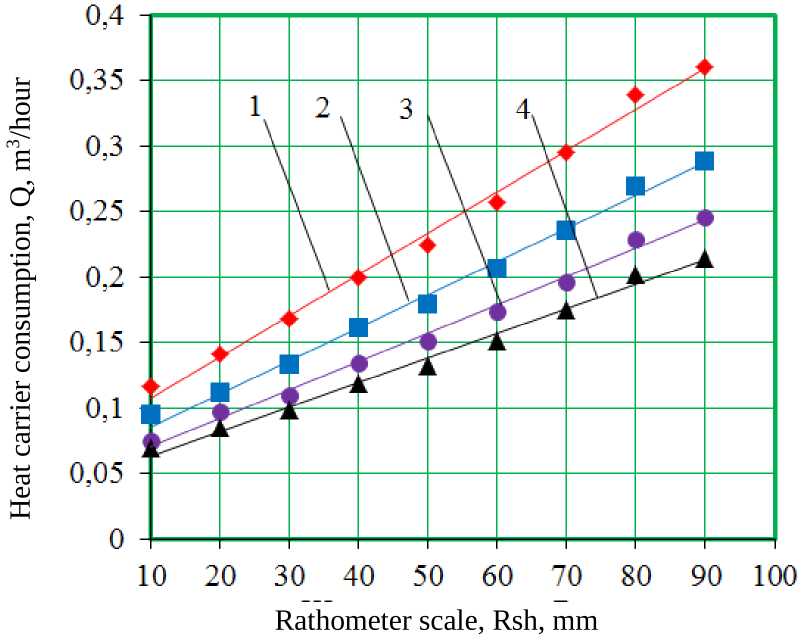
Figure 1. The design scheme of the proposed spherical concave pipe.

However, not enough research has been conducted on the effect of hydrodynamic regimes on the heat exchange process in the pipe of this profile. Therefore, this research work is aimed at studying the hydrodynamic regimes of the proposed spherical concave pipe [8-14].

In order to conduct experimental studies, the following plans were included in the research work in order to study the influence of variable factors on the hydrodynamic regime and heat exchange intensity in the device.

- making an improved profile of a spherical concave tube to a laboratory setup of a shell-and-tube heat exchanger for conducting experimental studies;
- experimental determination of cooling agent consumption and flow regimes;
- study of the effect of the flow regime on the heat exchange process;
- justify the optimal values of the construction parameters.

Experimental studies were conducted in two stages. In the first stage, the device is given a method of experimental determination of cooling agent consumption in the ferric concave pipe. Centrifugal pump for conveying the cooling agent in the shell-and-tube heat exchanger (7) Q_{max}=40 l/min; N_{dv}=0.37 kW; h_{max}=38m; V=220V; n_{rpm}=3000rpm/min according to GOST-2757030-91, rotometer 24 (RS-5; scale indicators in the range 0÷100; according to GOST-13045-81), spherical concave pipe (length l=800 mm and d=10 mm) and the full volume of the beaker was chosen to be 3.2 l. Fluid consumption and rate were determined using the volumetric method. For this, the filling time of the beaker was determined according to the rotometer readings 0÷90, and the fluid consumption and speed were determined using existing calculation methods [15-21]. Experimental studies were carried out with the following parameters of the pipe profile, that is, the length of the spherical recess S=25 mm, the radius of the spherical recess R=10; 20 and 30 degrees, the inner diameter of the pipe is D=10 mm and d=7 mm. The general experimental results are presented in Appendix V. Each experiment was repeated 5 times, and a graph of the change of heat exchange agent consumption depending on the rotameter scale indicators was constructed (Fig. 2). The experimental error did not exceed 5%.



1-Total consumption of liquid pump; 2– when R=10 g and pipe resistance is 1.25; 3– when R=20 g and pipe resistance is 1.48; 4– when R=30 g and pipe resistance is 1.68;

Figure 2. Dependence of heat exchange agent consumption on rotameter scale indicators

From the data given in Figure 2, it can be seen that for each case, when the rotometer scale indicators change from 0-90, the total consumption of the pump is Q=0.073-0.360 m^3/h, when the spherical concave radius is R=10 degrees liquid consumption Q=0.058-0.288 m^3/h when the spherical concave radius is R=20 degrees liquid consumption Q=0.049-0.246 m^3/h, and when R=30 degliquid consumption changed to Q=0.043-0.214 m3/h. The consumption change in each indicator increased with an average step of 0.03 m^3/h.

Using the method of least squares, the following empirical formulas were obtained for the results [7].

y = 0,0032x + 0,0747 R^2 = 0,9991 (1)

y = 0,0029x + 0,0645 R^2 = 0,9979 (2)

y = 0,0026x + 0,065 R^2 = 0,996 (3)

y = 0,0022x + 0,0686 R^2 = 0,9912 (4)

The method of determining the mode of flow of the cooling agent in a spherical concave pipe. Using the above experimental results, the speed of the heat exchanger moving inside the spherical concave pipe and its flow regimes were determined using the equation for determining the flow regime at the consumption, and a graph of the dependence of the heat exchanger flow regime on its speed was constructed (Figures 3, 4 and 5). Values of the speed of the heat exchange agent are given in Table 1. According to it, the fluid consumption is determined according to the following equation,m^3/hour [22,23];

$$Q = \omega \pi R^2 3600 \qquad (5)$$

in thisR^2-Diameter of the pipe through which the liquid flows, mm;ω- Liquid velocity, m/s; π-3.14.

From the equation (3.5), we determine the fluid velocity. In that case, the equation will look like this, m/s;

$$\omega = \frac{Q}{\pi R^2 3600} \qquad (6)$$

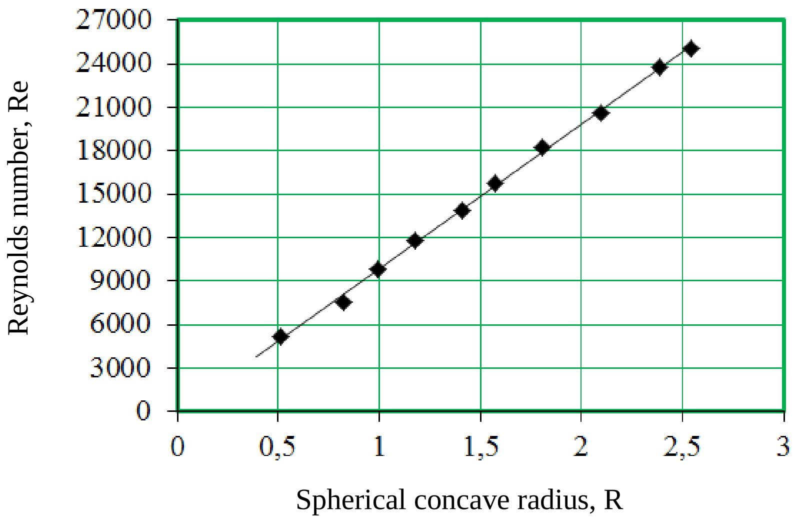
The flow regime of the heat exchange agent moving in the spherical concave pipe is determined according to the following equation;

$$Re = \frac{\omega d}{\nu} \quad (7)$$

where ν is the kinematic viscosity of the liquid, which is calculated as $1{,}006 \cdot 10^{-6}$ Pas and the temperature of the external environment is taken as 20 °C [24-29].

Table 1. Determined values of the speed of the heat exchanger

Rs Indicator name	0	10	20	30	40	50	60	70	80	90
When R=10 g and pipe resistance is 1.25:										
$\upsilon_{liq.}$	0.51	0.82	0.99	1.18	1.41	1.57	1.81	2.1	2.39	2.54
When R=20 g and pipe resistance is 1.48:										
$\upsilon_{liq.}$	0.43	0.69	0.85	1	1.18	1.33	1.52	1.8	1.96	2.16
When R=30 g and pipe resistance is 1.68:										
$\upsilon_{liq.}$	0.39	0.6	0.73	0.89	1.04	1.17	1.37	1.56	1.78	1.88



When R=10 gr-const.

Figure 3. Graph of dependence of the flow mode on the radius of the spherical concave.

From the data given in Figure 3, it can be seen that when the rotometer scale readings change from 0 to 90 for each case,spherical concave radius R=10 degrees const and the flow regime is shown to increase in the range of 5129 ÷25087 when the speed of the heat exchange agent varies depending on the shape of the rotometer, the speed of the heat exchange agent depends on the shape of the rotometer while the flow regime changes3855An increase in the range of ÷18704 was observed. This situation can be explained by the fact that with the increase of the concave radius of the spherical pipe, the hydraulic resistance in the pipe increases, and this, in turn, causes a decrease in the flow regime of the heat exchange agent. This situation makes it possible to fully use the heat exchange agent. But bringing the flow regime as close as possible to the laminar regime has a negative effect on the performance of the device. Using the method of least squares, the following empirical formulas were obtained for the results.

$y = 9904{,}1x - 75{,}253 \qquad R^2 = 0{,}9948 \qquad (8)$

$y = 9973{,}9x - 124{,}78 \qquad R^2 = 0{,}9987 \qquad (9)$

$$y = 10013x - 119{,}07 \qquad R^2 = 0{,}999 \qquad (10)$$

Conclusion

Recently, the acceleration of heat transfer using spherical concave tubes has attracted the attention of many researchers. Such pipe profiles seem to be the most promising solution to the problem of accelerating heat exchange both on the outer surface of pipes and inside them at a comparable rate of increase in hydraulic resistance. Acceleration of the process in shell-and-tube heat exchangers is considered by scientists to be the most effective case of using smooth ring-shaped bumps on the inner surface of the tubes. But the issue of optimizing the hydraulic resistance, developing a method for calculating it and accelerating the heat exchange in the device remains complicated. of clean vapors in spherical concave tubes, including little or no information on the acceleration of heat exchange in the condensation of water vapor, and the available information, for one reason or another, is still widely used in chemical and oil-gas engineering technology does not have a connection. Therefore, it is urgent to carry out a systematic analysis of this type of pipe profiles and to develop a new structural scheme of the pipe, as well as to accelerate heat exchange by studying their hydrodynamic regimes.

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