USE OF SWIRLERS IN HEAT EXCHANGERS

Akhunbaev Adil

Xalilov Ismoiljon

Alizafarov Bekzod

Xusanboyev Muhammadbobur

Ortiqaliyev, Bobojon

Muydinov Abdusamad

Abdulazizov Abdulloh

Xoshimov Avzabek

Fergana Polytechnic Institute, Fergana, Republic of Uzbekistan
E-mail: b.ortiqaliyev@ferpi.uz

Annotation

Shell and tube heat exchangers are one of the most common types of equipment in the chemical and oil refining industries and account for a quarter of all process equipment. Therefore, at present, shell-and-tube heat exchangers of increased thermal efficiency are of great interest on the part of the industry. This is due to the desire to increase the output of manufactured products, reduce the number of heat exchangers for transferring the same amount of heat, and reduce the cost of maintenance and repair of equipment. One of the structural elements that increase the thermal efficiency of shell-and-tube heat exchangers are ring swirlers.

Keywords: chemical and oil refining industries, heat exchangers, design efficiency.

Introduction

The effectiveness of application to shell-and-tube heat exchangers with annular swirlers is explained by the fact that with a slight change in the design of the device. This structural element improves heat transfer conditions, reduces the risk of sedimentation, eliminates stagnant zones and increases the design efficiency factor by about 1.5 times [1-7]. Thus, we can conclude that ring swirlers are a promising element for increasing the efficiency of heat transfer for shell-and-tube heat exchangers.

Research Object and Method

The currently used methods for manufacturing and installing annular swirlers have significant drawbacks. As a result, the annular swirlers manufactured by such methods have a high metal consumption, high manufacturing cost and do not provide the required reliability. Before us there was a need to review existing manufacturing technologies and offer new ones. At the same time, the goal is to simplify the manufacturing technology, reduce the metal consumption, and also increase the manufacturability of the design [8-13].

The designs of the annular swirlers used in the manufacture of heat exchangers have different designs and geometric features. From the whole variety of swirler designs, it is necessary to choose the most effective design. This goal is achieved by introducing new design geometric parameters that ensure the operability of the structure, in accordance with the technological features of production.

The main signs of low manufacturability of swirlers are the unreasonable design accuracy of functional parameters, low accuracy due to imperfect manufacturing technology. Therefore, the task of further increasing the efficiency of the production of shell-and-tube heat exchange equipment by improving the information design and technological support for the production of basic parts, in particular swirlers, is an urgent task [14-22].

Experimental studies of the intensity of heat transfer in the vortex apparatus have been carried out. Hot water with a temperature of 40–60°C and atmospheric air, the temperature of which at the inlet to the apparatus was about 15–25°C, were used as working media. The experiments covered the area of change of Reynolds numbers from 1100 to 4050 in the gas phase, calculated from the average air velocity (per the total cross section of the apparatus). The studies were carried out on an experimental setup, the scheme of which is shown in fig. 1.

The main element of the plant is a direct-flow vortex contact heat exchanger. The heat exchanger is a cylindrical vessel with a diameter of 100 mm and a working area height of 1000 mm. In the upper part of it there are tangential branch pipes for supplying air and hot water. The air supplied from above by a high-pressure fan 5 through tangential pipes 2 enters the working chamber 1, acquires a rotational-translational motion and then goes down along its inner surface. Hot water is also supplied from above tangentially through the swirler3 and moves downward in the form of a liquid film on the inner surface of the apparatus. As a result of such a supply of phases, a swirling highly turbulent gas-liquid flow is formed in the working chamber of the apparatus [23-31].

Next, the rotating gas-liquid flow enters the lower separation part of the apparatus. The gas flow is discharged from the apparatus through the lower axial fitting 10, and the liquid is removed through the side fitting 11 of the hopper-capacity 4.

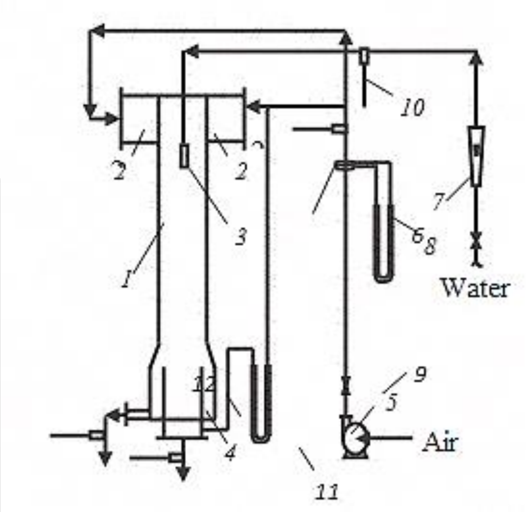

Figure 1. Scheme of the experimental setup:
1 – working chamber of the vortex apparatus; 2 – tangential gas swirlers; 3 – fluid swirler; 4 – hopper-liquid capacity; 5 – fan; 6 – air flow meter; 7 – water flow meter; 8, 9 – differential pressure gauges; 10 – thermocouples; 11 – fitting for gas outlet; 12 – fitting for draining liquid.

During the experiments, the following were measured: air flow rate using a standard diaphragm 6 and a U-shaped differential pressure gauge8; hot water consumption by rotameter 7; pressure drop in the vortex apparatus with a U-shaped differential pressure gauge 9; the temperature of the working media at the inlet to the apparatus and at the outlet of it by thermocouples of the TXK 10 type, connected to the KSP-4 potentiometer. The measurement of hot water and air temperatures was duplicated by glass thermometers, with a division value of 0.1°C.

The experiments were carried out at fictitious (average flow) air velocities w = 6–30 m/s and the mass flow ratios of liquid and gas L/G = 0.5–3. To obtain reliable data, taking into account the probability of a breakthrough of a certain part of the gas with poor contact with the liquid, the experiments for each mode were repeated 4–6 times. In this case, the rms relative error in determining the heat transfer coefficient did not exceed 6–9% [32-38].

The heat load (W) was determined by the heat balance both from the side of the liquid (hot water) Ql and gas (cold air) Qg:

$$Q_l = Lc_j(t_{ln} - t_{gn}) \qquad (1)$$

$$Q_g = Gc_l(t_{gk} - t_{gn}) \qquad (2)$$

where L is the mass flow rate of hot water, kg/s; cl – specific heat capacity of hot water, J/(kg K); tl and tln - hot water temperatures at the inlet to the apparatus and at the outlet of it, °C; G is the mass flow rate of cold air, kg/s; cg is the specific heat capacity of cold air, J/(kg K); tgn and tgk are the temperatures of cold air at the inlet to the apparatus and at the outlet of it, °C.

The results of experiments in which the values of Ql and Qg differed from each other by more than 5% were not subject to processing. (The difference between Ql and Qg by more than 5% is very rare and most likely it is due to measurement errors, and partly to heat losses, although the apparatus was thermally insulated).

The average driving force of heat transfer Δtav, °C, was calculated by the equation:

$$\Delta t_{\text{ср}} = \frac{(t_{\text{жн}} - t_{\text{гн}}) - (t_{\text{жк}} - t_{\text{гк}})}{\ln\left(\frac{t_{\text{жн}} - t_{\text{гн}}}{t_{\text{жк}} - t_{\text{гк}}}\right)} \qquad (3)$$

The results of one of the series of experiments are shown in fig. 2 as a dependence of the surface heat transfer coefficient KF on the fictitious air velocity w at various water flow rates. Water consumption was estimated by the linear irrigation density G, (kg/(m×h).

An analysis of the obtained experimental data showed that with an increase in the gas flow rate and irrigation density, the intensity of heat transfer increases [39-43]. This nature of the change in the heat transfer coefficient is explained by the growth of flow turbulence, the appearance of the relative velocity of liquid and gas, which contributes to the rapid renewal of the surface of the water film [41-47]. However, with an increase in loads both for liquid and gas, the pressure drop in the apparatus increases strongly and, at high values of irrigation density, liquid entrainment appears.

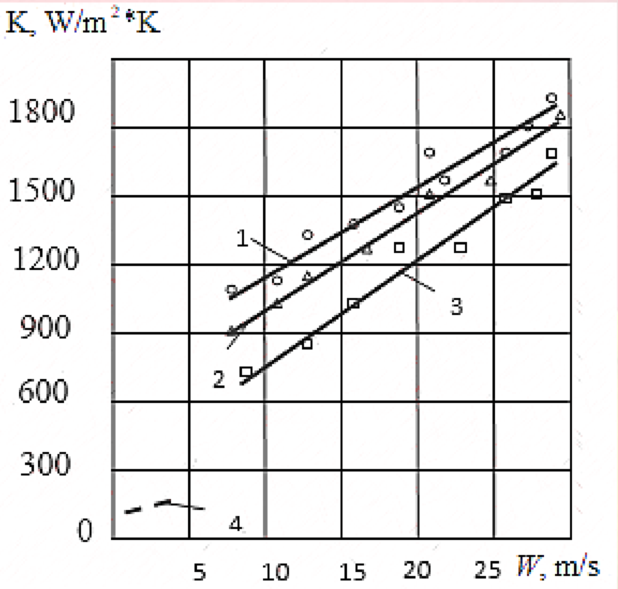

Figure 2. Dependence of the heat transfer coefficient KF on the gas velocity w and irrigation density Г: 1–3 – in the vortex apparatus at Г, kg/(m h): 1 – 2830; 2 - 1380; 3 - 570; 4 – in a packed column at G = 620 kg/(m h)

The obtained values of the heat transfer coefficients in the packed and in the vortex apparatus are compared. As can be seen from fig. 2, the intensity of heat transfer in the vortex apparatus is significantly higher than in the packing apparatus. In addition, the packed heat exchanger operated stably in a narrow range of air velocities, i.e. at 1.5–3.0 m/s. The vortex apparatus operated intensively at much higher gas velocities of 7–30 m/s. In this regard, it was not possible to determine the degree of heat transfer intensification in the form of ratios of heat transfer coefficients in the studied devices.

The processing of experimental data in the form of the dependence of the heat transfer coefficient KF on the ratio of the mass flow rates of liquid and gas L/G confirmed the increase in the intensity of heat transfer with an increase in gas velocity and irrigation density (Fig. 3).

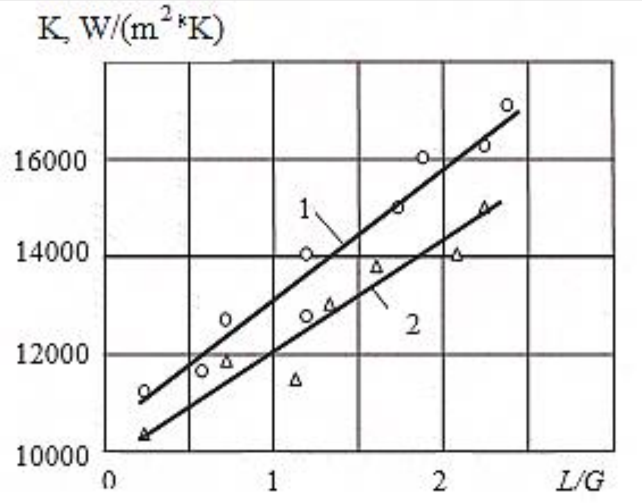

Figure 3. Dependence of the heat transfer coefficient KF on the ratio of mass flow rates of liquid and gas L/G at gas velocity w, m/s: 1 – 22; 2 - 17.

It follows from the analysis of the experimental material that when using highly swirling flows, it is possible to achieve a significant intensification of heat transfer. At the same time, with an increase in the Reynolds number Re, the intensification effect decreases, since at high Re numbers the flow becomes so turbulent that the hydrodynamic effect on heat transfer of disturbances introduced by the swirling flow affects less than the turbulent heat transfer.

The intensity of heat transfer was estimated by surface KF, W/(m2×K), and volumetric KV, W/(m3×K), heat transfer coefficients, which were determined using the basic heat transfer equation:

$$K_F = \frac{Q}{F \cdot \Delta t_{\text{cp}}} \qquad (4)$$

$$K_V = \frac{Q}{V \cdot \Delta t_{\text{cp}}} \qquad (5)$$

where Q is the amount of heat transferred from water to air, W; F is the heat exchange surface equal to the area of the inner surface of the working area of the apparatus, m2; V is the volume of the working area of the device, m3; Δtav is the average temperature difference of heat carriers in the apparatus, °C.

Research results

We have developed a design and manufacturing technology for the swirlers of shell-and-tube heat exchangers, which make it possible to increase the thermal efficiency and manufacturability. In solving this problem, we considered the following main questions:

1. Analysis of methods and structural elements that increase the thermal efficiency of heat exchangers.
2. Study of the influence of design parameters on the functional and technological characteristics of swirlers.
3. Evaluation of the Stressed State of Shells of Heat Exchangers with Swirlers Under the Action of Internal Pressure.
4. Synthesis of swirler designs based on functional and technological analysis of geometric parameters.

Summary

When solving this problem, we:

1. Regularities have been established for the change in the stress state of swirlers under the action of internal pressure, depending on the design parameters, which make it possible to optimize the dimensions of the swirlers, taking into account operating conditions.
2. Based on the hydrodynamic analysis of flows, it is proposed to distribute the flow in the cross section of the heat exchanger and exclude the formation of stagnant zones.
3. Implementation of functional-technological synthesis proposed a new design of the swirler, which allows to increase heat transfer at the entrance to the annular space and reduce hydraulic resistance.

References

1. Askarov, X. A., Karimov, I. T., & Mo'Ydinov, A. (2022). Rektifikatsion jarayonlarining kolonnalarda moddiy va issiqlik balanslarini tadqiq qilish. Oriental renaissance: Innovative, educational, natural and social sciences, 2(5-2), 246-250.
2. Axunboev, A., Alizafarov, B., Musaev, A., & Karimov, A. (2021). Analysis of the state of the problem of ensuring the operation of the rotating units. Barqarorlik va yetakchi tadqiqotlar onlayn ilmiy jurnali, 1(5), 122-126.
3. Tojiyev, R. J., Mullajonova, M. M., Yigitaliyev, M. M., & G'aniyeva, S. G. (2022). Improving the design of the installation for drying materials in a fluidized bed. ACADEMICIA: An International Multidisciplinary Research Journal, 12(1), 214-219.
4. Ахунбаев, А., & Муйдинов, А. (2022). Определение мощности ротора в роторно-барабанном аппарате. Yosh Tadqiqotchi Jurnali, 1(5), 381-390.
5. Tojiev, R., Alizafarov, B., & Muydinov, A. (2022). Theoretical analysis of increasing conveyor tape endurance. Innovative technologica: methodical research journal, 3(06), 167-171.
6. Sadullaev, X., Muydinov, A., Xoshimov, A., & Mamarizaev, I. (2021). Ecological environment and its improvements in the fergana valley. Барқарорлик ва етакчи тадқиқотлар онлайн илмий журнали, 1(5), 100-106.

7. Муйдинов, А. (2022). Экспериментальное исследование затрат энергии на перемешивание. Yosh Tadqiqotchi Jurnali, 1(5), 375-380.
8. Ахунбаев, А., & Муйдинов, А. (2022). Уравнения движения дисперсного материала в роторно-барабанном аппарате. Yosh Tadqiqotchi Jurnali, 1(5), 368-374.
9. Алиматов, Б. А., Садуллаев, Х. М., & Хошимов, А. О. У. (2021). Сравнение затрат энергии при пневматическом и механическом перемешивании несмешивающихся жидкостей. Universum: технические науки, (5-5 (86)), 53-56.
10. Xoshimov, A. O., & Isomidinov, A. S. (2020). Study of hydraulic resistance and cleaning efficiency of dust gas scrubber. In International online scientific-practical conference on" Innovative ideas, developments in practice: problems and solutions": Andijan.-2020.-51 p.
11. Axmadjonovich, E. N., & Obidjon o‘g‘li, X. A. (2022). Experimental determination of hydraulic residence. International Journal of Advance Scientific Research, 2(06), 6-14.
12. Obidjon o‘g‘li, X. A. (2022). Factors affecting the working process of industrial dust gases cleaning apparatus. Yosh Tadqiqotchi Jurnali, 1(6), 7-13.
13. Алиматов, Б. А., Садуллаев, Х. М., & Хошимов, А. О. У. (2021). Кўп поғонали барботаж экстракторида капролактамни икки босқичда экстракциялаш. Фарғона политехника институти илмий– техника журнали. (6), 40-44.
14. Ализафаров, Б. М. (2020). Ecological drying of fine dispersed materials in a contact dryer. Экономика и социум, (11), 433-437.
15. Тожиев, Р. Ж., Садуллаев, Х. М., Сулаймонов, А., & Герасимов, М. Д. (2019). Напряженное состояние вала с поперечным отверстием при совмесстном действии изгиба и кручения. In Энерго-ресурсосберегающие технологии и оборудование в дорожной и строительной отраслях (pp. 273-281).
16. Tojiyev, R., Isomidinov, A., & Alizafarov, B. (2021). Strength and fatigue of multilayer conveyor belts under cyclic loads. Turkish Journal of Computer and Mathematics Education, 12(7), 2050-2068.
17. Ergashev, N., & Halilov, I. (2021). Experimental determination length of liquid film in dusty gas cleaner. Innovative Technologica: Methodical Research Journal, 2(10), 29-33.
18. Karimov, I., & Halilov, I. (2021). Modernization of the main working shovels of the construction mixing device.
19. Ergashev, N. A., Davronbekov, A. A., Khalilov, I. L. C., & Sulaymonov, A. M. (2021). Hydraulic resistance of dust collector with direct-vortex contact elements. Scientific progress, 2(8), 88-99.
20. Ikromali, K., & Ismoiljon, H. (2021). Hydrodynamics of Absorption Bubbling Apparatus. Бюллетень науки и практики, 7(11), 210-219.

21. Ergashev, N., Ismoil, K., & Baxtior, M. (2022). Experimental determination of hydraulic resistance of wet method dushanger and gas cleaner. American Journal Of Applied Science And Technology, 2(05), 45-50.
22. Karimov, I., Xalilov, I., Nurmatov, S., & Qodirov, A. (2021). Barbotage absorbation apparatus. Barqarorlik va yetakchi tadqiqotlar onlayn ilmiy jurnali, 1(5), 35-41.
23. Rasuljon, T., Voxidova, N., & Khalilov, I. (2022). Activation of the Grinding Process by Using the Adsorption Effect When Grinding Materials. Eurasian Research Bulletin, 14, 157-167.
24. Axmadjonovich, E. N., Obidjon o‘g‘li, X. A., & Abduqayum o'g'li, A. M. (2022). Industrial application of dust equipment in the industrial wet method with contact elements and experimental determination of its efficiency. American Journal of Applied Science and Technology, 2(06), 47-54.
25. Ergashev, N. A., Mamarizayev, I. M. O., & Muydinov, A. A. O. (2022). Kontakt elementli ho‘l usulda chang ushlovchi apparatni sanoatda qo ‘llash va uning samaradorligini tajribaviy aniqlash. Scientific progress, 3(6), 78-86.
26. Ergashev, N. A., Xoshimov, A. O. O. G. L., & Muydinov, A. A. O. (2022). Kontakt elementi uyurmali oqim hosil qiluvchi rejimda ishlovchi ho ‘l usulda chang ushlovchi apparat gidravlik qarshilikni tajribaviy aniqlash. Scientific progress, 3(6), 94-101.
27. Ахунбаев, А. А., & Муйдинов, А. А. У. (2022). Затраты мощности на поддержание слоя материала в контактной сушилке. Universum: технические науки, (6-1 (99)), 49-53.
28. Alizafarov, B., Madaminova, G., & Abdulazizov, A. (2022). Based on acceptable parameters of cleaning efficiency of a rotor-filter device equipped with a surface contact element. Journal of Integrated Education and Research, 1(2), 36-48.
29. Abdulloh, A. (2022). Ho ‘l usulda chang ushlovchi va gaz tozalovchi qurilmada gidravlik qarshilikni tadqiq etish. Yosh Tadqiqotchi Jurnali, 1(5), 246-252.
30. Ergashev, N. A., Abdulazizov, A. A. O., & Ganiyeva, G. S. Q. (2022). Ho ‘l usulda chang ushlovchi apparatda kvarts qumi va dolomit changla-rini tozalash samaradorligini tadqiq qilish. Scientific progress, 3(6), 87-93.
31. Axmadjonovich, E. N., Abduqaxxor o'g'li, A. A., & Mahmudjon o'g'li, I. M. (2022). Determination of Efficiency for Cleaning Quartz Sand and Dolomite Dust in A Wet Method Dust Cleaning Machine. Eurasian Research Bulletin, 9, 39-43.
32. Khoshimov, A., Abdulazizov, A., Alizafarov, B., Husanboyev, M., Xalilov, I., Mo’ydinov, A., & Ortiqaliyev, B. (2022). Extraction of caprolactam in two stages in a multiple-stage barbotation extractor. Conferencea, 53-62.
33. Mukhamadsadikov, K. J., & ugli Ortikaliev, B. S. (2021). Working width and speed of the harrow depending on soil resistivity. Web of Scientist: International Scientific Research Journal, 2(04), 152-158.

34. Мухамадсадиков, К., Ортикалиев, Б., Юсоув, А., & Абдупаттоев, Х. (2021). Ширина захвата и скорости движения выравнивателя в зависимости удельного сопротивления почвы. Збірник наукових праць SCIENTIA.
35. Axunboev, A., Muxamadsodikov, K., & Qoraboev, E. (2021). Drying sludge in the drum. Barqarorlik va yetakchi tadqiqotlar onlayn ilmiy jurnali, 1(5), 149-153.
36. Mukhamadsadikov, K., & Ortiqaliyev, B. (2022). Constructive Parameters of Earthquake Unit Before Sowing. Eurasian Journal of Engineering and Technology, 9, 55-61.
37. Mukhamadsadikov, K. J. (2022). Determination of installation angle and height working body of the preseeding leveler. American Journal Of Applied Science And Technology, 2(05), 29-34.
38. Musajonovich, A. B. (2022). Methods Of Strength Calculation Of Multi-Layer Conveyor Belts. Eurasian Research Bulletin, 14, 154-162.
39. Ахунбаев, А. А., & Хусанбоев, М. А. (2022). Барабаннинг кўндаланг кесимида минерал ўғитларнинг тақсимланишини тадқиқ қилиш. Yosh Tadqiqotchi Jurnali, 1(5), 357-367.
40. Хусанбоев, М. (2022). Термическая обработка шихты стеколного производства. Yosh Tadqiqotchi Jurnali, 1(5), 351-356.
41. Ахунбаев, А. А., & Хусанбоев, М. А. У. (2022). Влияние вращения сушильного барабана на распределение материала. Universum: технические науки, (4-2 (97)), 16-24.
42. Хусанбоев, А. М., Ботиров, А. А. У., & Абдуллаева, Д. Т. (2019). Развертка призматического колена. Проблемы современной науки и образования, (11-2 (144)), 21-23.
43. Хусанбоев, А. М., Тошкузиева, З. Э., & Нурматова, С. С. (2020). Приём деления острого угла на три равные части. Проблемы современной науки и образования, (1 (146)), 16-18.
44. Хусанбоев, А. М., Абдуллаева, Д. Т., & Рустамова, М. М. (2021). Деление Произвольного Тупого Угла На Три И На Шесть Равных Частей. Central Asian journal of theoretical & applied sciences, 2(12), 52-55.
45. Тожиев, Р. Ж., Исомиддинов, А. С., Ахроров, А. А. У., & Сулаймонов, А. М. (2021). Выбор оптимального абсорбента для очистки водородно-фтористого газа в роторно-фильтровальном аппарате и исследование эффективности аппарата. Universum: технические науки, (3-4 (84)), 44-51.
46. Axunboev, A., Muxamadsodikov, K., Djuraev, S., & Musaev, A. (2021). Analysis of the heat exchange device complex in rotary ovens. Barqarorlik va yetakchi tadqiqotlar onlayn ilmiy jurnali, 1(5), 127-132.
47. Rasuljon, T., & Bekzod, A. (2022). Theoretical research of stress in rubber-fabric conveyor belts. Universum: технические науки, (4-12 (97)), 5-16.