Modern American Journal of Engineering, Technology, and Innovation
ISSN(E): 3067-7939
Volume 01, Issue 06, September, 2025
Website: usajournals.org
This work is Licensed under CC BY 4.0 a Creative Commons Attribution 4.0 International License.

ANALYSIS OF INTENSIFICATION OF HEAT EXCHANGE USING A SPIRAL SPRING

B. J. Khursanov
Acting Associate Professor, Fergana State
Technical University, Fergana, Republic of Uzbekistan
E-mail: boyquzi.xursanov@fstu.uz

Abstract
The article presents problems of heat exchange processes and devices and ways to solve them. Methods of intensifying processes in spiral-ring heat exchangers are analyzed. Turbulizers transform the boundary layer of the heat carrier on the inner surface of the pipes into a vortex and absorb it, as a result of which the thermal resistance decreases and the heat transfer process accelerates.

Keywords: Heat exchange, heat transfer agent, spiral-spring, spiral twist angle, internal surface, heat transfer coefficient, intensification method.

Introduction

New designs of heat exchangers should have a higher heat transfer coefficient than similar devices used in industry, be corrosion resistant, have less metal retention, and consume less energy to move heat transfer agents through the device. One of the methods for creating promising heat exchangers is the use of surfaces that break the boundary layer of the working medium [1,2,3].
Research objective; The spiral wire-spring heat exchangers proposed by us are promising. In these devices, the heat exchange surface is performed by spiral wire springs made in the form of a coil inside the tube. Therefore, spiral wire springs should be widely used in heat exchange devices based on analysis. Spiral wire turbulators do not only turbulize the part of the flow in front of the wall, but also cause the entire flow to rotate around its axis [4-7].

Modern American Journal of Engineering, Technology, and Innovation
ISSN(E): 3067-7939
Volume 01, Issue 06, September, 2025
Website: usajournals.org
This work is Licensed under CC BY 4.0 a Creative Commons Attribution 4.0 International License.

Research methods

Such heat transfer accelerators are characterized by the following main methods and advantages:

- the heat transfer area increases;
- the flow near the pipe surface is accelerated, as a result of which the maximum velocity and temperature gradient is observed;
- the viscous bottom layer is disrupted;
- the combined effectiveness of twisting and flow disruption improves the relationship between heat transfer and hydraulic resistance;
- technological simplicity in manufacturing.

Spiral wire springs were experimentally studied by N.V. Zozulya and I.N. Shkuratov, Z. Nagaokiy, V.M. Azarskov, A.Klachak and others [8-14].

Results

The main parameters of a pipe with a wire connection are: pipe diameter D, wire diameter d, wire connection pitch s, and spiral twist angle
Figure 1 shows a coiled wire spring.

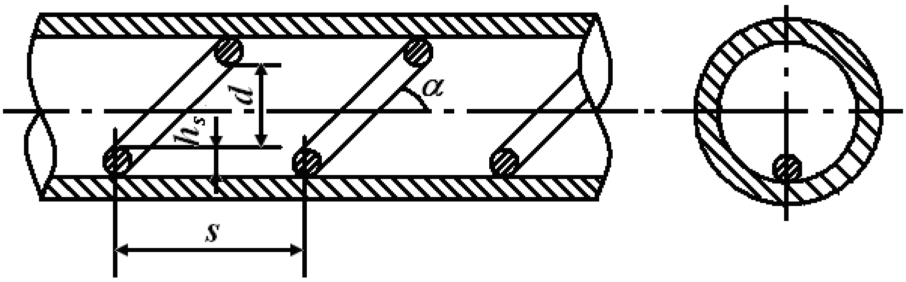

Figure 1. Spiral spring inside the tube.

In the work of A. Klachak, heat transfer and pressure loss were studied in a pipe with a diameter of 25.2 mm and a length of 1500 mm (l/d=59.5). The wire diameter varies from 2.0 to 3.4 mm (d/D=0.079…0.135), the spiral pitch varies from 10 to 66 mm. The spiral twist angle is from 320 to 760. Hindustan Petroleum Corp (India) oil was used as the working fluid. The experiments were conducted in the range Red=30…700.

Modern American Journal of Engineering, Technology, and Innovation
ISSN(E): 3067-7939
Volume 01, Issue 06, September, 2025
Website: usajournals.org
This work is Licensed under CC BY 4.0 a Creative Commons Attribution 4.0 International License.

The experimental results are presented in the form of graphs Nu=f(Re), $\lambda_\varphi = f(Re)$ The generalized results of the experimental results are expressed by the following equation:

$$Nu_d = 1{,}65 \cdot tg\varphi \, \mathrm{Re}_{eq}^{m} \, \mathrm{Pr}^{0{,}35} \left(\frac{\mu_f}{\mu_w} \right)^{0{,}14} \quad (1)$$

In a spiral spring tube, the increase in the Nusselt number for oil is 1.5...4.0, which is significantly higher than for turbulent flow.

N.V. Zozulya and I.N. Shkuratov conducted an experimental study of spiral wire springs in transformer oil flow. The study was conducted in the range Re=1800÷6300.A. [15-19].

Klachka studied the heat transfer in a flowing water pipe with a diameter of 6.8 mm and a length of 240 mm (l/d=35). The experiments were carried out in the range $Re_d = 1{,}7 \cdot 10^3 \ldots 2 \cdot 10^4$ (turbulent regime), Pr=2.5…9.0. The general equation for heat transfer takes the following form:

$$Nu_d = 1{,}04 \, \mathrm{Re}_d^{0{,}54} (s/D)^{-0{,}29} (d/D)^{0{,}35} \quad (2)$$

Equation (1.2) is valid in the range s/D=0.57…286; d/D=0.1…0.22.

Z. Nagaoki conducted an experimental study of spiral wire springs in water flow. The study was conducted in the ranges Re=4600÷23000, l/d=0.26÷1.78; h/d=0.0335÷0.15.

I.N. Shkuratov conducted experimental studies on heat transfer and hydraulic resistance in a pipe with a diameter of 25 mm and a length of 1500 mm (l/d=60). The wire diameter is 2 and 3 mm (d/D=0.08 and 0.12), and the spiral pitch varies from 20 to 132 mm. The spiral twist angle is in the range of 300…750. The experiment was conducted in turbulent mode, using a 50% glycerin solution and water as the working fluid ($Re_d = 3 \cdot 10^3 \ldots 8 \cdot 10^5$) [20-27].

Analysis of the results shows that the increase in the heat transfer coefficient in turbulent flow is 1.3-1.5 compared to a smooth pipe, which is less than in the laminar flow regime. In this work, heat transfer and hydraulic resistance in a pipe with a diameter of 13.81 mm and a length of 605 mm (l/d=43.8) were fully studied. 11 variants of spiral springs were studied. Spiral springs differ in wire

Modern American Journal of Engineering, Technology, and Innovation
ISSN(E): 3067-7939
Volume 01, Issue 06, September, 2025
Website: usajournals.org
This work is Licensed under CC BY 4.0 a Creative Commons Attribution 4.0 International License.

diameter and spiral pitch: d=0.5…3 mm, s=10…60 mm, d/D=0.033…0.207, Reynolds number varies from $4\cdot10^3$ to $5\cdot10^4$.

The results of the study are presented in the form of graphs Nu=f(Re) and λ=f(Re). In the study, heat transfer and hydraulic resistance in a pipe with a diameter of 13.81 mm and a dimensionless length l/D=43.8 were fully studied. The Reynolds number varies from 6000 to 40000. The main parameters of the studied spiral spring are presented in the form of a table [28-33].

The results of the heat exchange experiment are summarized according to the following formula

$$\frac{Nu}{Nu_0} = 1{,}85 + 2{,}5\frac{2h}{d} - \frac{0{,}85 + 2{,}5(2h/d)}{2{,}8 + 12{,}6(2h/d)}\frac{t}{d} \quad (3)$$

The equation is valid in the ranges 0.0667<2h/d<0.435; 0.75<t/d<4.4; 6·103<Re<4·104.

The calculated results of the thermal hydraulic efficiency are presented in the form of graphs Nu=f(Re) and ξ=f(Re).

The use of the best variant of spiral springs and the same hydraulic resistances compared to a smooth pipe leads to an increase in heat capacity by 40%.

Also, the results of the study of the heat exchange process during the flow of transformer oil in a pipe with a spiral spring are presented. The Reynolds number varies in the range 30<Re<2000, 300<Re<675. The geometric characteristics of the channel vary in the following range: s/d=2.62÷0.83; hs/d=0.085÷0.14; α_0=32÷610.

The following equation is proposed to calculate the Nu number in a pipe with a spiral spring

$$\overline{\text{Nu}} = 1{,}65\,tg\alpha\left(\text{Re}_{De}\right)^{0{,}25(tg\alpha)^{-0{,}38}}\,\text{Pr}^{0{,}35}\left(\mu/\mu_{\tilde{n}\grave{o}}\right)^{0{,}14} \quad (4)$$

The efficiency of intensification with a decrease in the spiral pitch and an increase in the height of the installation is 150-400%.

V.M. Azarskov studied the laminar flow of viscous Newtonian fluids in a spiral wire spring [34].

The following generalized equation is used for application in computational practice

Modern American Journal of Engineering, Technology, and Innovation
ISSN(E): 3067-7939
Volume 01, Issue 06, September, 2025
Website: usajournals.org
This work is Licensed under CC BY 4.0 a Creative Commons Attribution 4.0 International License.

$$\overline{Nu} = 0{,}23\,\mathrm{Re}^{0,7}\,\mathrm{Pr}^{0,35}(d/D)^{0,7}(9 - s/D)^{0,5} \quad (5)$$

The scope of the relationship: Re=80÷1200; s/D=0.71÷4.3; d/D=0.714÷0.171.
The experimental and calculated deviations do not exceed 12%. In the case of corrugated pipes, the heat transfer coefficient increases by 2-4.5 times, depending on the geometric parameters. The heat exchange surface increases by 10-60% compared to a smooth pipe. The results of the study are presented in the form of a graph $\overline{Nu}$=f(Re).
The following generalized equation is used to calculate the value of the hydraulic resistance coefficient

$$\xi = \frac{530}{\mathrm{Re}^{0,36}}\left(\frac{d}{D}\right)^{1,4}\exp\left[-\left(\frac{s}{D}\right)^{0,65}\right] \quad (6)$$

The experimental and theoretical deviation does not exceed 14%. The scope of application of the relationship: s/D=0.71÷4.3; d/D=0.071÷0.17.
Compared with horizontal groove turbulators, this type of turbulators is less suitable for small spiral pitches, and the thermal contact of the spring with the pipe is not reliable, that is, the spring is not tightly attached to the inner surface of the pipe, these shortcomings reduce the effectiveness of their use at relatively small pitches.

Conclusion

One of the ways to create promising heat exchangers is the use of surfaces that erode the boundary layer of the working environment. In this regard, spiral-spring heat exchangers proposed by us are promising. In these devices, the heat exchange surface is performed by spiral springs made in the form of folds in the pipe. When the working medium moves along the pipe channel with the surface in a fold position, secondary flows and centrifugal forces appear in the boundary zone.

References

1. Yusupbekov N.R., Nurmukhamedov H.S., Zokirov S.G. Basic processes and devices of chemical technology. – Tashkent: «Sharq», 2003.

This work is Licensed under CC BY 4.0 a Creative Commons Attribution 4.0 International License.

2. Z. Salimov. Basic processes and devices of chemical technology. Textbook for students of higher educational institutions. T.1. - Tashkent: Uzbekistan, 1994. -366 p.
3. Kalinin E.K. et al. Intensification of heat exchange in channels. /Kalinin. - M.: Mashinostroenie, 1990, 206 p.,
4. Yusupbekov N.R., B.E. Mukhamedov, Sh.M. Gulomov. Control systems of technological processes. - Tashkent: Ukituvchi, 1997. -704 p.
5. Kafarov V.V. Methody cybernetic and chemical and chemical technology. - M.: Khimiya, 1985. – 448 p.
6. Mamarizayev, I., & Abdunazarov, A. (2022). Multi-stage bubble extractor with increased contact time. Eurasian Journal of Academic Research, 2(7), 112-116.
7. Komilova, K. (2022). Analysis of devices used in the technological process. Eurasian Journal of Academic Research, 2(7), 106-111.
8. Khursanov, B. J., & Alimatov, B. A. (2020). Extraction of redkix metallov iz otvalov GOK. Universum: technical science, (6-1 (75)), 42-45.
9. Khursanov, B. J., & Abdullaev, N. Q. (2022). Influence on efficiency of gas quantity extraction process. Eurasian Journal of Academic Research, 2(6), 321-324.
10. Khursanov, B. J., & Honkeldiev, M. A. (2022). Energy-saving bubble extractor with extended contact time. Eurasian Journal of Academic Research, 2(6), 115-117.
11. Khursanov, B. J. (2022). Methods for calculating the economic efficiency of new technology. World Economics and Finance Bulletin, 10, 112-116.
12. Khursanov, B. J., & Alimatov, B. A. (2020). Extraction of redkix metallov iz otvalov GOK. Universum: technical science, (6-1 (75)), 42-45.
13. Khursanov, B. J. (2022). Extraction of rare metals from mining dumps in bubbling extractors. American Journal Of Applied Science And Technology, 2(05), 35-39.
14. Khursanov, B. J., & Alimatov, B. A. (2022). Issledovanie Vzaimnogo Unosa Faz V Barbotajnom Ekstaktore S Uvelichennym Vremenem Kontakta. Central asian journal of theoretical & applied sciences, 3(5), 28-33.
15. Dusmatov, A. D., Akhmedov, A. O'., Abdullaev, Z. J., & Gaparov, K. G. (2022). Mejdusloevye sdvigi dvuxsloynyx kombinirovannyx plastin i

This work is Licensed under CC BY 4.0 a Creative Commons Attribution 4.0 International License.

obolochek s uchetom usadki kompozitnyx sloev. Oriental renaissance: Innovative, educational, natural and social sciences, 2(4), 133-141.

16. Khursanov, B., Latifjonov, A., & Abdulhakov, U. (2021). Application of innovative pedagogical technologies to improve the quality of education. Scientific progress, 2(7), 689-693.
17. Khursanov, B., & Abdullaev, N. (2021). Fundamentals of equipment of technological processes with optimal devices. Scientific progress, 2(7), 679-684.
18. Khursanov, B., & Akbarov, O. (2021). Calculation of gas volume in the mixing zones of extended contact time barbota extractor. Scientific progress, 2(7), 685-688.
19. Alimatov, B. A., Sokolov, V. N., Salimov, Z. S., & Khursanov, B. J. (2003). Issledovanie raspredeleniya kapel po razmeram v mnogostupenchatom barbotajnom ekstractore. Journal of applied chemistry, 76(8), 1309-1311.
20. Karimov, I., Boykuzi, K., & Madaliyev, A. (2021). Volume-Surface Diameters of Drops in Bubble Extractor. International Journal of Innovative Analyzes and Emerging Technology, 1(5), 94-99.
21. Khursanov, B. J., Mamarizayev, I. M. O., & Akbarov, O. D. O. (2021). Operation of mixing zones of barbotage extractor in stable hydrodynamic regime. Scientific progress, 2(8), 170-174.
22. Khursanov, B. J., Mamarizayev, I. M. O., & Akbarov, O. D. O. (2021). Application of constructive and technological relationships in machines. Scientific progress, 2(8), 164-169.
23. Khursanov, B. J., Mamarizayev, I. M. O., & Abdullayev, N. Q. O. (2021). Application of interactive methods in improving the quality of education. Scientific progress, 2(8), 175-180.
24. Isomidinov, A., Boykuzi, K., & Khonnazarov, R. (2021). Effect of Rotor-Filter Device Operation Parameters on Cleaning Efficiency. International Journal of Innovative Analyzes and Emerging Technology, 1(5), 100-105.
25. Isomidinov, A., Boykuzi, K., & Madaliyev, A. (2021). Study of Hydraulic Resistance and Cleaning Efficiency of Gas Cleaning Scrubber. International Journal of Innovative Analyzes and Emerging Technology, 1(5), 106-110.

This work is Licensed under CC BY 4.0 a Creative Commons Attribution 4.0 International License.

26. Alimatov, B. A., & Khursanov, B. J. (1998). Raschet velichiny otstoynoy zony bubble extractor. Nauch. tech. Journal. Ferg. polytechnic in-ta. Fergana, 1(2), 86-89.
27. Alimatov, B., & Khursanov, B. (2020). Analysis of droplets size distribution and interfacial surface during pneumatic mixing. Asian Journal of Multidimensional Research (AJMR), 9(6), 165-171.
28. Alimatov, B. A., Sokolov, V. N., & Khursanov, B. J. (2001). Vliyanie gazosoderjaniya na proizvoditelnost barbotajnogo ekstractora po tyajeloy jhidkosti. NTJ FerPI, Scientific-technical journal (STJ FerPI), 2, 93-94.
29. Akhunbaev, A. A., Tuychieva, Sh. Sh., & Khursanov, B. J. (2020). Uchyot dissipation energy and processes of dry dispersive material. Universum: technical science, (12-1 (81)), 35-39.
30. Dusmatov, A. D., Khursanov, B. J., Akhrorov, A. A., & Sulaymanov, A. (2019). Issledovanie napryajenno deformirovannoe sostayanie dvukhsloynyx plastin i obolochek s uchetom poperechnyx sdvigov. In Energo-resursosberegayushchie technology and equipment in road and construction industry (pp. 48-51).
31. Mirzakhanov, Yu. U., Khursanov, B. J., Akhrorov, A. A., & Sulaymanov, A. (2019). Primenenie parametrov natyajnogo rolika pri teoreticheskom izuchenii dinamiki transportiruyushchix lent. In Energo-resursosberegayushchie technology and equipment in road and construction industry (pp. 134-138).
32. Alimatov, B. A., Sadullaev, Kh. M., Karimov, I. T., & Khursanov, B. J. (2008). Metody rascheta i konstruirovaniya jhidkostnykh ekstractorov s pnevmoperemeshivaniem.
33. Khursanov, B. J. (2022). An Innovative Approach to the Design of Technical and Technological Processes of Production. Eurasian Research Bulletin, 11, 15-19.
34. Khursanov, B. J. (2022). The Factors of Ensuring Sustaining Manufacturing Competitiveness. Eurasian Journal of Engineering and Technology, 9, 93-100.