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Investigating the effect of turbulator, nanofluid and geometry on the thermal performance of shell and tube heat exchangers

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Abstract

In recent years, in order to optimize shell and tube heat exchangers, active and passive methods are used. In the present work, the performance of using twisted tape and microfin turbulators, using nanofluid and changing geometry as a passive method to increase heat transfer in a shell and tube heat exchanger has been evaluated. For this purpose, the shell and tube heat exchanger with the percentage of baffle cutting and the number of different tube passes in four different modes (use of water fluid on the shell side and tube containing supercritical carbon dioxide gas without the presence of turbulator, use of water fluid on the shell side and tube containing supercritical carbon dioxide gas with the presence of turbulator, the use of water-aluminum oxide nanofluid with a volume fraction of 0.1, 0.2, 0.3, 0.4 and 0.5% on the side of the shell and tube containing supercritical carbon dioxide gas without the presence of turbulator and also the use of water-aluminum oxide nanofluid on the side of the shell and tube containing supercritical carbon dioxide gas with the presence of an turbulator) are studied using HTRI software. The results show that the highest value of the heat transfer coefficient on the shell side and, as a result, the appropriate thermal efficiency is related to the case where the baffle cut is 30%. On the other hand, with the increase in nanofluid concentration, the pressure drop on the shell side increases from 4.48 to 5.66%. Also, the results show that the use of a microfin turbulator is more suitable than a twisted tape turbulator and the use of a microfin turbulator increases the heat transfer coefficient on the shell side by 5.76 to 12.77% compared to the use of a twisted tape turbulator. Also, it increases the heat transfer coefficient of the pipe side by 62 and 78% on average, respectively, compared to the case without the turbulator. In addition, the maximum heat transfer coefficient on the shell side occurs at the number of tube passes of 3, and when the number of tube passes is greater than 3, the heat exchanger has a drop in thermal performance, and this indicates a decrease in heat exchanger efficiency in this state.

Keywords: shell and tube heat exchanger, twisted tape & microfin turbulator; nanofluids; HTRI.

1. Introduction

Today, due to the increase in the price of energy, political events and wars over energy sources that affect energy in an extremely large way at the global level, the importance of optimal consumption of fuel and energy is felt more than ever, and scientists are always looking for research. They are new for optimizing industrial thermal devices. One of the most widely used heat exchange devices, which are the most used among energy equipment in various industries, especially oil, gas and petrochemical, are shell and tube heat exchangers, which are used in all refineries and power plants. Exceptions are used and thermal optimization is done as much as possible using active and passive methods.

Passive methods have been more interested by researchers because these methods are much less expensive than active methods, and therefore the use of turbulators, nanofluids, finned tubes, etc., is of great interest compared to its thermal efficiency.

The use of turbulator and nanofluid as a passive method in heat exchangers, which by creating stronger swirling and swirling movements on the boundaries, increases the displacement heat transfer coefficient and is a great help to the thermal efficiency of the pre-designed shell and tube heat exchanger.

An overview of the past works of the present work is presented in the full article [1-9]. Using the latest parameters related to the calculations of thermophysical properties of nanofluids where the properties are a function of nanoparticle diameter and nanofluid temperature and using supercritical carbon dioxide fluid inside tubes containing two types of turbulators and comparing the thermal performance of nanofluid with concentration different problems on the shell side, as well as investigating the effect of sediment in the shell and tube heat exchanger by numerical solution method, are some of the works that have not been paid attention to yet. In the following, to calculate the properties of the water-aluminum oxide nanofluid used in the present work, the relationships between the variable properties of Khanafar and Vafai [10] are used.

2. Description of the problem

The present work is an AES type shell and tube heat exchanger containing aluminum oxide nanofluid in the water base fluid on the shell side and supercritical carbon dioxide gas on the tube side containing the twisted tape and microfin turbulators, designed by HTRI 7[11] software and in terms of The geometric specifications are similar to Kermani's design [12] and Leung et al.'s design [13].The heat exchanger used in the present work is shown in Figure 1. The working conditions and turbulent characteristics of the devices are listed in Tables 1 and 2 in full paper. Also, the geometry of the turbulators used in this work ((a) twisted tape and (b) microfin [14]) is presented in Figure 2. The characteristics of supercritical carbon dioxide fluid have been introduced to HTRI 7 [11] software using Refprop 9 [15] and the Peng-Robinson equation of state was chosen for this purpose.

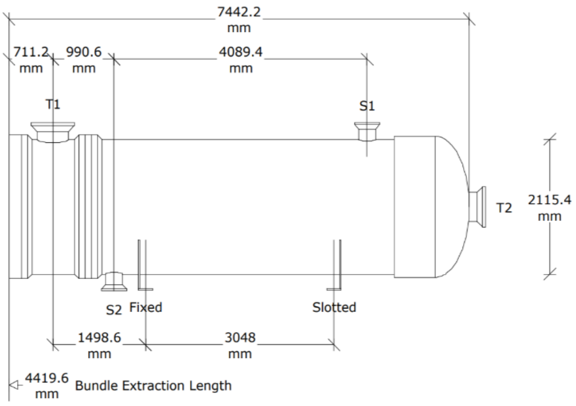
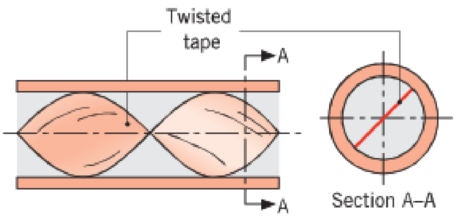
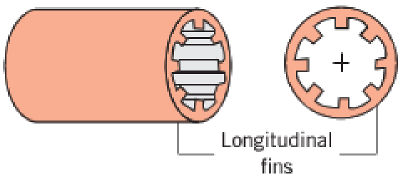


Figure 1. The heat exchanger used in the present work[12, 13]



(a)



(b)

Figure 2. Geometry of turbulators used in the present work (a) twisted tape and (b) microfin [14]

3. Discussion and Results

Tables 1 and 2 show the effect of the use of the twisted tape and microfin turbulator. According to these tables, it can be seen that if the turbulator is used, the pressure drop inside the heat exchanger increases. The results also show that the pressure drop increases with the increase in the number of passes. On the other hand, if there is a turbulator, the convection heat transfer coefficient increases. Also, with the increase in the number of pipe passes, this coefficient increases. By comparing the results of table one and two, it can be seen that if a microfin turbulator is used, the convection heat transfer coefficient is higher and the pressure drop is lower than the case when a twisted tape turbulator is used.

Table 1. Investigating the effect of the twisted tape turbulator

	with turbulator		without turbulator	
Tube Pass	h_t (W/m^2K)	ΔP_t (kPa)	h_t (W/m^2K)	ΔP_t (kPa)
1	284.2	18.169	175.2	17.72
2	485.52	23.647	299.34	21.033
3	667.32	28.332	414.41	20.354
4	835.86	44.087	515.40	26.573
5	1149.6	93.947	709	40.851

Table 2. Investigating the effect of the microfin turbulator

	with turbulator		without turbulator	
Tube Pass	h_t (W/m^2K)	ΔP_t (kPa)	h_t (W/m^2K)	ΔP_t (kPa)
1	300.58	17.73	175.2	17.72
2	526.4	21.033	299.34	20.985
3	733.99	20.354	414.41	20.182
4	928.96	26.573	515.40	26.099
5	1296.4	40.851	709	38.84

Conclusions

In this research, the thermal design of the shell and tube exchanger containing the twisted tape and microfin turbulators was investigated, and the AES type exchanger with water-aluminum oxide nanofluid was used on the shell side. The results show that by increasing the concentration of nanofluid on the shell side and using the twisted tape and microfin turbulators, the convection heat transfer coefficient and as a result the thermal performance of the exchanger improves dramatically. And it was found that the increase in the heat transfer rate using nanofluid is very small compared to using a turbulator. Also, by comparing two types of turbulator, it was found that the microfin turbulator has better efficiency in terms of heat transfer and pressure drop than the twisted tape turbulator, and it increases the heat transfer coefficient by 76.5 to 12.77% compared to the twisted tape turbulator. In addition, the effect of changing some geometrical parameters of the heat exchanger was investigated and the best thermal efficiency for the heat transfer coefficient of the shell side was determined for the percentage of baffle cut of 30% and the number of tube passes of 3. Also, the results show that with the increase in sediment thickness, the heat transfer coefficient of the shell side displacement and pressure drop increases.

4. References

[1] Antonopoulou, C., Gkountas, A., Atsonios, K., Bakalis, P., Skiadopoulos, A., Grammelis, P., and Manolakos, D., 2023, Parametric Analysis of Heat Source and Sink and Design of Heat Exchangers for Trilateral Flash Cycle (TFC), *8th World Congress on Momentum, Heat and Mass Transfer (MHMT'23)* .

[2] Razzaghi, M. J. P., Daemiashkezari, M., Abdulfattah, A. N., Afrouzi, H. H., and Ahmad, H., 2022, Thermo-hydraulic performance evaluation of turbulent flow and heat transfer in a twisted flat tube: A CFD approach. *Case Stud. Therm. Eng*., 102107.

[3] Xifeng, W., Xiaoluan, Z., Mahariq, I., Salem, M., Ghalandari, M., Ghadak, F., and Abedini, M., 2022, Performance Optimization of the Helical Heat Exchanger With Turbulator. *Front. Energy Res*., 9, 789316.

[4] Sanserwal, M., Yadav, D., Bhardwaj, M., and Singh, G., 2022, Enhancing the thermal performance of a double pipe heat exchanger in turbulent flow conditions. *Int. J. Thermodyn*., 25(2), 99-111.

[5] Aminifar, F., Ghafouri, A., and Falavand Jozaei, A., 2020, Experimental Investigation of Hydro-Thermodynamics Performance of Shell and Tube Heat Exchanger Using Nanofluid, Triangular-Cut Twisted Tape and Corrugated Pipes. *Modares Mechanical Engineering*, 20(10), 2593-2603.

[6] Singh S. K., and Sarkar, J., 2020, Improving hydrothermal performance of hybrid nanofluid in double tube heat exchanger using tapered wire coil turbulator, *Adv. Powder Technol*. 31(5), 2092-2100.

[7] Fares, M., Mohammad, A. M., and Mohammed, A. S. , 2020, Heat transfer analysis of a shell and tube heat exchanger operated with graphene nanofluids. *Case Stud. Therm. Eng*. 18, 100584.

[8] Yılmaz İ. H., Mwesigye A., and Göksu, T. T., 2020, Enhancing the overall thermal performance of a large aperture parabolic trough solar collector using wire coil inserts, Sustain. *Energy Technol*. Assess., 39, 100696.

[9] Kayabasi, E., Alperen, M. A., and Kurt, H., 2019, The effects of component dimensions on heat transfer and pressure loss in shell and tube heat exchangers. *Int. J. Green Energy*, 16(2), 200-210.

[10] Khanafer, K. and Vafai K., 2011, A critical synthesis of thermophysical characteristics of nanofluids, *Int. J. Heat Mass Transf.*, 54, 4410-4428

[11] Kara, Y. A., and Güraras, Ö., 2004, A computer program for designing of shell-and-tube heat exchangers. *Appl. Therm. Eng.*, 24, 1797-1805. .

[12] Kermani, Ehsan, 2014, Studying the effect of using internal microfin tube on heat transfer and pressure drop of aluminum oxide water nanofluid in shell and tube heat recovery exchanger, Master's thesis, Kashan University, Kashan.

[13] Leong, K.Y., Saidur, R., Mahlia, T.M.I., and Yau, Y.H., 2012, Modeling of shell and tube heat recovery exchanger operated with nanofluid based coolants, *Int. J. Heat Mass Transf*., 55, 808-816.

[14] Bergman, T., L., and Lavine , A. S., 2017, *Fundamentals Of Heat and Mass Transfer*, 8th edition, John Wiley & Sons, Inc.

[15] Huber, M. L., Lemmon, E. W., Bell, I. H., and McLinden, M. O., 2022, The NIST REFPROP Database for Highly Accurate Properties of Industrially Important Fluids, *Ind. Eng. Chem. Res.*, 61(42), 15449–15472.