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Numerical Study and Sensitivity Analysis in Tubular Heat Exchangers with Perforated Conical Rings Carrying Water-Aluminum Oxide Nanofluid

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ABSTRACT: In this paper, the hydrodynamic behavior and heat transfer of a nanofluid turbulent flow in an exchanger equipped with perforated conical rings are simulated numerically. Water-based fluid and Al2O3 nanoparticles with a weight percentage of zero to 5% are considered as nanoparticles that increase heat transfer. The governing equations are solved using the computational fluid dynamics method with the help of ANSYS-Fluent software in the range of Reynolds 12000-2000. After validation of the numerical solution method with the available experimental results, the effect of geometric parameters and flow characteristics such as Reynolds number, number of rings used, number of holes used and volume fraction of nanoparticles on the heat transfer characteristics of the heat exchanger have been studied. The results show that the use of perforated conical rings has a significant effect on improving heat transfer in heat exchangers and this method can be used in practical applications. The results show that with increasing the number of conical rings, decreasing the number of holes, and increasing the weight fraction of nanoparticles, the Nusselt number and the coefficient of friction increase. Based on the results, it can be seen that the proposed loop can increase the Nusselt number by 5.3 times compared to the tube without the loop. In addition, Al_2O_3 nanoparticles have a favorable effect on increasing heat transfer and with increasing the volume fraction of Al_2O_3 nanoparticles from zero to 5%, Nusselt number per m = 1 and n = 3 about 92% increase in Nusselt number has been observed.

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1- Introduction

One of the most widely used turbulators used in thermal applications is conical rings, which are among the most widely used tools in improving heat transfer due to their easy installation, low cost, and high efficiency. This type of ring was first used by Yakut et al. [1]. Dormus [2] investigated heat transfer and exergy losses in cut conical rings using laboratory tests. Promonagh and Emesa [3] studied the heat transfer behavior in tubes with conical rings and spiral turbulence. Using experimental tests and numerical simulations, Liu et al. [4] studied the characteristics of free heat transfer in circular tubes with conical rings. Another passive method of improving heat transfer in heat exchangers is the use of different types of nanoparticles, which has been considered by many researchers in recent years. Javaherdeh et al. [5] numerically studied the thermal and hydrodynamic behavior of the turbulent flow of non-Newtonian nanofluids in the reverse flow arrangement in a helical two-tube heat exchanger.

A review of studies shows that the heat transfer performance of conical rings is very good, but research in this area has not been completed and more studies are needed to achieve the optimal structure. Accordingly, the main purpose of the present study is to study the effect of the hole on conical rings and the effect of its geometric characteristics on thermal performance.

2- Numerical Modeling

The geometric model of a tubular heat exchanger equipped with perforated conical rings is shown in Fig. 1. Fig. 1 also shows the geometric of the perforated conical ring. The length is 1250 mm and the inner and outer diameters are 48 mm and 51 mm, respectively. The length of the conical rings is equal to 50 mm and their thickness is equal to 1.5 mm and is fixed. Numerical results are extracted for different values of the number of conical rings and different numbers of holes n equal to zero, 3, 6, and 9. Also, water fluid has been used as the base fluid and Al2O3 nanoparticles.

To numerically solve the nanofluid flow equations, the single-phase turbulent flow model k-ε has been used with the help of ANSYS-Fluent software. In order to ensure temperature expansion, the initial length before the rings are placed is selected. At the inlet of the pipe, the condition of uniform temperature and velocity profile according to the temperature of 298oK is considered. The wall of the pipe is exposed to constant heat flux, and at the outlet of the pipe, Newman-type boundary conditions are selected.

3- Response Level Method

In this study, in order to sensitivity analyze and investigate the effect of four input parameters including the number of

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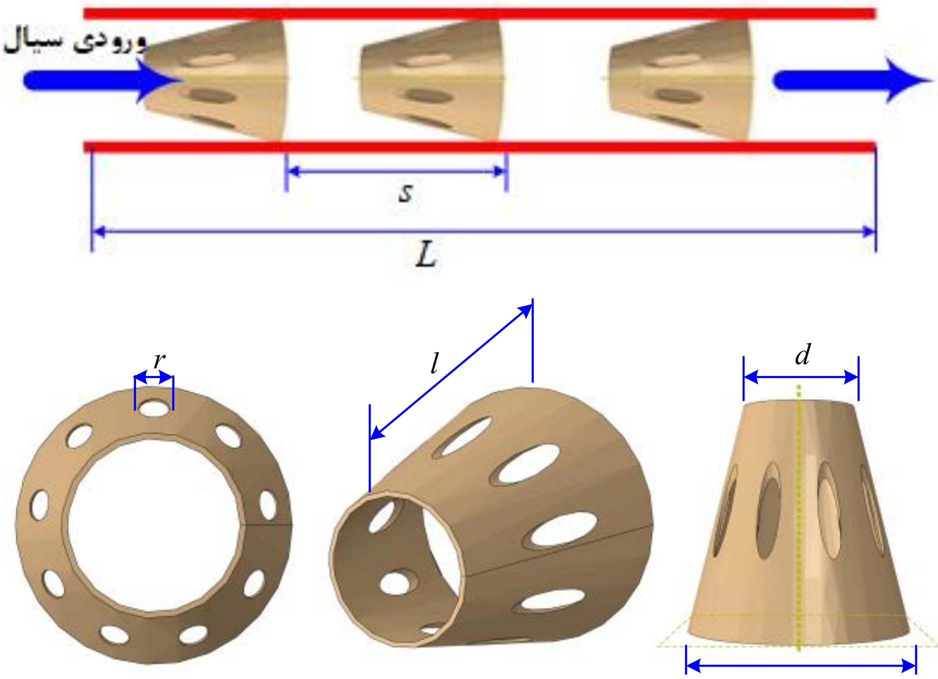

Fig. 1. Pipe heat exchangers equipped with perforated conical rings

holes created, n, the number of conical rings, m, Reynolds number, Re, as well as the volume fraction of Al2O3, φ on the responses including the Nusselt number and coefficient of friction in heat exchange of pipe tubes equipped with perforated conical rings response surface methodology is used. The central composite design method for the four input variables consists of 21 experiments. After completing the numerical analysis, Nu and f are used to determine the polynomial coefficients of the model and sensitivity analysis. Design-Expert software is used for statistical analysis.

4- Results and Discussion

In this section, the effect of different parameters of perforated conical rings on heat fields and flow is studied. Fig. 2 shows the average Nusselt number and the coefficient of friction in terms of Reynolds number for different values of conical rings and holes, respectively. According to the results, it is observed that with increasing Reynolds from 2000 to 12000, the Nusselt number increases significantly in all cases. This is mainly due to the fact that in high Reynolds, the presence of conical rings causes more turbulence in the fluid flow and as a result, the turbulence of the thermal boundary layer increases heat transfer in this type of heat exchange. Also, it is observed that with increasing Reynolds, the coefficient of friction changes less, because with increasing Reynolds number, the turbulence of the flow increases, and the effect of excitation on the coefficient of friction decreases. Another factor in reducing the coefficient of friction with increasing Reynolds number is that with increasing Reynolds number, the flow rate increases, and as a result, the average velocity of the current increases.

Fig. 3 shows the flow lines in the case of m=6 and Re=5000 and in different cases the number of holes of the conical ring. According to these results, it is observed that increasing the

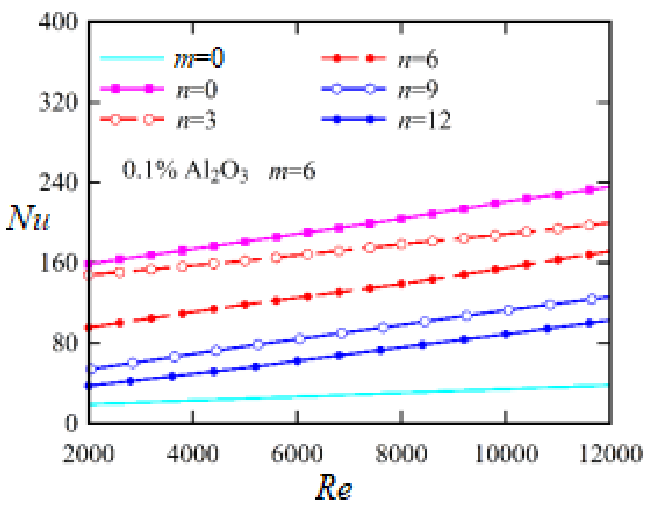

Fig. 2. Mean Nusselt number in terms of Reynolds number for different values of conical rings

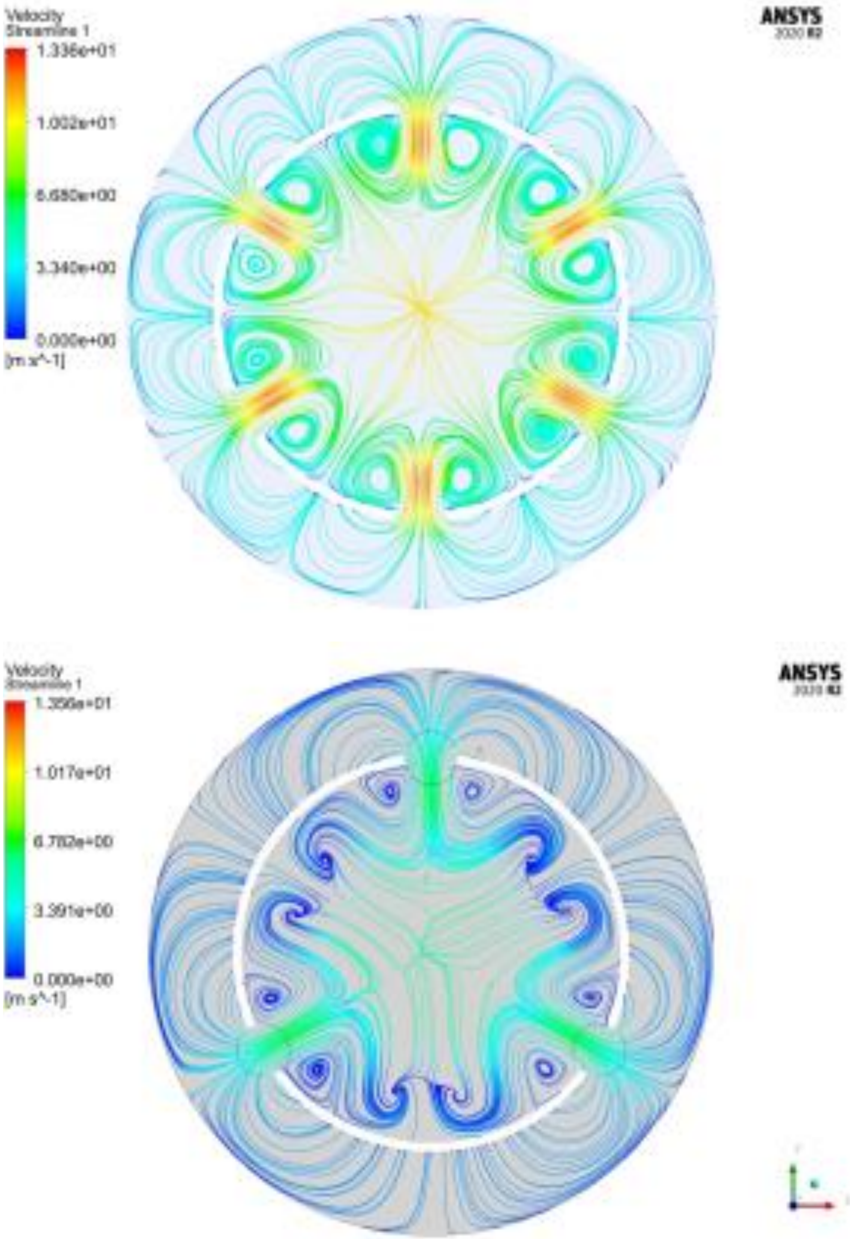

Fig. 3. Flow velocity lines in the middle of the provided conical rings with 3 and 6 holes

number of holes reduces the difficulties against the fluid flow and as a result, the Nusselt number and the coefficient of friction of the tubular heat exchanger with conical rings are reduced.

5- Conclusion

In the present study, using numerical simulation, the thermal performance, and sensitivity analysis in the exchange of tubular heat with conical rings were investigated. Based on the results of numerical analysis and sensitivity analysis, a summary of the important results of the present study is as follows:

- As the number of rings increases from 1 to 8, the average Nusselt number in the Reynolds 2000 and 12000 increases by about 182% and 140%, respectively.
- The minimum increase of the average Nusselt number is obtained by using this type of turbulence per m =1, which is about 239% more than the pipe without turbulence.
- With increasing the volume fraction of Al2O3 nanoparticles from 0 to 5%, the Nusselt number per m=1 and n=3 about 92% increase in the average Nusselt number has been observed.
- The Nusselt number of the heat exchanger increases by increasing the Reynolds number from 2000 to 5000 for aqueous and nanofluid fluids with a mass fraction of 0.5% by about 11% and 42%, respectively.

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