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Analysis of a Double Pipe Heat Exchanger with Straight and Helical Fins

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Abstract- In this work, the thermo hydraulic performance of a proposed design of an air-to-water double pipe heat exchanger with helical fins on the annulus gas side, is numerically studied. Three-dimensional computational fluid dynamics (CFD) simulations are performed, using the FLUENT software in order to investigate the gas side fluid flow, turbulence, heat transfer, and power consumption for different configurations of the heat exchanger. CFD performance analysis is conducted under turbulent flow conditions for configurations with helical fins. The numerical model is first verified against experimental data available in the literature, for a double-pipe heat exchanger with longitudinal fins. Then, longitudinal fins are considered as a reference configuration and a comparative analysis of the thermo hydraulic performances of the different helical fin configurations and the reference configuration is conducted. The flow field characteristics of the helical fin configurations are clearly demonstrated and discussed. Key design parameters such as the heat transfer coefficient, pressure drop, and thermal performance enhancement factor are evaluated to predict the overall performance of the heat exchangers.

Keywords: Heat transfer, Fluid flow, Turbulent Flow, Double Pipe Heat exchanger, Helical Fin.

I. INTRODUCTION

Growing need to develop and improve the effectiveness of heat exchangers has led to a broad range of investigations for increasing heat transfer rate along with decreasing the size and cost of the industrial apparatus accordingly. One of these many apparatus which are used in different industries is double pipe heat exchanger. This type of heat exchanger has drawn many attentions due to simplicity and wide range of usages. In recent years, several precise and invaluable studies have been performed in double pipe heat exchangers.

In this we traced the history of publications regarding double pipe heat exchanger back to its beginnings in the late 1940s [3, 4]. The studies broadly support the view that this type of heat exchanger is heading towards a considerable progress. Through these years, a plethora of researches have been carried out which fall into various categories. In some cases, just the working fluids characteristics and their modifications were studied. Some investigated active methods, passive methods, compound methods, geometry change and the other heat enhancement methods.

II. COMPUTATIONAL FLUID DYNAMICS

Fluid (gas and liquid) flows are governed by partial differential equations (PDE) which represent conservation laws for the mass, momentum and energy.

Computational Fluid Dynamics (CFD) is used to replace such PDE systems by a set of algebraic equations which can be solved using digital computers. The basic principle behind CFD modeling method is that the simulated flow region is divided into small cells.

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Differential equations of mass, momentum and energy balance are discredited and represented in terms of the variables at any predetermined position within or at the centre of cell. These equations are solved iteratively until the solution reaches the desired accuracy (Ansys Fluent 14.0).

CFD provides a qualitative prediction of fluid flows by means of

- Mathematical modeling (partial differential equations)
- Numerical methods (discretization and solution techniques)
- Software tools (solvers, pre- and post-processing utilities)

III. METHODOLOGY

1. Specifications of Double Pipe Heat Exchanger Used:

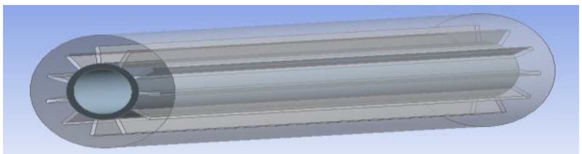
The experimental study is done in a double pipe heat exchanger having the specifications as shown in table below:-

Table 1. Structural parameters.

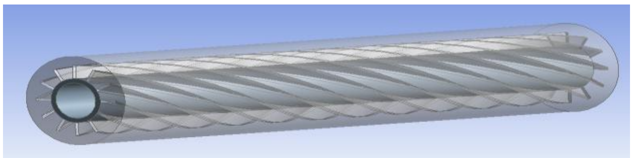
Fin material	Aluminium
Fin number, N	10,11, 12
Fin width, b	0.6 mm
Inner tube internal diameter Di	8 mm
Inner tube external diameter Do	10 mm
annulus internal diameter Ds	20 mm
Tube length, L	100 mm

2. Computational Domain:

The aim of this research to numerically study and compare different configurations of straight and helical fins in a double pipe heat exchanger. The working fluids are air and water, cold air flows in the annulus side while hot water flows in the inner tube side in counter-current configuration. Six double pipe heat exchangers are considered, three with longitudinal fins used to validate the numerical model, and three with helical fins with a variable fins.



(a)



(b)

Fig 1. CFD domain.

3. Boundary Conditions:

3.1 Inlet:

$$U = U_{in} = \text{constant}$$
$$T = T_{in} = \text{constant}$$
$$I = 1\%$$

3.2 Outlet:

Static pressure

3.3 Tube:

no-slip condition

$$T = T_w = \text{constant}$$

3.4 Fin:

no-slip condition

Coupling of conduction and convection

4. Meshing of Domain:

In this study, a general curve linear coordinate grid generation system based on body–fitted coordinates was used to discrete the computational domain into a finite number of control volumes. The geometries of the problems are carefully constructed. All cases were modeled and meshed with the GAMBIT [12].

FLUENT also comes with the CFD program that allows the user to exercise the complete flexibility to accommodate the compatible complex geometries. The refinement and generation of the grid system is important to predict the heat transfer in complex geometries.

In other words, density and distribution of the grid lines play a pivotal role to generate accuracy. Due to the strong interaction of mean flow and turbulence, the numerical results for turbulent flows tend to be more dependent on grid optimization than those for laminar flows [11].

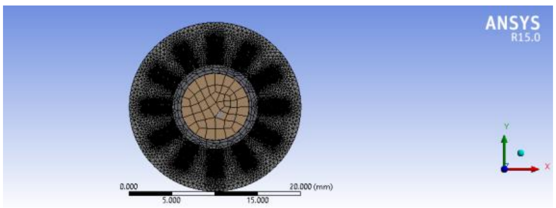


Fig 2. Mesh Model.

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IV. RESULTS

From the above results, it can be concluded that the numerical model provides reliable results and has a reasonable precision. The model is next used to predict the heat transfer and thermos-hydraulic performances for different configurations of a double-pipe heat exchanger with helical fins.

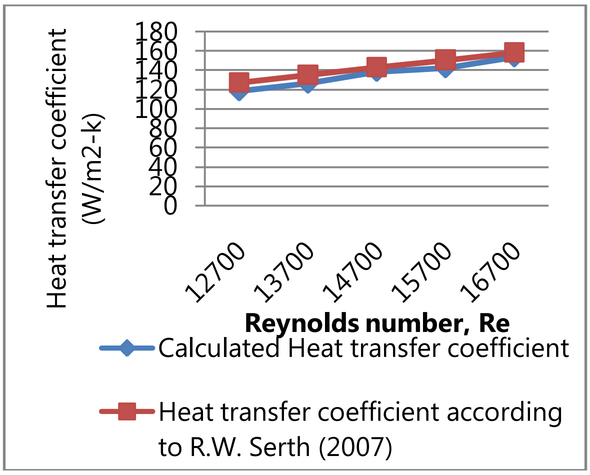


Fig 3. Plot of heat transfer coefficient versus Re for longitudinal fins.

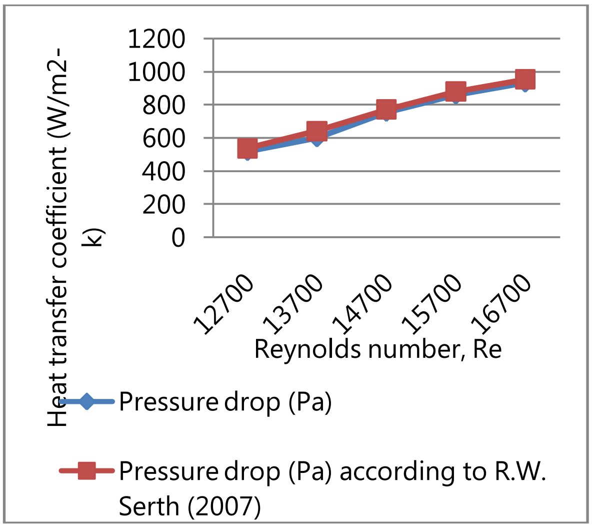
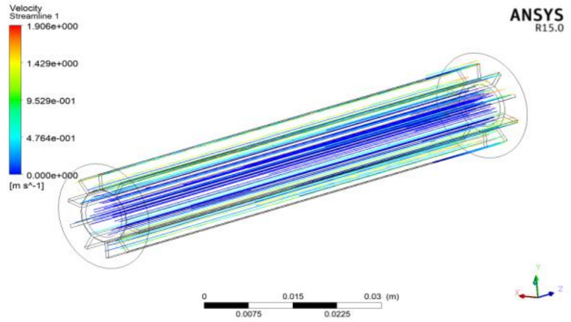
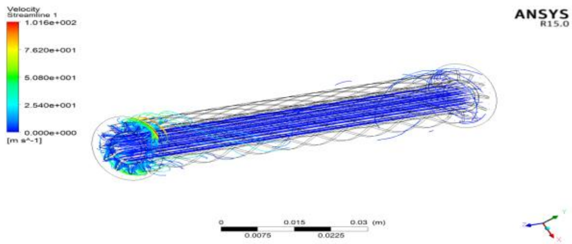


Fig 4. Plot of pressure drop versus Re for longitudinal fins.



(a) DPHE with straight fins.



(b) DPHE with helical fins.

Fig 5. Perspective view of velocity streamlines for Re = 12700.

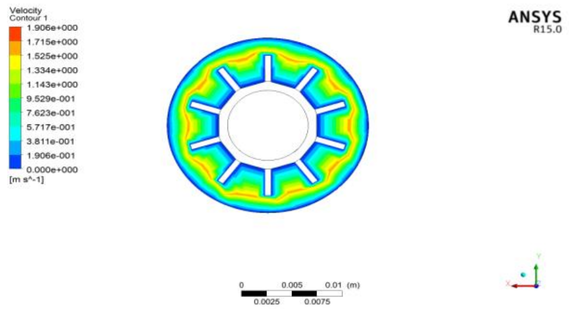


Fig 6. Velocity contour.

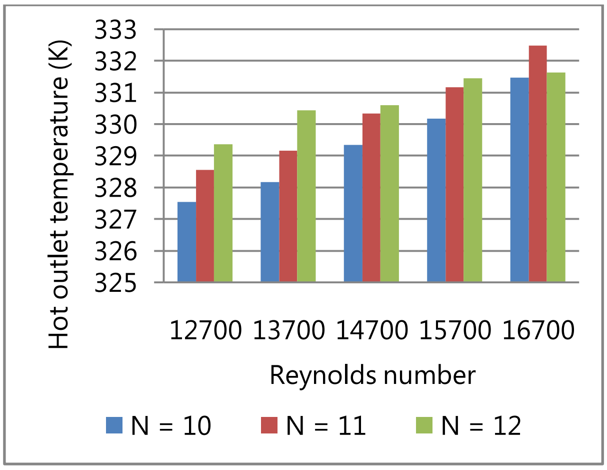


Fig 7. Temperature variation with straight fins.

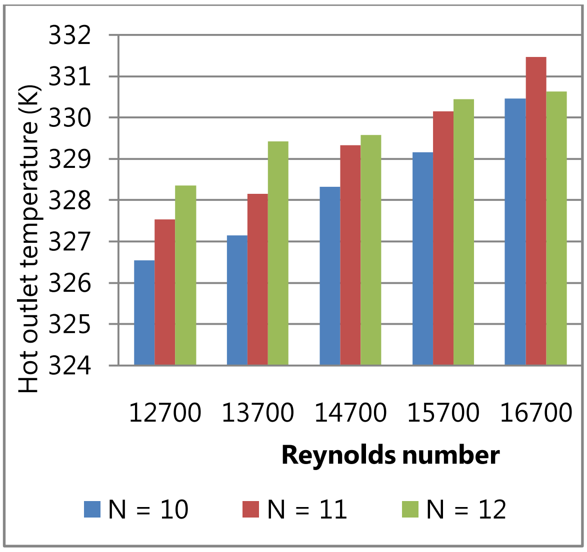
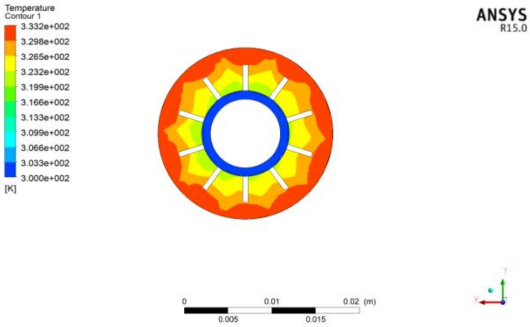


Fig 8. Temperature variation with helical fins.



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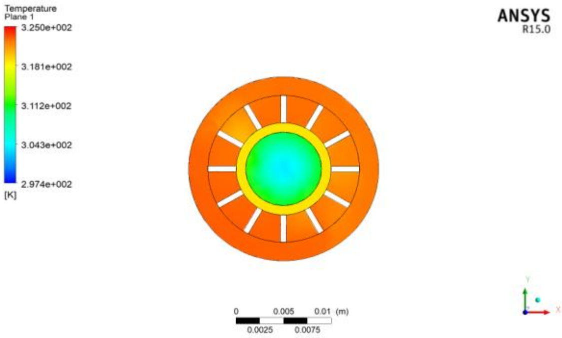

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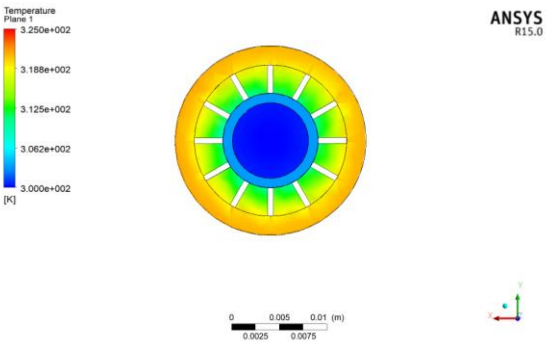

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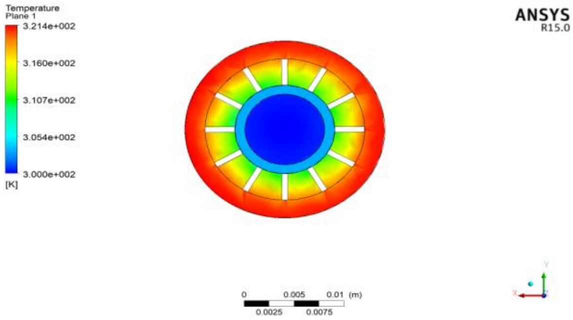
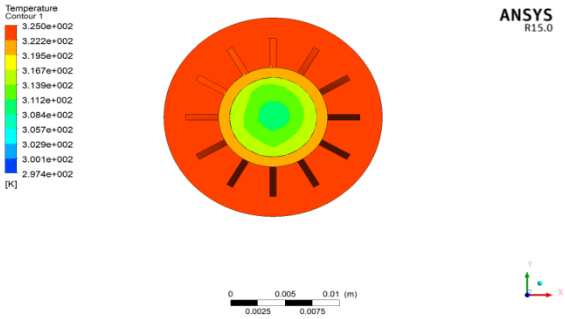


(d)



(e)

Fig 9. Temperature variation contours on the plane.

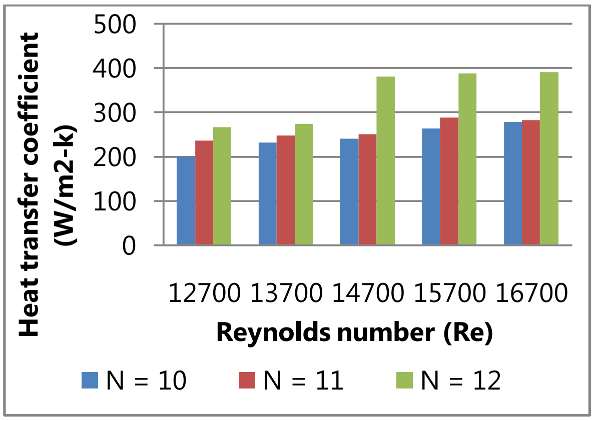


Fig 10. Variation of heat transfer coefficient in DPHE with straight fins with number of fins.

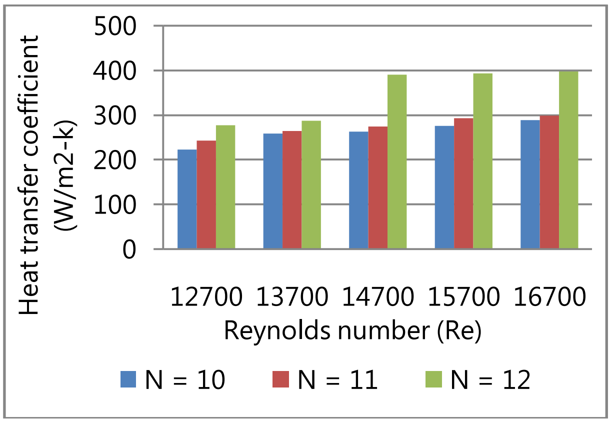


Fig 11. Variation of heat transfer coefficient in DPHE with helical fins with number of fins.

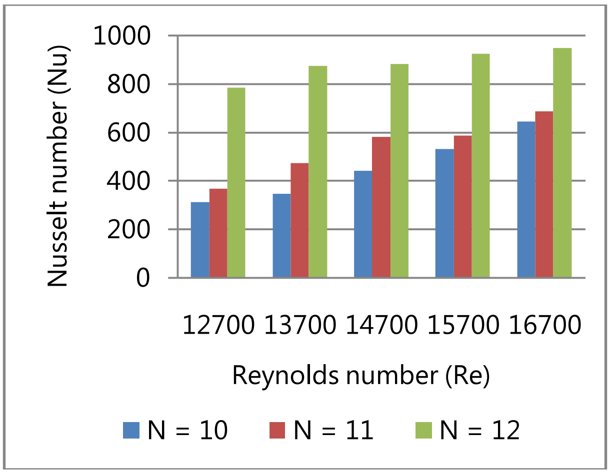


Fig 12. Variation of Nusselt number in DPHE with straight fins with number of fins.

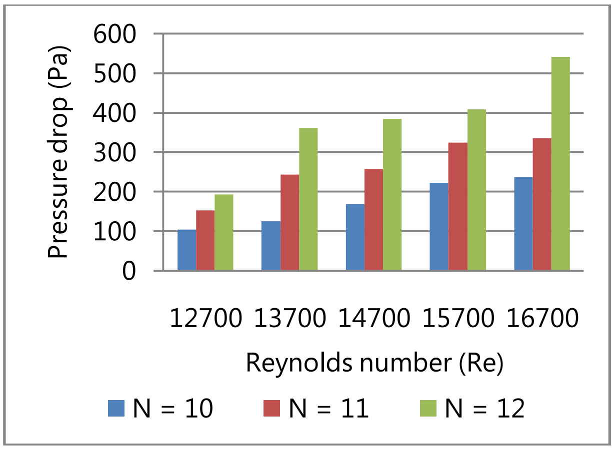


Fig 15. Variation of pressure drop in DPHE with straight fins with number of fins.

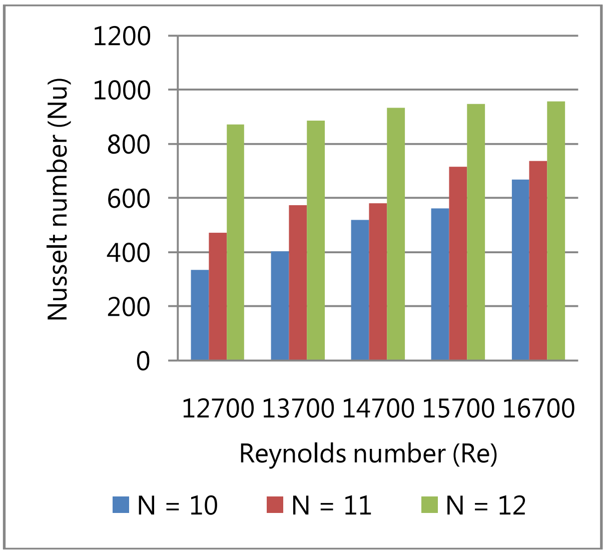


Fig 13. Variation of Nusselt number in DPHE with helical fins with number of fins.

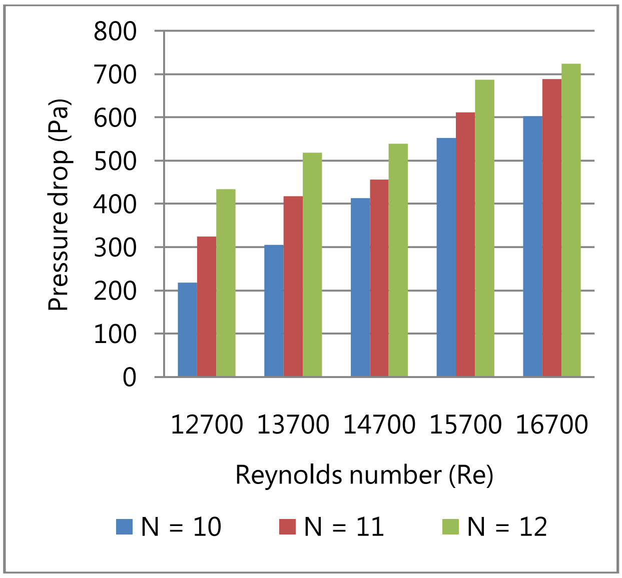


Fig 16. Variation of pressure drop in DPHE with helical fins with number of fins.

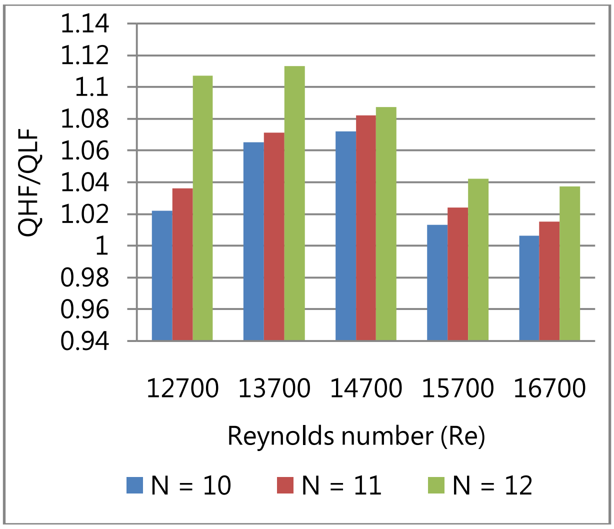


Fig 14. Ratio of heat transfer rate of heat exchanger with helical fins to that with longitudinal fins plotted versus Re.

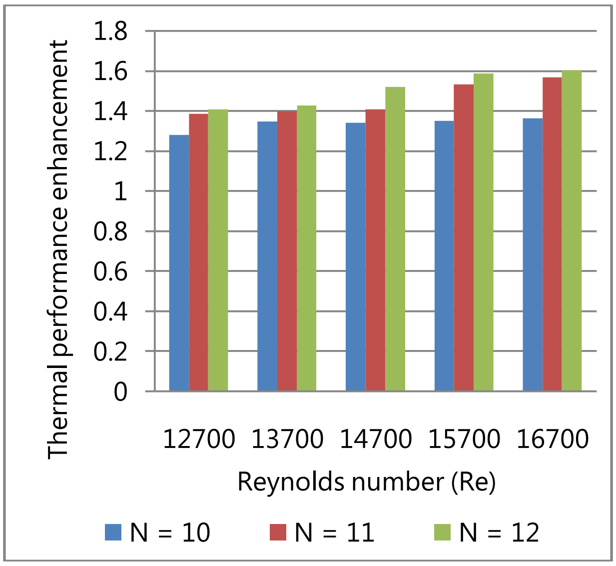


Fig 17. Thermal performance enhancement factor for DPHE with straight fins versus Re.

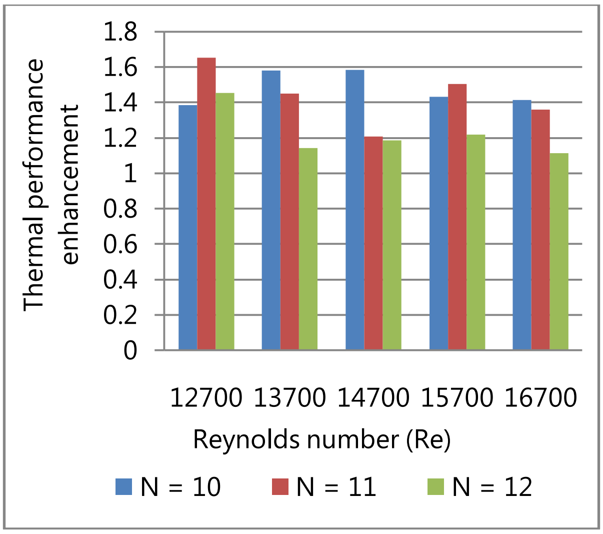


Fig 18. Thermal performance enhancement factor for DPHE with helical fins versus Re.

V. CONCLUSION

The following conclusions were drawn from the obtained results. Helical fins result in a higher heat transfer surface area than longitudinal fins. Overall, the thermo hydraulic performance of double-pipe heat exchangers is better with helical fins than with longitudinal fins, which indicates that the pressure loss of helical fins is offset by the improvement in the heat transfer rate.

In all the configurations, the annulus-side heat transfer coefficient ha increases with increasing Reynolds number. For the annulus with helical fins, ha also increases with increasing number of fins spacing. The higher velocity results in significant increase in the annulus heat transfer surface area result in a considerable thermal enhancement of ha on the gas side, especially for higher helical fin spacing. Finally, the helical fin configuration for double-pipe heat exchangers is demonstrated to be effective in enhancing the heat transfer and improving the thermo hydraulic performance of this type of heat exchanger.

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