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# Numerical comparison of shell-side performance for shell and tube heat exchangers with trefoil-hole, helical and segmental baffles

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## HIGHLIGHTS

- Shell side performance of a STHX with different baffle types was studied.
- Trefoil-hole baffles provide considerable heat transfer enhancement.
- Helical baffles give higher heat transfer coefficient per unit pressure drop.

## ARTICLE INFO

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## ABSTRACT

Shell-and-tube heat exchanger, is one of the most widely used heat exchange apparatus in various industrial process and research fronts. Baffle selection is critical to control and improve the thermo-hydraulic performance of this type of heat exchanger. In this paper, three-dimensional computational fluid dynamics (CFD) simulations, using the commercial software ANSYS FLUENT, have been performed to study and compare the shell-side flow distribution, heat transfer coefficient and the pressure drop between the recently developed trefoil-hole, helical baffles and the conventional segmental baffles, at low shell side flow rates. In this numerical comparison, the whole heat exchangers consisting of the shell, tubes, baffles and nozzles are modeled, the numerical model predicts the thermo-hydraulic performance with a considerably good accuracy, by comparing with experimental data for single segmental baffles. The model is then used to compute and compare the thermo-hydraulic performance for the same heat exchanger with trefoil-hole and helical baffles. The results show that the use of helical baffles results in higher thermo-hydraulic performance while trefoil-hole baffles has a higher heat transfer performance with large pressure drop compared to segmental baffles.



## 1. Introduction

Heat exchangers have an important role in various engineering processes. According to [1] more than 35–40% of heat exchangers are of the shell-and-tube heat exchangers (STHXs) type, this is mainly due to their wide range of allowable design pressures and temperatures, their rugged mechanical construction, and ease of maintenance [2]. STHXs contain a number of tubes packed in a shell with their axes parallel to that of the shell. The process of heat transfer takes place as one fluid flows inside the tubes, while the other fluid flows on the shell side across the tube bundles. Baffles are used to control the shell-side flow distribution as well as enhancing heat transfer. Hence, the form and structure of the baffles are of crucial importance for the performance of this type of heat exchangers.

The design and rating of STHXs can be difficult, especially when evaluating the shell side thermo-hydraulic performances. This difficulty is further complicated due to the presence of various leakages and secondary flows. Nowadays, the evaluation of these performances is almost exclusively done using commercial software such as Heat Transfer Research, Inc. (HTRI). HTRI developed the Stream Analysis method described [3], which is considered one of the most rigorous methods available for computing the shell side coefficients. However, most of the data needed for its implementation remain proprietary. Several empirical methods calculating shell-side heat transfer coefficient and pressure drop have been well developed. The most accurate is the Bell-Delaware method

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**Nomenclature**

*Latin symbols*

| | |
|---|---|
| $A_{cross}$ | cross-flow area at the shell centerline, mm$^2$ |
| $A_o$ | heat exchange area based on the external diameter of tube, mm$^2$ |
| $B$ | baffle spacing, mm |
| $c_p$ | specific heat capacity, J/(kg K) |
| $c_i$ | coefficients in $k-\varepsilon$ model |
| $D_s$ | internal shell diameter, mm |
| $D_o$ | external tube diameter, mm |
| $h$ | average heat transfer coefficient, W/(m$^2$ K) |
| $k$ | turbulent fluctuation kinetic energy, m$^2$/s$^2$ |
| $L$ | tube total effective length, m |
| $\dot{m}$ | mass flow rate, kg/s |
| $n_t$ | number of tubes |
| $P_t$ | tube pitch, mm |
| $Pr$ | Prandtl number |
| $\Delta p$ | pressure drop, Pa |
| $Q_{ave}$ | average heat transfer rate, W |
| $Re$ | Reynolds number |
| $T_{in}$ | inlet temperature, K |
| $T_{out}$ | outlet temperature, K |
| $\Delta T$ | logarithmic mean temperature difference, K |
| $u$ | average velocity, m/s |
| $x, y, z$ | Cartesian coordinate |

*Greek symbols*

| | |
|---|---|
| $\Gamma$ | generalized diffusion coefficient |
| $\varepsilon$ | turbulent kinetic energy dissipation rate, m$^2$/s$^3$ |
| $\lambda$ | thermal conductivity, W/(m K) |
| $\mu$ | dynamic viscosity, kg/(m s) |
| $\nu$ | kinematic viscosity, m$^2$/s |
| $\rho$ | density, kg/m$^3$ |
| $\sigma_k$ | Prandtl number for $k$ |
| $\sigma_\in$ | Prandtl number for $\in$ |

*Subscripts*

| | |
|---|---|
| in | inlet |
| out | outlet |
| s | shell side |
| t | tube side |
| *turb* | turbulent |

[4], the method can be used in its complete or simplified version [5]. Although not highly accurate, the simplified version is straight forward and can be easily used. The complete version is more accurate but relatively lengthy and involved.

Segmental baffles (Fig. 1a) are most commonly used in conventional STHXs [6] to support tubes and change flow direction. The fluid flow in a tortuous, zigzag manner across the tube bundle in the shell side, the use of segmental baffles improves heat transfer by enhancing turbulence or local mixing on the shell side of the exchanger, however, the conventional STHXs with segmental baffles present some major inconveniences [7,8]: (1) the pressure drop across the shell is very high due to flow separation at the edge

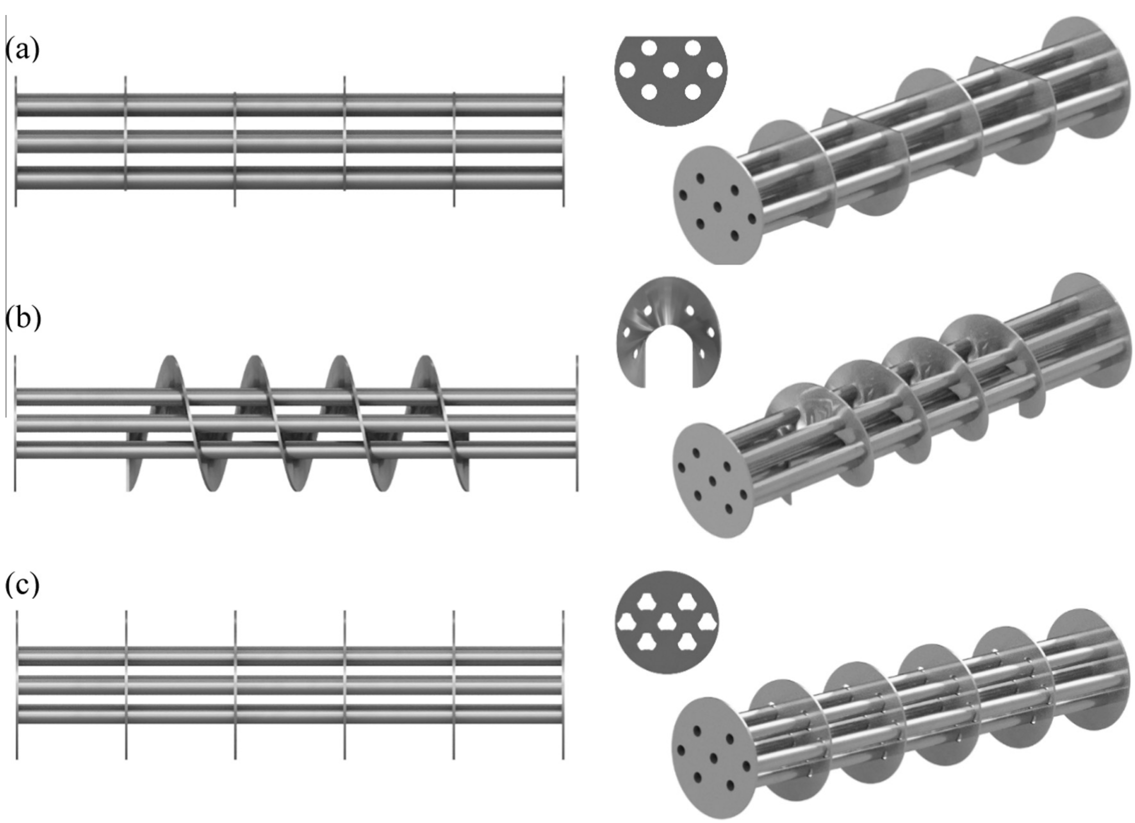


**Fig. 1.** Model of tubes bundles with different baffles type: (a) segmental baffles, (b) helical baffles, and (c) trefoil-hole baffles.