Simulating Analysis on Performances of Shell-Side in Trefoil-Hole and Quatrefoil Hole Baffle Heat Exchangers

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Abstract— This paper provides a comprehensive heat transfer devices and their relative merits for wide variety of industrial applications. The effectiveness of a heat transfer enhancement technique is evaluated by the Thermal Performance Factor which is a ratio of the change in the heat transfer rate to change in friction factor. Various types of inserts are used in many heat transfer enhancement. Shell-side performances of trefoil perforated plate baffle heat exchanger with equilateral triangle tube layout and quatrefoil-hole baffle heat exchangers with square tube arrangement have been studied numerically. Through establishment of periodic model of heat exchangers with three different trefoil and quatrefoil opening heights of 2.0mm, 2.5mm and 3.0mm, the influence of opening height on the shell-side performances has been studied. The results indicate that the enlargement of opening height decreases pressure drop and heat transfer coefficient while the reduction of it causes dramatic pressure loss with a modest increase of heat transfer coefficient. The heat transfer coefficient per unit pressure drop of trefoil-hole baffle heat exchangers is higher than that of heat exchangers with quadrifoil-hole baffles.

Keywords: Nusselt Number, Reynolds Number, Heat transfer coefficient, Pressure

I. INTRODUCTION

A heat exchanger is a device in which heat is transferred from one uid to another. Heat exchangers are used in many various applications. One example is a car, where heat from the air around the engine is transferred to the air inside the car. In this way the car is warmed up and the engine is not overheated. Another example is ventilation. The hot air going out of a building transfers some of its heat to the cold air entering the building.

There are some parameters that are important for all heat exchangers. Since the purpose of the heat exchanger is to transfer energy, the heat flow rate, Q, is always of great interest. The same equation also shows what properties that are significant for the heat flow, heat transfer coefficient (in some literature the notation for heat transfer coefficient is h), A, heat transfer area and dT, the temperature deference, are the variables that should be maximized in order to get as high heat ow rate as possible.

$$Q = h\ A\ dT$$

The process of heat exchange between two fluids at different temperatures and separated by a solid wall is found in many engineering applications. The equipment used to implement such heat exchange process is termed as a heat exchanger. A heat exchanger is a device in which two fluid streams, one hot and one cold, are brought into thermal contact with each other in order to transfer heat from the hot fluid stream to the cold one. It provides a relatively large surface area of heat transfer for given volume of the equipment.

II. LITERATURE REVIEW

The empirical study of literature attracts scholarship particularly in the areas of reception and audience studies and in cognitive psychology when it is concerned with questions of reading. In these two areas research and studies based on the framework are steadily growing. Further fields where the framework in various revised and expanded versions attracts scholarship is (comparative) cultural studies.

1) R Karwa et al [1] studied the heat transfer and friction in an asymmetrical rectangular duct with some solid and perforated baffles with relative roughness. The friction factor for the solid baffle was found between 9.6-11.1 times than smooth duct which decreases in perforated baffle. The baffle which has an open area gives the highest heat transfer. Maheshwari examined the effect of change in pitch ratio and open area on mass transfer. Perforated baffle has 47% mass transfer which is greater than that of solid baffle i.e 26 %.
2) M. K. Rowinski et al [2] Studied the the effect of local heat transfer and friction factor in a rectangular pipe with inclined and perforated baffles. Two baffles were used in this experiment, one was mounted at the top and another one varied to identify optimum configuration for enhancement of heat transfer. Experimentally investigated the heat transfer and friction factor by varying number of ribs. Heat transfer augmentation was studied in a fully developed square channel with V shaped rib.
3) A. Singh et al [3] Attached the baffles was at top and bottom of wall. Some merits of porous baffle are, (a) more heat escape (b) due to light weight it is used in aerospace application. Similar article on enhancement of cooling by using porous baffle which reduces the temperature of wall. They found that in porous baffle heat transfer increases 2 to 4 times than that of solid baffle.
4) W. Liu et al [4] corrugated channel in the heat exchanger as these have high heat transfer efficiency and turbulent flow with low velocity. Some of the inventors studied flow and transfer of heat through a corrugated channel and inclined angle between plate and overall flow direction and found maximum heat transfer rate at an angle of 80^0. Flow pattern are less effective for heat transfer at higher angle.
5) J. Lutcha et al [5] reported that in most of enhancement techniques, a variety of inserts have been used in circular channel, particularly when turbulent flow was considered. They used coil wire inserts, brush inserts, mesh inserts, strip inserts, twisted tape inserts etc. In order to enhance heat transfer in internal flow, tape is inserted in channel. Many industries apply this technique.

6) Y.Q. Wang et al [6] The heat transfer rate and pressure drop characteristics of turbulent flow of air through uniformly heated circular tube fitted with drilled cut conical rings with three space ratios (X=5.4, 6.4, and 8.4) have been studied experimentally. The flow characteristics are governed by space ratio (the ratio of the distance between drilled conical ring and the inner diameter of tube) The results show that the process of drilling of the conical ring inside tube gives high rates of heat transfer more than that in the conical ring without drilling.
7) Q. Dong et al [7] In their experimental investigations they studied the effect of combined wedge ribs and winglet type vortex generators (WVGs) on heat transfer and friction loss behavior for turbulent air flow through a constant heat flux channel. To create reverse flow in channel, two types of wedge (right-triangle) ribs were introduced .The arrangements of both types of ribs placed inside the opposite channel walls are in-line and staggered arrays. To generate longitudinal vortex flow through the tested section, two pairs of the WVGs with the attack angle of 60º were mounted on test channel entrance.
8) Chunyi Liu et al [8] investigated the effect of three test tubes fitted with single, twin, and triple twisted-tapes on heat transfer. The tubes fitted with twin and triple twisted-tapes could offer the higher values of heat transfer augmentation with the similar levels of performance factor as those found in the tube fitted with single twisted tape.
9) H. Bodineau et al. [9] studied flow passing thought a channel with only single helical baffle. A comparative study between three different channels was conducted by the authors. In the first case, a channel without any baffle was examined. In the second case, the same channel with only one helical baffle was considered. And in the third case, the same channel with two helical baffles was examined.
10) W. Roetzel et al [10] evaluated heat transfer and pressure losses in a rectangular channel with baffles. The author concluded that baffles raise the pressure losses as well as heat transfer coefficients. Thermo hydraulic parameters in a rectangular channel which were heated by perforated fins of different heights were investigated .The effects of turbulent flow with rectangular pipe containing the different shapes of baffles were studied.
11) B. Peng et al. [11] determined the mean heat transfer coefficients in a rectangular channel with porous obstacles. From this work, it can be concluded that use of porous baffles increase heat transfer as compared to no baffle.

III. Methodology

CFD is useful for studying fluid flow, heat transfer; chemical reactions etc by solving mathematical equations with the help of numerical analysis. CFD resolve the entire system in small cells and apply governing equations on these discrete elements to find numerical solutions regarding pressure distribution, temperature gradients. This software can also build a virtual prototype of the system or device before can be apply to real-world physics to the model, and the software will provide with images and data, which predict the performance of that design. More recently the methods have been applied to the design of internal combustion engine, combustion chambers of gas turbine and furnaces, also fluid flows and heat transfer in heat exchanger. The development in the CFD field provides a capability comparable to other Computer Aided Engineering (CAE) tools such as stress analysis codes.

A. Pre-processor: Establishing the model

Identify the process or equipment to be evaluated.

- Represent the geometry of interest using CAD tools.
- Use the CAD representation to create a volume flow domain around the equipment containing the critical flow phenomena.
- Create a computational mesh in the flow domain.

B. Solver:

- Identify and apply conditions at the domain boundary.
- Solve the governing equations on the computational mesh using analysis software.

C. Post processor: Interpreting the results

- Post-process the completed solutions to highlight findings.
- Interpret the prediction to determine design iterations or possible solutions, if needed

D. Design of Modified System:

In order to enhance the low temperature of the outlet from the heat exchanger with help of changing formation of geometry in a heat exchanger cross-section, the fluid is passed through the tube of an another heat exchanger. Thus we can obtain two advantages:-

- The temperature of the incoming fluid is decreased at in heat exchanger. It enhances the temperature with providing cross-sectional changes on it hence the turbulence of the heat exchange can be improved.
- By increasing the temperature of outgoing fluid can be prevented at the low effectiveness.

E. Steps involved in CFD Analysis

1) *Preprocessing:*
   a) Defining the problem (Computational Domain)
   b) Mesh generation
2) *Solving*
   a) Specifying the fluid and flow properties
   b) Choosing the discretization scheme
   c) Setting boundary conditions
3) *Post Processing*
   a) Examine the results
   b) Vector plots
   c) Contour plots
   d) 2D and 3D Surface plots

IV. Result & Discussion

Shell side fluid flows through trefoil and quadrifoil holes, and generates jet flow, which could scour the following flow zones and excite its underlying capacity in enhancing heat transfer. So jet flow is a critical factor that affects the performance of the shell side. For a given flow velocity of shell side, the increase of jet velocity and intense heat transfer are at the price of relative high resistance when opening height is small; on the contrary, pressure drop may decline with insufficient shell side heat transfer when opening height becomes larger. For heat exchangers with various kinds of baffles, velocity is a primary element, and it is far more significant than that as it comes to perforated plate baffle heat exchangers.

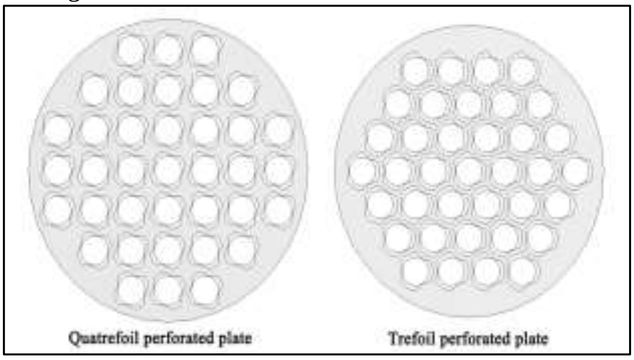

Fig. 1:

S.No.	Nusselt No.	Reynold No.
1	38	3200
2	45	6100
3	61	8000
4	70	10500
5	90	13000
6	110	14000
7	115	16500
8	119	17000
9	121	19000
10	122	21000

Table 1: Value of Nusselt Number Vs Reynold Number

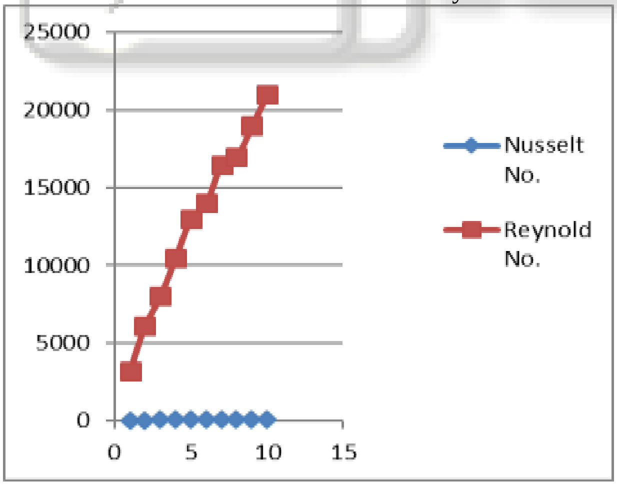

Fig. 2: Nusselt Number Vs Reynold Number

S.No.	Heat Transfer Coefficient (h)			Reynold Number(Re)
	H=3.0mm	H=2.5mm	H=2.0mm	
1	1.8	2.0	2.1	5000
2	2.8	3.3	4.5	10000
3	5.3	5.6	6.6	15000
4	6.7	7.1	8.5	20000
5	8.3	9.4	10.2	25000

Table 2: Value of Heat Transfer Coefficient (h) Vs Reynold Number

The above figures illustrate that the heat transfer coefficient per unit pressure drop of trefoil perforated plate heat exchanger is higher than that of heat exchanger with quadrifoil-hole baffles. It shows the shell-side performance of heat exchanger with trefoilperforated plates is superior to that of quadrifoil-hole baffle heat exchanger.

V. Conclusion

The influence of aperture sizes of quadrifoil-hole and trefoil-hole on thermos-hydraulic performance also has been analyzed. For the heat transfer coefficient and pressure drop in shell sides, heat exchanger with trefoil perforated plates is more sensitive to the aperture sizes than that with quatrefoil perforate plates. As to heat transfer coefficient per unit pressure drop which reflects comprehensive performance of heat exchanger in certain degree, it changes more violent for quatrefoil-hole baffle heat exchanger.

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