Numerical Analysis On The Effect Of Heat Transfer Rate By Varying The Tube Arrays In A Cross-Flow Heat Exchanger

T. Kanthimathi[1] Dr. P. Bhramara[2] G. Naga Sai Ram[3]

Abstract- Enhancement of heat transfer rate is the major requirement in a heat exchanger. Cross flow heat exchangers are the one which can give greater enhancement in the heat transfer rate and are also known for compactness. The present paper focuses on the increasing effect of the inner tube array on the overall heat transfer rate in a cross flow heat exchanger. A numerical analysis using Autodesk CFD is carried out with two different tube arrays in the exchanger. From the analysis it is found that with the increase in tube array the overall heat transfer rate has increased. Usage of the higher size of tube array have proved that the overall heat exchange has been improved.

Index Terms- Heat transfer enhancement, Cross flow heat exchanger, tube array, overall heat transfer rate, numerical analysis, compactness, Auto desk CFD

1 INTRODUCTION

A heat exchanger is an subtle device which helps in the exchanging the heat from the higher temperature body to lower temperature body. There are many classifications available in heat exchanger that have been recognized by the TEMA, and ASME and many more. The cross flow heat exchanger comes under the relative direction of fluid type of heat exchanger and there are no mixing and mixing type of cross flow heat exchanger and the non-mixing type is easy to operate. The cross flow unmixed type of the heat exchanger consists of the shell case with two vents as inlet and outlet. The cross tubes are place horizontally in the shell by the side walls as the extrusion surface. Hot water is made to flow in the shell and cold water is made to flow through the tubes. The heat transfer mode that can be used in cross flow heat exchanger is liquid to liquid and gas and also the refrigerant. The basic application involves in the implementation of the compact spaces and mobility. A car radiator and evaporator coil can be a best examples of the cross flow heat exchanger.

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2 LITERATURE REVIEW

Aravind A Dev[1] has performed numerical analysis on multi stream cross counter flow heat exchanger. Results indicate that cross counter flow heat exchanger is having better performance compared to purely cross flow or counter flow and the model developed can be used for other heat exchangers for energy efficiency. Dr. M.K. Chopra[2] has performed thermal and experimental analysis of a cross flow unmixed heat exchanger by varying the volume fractions of hot fluid (water and coolant mixed). Results indicate that the performance of unmixed heat exchanger deteriorates when percentage of coolant in water coolant mixture exceeds 50% because viscosity will be excessive the circulation of fluid will affect and heat transfer rate decreases. Ali Al-Saif[3] investigated transient response of a cross flow heat exchanger by varying mass flow rate and inlet temperatures. A parametric study is carried out to address the inlet conditions. A numerical analysis is carried out by Passakorn vessakosal[4] to evaluate the effect of fouling in across flow heat exchanger, an unstructured control volume finite element method is developed. Results indicate that heat transfer rate depends on the eccentricity and the thermal conductivity ratio of fouling material and the fluid. Luben Cabezas-Gomez[5] has performed analysis of a cross flow heat exchanger with a variation in the flow arrangement with two rows of tubes and the results have shown that heat transfer rate increased with the proposed arrangement. Hélio Aparecido Navas[6] developed a new methodology for the thermal performance of a cross flow heat exchanger. results are

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validated through comparison with analytical solutions for one-pass cross-flow heat exchangers with one to four rows and with approximate series solution for an unmixed–unmixed heat exchanger, obtaining in all cases very small errors

In this article we simulated the performance of a cross flow unmixed heat exchanger by varying the number of tube arrays for cold fluid at constant mass flow rate.

3 METHODOLOGIES

The basic equation that governed by the the overall heat transfer rate and the average heat transfer rate shows that the surface are plays the key important role for the achievement of the overall heat transfer rate.in terms of the cross flow unmixed heat exchanger the possibility of the surface are plays an significant role. Since it has the tubes of the different array the heat transfer rate is quiet high an often follows the distributive uniformity in the heat exchanging phenomena. It is known the effect is possible from the equations by how well is the quantized these phenomena is the interesting part of this study.

From the governing equations of the relation is derived as follows.

$$U = \frac{\dot{Q}_{avg}}{A_{surface} \cdot LMTD \cdot k} \quad (1)$$

It can be transformed that the surface is can be written as following

$$A_{surface} = \pi \cdot d \cdot L \cdot n_p \quad (2)$$

So the equation (1.1) becomes as follows

$$U = \frac{\dot{Q}_{avg}}{\pi \cdot d \cdot L \cdot n_p \cdot LMTD \cdot k} \quad (3)$$

It can be observed that from the above equations that

$$U \alpha \dot{Q}_{avg} \quad (4)$$

and

$$LMTD = \frac{(T_{hot\ in} - T_{cold\ out}) - (T_{hot\ out} - T_{cold\ in})}{\ln\left[\frac{(T_{hot\ in} - T_{cold\ out})}{(T_{hot\ out} - T_{cold\ in})}\right]} \quad (5)$$

From the equations (4) and (5)

$$U \alpha n_p \quad (6)$$

Where

U is the overall heat transfer rate.

$\dot{Q}_{avg}$ is the average if the heat transfer rate.

$A_{surface}$ is the surface area of the tubes.

d is the diameter of the pipe.

L is the length of the pipe.

n_p is the number of the tubes.

k is the correction factor depending upon the flow.

$LMTD$ is the log mean temperature difference.

The basic expression for the calculation of the $\dot{Q}_{avg}$ is given by the following equations.

$$Q_{hot} = \dot{m}_h \cdot c_{p_h} \cdot (T_{hot\ in} - T_{hot\ out}) \quad (7)$$

$$Q_{cold} = \dot{m}_c \cdot c_{p_c} \cdot (T_{cold\ in} - T_{cold\ out}) \quad (8)$$

$$\dot{Q}_{avg} = \frac{Q_{hot} + Q_{cold}}{2} \quad (9)$$

For the LMTD equation since we know the all the fluid temperatures

$$LMTD = \frac{(T_{hot\ in} - T_{cold\ out}) - (T_{hot\ out} - T_{cold\ in})}{\ln\left[\frac{(T_{hot\ in} - T_{cold\ out})}{(T_{hot\ out} - T_{cold\ in})}\right]} \quad (10)$$

The correction factor depends upon the type of flow it is made as user control parameter and is calculated from the graph provided in the data book..

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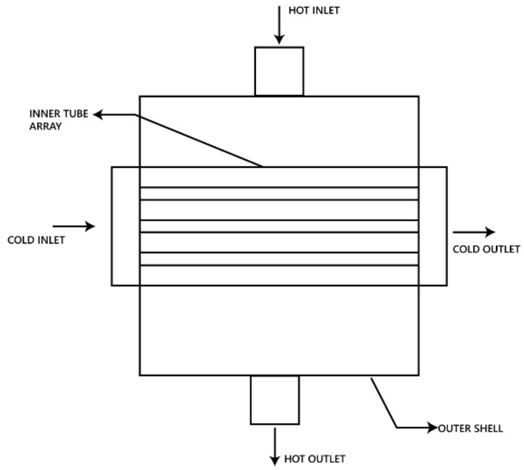

Figure 1 the basic scheme of the cross flow un mixed type of heat exchanger

The numerical analysis is carried on the CFD package known as the Autodesk CFD 2016 and the type of the solver used was the *k-ε* with intelligent wall faction was offered. A standard tetrahedron mesh with the refinement of 3 degrees was designed. The boundary conditions are applied for the inlet are velocity inlet with the temperature and the outlet type as the pressure outlet. The simulation was made to operate with the force convection one under simplified case of the air.

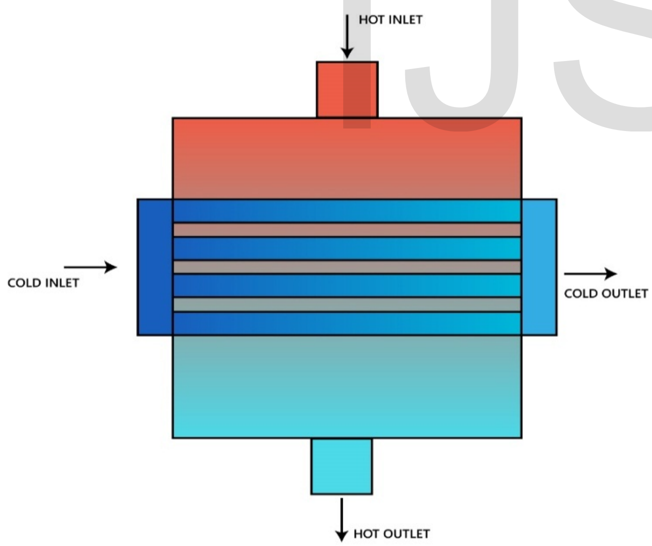

Figure 2 the boundary conditions of the simulated model

The convergence is made for the validation of the results rather than concluding them with some iterations. The configurations that was simulated was 4x4 and 2x2 size array tubes filled with the water and the shell is made to be stainless steel. The solver always specifies the pure turbulent flow because most of the heat exchangers comes to fall in the higher Reynolds number.

Parameters	Hot inlet	Hot Outlet	Cold inlet	Cold Outlet
Velocity (m/s)	0.8		0.8	
Temperature ^{0}C	60	57	27	27.7

Table 1: Inlet outlet conditions for 2 tubesarrays

Parameters	Hot inlet	Hot Outlet	Cold inlet	Cold Outlet
Velocity (m/s)	0.8		0.8	
Temperature ^{0}C	60	51	27	27.9

Table2.Inlet outlet conditions for 4 tube arrays

4 Results.

The results obtained from the successive iterations for the both the cases as the following. This show the temperature distribution of the liquid domains of the cross flow heat exchanger.

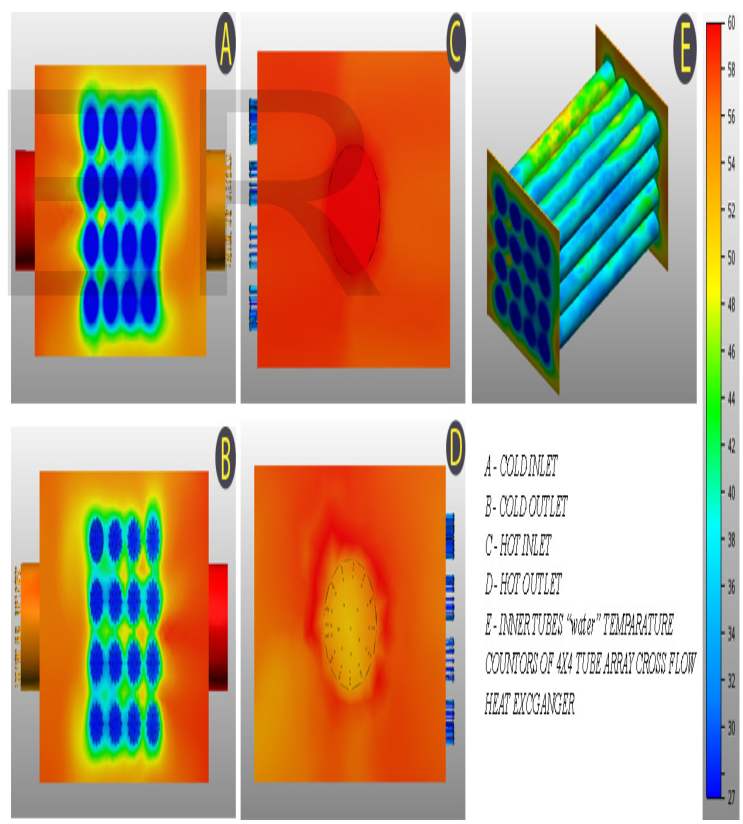

Figure 3 the inlets and outlets of the 4x4 array cross flow unmixed heat exchanger

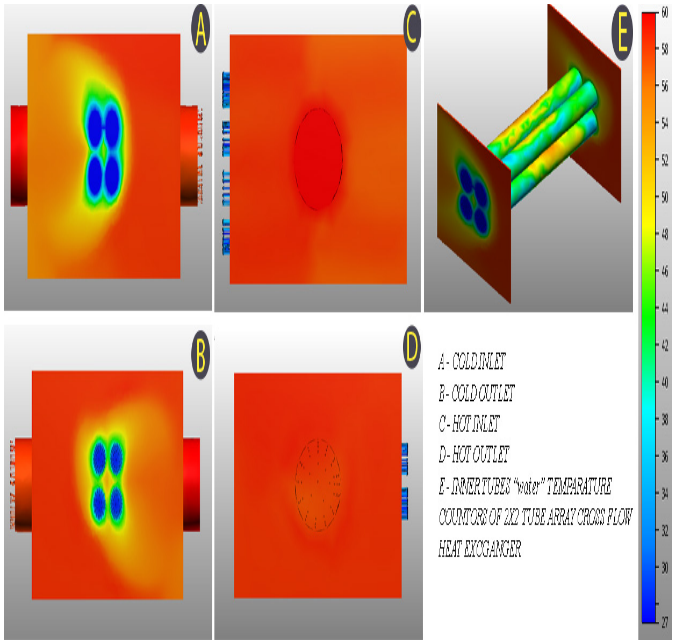

Figure 4 the inlet and outlets of the 2x2 array cross flow unmixed heat exchanger.

The observation has made clear that the numerical simulation has given the proportional relation between the number of the tubs and the overall heat exchanging rate. With the increase of the tubes it is proved that the cold water hasn't got heated up by the exchanging the heat to a larger extent and this helps in the recovery of the cold water to make an closed cyclic rotation of the cold fluid until the cold fluid reach an segregated temperatures that of the hot fluid.

5 CONCLUSION

In the present paper a cross flow unmixed heat exchanger analysis is carried out numerically. The effect of number of tube arrays in the cold tube side on the heat transfer rate is investigated. Results show that for a 2 tube array the temperature decrease in the hot fluid is about 3^0C. For a four tube array arrangement the decrease in the hot fluid temperature is 9^0C. Because of the increase in the number of arrays the heat lost by hot fluid has increased by 67%which in turn increases overall heat transfer rate of the heat exchanger. The restriction on the increase in the number of arrays is because of the increase in the area and total weight of the heat exchanger. This analysis can be further extended to find the optimum number of tube arrays required to increase the heat transfer rate and also to have compact model

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