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Heat Transfer in Rectangular Duct with Inserts of Triangular Duct Plate Fin Array

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Abstract: In compact plate fin heat exchanger for increasing the rate of heat transfer, triangular duct plate fins array are useful. Generally, triangular duct plate fin array inserts causes increase surface area introduces in the rectangular duct continuously disrupts the thermal boundary layer of fluid on the duct. This analysis has done on a single unit of duct with inserts of triangular duct plate fin array and this investigation is useful to increase the thermal performance of a heat exchanger. Analysis, triangular duct plate fin array inserts increase the heat transfer rate with expectation of mass flow rate of fluid.

Keywords: Compact plate fin heat exchanger, Heat transfer, Triangular duct plate fin array, Rectangular duct

1. INTRODUCTION

Heat exchanger is equipment. Which have designed for the effective transfer of heat energy between two fluids one is hot fluid and other is cold fluid. The purpose of heat exchanger is either to remove heat or to add heat to a fluid. The heat exchangers used in aircrafts, the demand on Performance is less but the volume and weight of the heat exchanger must be as soon as minimum. These requirements have led to the development of other unique heat exchangers known as compact heat exchangers. Compact heat exchangers have a large surface area. Plate fin exchanger is a one type of compact heat exchanger. In compact heat exchanger the heat transfer surface area is enhance by providing extended metal surface. This is interfaced between the two fluids.

2. RELATED WORK

M. Picon-Nunez et. al. proposed a methodology for the design of compact plate fin heat exchangers and pressure drop, have taken as a design objective. They developed a thermo-hydraulic model and represent the relationship between pressure drop, heat transfer co-efficient and exchanger volume. They also presented Design algorithms for cross-flow and counter-flow arrangements that results was comparing with case studies from the literature. This method requires a specification of the surface on each of the streams that will take the heat transfer.

Manish Mishra et. al. proposed an Optimum design of cross flow plate-fin heat exchangers through genetic algorithm. They applied optimization to minimizing the total annual cost for specified heat duty with flow restrictions. They considered multilayer plate-fin heat exchanger and obtained the optimum values for design variables and the fin geometrical parameters for the minimum total cost. For the validation, optimization of a reduced model plate fin heat exchanger has been compared with the solution of conventional optimization technique. Comparisons have done with the cases when no restriction is there on the upper limit of Reynolds number and with the laminar flow restriction.

Nilesh K. Patil et. al. They have numerical investigated the effect of operating parameters on plate fin heat exchanger, for offset strip fins, having rectangular cross section and a steady state model for the core dimensions of a plate fin cross flow heat exchanger have developed by using MATLAB. Design variables such as surface areas, free flow areas, exchanger core size have calculated for the operating parameters of cross flow CHE. The effects of effectiveness of the CHE on size of the heat exchanger have also calculated by varying effectiveness from 0.8 to 0.9 with different operating parameters. It got the effect of change in mass flow rate ratio on the flow lengths is negligible at lower value of effectiveness but it shows very step growth at higher effectiveness. It investigation are helpful for sizing the system and design optimization.

Masoud Asadi, et. al. they have studied the surfaces for obtaining high rate of heat transfer within the imposed size constraints. The sinusoidally curved wavy passage geometry has used to enhance heat exchanger performance and concluded that the Wavy channels provide significant heat transfer enhancement, and due to sinusoidal curve of the surfaces, calculation of heat transfer area is difficult. They carried work in an appropriate (transitional) Reynolds number regime. They authors have introduced a new method to calculate total heat transfer area in a plate-fin heat exchanger with waviness surfaces.

Mukesh Goyal et. al. proposed a two dimensional model for Multi stream plate fin heat exchangers. The model was based on finite volume analysis with multi stream plate fin heat exchangers for cryogenic applications. They discretised the heat exchanger core in both the axial and transverse directions and considered the effects of secondary parameters like axial heat conduction through the heat exchanger metal matrix, parasitic heat in-leak from surroundings, effects of variable fluid properties, metal matrix conductivity. They suggested that the numerical model can be use for rating calculations of multi stream PFHE for cryogenic applications.

C. Mageswaran et. al. 2016 analyzed a Heat Transfer and Friction in Rectangular Duct with Pin-Fin Arrays. They have investigated heat transfer of pin-fin heat sinks with circular, square and diamond cross sections. Ensemble of pin-fin heat sinks with in-line and staggered arrangements were designed and tested experimental. They examined the fin density effect on heat transfer and friction characteristics and concluded that in all, the circular pin-fin arrangement shows an appreciable influence of fin density and no effect is seemed in case of square fin geometry. For the staggered arrangement, the heat transfer coefficient increases with the rise of fin density with the penalty of pressure drop. In a diamond pin-fin results show that there was lowest pressure drop with better performance than that square configuration.

3. ANALYSIS

3.1 Principal of Working:

The triangular duct plate fin array is inserts on a rectangular duct. Triangular duct plate fin array are made by aluminum material. The hot fluid is passing through this triangular duct passages and the cold fluid is passing through rectangular duct passages. The triangular shape of duct plate fins acts as a heat exchanger. When the hot fluids passing through passages made on heat exchanger, heat is transfer from hot fluids to cold fluids. The triangular shape of duct plate on which hot fluids is flowing, transfer more heat due to extended surface area contact. The cold fluids receive heat energy from hot fluids and get heated.

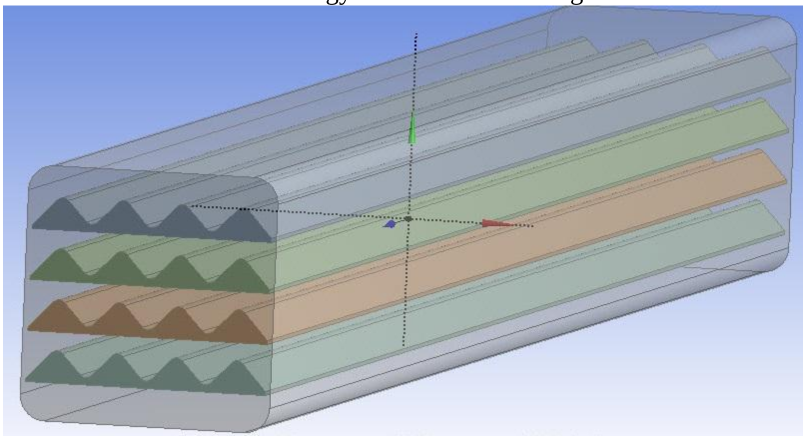

Figure1.Rectangular duct with inserts of triangular duct plate fin array

3.2 Design Step:

The following steps are involved in the design procedure of triangular duct plate fin array

A. Heat Transfer Areas
the surface areas, for hot fluid (A_h) and cold fluids (A_c) sides are computed from the geometry.

B. Free Flow Area And Frontal Area
The frontal area or the free flow area is computed. The length, width and height of the rectangular duct heat exchanger are assumed.

C. Fluid Temperatures And Fluid Thermo Physical Properties
On each fluid side are select from thesis or literatures.

D. Calculation of Heat Transfer Coefficient
The Reynolds number, colburn factor (j) and friction factor (f) on each side are calculated by using available correlations.

E. Determination of Overall Heat Transfer Coefficient.
The heat transfer coefficients on both hot and cold sides are computed. The overall heat transfer coefficient is calculated by the formula:

$$\frac{1}{U0A0} = \frac{1}{\eta oh\ hh\ Ah} + \frac{tw}{KwAw} + \frac{1}{\eta oc\ hcAc} \qquad (2.0)$$

Where
η_o = overall surface effectiveness of fins
η_f = fin efficiency
h = heat transfer coefficient

F. Number of transfer units are calculated by the relation

$N_{tu} = \frac{Uo\ Ao}{Cmin}$ (2.1)

G. E-NTU method are apply for calculation of Outlet temperature

H. After finding the outlet temperature heat transfer rate is computed from relation

$Q = h \times A \times (\Delta t)$ (2.2)

4. RESULTS AND DISCUSSION

For initial design the dimensions of a rectangular duct heat exchanger is considered as shown in table-3.1, and thermal and fluid properties of rectangular duct and triangular duct plate fins array also considered as shown on table-3.2.

Table -3.1 Input Dimensions of Rectangular Duct

Parameter	**Symbols**	**Units**	**Dimensions**
Core Length	L_1	mm	900
Core Width	L_2	mm	100
Core Height	L_3	mm	100
Plate Thickness	t_w	mm	6

Table -3.2 Thermal and Fluid Properties of Rectangular duct and triangular Duct Plate Fins array

Parameter	**Symbols**	**Units**	**Hot**	**Cold**
Fluid used			Hot fluid	Cold fluid
Specific heat	c_p	J/kg- K	5197.5	5197.5
Viscosity	μ	Pa-s	0.0000154	0.0000148
Prandtl number	Pr		0.6685	0.67
Density	ρ	kg/m^3	1.7404	0.2808
Inlet temperature	t_i	K	358.83	313.94
Mass flow rate	□	Kg/s	4.5	5

The analysis of heat exchanger having 4.5 and 5.0 Kg/s mass flow rate has taken for hot and cold fluids respectively. The above design steps are used on analysis and calculations have done. This analysis is for the inlet temperature of hot fluid and cold fluid is respectively 358.83, 358.86, 358.69, 358.86, 358.83, 359.32 and 313.94, 313.6, 312.7, 315.08, 316.55, 315.75 K.

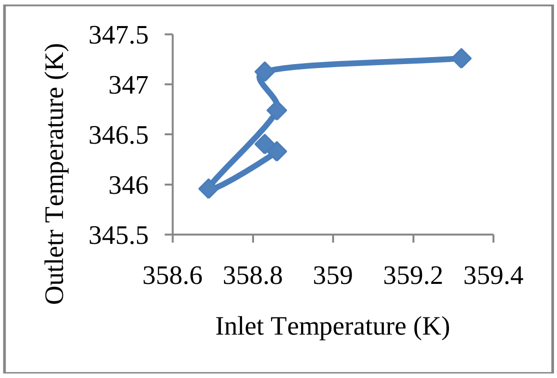

Figure2. Outlet Temperature profile

The above graph shows the result of rectangular duct with insert of triangular duct fins array form the Analysis. in terms of Inlet and outlet temperature of hot fluid.

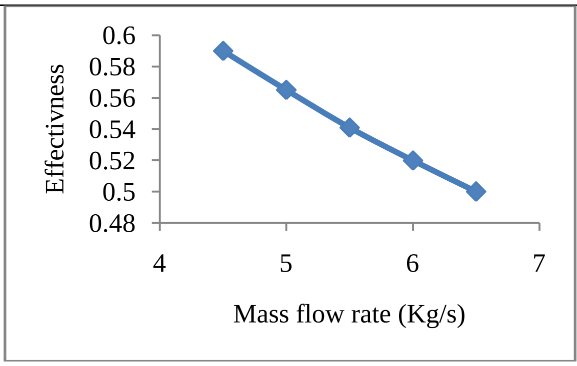

Figure 3: Graph represent Effectiveness Vs Mass flow rate at 310 K Hot fluid temperature

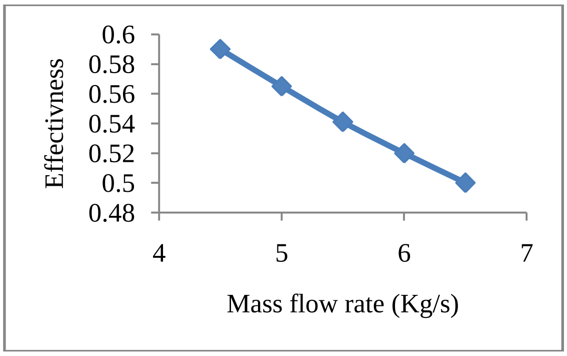

Figure 4: Graph represent Effectiveness Vs Mass flow rate at 320 K Hot fluid temperature

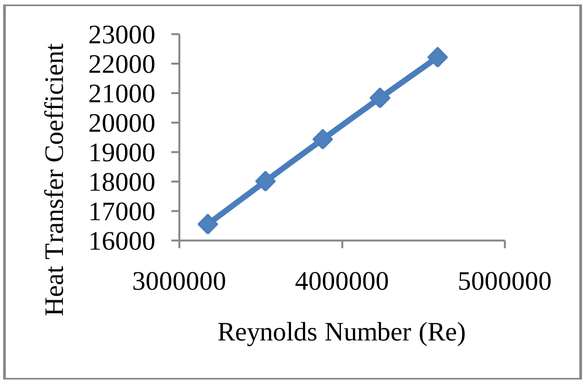

Figure 5: Graph represent Heat transfer coefficient Vs Reynolds No. at 4.5 Kg/s Hot fluid Mass flow rates

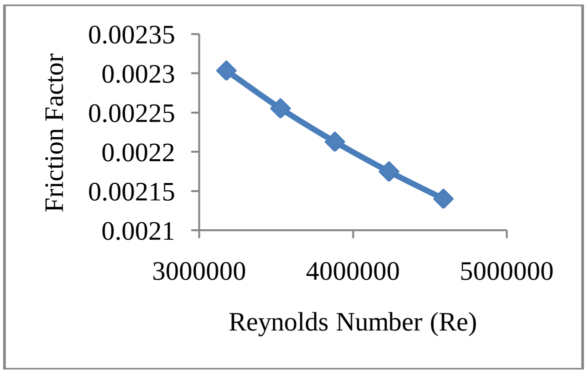

Figure 6: Graph represent Friction factor Vs Reynolds No. at 4.5 Kg/s Hot fluid Mass flow rates

The above graph show the result of rectangular duct with insert of triangular duct fins array between the effectiveness and mass flow rate, heat transfer coefficient and Reynolds number, friction factor and Reynolds number. It is clear that from the graph effectiveness decrease with increasing the Mass flow rate of hot fluid, Heat transfer coefficient increase with increasing Reynolds number and friction factor decrease with increasing Reynolds numbers for hot fluids.

5. CONCLUSION

It is very much clear that insertion of a triangular duct plate fin array in a rectangular duct or pipe increase the thermal performance of the duct or pipe. The cold fluid's temperature at the outlet of the duct or pipe has been increased due to the insertion of a triangular duct plate fin array in the duct or pipe. The reason for the increment of these parameters is that, due to the insertion of a triangular duct plate fin array a more surface contact is created in the duct or pipe which helps the fluid to take more and more heat from the fluid.

So it may be concluded that,

1. Plate fin heat exchanger having rectangular duct with insert of triangular duct plate fins array disturb the flow, due to this the heat transfer between fluids having surface area increase.
2. The Reynolds number increases with respective friction factor decreases for hot fluids.
3. The mass flow rate of fluids increases then the effectiveness also increases for hot fluids.
4. The convective heat transfer coefficient increase with increase of Reynolds number for fluids.

Further detailed studies can be carried out in this area either through experiments or with the aid of software. Reynolds number and friction factor values can be obtained for rectangular duct with the same mass flow rate of fluids at other pattern of plate fin geometry.

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