ISSN:2321-0613

Numerical Investigation on Air Side Performance of Fin and Tubeheat Exchanger with Different Types of Fins

Ishwar J.Dhangar
Department of Mechanical Engineering
RKDF (RGPV) Bhopal, India

Abstract— The present thesis deals with the behaviour of fin and tube heat exchangers; fin tube heat exchangers are mostly employed to gas to liquid heat exchangers; it is an effective way to reduce the air side thermal resistance which often accounts for about 90% of the overall thermal resistance. Fin and Tube heat exchangers are widely used in various engineering fields such as heating, ventilation and air conditioning, refrigeration, automobiles and air intercoolers. Thus the study of behavior of fin and tube heat exchangers becomes quite necessary. The present study deals with the analysis of different types of heat exchangers with different types of fin mounted on it. The study is based on numerical approach of investigation where 3D models have been used. Three different types of fin namely plain fin, slit fin and vortex generator fins have been used. These different fin tube heat exchangers have been\ analyzed under certain set of operating conditions and their air side behavior is investigated As the inlet velocity of air is increased the Reynolds number of air side fluid i.e. air was increased and it was observed that the pressure drop measured in the different types of fin was increased due to increased air velocity and hence causing fall in friction factor; the air outlet temperature measured was decreasing as the Reynolds number was increasing; the air outlet temperature was decreasing due to increased turbulence in the air stream due to higher inlet air velocity. The observations of different types of fin and tube heat exchanger when compared it was concluded that it was observed that fin tube with vortex generator have higher outlet temperature & lowest pressure drop & friction factor. So it is the best heat exchanger within the given operating parameters.

Key words: Air Side Performance**,** Fin & Tubeheat Exchanger

I. Introduction

A Heat Exchanger is a device to transfer heat from hot fluid to cold fluid across an impermeable wall. Fundamental of Heat Exchanger principle is to facilitate an efficient heat flow from hot fluid to cold fluid. This heat flow is a function of the temperature difference between the two fluids, the area where heat is transferred, and the conductive/convective properties of fluid and the flow state this relation was formulated by Newton and called as Newton’s law of cooling, which is given in equation (1.1)

$$Q = h*A*\Delta t$$

Where h:-heat transfer co-efficient [w/m2k], where fluids conductive/convective properties and the flow state comes in the picture

A: heat transfer area [m2] and Δt: temperature difference[k]

A fin and tube heat exchanger is a piece of equipment built for efficient heat transfer from tube side to fin side. They are widely used in refrigeration, air conditioning, power plants, chemical plants, petrochemical plants, petroleum refineries. Fins are used to increase the effective surface area of heat exchanger tubing. Finned tubes are used when the heat transfer coefficient on the outside of the tubes is appreciably lower than that on the inside. Various types of fins can be used to increase the effective heat transfer such as plain fin, slit fin, spiral fin, fin with delta wing vortex generator fin. The aim was to find the best suitable fin for a considered application. Various researchers have done remarkable work in the field and have analyzed, various possibilities in different working condition

A. Plain Fin

Round tube heat exchangers with plain fins have been studied for decades, and many correlations are available. That of gray and Webb(1986); it was modified and extended by Wang and clang (1988) to include a broader set of data, and that correlation and f factor correlation by Wang et al.(1996) are useful because of the wide range of parameters covered. In order to enhance generality abumadiet.al (1988) may be useful. Rich (1973) and Wang.et.l (1996) reported that heat transfer and friction factors do not depend strongly on fin spacing. Gray and Webb (1986) provided a j factor independent of fin spacing but a friction correlation f increasing as fin spacing decreased. Yan and sheen concluded that both heat transfer and pressure drop increase as fin spacing decreases, from fin spacing 2.0 to 1.4 mm. Disagreement in the literature as to effect of fin spacing may be due to geometrical variation and experimental uncertainties; however most investigators concluded that f is higher for a smaller fin spacing and j is relatively independent of fin spacing.[1][2][3][4]

B. Slit Fin

Fin spacing may have stronger effect on slit fin patterns. Wang et.al (1999b) confirmed both heat transfer coefficient and pressure drop decreased as fin spacing increased. As with other geometries there is a relatively small effect of number of tube rows on friction factor and decreased j factor for an increasing number of tube rows.[12]

C. Fin with Vortex Generator

In recent years vortex generators such as fins, ribs, wings, etc. have been successfully used for heat transfer enhancement of the modern thermal systems. Vortex generators form secondary flow by swirl and destabilize the flow. They generate the longitudinal vortices and create rotating and secondary flow in the main flow which can raise turbulent intensity, mix the warm and cold fluid near and in the center of channel and increase the heat transfer in the heat exchangers. Different types of vortex generators such as rectangular and triangular are available.

In 1994 firebug et al experimentally compared the effect of vortex generator on the heat transfer and flow losses in heat exchangers for the Reynolds number between 600-3000 for the staggered fin-tube arrangement, their results showed that the heat exchanger element with round tubes and vortex generator increases heat transfer only 10%but about 100% in flat tube. They also showed that pressure drop in flat tube bank with vortex generator is nearly half than that of round tube.

The effect of two pairs of vortex generator in a flat tube bank was experimentally studied by wang.et.al. They showed that heat transfer enhancement in flat tube bank with and without vortex generator was 47.5 % in constant mass flow. 41.4% in constant power consumption; and 37.5 for constant pressure drop.[6][8][10]

II. JUSTIFICATION OF WORK

Huge experimental data and analysis was available for different fin and tube heat exchangers performance. And the present study is obviously the lack of information of numerical information concerning such a comparison. The aim is to show for what types of fin and tube heat exchaeffective for heat transfer enhancement and pressure loss.

A. Problem Definition

Various researchers have thoroughly studied the flow pattern over various types of heat exchangers; whereas these studies were mainly focused on small tube diameter and small tube rows, which are usually used in condensers or evaporators in refrigeration engineering. However in some application such as intercooler of multistage compressor, the number of tube rows and outside diameter of tubes are large therefore, it is essential to investigate the heat transfer and friction characteristics of fin and tube heat exchangers with large tube diameter and large number of tube rows.

In the present study air side heat transfer and friction performance of large number of tube rows (N=12) and large tube diameter(D_0 =18) are numerically studied and compared.

B. Objectives of the Study

The main objective of this study is to compare the effect of different types of fin in finned tube heat exchanger i.e. to evaluate their performance parameters in a cross flow fin and tube heat exchangers; which includes:

- Modeling of the test setup in annoys design modeler.
- To determine their air side thermal performance parameters like heat transfer co-efficient, friction factor, and pressure drop of finned tube heat exchanger under balanced flow condition.
- To compare the numerically obtained values of each type of fin.

III. METHODOLOGY

Present work is investigated numerically using commercial CFD software ANSYS Fluent. The work consists of

- Selecting the computation domain and associated governing equations along with boundary conditions.
- Creating the required 3D computational domain in ANSYS Workbench Design Modeler.
- Meshing the model using ANSYS Workbench.
- Select the solver formulation.
- Chose the basic equation to solved: laminar or turbulent (or in viscid), heat transfer models.
- Specify the material properties.
- Specify the boundary conditions.
- Adjust the solution control parameter.
- Initialize the flow field.
- Calculate a solution.
- Examine the results.
- Save the results.

IV. MATHEMATICAL MODELING AND NUMERICAL IMPLEMENTATION

This chapter deals with the mathematical and numerical aspects of the present problem. Under mathematical modelling, assumptions made in the formulation of the problem, applicable governing equation and associated boundary conditions needs to be applied, have been discussed. Numerical implementation discusses and lists all models, values of constants required to run the simulation along with all pre-processing activities of solid modelling and meshing.

V. MATHEMATICAL MODELING

Mathematical modelling is the actual representation of any system in mathematical form. For this simple approximations and idealizations are employed. Different laws such as physical laws and conservation laws such as mass, momentum and energy conservation laws are employed. In this present chapter for solving the present problem the assumptions made are given. The basic governing equations required are given. Boundary conditions and computational domain are discussed. For solving the problem numerically solid model, meshing and required solver set up is discussed.

VI. GOVERNING EQUATIONS

The following Governing equations are considered:

A. Mass Conservation:

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$$

B. Momentum Conservation in Y direction

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w = g\beta(T - T_\infty) + u\frac{\partial^2 v}{\partial x^2} + v\frac{\partial^2 v}{\partial y^2} + w\frac{\partial^2 v}{\partial z^2}$$

C. Energy Equations

$$\rho C_p\left(u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} + w\frac{\partial T}{\partial z}\right) = k\left(\frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} + \frac{\partial^2 T}{\partial z^2}\right)$$

Boundary conditions & material
Fin and tube material: copper
Air inlet temperature: 288 k
Tube inside temperature: 340k
Air inlet: velocity inlet with constant temperature.
Air outlet: pressure outlet
Tube inside: constant temperature wall.

D. Numerical Implementation

In numerical implementation solid model is created of the given problem by using any modelling software. This solid model is discredited in number of elements. The above given governing equations are solved for each and every element.

VII. SOLID MODELLING

Models are constructed to study the air side performance of fin and tube heat exchangers. Schematic model of finned tube heat exchangers.

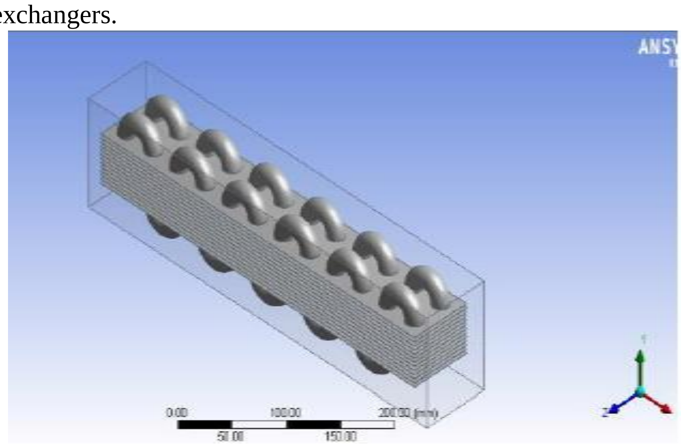

Fig. 1: Simple Fin

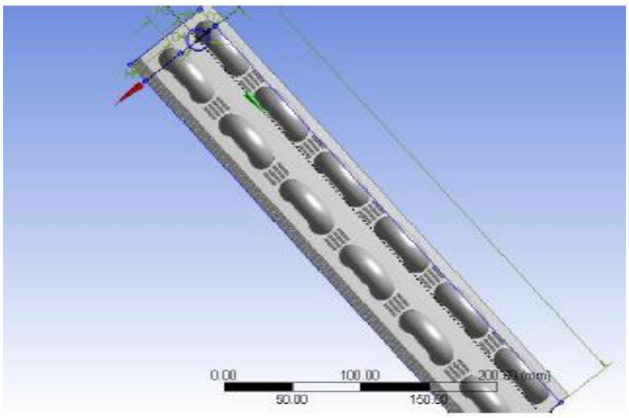

Fig. 2: Slit Fin

A. Geometric Dimensions of Fin Tube Heat Exchanger:

Internal diameter (D_i): 16 mm
Outer diameter (D_o): 18 mm
Fin thickness: 0.5 mm
Fin collar outside diameter (D_c): 19 mm

Fin pitch: 4.1 mm
Transverse tube pitch: 34
Longitudinal tube pitch: 34

B. Dimension of Slit:

Slit length: 12 mm
Slit width: 2.2 mm
Slit spacing: 2 mm

VIII. RESULTS AND DISCUSSIONS

In this chapter the air side thermal performance of heat exchangers were analyzed. All the three different types of heat exchangers were operated under same operating conditions. And their individual behaviors have been analyzed and their performances are compared afterwards.

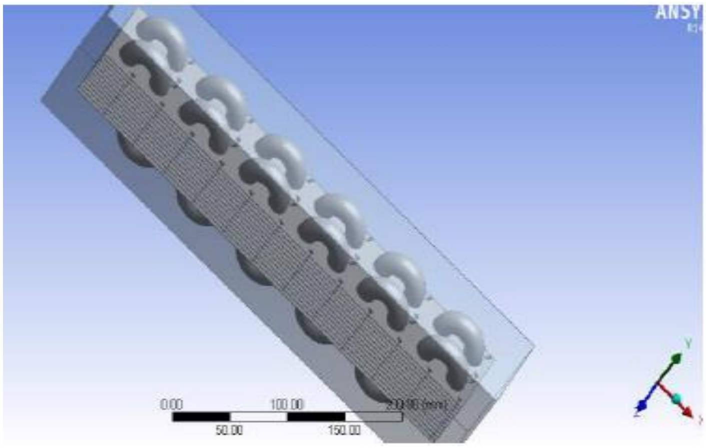

Fig. 3: Schematic view of finned tube heat exchanger with vortex generator

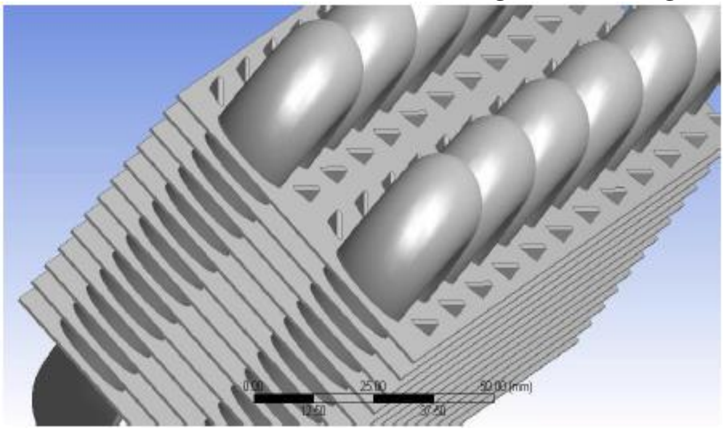

Fig. 4: Enlarged view of finned tube heat exchanger with vortex generator

IX. OBSERVATIONS

A. Pressure Drop

Reynolds number	4000	5205	6506	7808	9109
Plain fin	41.56	69.84	103.95	145.72	194
slit fin	41.61	62.05	94.02	137.37	174.6
Vortex Generator fin	33.42	57.42	86	121	163.04

Table 1: Pressure Drop

B. Temperature at Outlet

Reynolds Number	4000	5205	6506	7808	9109
Plain Fin	41.56	69.84	103.95	145.72	194
Slit Fin	41.61	62.05	94.02	137.37	174.6
Vortex Generator Fin	33.42	57.42	86	121	163.04

Table 2: Temperature at outlet

C. Friction Factor

Reynolds Number	4000	5205	6506	7808	9109
Plain Fin	41.56	69.84	103.95	145.72	194
Slit Fin	41.61	62.05	94.02	137.37	174.6
Vortex Generator Fin	33.42	57.42	86	121	163.04

Table 3: Friction factor

X. CONCLUSION

It is observed that fin tube with vortex generator have higher outlet temperature & lowest pressure drop & friction factor. So it is the best heat exchanger within the given operating parameters. As Reynolds number increases; the pressure drop increases & fluid outlet temperature decreases.

That concludes that with increase in Reynolds number the disturbances are increased and the heat transfer reduces

REFERENCES

[1] Numerical study of fin spacing effects in annular-finned tube heat exchangers”. International journal of heat and mass transfer47 (2004) 1953 – 1964 Misandormon, Ulrich gross, 2003.
[2] Numerical study on a slit fin-and-tube heat exchanger with longitudinal vortex generators
[3] Jiong li, shuangfengwang, jinfangchen, yong-gang lei
[4] “CFD Applications in various heat exchangers design: A review” applied thermal engineering32(2012)1-12
[5] Muhammad mahmoodaslambhutta,sarfaraz khan.,2011
[6] “Numerical study on a slit fin and tube heat exchanger with longitudinal vortex generators” international journal of heat and mass transfer 54(2011) 1743 – 1751. Jiongli.,s wang.,2010
[7] “Experimental and numerical investigation on air side performance offin and tube heat exchangers with various fin patterns” Experimental thermal and fluid science 33(2009) 818 – 827.
[8] An investigation of the air side performance of the slit fin and tube heat exchangers, Int. journal of refrigeration Vol.22(8) pg 595-603 Wang, C.C., Tao, W.H. and Chang,C.J..