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CFD Analysis of Heat Transfer in a Pipe Having Finned Tube with Different Fin Profile

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Abstract- The primary interest is to determine how the extended surface (i.e., the fin) will enhance the air-side heat transfer performance of this kind of heat exchanger. It is very important to consider the heat transfer rate (heating or cooling), which is normally limited by the thermal resistance This thesis concerned with computer simulation study of tube with different fins used to enhance their heat transfer performance subjected to natural convection heat transfer. In the present study the performance of a heated pipe having fins of various configurations using ANSYS 16.0 is analyzed. The material under consideration is aluminum and the free stream fluid is air. Base width and height of the fin were kept constant for all the three types. The heat transfer rate from the fins and the overall heat transfer rate has been calculated and compared for various fin configurations. Also the overall heat transfer co-efficient has been found out. Temperature contours for various fin configuration has been plotted showing the convection loops formed around the heated pipe surface. After comparing it is shown that we can find that the best configuration for this type of convective heat transfer of a heated pipe is a trapezoidal fin as they have the highest total heat transfer rate.

Keywords: - Triangular fins, Rectangular fins, turbulent flow, heat transfer and pressure drop.

I. INTRODUCTION

Extended surfaces or fins are commonly found on electronic components ranging from power supplies to transformers. The dissipation and subsequent rejection of potentially destructive self-produced heat is an important aspect of electronic equipment design. The dissipation of heat is necessary for its proper function. The primary interest is to determine how the extended surface (i.e., the fin) will enhance the air-side heat transfer performance of this kind of heat exchanger. It is very important to consider the heat transfer rate (heating or cooling), which is normally limited by the thermal resistance on the air side of the heat exchanger.

Improving the fin geometry or fin pattern is one way to augment the heat transfer rate of the fin-and-tube heat exchanger, but this method may require more fan power because of the loss associated with the pressure drop. In order to solve the aforementioned problems, finding the optimized fin configuration would be valuable in designing and creating the heat exchanger. In addition, we must realize that the effect of fin configurations, tube arrangements, and operating conditions has significance for the air-side heat transfer performance and flow characteristics of fin-and-tube heat exchangers.

Until now, many researchers have investigated those effects of plain fins, wavy fins, louver fins, slit fins, compounded fins, circular (or annular) fins, and several spiral fins on the air-side performance. Currently, the spiral fin-and-tube heat exchanger earns its popularity in waste heat recovery system applications.

II. REVIEW OF PAST RESEARCH

Naik, Hemant et al. (2020) presented fluid flow and heat transfer characteristics of different possible RWP locations concerning each tube are examined. Further, for higher performance, a search for an effective angle of attack ranging from 15° to 60° is also performed for optimized locations.

Taler, Dawid et al. (2020) examined a two-pass double-row plate-fin and tube heat exchanger (PFTHE) made of circular or oval pipes. A method for determining the air side Nusselt number on individual pipe row was developed, using the results of CFD (Computational Fluid Dynamics) modeling of the heat exchanger.

Taler, Dawid et al. (2020) presented a new method of modeling the transient operation of PFTHE, considering that the Nusselt numbers on the air side of individual tube rows are calculated from different empirical relationships.

Biçer, Nihat et al. (2020) presented a novel and innovative baffle design was offered in order to considerably reduce shell side pressure loss without compromising thermal performance. Computational fluid dynamics (CFD) was utilized to simulate and visualize 3-D turbulent flow field in the shell side so as to investigate various shapes of baffles for preliminary baffle design purposes.

Gupta, Sachin et al. (2020) investigated the effect of employing a rectangular winglet having a punched hole on heat transfer and flow resistance characteristics in a fin-tube heat exchanger with the help of numerical simulations.

Naik, Hemant et al. (2020) investigated the irreversibility's caused by fluid flowing under the effect of isothermal walls of fin-tube heat exchanger in the presence of longitudinal vortex generators.

Gupta, Arvind et al. (2020) performed Numerical simulations for investigating the effect of punching a rectangular winglet having hole from fin surface, on the heat transfer and flow resistance characteristics in a fin-tube heat exchanger.

Waser, Remo et al. (2020) presented a new modeling method which allows for the optimization of complex heat exchanger designs such as fin-tube concepts in latent storages units is proposed.

Kute S. B. and Sonage B. K (2018) present study for consideration of replacement in fire tube boiler. Flue gas side surface heat transfer coefficient is the criteria used for the comparison. Heat transfer performance of helically ribbed tube (Rifled Tube) is compared with that of plain tube experimentally.

III. DESIGN METHODOLOGY

For CFD simulation, first of all geometry of the tube was created using ANSYS 15.0. After geometry creation next step is to mesh the geometrical model, which was also done using ANSYS. Next step in ANSYS is to declare continuum type and boundary type for the surfaces generated. Finally a mesh file is created, which is imported in FLUENT.

After importing mesh file in FLUENT, dimensional units for CFD domain are specified. In FLUENT desired turbulence model was selected for viscous modeling review. After selection of turbulence model boundary conditions are specified. Fluent has capability to store value of physical parameters for any point in the domain for analysis. Seven points were created to store the value physical parameters such as temperature, velocity and pressure.

IV. DESCRIPTION OF CIRCULAR FINNED TUBE

Table 1. Dimensions of the fin tube.

Specification	Dimensions
Outer dia.	50 mm
Fin height, H	15 mm
Fin thickness, t	1 mm
No. of fins	40
Cross-section of tube	circular
Cross-section of fin	Rectangular, triangular and trapezoidal
Material for tube and fins	Aluminum

V. GEOMETRIC MODELLING

Geometry: geometry generation is first step for making CFD domain. In ANSYS we can create both 2-D and 3-D shapes. In our case 3D geometry of the tube with various shapes of fins was created. In most of the problems shape of the domain is very complex. Some special operations are given in geometry mode to model complex geometries. The most significant operations are: unite, subtract, split, move, copy, align, rotate, translate etc. Figure 1 shows 3-D geometry used in our case.

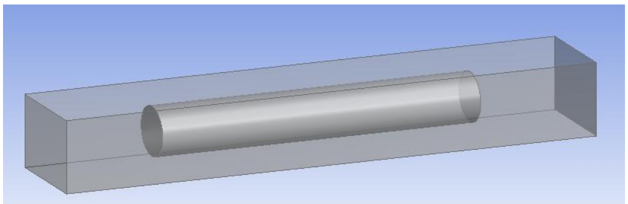

Fig 1. Tube without fin.

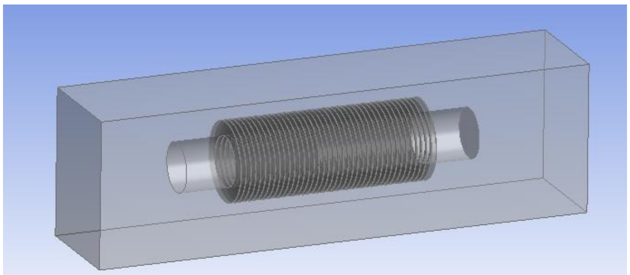

Fig 2. Tube with rectangular fin.

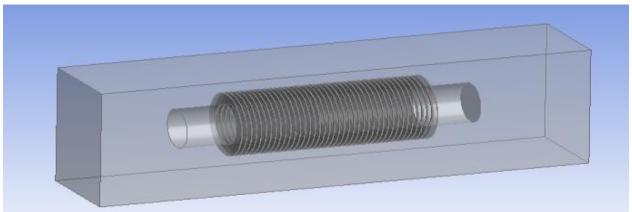

Fig 3. Tube with triangular fin.

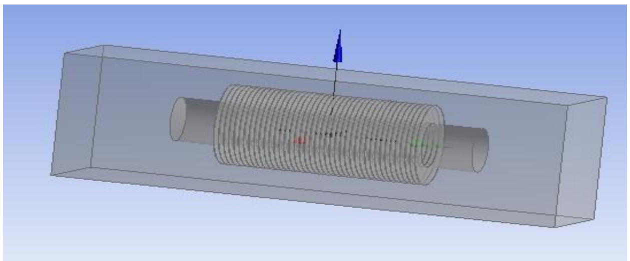

Fig. 4. Tube with trapezoidal fin.

VI. EFFECT OF TRAPEZOIDAL FIN ON THE PERFORMANCE OF VERTICAL TUBE

By completion of all the test runs in Fluent, several key performance indicators were studied to understand the heat transfer characteristics and trends for each pin-fin configuration. To understand results we study temperature based results in graphical mode and pressure based results.

1. Temperature Contour:
Simulation was carried out for various mass flow rates of air from 0.2-0.8 Kg/s. The temperature counters of the vertical tube with triangular fin, maximum temperature of 318.94 K for mass flow rate of 0.2 Kg/s is observed at the wall due to convection specified and the boundary.

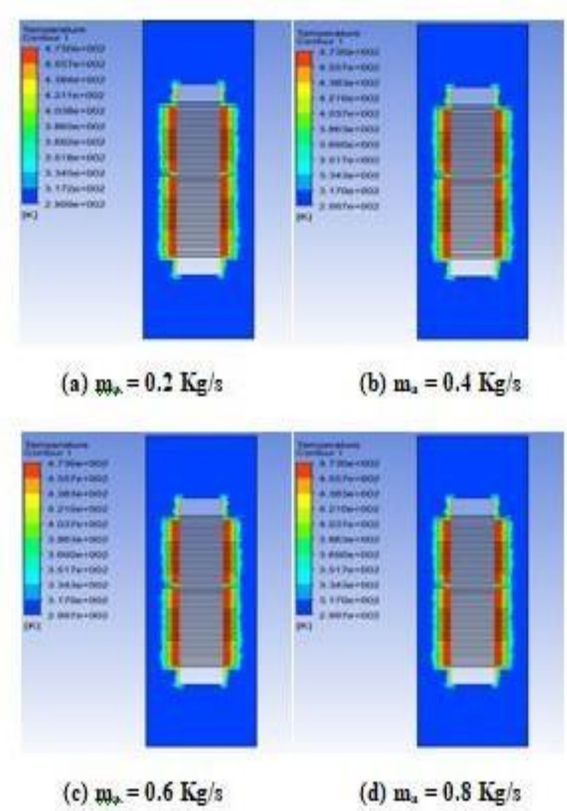

Fig 5. Temperature contour plot for different flow rates and with trapezoidal fin.

Table 2. Cold air outlet temperature for different flow rate with trapezoidal fin.

S.No	m_{air}, Kg/s	Tube wall temperature, K	Cold air inlet temperature, K	Cold air outlet Temperature, K
1	0.2	380 K	300 K	318.2256
2	0.4	380 K	300 K	314.0082
3	0.6	380 K	300 K	311.9094
4	0.8	380 K	300 K	311.1471

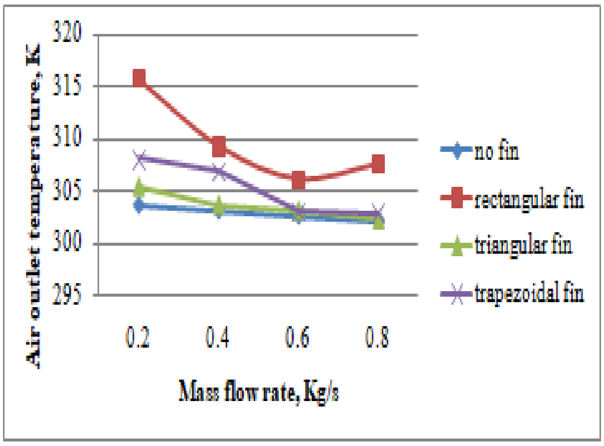

Fig 6. Variation of cold water temperature for different flow rate with no fin, rectangular fin, triangular fin and trapezoidal fin.

Fig. 6 indicates the temperature plot of different fin profiles with mair = 0.2-0.8 kg/s. It depicts that the cold air outlet temperature for the triangular finned tube is lower than the rectangular and triangular finned tube. Fins promote boundary layer separation of the fluids and disturb the whole bulk flow field inside circular tubes. Separation and restarting of the boundary layers increases the heat transfer rate.

The variation of outlet temperature of cold air for varying mass flow rates of cold air with wall temperature being fixed. It indicates as the mass flow rate increases the outlet temperature decreases for all profiles.

This is because for a fixed value of main heat energy dissipated from the inner tube remains constant and hence as mair is increased heat transfer rate is being increased due to the increased turbulence, but the retention time of the fluid in the exchanger will be reduced which decreases the cold water outlet temperature. Drop in outlet temperature or the triangular profile is marginally lesser than the other three types showing its poor performance.

2. Pressure Plots:

Fig. 14 represents the pressure drop variation for unfinnedand finned tube for various mass flow rates of cold fluid. It can be seen that pressure drop for unfinned tube is maximum for higher mass flow rates. Higher pressure losses increase the pumping power. Since the pressure losses are more in case of for higher mass flow rate, the pumping power required will bemore when compared to other mass flow rates.

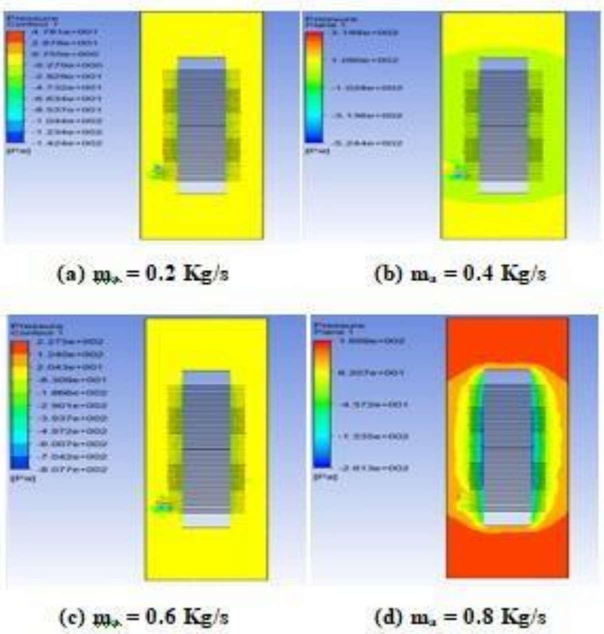

Fig 7. Pressure contour plot for different flow rates and with trapezoidal fin.

Fig. 7 represents the pressure drop variation for rectangular, triangular and trapezoidal finned and the unfinned tube for various mass flow rates of cold fluid. It can be seen that pressure drop for triangular finned tube is lesser than the finned and unfinned tube. In case of a rectangular finned tube minimum pressure drop was observed at 0.2 Kg/s.

Table 3. Pressure drop for different flow rates and with trapezoidal fin.

S.No	m_{air}, Kg/s	Pressure drop
1	0.2	0.34
2	0.4	1.69
3	0.6	8.9
4	0.8	17

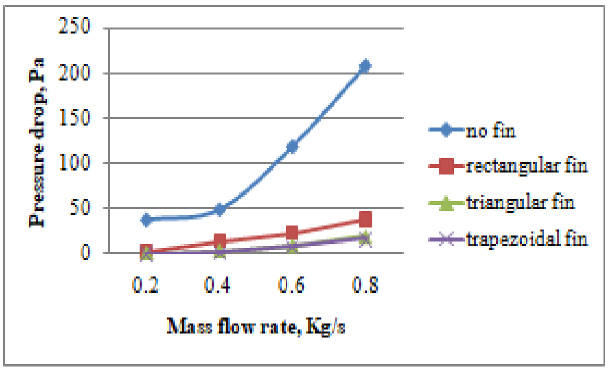

Fig 8. Variation of pressure drop with varying mass flow rates of air with different fin and no fin.

Table 4. Heat transfer coefficient and heat transfer rate for different flow rates with trapezoidal fin and no fin.

S.No	m_{air}, Kg/s	Heat transfer coeff. (W/m²/k)	Heat rate (W/m²)
1	0.2	55.55556	1612
2	0.4	111.1111	2716
3	0.6	166.6667	1826.4
4	0.8	222.2222	2240

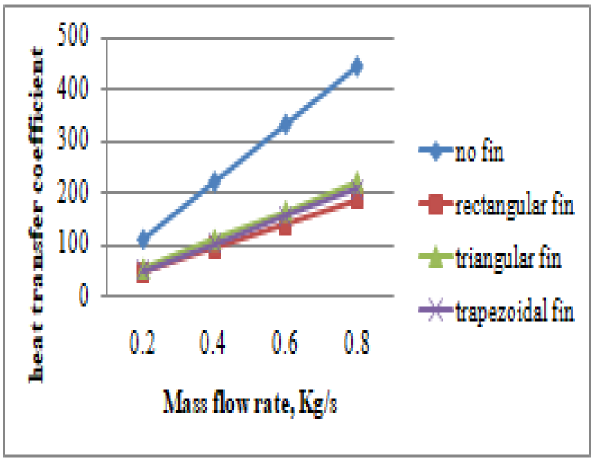

Fig 9. Variation of heat transfer coefficient with varying mass flow rates of air with different fins and no fin.

Fig. 9 shows the variation of heat transfer coefficient for different varied mass flow rate at 0.2-0.8 kg/s. It is observed that annular heat transfer coefficient is found to be increased after 0.4 Kg/s for finned structure since effective heat transfer coefficient is related to the efficiency of the fin as Annular =Inefficiency × normal. Further on comparing the values for different flow rates it is observed that for 0.8 Kg/s, the heat transfer coefficient is slightly higher than the others at all mass flow rate conditions.

Fig. 10 shows the variation of heat transfer rate for different varied mass flow rate at 0.2-0.8 kg/s. It is observed that heat transfer rate is found to be higher at 0.8 Kg/s. Further on comparing the values for different flow rates it is observed that for 0.8 Kg/s, the heat transfer rate is slightly lower for finned and unfinned tube than the others at all mass flow rate conditions.

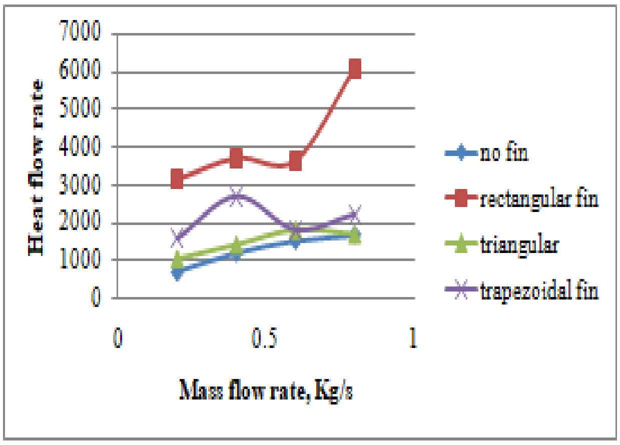

Fig 10. Variation of heat transfer rate with varying mass flow rates of air with different fins and no fin.

VII. CONCLUSIONS

The various conclusions from study are as follows:

Results indicated finned configurations show an overall improvement in the thermal characteristics compared with unfinned one.

For better Performance the mass flow rate of the cold fluid should be kept low where as that of the hot liquid should be high. Triangular finned configuration show a marginal improvement over the other in terms of temperature rise, heat transfer rate and heat transfer coefficient. Triangular fins showed minimum pressure drop for all mass flow rates.

Heat transfer rate is slightly lower for finned and unfinned tube than the others at all mass flow rate conditions. It can be seen that pressure drop for unfinned tube is maximum for higher mass flow rates. Higher pressure losses increase the pumping power. Since the pressure losses are more in case of for higher mass flow rate, the pumping power required will be more when compared to other mass flow rates.

In addition to this even they provide the advantage of lesser material and hence reduced weight. Hence it can be concluded that trapezoidal finned configuration can be a better alternative compared to the triangular and rectangular because of reduced pressure drop and reduced weight of the finned assembly even though the thermal performance is being marginally reduced.

It depicts that the cold air outlet temperature for the finned tube is lower than the bare tube. Fins promote boundary layer separation of the fluids and disturb the whole bulk flow field inside circular tubes. Separation and restarting of the boundary layers increases the heat transfer rate.

The variation of outlet temperature of cold air for varying mass flow rates of cold air with wall temperature being fixed. It indicates as the mass flow rate increases the outlet temperature decreases for all profiles.

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