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Internal Finned Tube Heat Transfer Equipment for Higher Performance

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Abstract

The performance of internal finned tube heat exchanger studied through numerical simulation using Fluent 14 to get the best design parameters and compared between plain circular tube (without fins) and finned internal tube for different flow conditions. During this study the mass flow rate as well as the constant heat flux applied on to the outer surface of the pipe. Here the length of the pipe is considered as 1m, the inner diameter of the pipe is 44 mm and the material for the pipe and fin is chosen as aluminium. 3D simulation using conservation equations of mass, momentum and energy with two equation based k- ε turbulent model is considered for this purpose. From this experiment it was that the thermal performance of the internal finned tube was far better than that of the plain tube but at the penalty of pressure drop.

Keywords-- Friction factor, Nusselt Number, heated surface, CFD, wall temperature

I. Introduction

Heat transfer equipments with internally finned tubes fins plays a very vital role in transferring the heat from the heated wall to fluid and are extensively used in many industrial and commercial applications to increase thermo-hydraulic behavior. In many industries such as power plants, chemical plants and petroleum industries attention is also focused to reduce the size of the heat transfer equipments so as to occupy less space without sacrificing the thermo-hydraulic performance by varying the number, shape and size of the fins. Recently experimental study performed by different researchers shows that friction factor and Nusselt number is higher for rectangular and triangular fins compared to round crest fins [1]. Moore and Joshi [2] concluded from experimental investigation by introducing a small amount of tip clearance in pin fin increases the heat transfer and reduces the pressure drop. Moon and Lau [3] conducted experimental study on rectangular channel to study the steady heat transfer between the two blockages having holes in the turbulent for nine different staggered arrays of holes in the blockages. They found that the blockages enhanced the heat transfer, but the pressure drop was increased significantly. For an offset fin array it was seen that the friction factor decreases when the Reynold's number changes from 10000 to 20000 and at higher Reynolds number the friction factor is increased [4]. Experimental investigation conducted by Islam, Mozumder and Mohapatra, Mishra [5] for smooth tube and T-shaped internally fined tube revealed that the average heat transfer coefficient of finned tube was two times of smooth tube and the friction factor was five times than that of smooth tube. Based on the above mentioned studies a comparison of fluid flow and heat transfer characteristics between smooth tube and internally finned tube for a turbulent flow conditions has been chosen for the present investigation. The experiment is performed for developing flow condition and is subsequently validated numerically using **Fluent 14**. We have also tried to match the present computation with the existing experiment of Islam, Mozumder and Mohapatra, Mishra [5, 6] for temperature distribution.

II. Numerical solution procedure

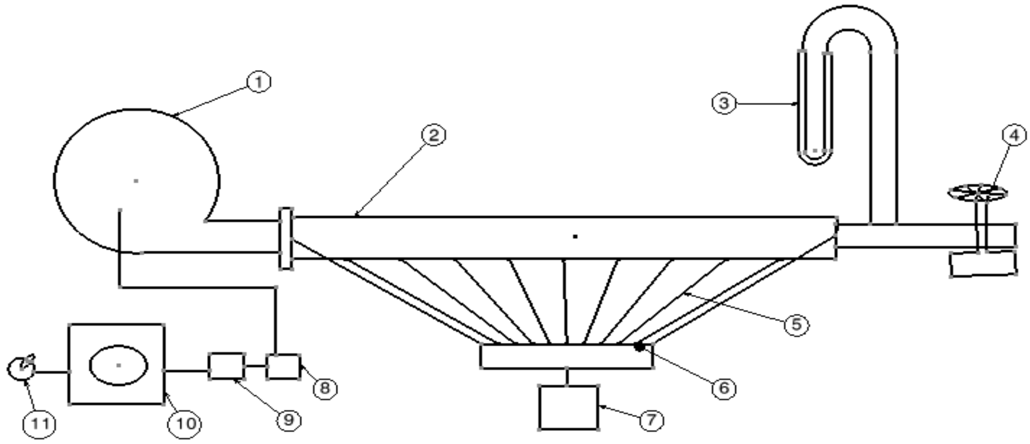

Fig. 1 Schematic diagram of the test rig

1. Blower 2. Test section 3. Manometer, 4. Flow regulator, 5. Thermocouple 6. Selector switch 7. Temperature indicator 8. Voltmeter, 9. Ammeter, 10. Voltage regulator, 11. On/Off swit

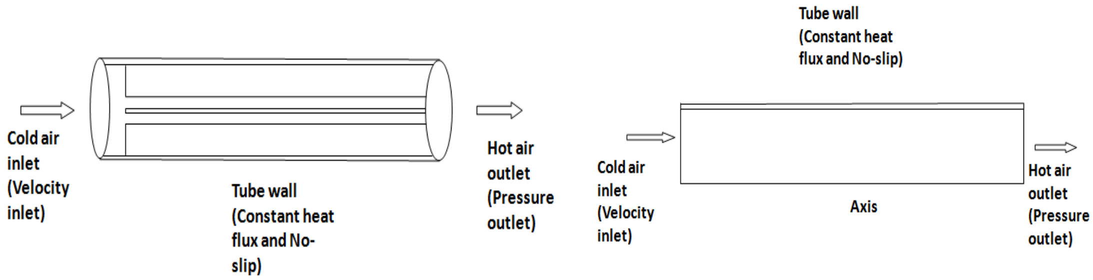

Fig. 2 Schematic diagram of computational domain and the boundary condition applied to it (a) finned tube; (b) un-finned tube

The computational investigation is carried out for two cylindrical aluminium pipes exactly of the same size and shape as has been used in the experiment as shown in the Fig. 3a. For smooth tube two dimensional axi-symmetric models has been chosen as shown in the Fig. 3b. The flow field and temperature field in the finned tube domain would be computed by using 3-D (two dimensional axi-symmetric model for smooth tube), incompressible Navier-Stokes equations with a two equation based *k*- ε turbulence model along with the energy equation of Fluent 14. The fluid used in the simulation is air, at room temperature (35 ^{0}C), and is treated to be incompressible at the injection velocity (which is below 10 m/s).

III. Results and discussions

Fig. 3a and 3b shows the boundary conditions respectively for finned tube and smooth tube. As the density is taken as a function of temperature according to ideal gas equation therefore SIMPLE algorithm with PRESTO (Pressure Staggered Option) scheme has been used for better convergence. Under relaxation factors (0.3 for pressure, 0.7 for momentum and 0.8 for *k* and ε) were used for the convergence of all the variables. Convergence of the discretized equations were said to have been achieved when the whole field residual for all the variables fell below 10^{-3} except energy equation and for energy equation residual was set 10^{-6}.

Fig.4a shows the axial wall temperature distribution for smooth tube and finned tube. It can be seen from the plot the wall temperature increases along the axial direction and falls a little towards the end in case of experiment because of contact resistance. It is also marked from the plot the wall temperature of finned tube is low compare to smooth tube for same Reynolds number and heat flux which indicates higher heat transfer rate for the case finned tube. Tube outlet temperatures as a function of Reynolds numbers has been shown in Fig. 4b. It can be seen from the Fig. 4b as the Reynolds number increases the tube outlet temperature decreases both the case of present CFD as well as experimental results and a good matching was found between the present CFD and experimental results with a maximum difference 1%.

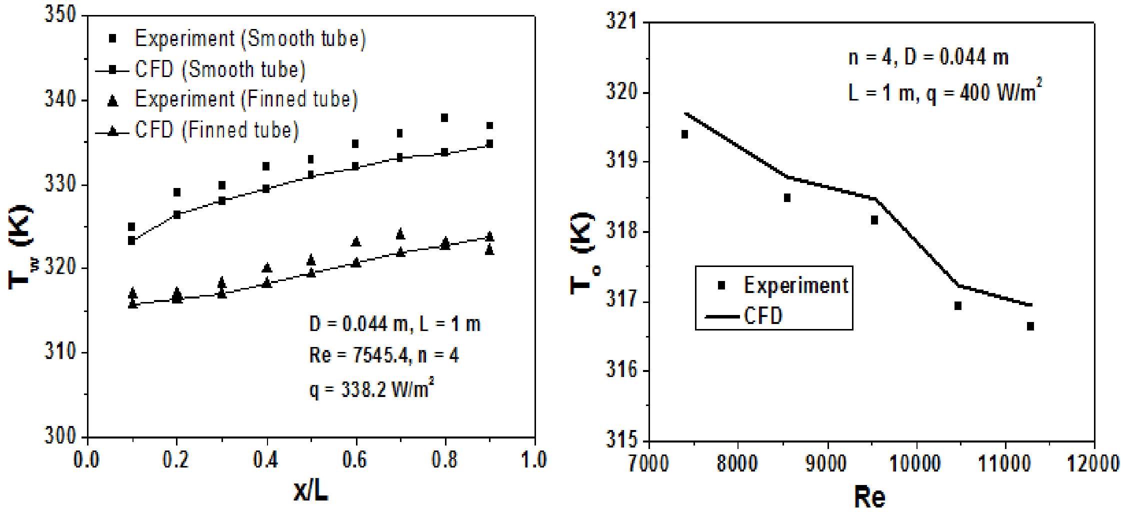

Fig. 4 Comparison between smooth tube and finned tube

(a) wall temperature; (b) tube outlet temperature

Comparison of heat transfer coefficient for smooth tube and finned tube

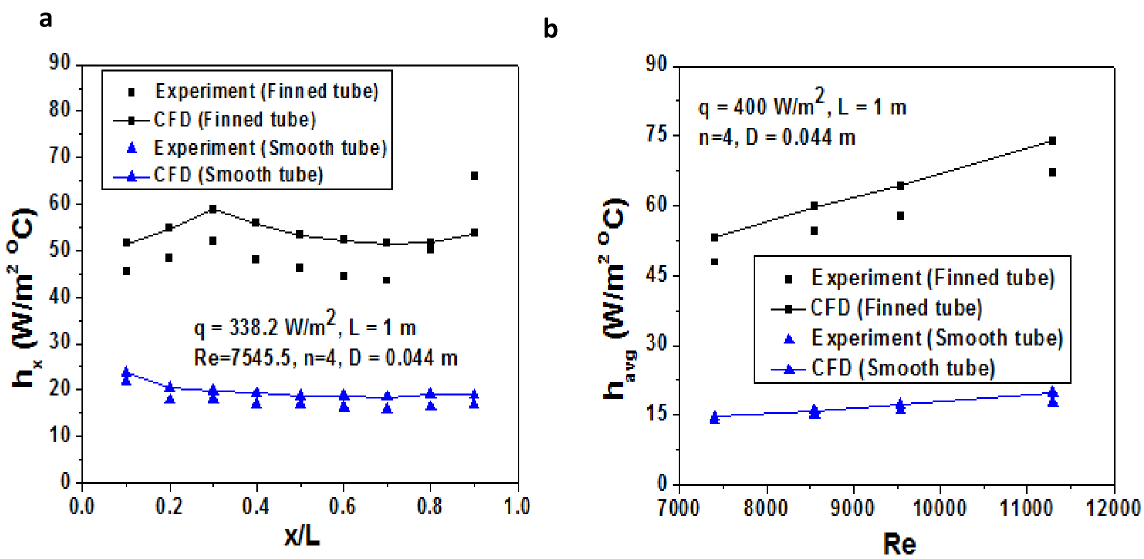

Fig. 5 Comparison between smooth tube and finned tube

(a) local heat transfer coefficient; (b) average heat transfer coefficient

The local heat transfer coefficient along the length tube has been shown in the Fig. 5a. The numerical and experimental investigation was performed for smooth tube and finned tube for a Reynolds number 7545.5 and the tube wall was subjected to a heat flux of 338.2 W/m^2. It can be seen from the plot for smooth tube the heat transfer coefficient slowly decreases up to one half length of the tube and after that it remains almost constant which signifies initially the heat to the air is more and later on it remains almost constant. But in case of finned tube the situation is entirely different. It can be visualized from the Fig. 5b heat transfer coefficient initially increases up to one third length of the tube and after that it falls and again it rises towards the end of the tube. Hence it is evident from the plot first and last one third length of the tube the heat transfer to the air is predominantly due to convection where as at the middle one third portion of the tube heat transfer to the air is low. It is important to note here in experiment case due to the end effect the value of heat transfer coefficient shoots up towards the end for finned tube whereas there is marginal rise of heat transfer coefficient at the end for smooth tube. Fig. 5b shows the average heat transfer coefficient increases with Reynolds number both for smooth as well as for finned tube. But the heat transfer coefficient rises rapidly in finned tube compared to smooth tube which indicates more heat transfer in case finned tube compared to smooth tube. It can be seen from the plot heat transfer coefficient of finned tube is almost three times the heat transfer coefficient of smooth tube which suggests higher heat transfer rate in case of finned tube.

IV. Conclusions

Numerical and experimental investigations have been performed to study the fluid flow and heat transfer characteristics of finned tube and un-finned tube. The fluid flow and heat transfer performance of experimental results have been matched with the present CFD results using Fluent 14. Experiment was performed for Reynolds number range from 7000 to 12000 with wall heat flux maintained between 300 W/m^2 to 650 W/m^2. From the analysis the following conclusions can be drawn:

For a thermally and hydro-dynamically developing region the heat transfer is increased by 5% using the rectangular longitudinal finned tube compare to smooth tube. Using finned tube the heat transfer coefficient is enhanced almost three times compare to smooth tube. The friction factor has been increased on an average three times in finned tube compared to smooth tube for same Reynolds number.

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