Experimental Investigation of Finned Tube Heat Exchanger

Jignesh M. Chaudhari  Dattatraya Subhedar  Nikul Patel
Mechanical Dept. & CSPIT, Changa  Mechanical Dept. & CSPIT, Changa  Mechanical Dept. & MS Uni. Vadodara

Abstract — As far today's demand is to manufacture a compact car so there is an urgent need to design an effective heat exchanger. In this paper the effect of finned heat exchanger over a without finned heat exchanger on overall heat transfer coefficient is studied. The overall heat transfer coefficient is studied for both heat exchanger with air velocity 3m/s, 4m/s, 5m/s and 6m/s and coolant flow 180 Lit/hr, 260 Lit/hr, 340 Lit/hr, 420 Lit/hr and 500 Lit/hr. Finned-tube heat exchangers are common and vital components in many energy systems Fin-and-tube heat exchangers are widely used in several domains such as heating, ventilating, refrigeration and air conditioning systems. The fin performance is commonly expressed in terms of heat transfer coefficient and fin effectiveness, which is defined as the ratio of the heat transfer rate with fin to the heat transfer rate in without fin heat exchanger. This case is the one providing the maximum heat transfer rate because this corresponds to the maximum driving potential (temperature difference) for convection heat transfer. The research work summarized in this presents a combined analytical, experimental and numerical investigation of Overall heat transfer coefficient of coolant as water by use of circular finned tube heat exchanger and without fin tube exchanger with force convection. The heat transfer and pressure drop results for the pin fin heat exchanger were compared with the results for a smooth-tube heat exchanger. The experimental system is quite similar to cars' cooling system. The compares the heat transfer coefficient, pressure drop, overall heat transfer coefficient with the finned tube heat exchanger and without finned tube heat exchanger. From the experiment Finned-tube heat exchanger gives the overall heat transfer coefficient 14.07W/m2K.

Keywords: Finned Tube Heat Exchanger; Water; Circular Fin; Temperature; Overall Heat Transfer Coefficient; Performance

1. INTRODUCTION

The heat exchanger is a device, which used to transfer thermal energy between two fluids, between a solid surface and a fluid or between solid partials and a fluid. The demand high for small specification heat exchanger device which increasing due to their requirement in application such as Automobiles, aerospace, etc.[1] An important parameters affecting in heat transfer are Reynolds number, fin height and fin space (pitch). Heat transfer can be successfully improved by controlling these parameters. Reynolds number, fin height, fin material, fin pitch, fin size, fin space are most effective parameters effect on Heat Exchanger. The maximum heat transfer rate was observed at 42000 Reynolds number, 20 mm fin height [8] Fins have a very vast area of application. Finned-tube heat exchangers are common and vital components in many energy systems Fin-and-tube heat exchangers are widely used in several domains such as heating, ventilating, refrigeration and air conditioning systems[2]. In various applications heat from the fins is dissipated by natural as well as forced convection and radiation. Various types of fins are rectangular, square, cylindrical, annular and tapered or pin fins, to a combination of different geometries, have been used. These fins may protrude from either a rectangular or cylindrical base.[7] The fin performance is commonly expressed in terms of heat transfer coefficient and fin effectiveness, which is defined as the ratio of the heat transfer rate with fin to the heat transfer rate in without fin heat exchanger. This case is the one providing the maximum heat transfer rate because this corresponds to the maximum driving potential (temperature difference) for the convection heat transfer. The purpose of the fin is to increase the product of the surface area and the heat transfer coefficient. [4] It is very useful in the heat exchanger design or in the estimation of heat exchanger performance if we know the fin efficiency. In many textbooks introduced the fin efficiency derived from the following three assumptions: (a) constant fluid temperature, (b) uniform heat transfer coefficient, and (c) one dimensional heat conduction in the fin. However most actual heat exchangers may not satisfy only one of these three assumptions. A lot of experiments have been performed to measure the heat transfer coefficient of the heat exchanger having fins.[3]

The circular finned-tube bundles are commonly used in the industries. In order to improve the air-side heat transfer performance of these bundles, such as to increase the fin efficiency and compactness as well as to reduce the pressure losses, much empirical work has been done diligently [5] The heat transfer increases as the surface area of the radiator assembly is increased. So, do the car having inside better space, the manufacturers of commercial vehicles are facing a substantial increase of heat release into the cooling system and they change the geometry the arrangement of tubes in automobile radiator to increase the surface area for better heat transfer. The modification in arrangement of tubes in radiator is carried out by studying the effect of pitch of tube.[6]

The present work the effect of circular fin of Aluminum in Heat exchanger is studies experimentally.

© 2014, IJIRAE- All Rights Reserved
Experiment Setup

The schematic diagram of experimental setup as shown in Figure:1, which used in this research, a Reservoir Tank with capacity 35 liters, Heater coil of 2kW heating capacity, a Centrifugal Pump with Motor, a Rotameter with range 0 to 1000 LPH, a Blower of Motor 5HP with Fan, Constant Duct, Temperature Indicator of 12 channel, Variac up-to 0~260 volts, four Thermocouples rang 0°C to 100°C, Temperature Gun -50°C to 450°C, Manometer, U-Tube Manometer 0 to 250 mm of Hg, and Cross Flow Heat Exchanger specification as per Table.

In this test a cross flow heat exchanger (automobile radiator) which installed inside the air flow channel (constant duct) and its configuration is louvered fin and tube type. Coolant as water as through tube (10 passes) with cross section. The radiator of engine was 50cm in length and 50cm height as in fig. and total number of 10 tubes. The radiator consists of fins, tubes, upper and lower hose and the outer frontal area. All the 10 tubes were in a single row and each tube was 8mm thick.
**Table 1. Specifications**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Title</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fin Material</td>
<td>Aluminum</td>
</tr>
<tr>
<td>2</td>
<td>Tube Material</td>
<td>M.S</td>
</tr>
<tr>
<td>3</td>
<td>Tube Internal Diameter</td>
<td>0.013 m</td>
</tr>
<tr>
<td>4</td>
<td>Tube Outer Diameter</td>
<td>0.0146 m</td>
</tr>
<tr>
<td>5</td>
<td>Fin Outer Diameter</td>
<td>0.0343 m</td>
</tr>
<tr>
<td>6</td>
<td>Fin Thickness</td>
<td>0.001 m</td>
</tr>
<tr>
<td>7</td>
<td>Fin Space</td>
<td>0.03933 m</td>
</tr>
<tr>
<td>8</td>
<td>No. of Fins</td>
<td>900</td>
</tr>
<tr>
<td>9</td>
<td>No of Tube Pass</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>Total Length of Tube</td>
<td>0.5 m</td>
</tr>
</tbody>
</table>

**Calculation of Heat Exchanger**

In these setup experiments, the fluid flowing inside the tube transfer heat to the outside air flowing in the air flow channel. The air-side and tube-side heat transfer rates can be calculated as:

\[
Q_a = \dot{m}_a C_{p,a} (T_{a,o} - T_{a,i})
\]

\[
Q_f = \dot{m}_f C_{p,f} (T_{f,o} - T_{f,i})
\]

where \(Q_a\) and \(Q_f\) are heat transfer rates at the air and fluid flows respectively. The arithmetic average of the heat transfer rate is:

\[
Q_{avg} = 0.5 (Q_a - Q_f)
\]

The performance of the heat exchanger is analyzed by the conventional \(\varepsilon = NTU\) technique and the effectiveness, \(\varepsilon\), is defined as:

\[
\varepsilon = \frac{Q_{avg}}{(\dot{m} C_p)_{min} (T_{hi} - T_{ai})}
\]

The relationship of the effectiveness, the number of transfer unit (NTU), and the minimum capacity flow rate \((\dot{m} C_p)_{min}\) at the air-side could be:

\[
\varepsilon = \frac{1}{C} [1 - e^{-(1-e^{-NTU})}]
\]
Using equations (5) and (6) the experimental overall heat transfer coefficient, UA could be evaluated.

**Result and Discussion**

To predict the effect of fin the various parameters are like, coolant mass, air flow velocity, heat and etc. The evaluate the accuracy of the measurements, experimented system is tested with water & the experimented Overall Heat Transfer Coefficient is compared with standard correlation Dittus-Boelter equation (for turbulent flow). The experiment result are match 0.60% with the different result.

**Effect of Water Flow Rate on the Overall Heat Transfer Coefficient:**

![Figure 4: Effect of Water Flow rate on the overall heat transfer coefficient in Without finned tube heat exchanger](image)

![Figure 5: Effect of Water Flow rate on the overall heat transfer coefficient Finned tube heat exchanger](image)

**Effect of Fluid Flow Rate on the Water Pressure Drop**

![Figure 6: Effect of fluid Flow rate on the water pressure drop in Without finned tube heat exchanger](image)
As shown in fig.(4) & fig.(5) it is found that overall heat transfer rate is proportional to coolant mass flow rate. In without fin-heat exchanger it is found that for mass flow rate 0.049 kg/sec & air velocity flow rate 3 m/s overall heat transfer rate 12.10 W/m²K and in with fin heat exchanger same coolant mass flow rate and air velocity flow rate overall heat transfer rate 14.07 W/m²K. So, Overall heat transfer coefficient of the coolant fluid for with fin heat exchanger more than without fin heat exchanger. As can be seen, the overall heat transfer coefficient of fluid increase significantly with fluid fluid flow rate.

![Figure:7 Effect of fluid Flow rate on the water pressure drop in Finned tube heat exchanger](image)

As shown in fig.(6) & fig.(7) it is found that water pressure drop is proportional to coolant mass flow rate. In without fin-heat exchanger it is found that for mass flow rate 0.049 kg/sec & air velocity flow rate 3 m/s water pressure drop 22 mm/Hg and in with fin heat exchanger same coolant mass flow rate and air velocity flow rate water pressure drop 24 mm/Hg. So, Coolant pressure drop in with fin heat exchanger more than without fin heat exchanger. As can be seen, the coolant pressure drop of water increase significantly with fluid flow rate.

**Effect of Coolant Fluid Flow on Reynolds Number and Nusselt Number**

![Figure:8 Effect of fluid Flow rate on Reynolds Number and Nusselt Number in Without finned tube heat exchanger and Finned Tube Heat Exchanger](image)

As shown in fig.(8) it is found that Nusselt Number is proportional to Reynolds Number at constant Air Velocity 3m/s. In without fin-heat exchanger and Finned tube Heat Exchanger. As shown in Fig.8 at constant Air Velocity 3m/s, Heat 80 volts, and change coolant mass flow rate Reynolds Number increase with increase Nusselt Number.

**Effect of Air Velocity on the Overall Heat Transfer Coefficient**

![Effect of Air Velocity on the Overall Heat Transfer Coefficient](image)
As shown in fig.(9) & fig.(10) it is found that overall heat transfer rate is proportional to air velocity m/s. In without fin-heat exchanger it is found that for mass flow rate 180 LPH & air velocity flow rate 3 m/s overall heat transfer rate 12.10 W/m²K and in with fin heat exchanger same coolant mass flow rate and air velocity flow rate overall heat transfer rate 14.07 W/m²K. So, Overall heat transfer coefficient of the coolant fluid for with fin heat exchanger more than without fin heat exchanger. As can be seen, the overall heat transfer coefficient of fluid decrease significantly with air velocity rate increases.

CONCLUSIONS

A complete set of numerical parameter studies on automobile radiator has been presented in detail in this paper. The calculation have been carried out by well verified and validated rating. The corresponding mathematical formulation has been briefly described within the paper. A first part of the parametric studies has been focused on the influence of working condition on fluid(mass flow rate, input parameters).

In Cross flow heat exchanger experiment setup is a useful tool for analyzing different parameters of finned tube heat exchanger and heat loss related testing, it will provide information on the variables heat effects on water temperature. The model will help characterize heat exchanger performance and provide a basis for assessing current temperature controlling condition. Classification and Design details helps to understand the working and industrial application of heat exchangers.

As shown in graph we conclude that the Overall heat transfer rate of finned tube heat exchanger is greater than without finned tube heat exchanger. Now as we increases the air velocity heat transfer rate of finned tube heat exchanger is increases because the Reynolds number is increases the nusselt number is also increases because nusselt number is directly proportional to the heat transfer coefficient. So, heat transfer rate is increases.

ACKNOWLEDGMENTS

I would like to express my deep sense of gratitude and respect to my Guide Assistant. Professor Dattatraya Subhedar, of Mechanical Engineering Dept. of M.Tech. C.S.P.I.T. University, Changa and my Co-Guide Assistant. Professor Nikul Patel, of Mechanical Engineering Dept. of M.Tech. M.S. University, Vadodara for their excellent guidance, suggestions and constructive criticism. They provided me this opportunity to work in this inspiring project. Throughout my dissertation period, they provided encouragement, sound advice, good teaching and lots of ideas. I consider myself extremely lucky to be able to work under the guidance of such a dynamic personality.

It gives me immense pleasure an expressing my heartfelt gratitude to Mr. Vijay Chaudhary H.O.D, Mechanical Engineering Dept. of C.S.P.I.T. University, Changa. For all the cooperation he has rendered in the successful completion of this work.

I would like to thank my family, who have continually given me their love and encouraged me to reach my dreams. I could not have done this without you. I would also like to thank Staci who has been my constant sounding board and my biggest fan during the experimental and writing phases of this work.

Most importantly I would like to thank God. Thank you for all of these blessings.
### NOMENCLATURE

- **A**: Area (m²)
- **V_a**: Velocity of Air
- **m_{i_a}**: mass flow rate of Air
- **m_{w}**: mass flow rate of Water
- **t_{i_a}**: inlet Air temperature °C
- **t_{o_a}**: outlet Air temperature °C
- **t_{i_w}**: inlet water temperature °C
- **t_{o_w}**: outlet Water temperature °C
- **T_a**: Air temperature difference °C
- **T_w**: Water temperature difference °C
- **D_o**: Fin outer diameter (m)
- **d_i**: Tube inner diameter (m)
- **d_o**: Tube outer diameter (m)
- **m_{i_\text{air}}**: mass flow rate of Air (Kg/s)
- **m_{w}**: mass flow rate of Water (Kg/s)
- **N_T**: Number of Tubes
- **N_f**: Number of Fins on each tube
- **N_F**: Total Number of Fins
- **\eta_o**: Surface efficiency of air-side
- **\eta**: Fin efficiency
- **A_o**: Surface area of air-side (m²)
- **A_i**: Surface area of tube-side (m²)
- **Q_a**: Heat transfer rate of Air (W)
- **Q_w**: Heat transfer rate of Water (W)
- **C_{p_a}**: Specific heat of Air (J/Kg-K)
- **C_{p_w}**: Specific heat of Water (J/Kg-K)
- **\rho_a**: Density of Air (Kg/m³)
- **\rho_w**: Density of Water (Kg/m³)
- **\mu_{air}**: Dynamic Viscosity of Air (Kg/m.s)
- **\mu_w**: Dynamic Viscosity of Water (Kg/m.s)
- **K_a**: Thermal conductivity of Water (W/m.K)
- **K_w**: Thermal conductivity of Water (W/m.K)
- **\varepsilon**: Effectiveness (%)
- **C**: Heat capacity flow rate
- **C^***: \(C_{p_{min}}/C_{p_{max}}\)
- **D_h**: Hydraulic diameter (m)
- **L**: Tube length (m)
- **l**: Fin length (m)
- **\delta**: Fin thickness (m)
- **s**: Fin space (m)
- **A_b**: Bare tube area (m²)
- **K_{t}**: Thermal conductivity of Fin
- **F_t**: Fin thickness (m)
- **A_F**: Surface area of Fin (m²)

**NTU**: Number of transfer unit

- **Re_a**: Reynolds number of Air (dimensionless)
- **Re_w**: Reynolds number of Water (dimensionless)
- **Pr_a**: Prandlt number of Air (dimensionless)
- **Pr_w**: Prandlt number of Water (dimensionless)
- **Nu_a**: Nusselt number of Air (dimensionless)
- **Nu_w**: Nusselt number of Water (dimensionless)
- **h_i**: Heat transfer coefficient at tube-side (W/m²K)
- **h_{0 or_a}**: Heat transfer coefficient at air-side (W/m²K)
REFERENCES


