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Enhancement of Heat Transfer Characteristics using Aerofoil Fin over Square and Circular Fins

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***Abstract:** The thermal conductivity of fin material, its geometrical profile and the mode of heat transfer etc, are the key factors which generally affects the heat transfer from fins. The present research deals with the improvement in heat transfer characteristics and the investigation of fin performance efficiency by using fins of varying geometrical profiles in pin fin apparatus. In this study the heat transfer characteristics inside a rectangular duct with circular, square and aerofoil geometrical profiles of fins were analyzed experimentally. The intention of the present work is to evaluate the heat transfer coefficient, Reynolds number, Nusselt number, pressure drop and efficiency of fin with circular, square and aerofoil geometrical profiles and all the results obtained will be compared with those from a circular fin of same material surface. In the present study, experimental results of the heat transfer characteristics of all the three geometrical profiles of fins under constant heat flux conditions are presented. Experiments are performed at various Reynolds numbers in the range of 1000–9000 and heat fluxes in the range of 0.91–3.64 kW/m^2. The predicted results are validated by comparing with measured data. The predicted results are in reasonable agreement with the experiments. It is found that with increase in Reynolds number, the Nusselt number and thermal performance increases, for a fin having aerofoil profile as compared with a fin with square and circular profile. These are because of delayed separation of air and increase in contact time for a fin having aerofoil profile as compared with a fin with square and circular profile.*

***Index Terms:** forced convection, heat transfer enhancement, fin with aerofoil, square and circular profile.*

I. INTRODUCTION

Mostly the fins are used in heat exchanging devices such as radiators in cars, computer CPU heat sinks, and heat exchangers in power plants. The use of fins is also in newer technology such as hydrogen fuel cells. Fins are employed in a wide variety of engineering applications. Fins are used in power plant technology to increase the rate of heat transfer through economizers and condensers. Fins are also used in automotive sectors like cooling of internal combustion engine. Fins are employed to remove the heat from integrated circuits in the electronic circuits, in nuclear power plants to exchange the heat between two fluids. In the design of electronic packages to increase the temperature of electronic components above the allowable limit. Therefore there is need to increase heat transfer rate for working a device at designed efficiency.

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Many researchers have mentioned through their literature, the heat transfer coefficient or heat transfer area affects heat transfer rate. In case of natural convection there is only scope for increasing heat transfer area by providing finned surfaces.

The fins orientations and the geometric parameters of fins mainly affects enhancement ratio of heat transfer.

P Moorthy et al [1] investigated the effect of three types of fin shapes viz. plane, wavy and rectangular grooved fins on the performance of compact finned flat tube heat exchangers. The investigation was carried out for in-line and staggered arrangements. They also analyzed effect of varying air velocity and the tube inclination angles on thermo-hydraulic performance. They observed staggered arrangement gives higher heat transfer and pressure drop compared to inline fin. Also observed plain fin gives higher efficiency and rectangular fin gives higher heat transfer. Ravi Kumar Sangewar [2] studied the pin fin arrays performance of copper and aluminium material with staggered as well in-line arrangement over a flat plate. It was observed that staggered array gives 15% more heat transfer coefficient than in-line array. Also commented pressure drop for staggered array is 10% more compared with the in-line array.

Sharma et al [3] experimentally investigate the temperature field inside the fin and also analyzed it using finite element method. It was observed that rectangular geometry was most suitable as it dissipate more heat. Also found that copper was most suitable material than any other material. They validated the results with simulated results. A. Guvenc et al [4] experimentally investigate the heat transfer in rectangular fin-arrays mounted on a vertical base. For experimentation the fin spacing was varied from 4.5 to 58.75 mm while fin height was varied from 5 to 25 mm. It was observed that the heat transfer enhancement with vertically oriented bases was higher than horizontally oriented bases for fin arrays of the same geometry.

Sinan Caliskan et al [5] experimentally investigated the effect of hexagonal and cylindrical pin fins into the rectangular channel. The experiments were conducted with different fin geometry, fin array, Reynolds number and ratio of fin spacing and its hydraulic diameter. The heating plate made up of stainless steel foil was used for experimentation. It was observed that the hexagonal fins provide the best heat transfer performance when compared with cylindrical fins. It was also observed that the maximum thermal performance factor was obtained for Re = 3188 and staggered array.

In the present work, the experimental investigations were carried out to analyse the effect on heat transfer characteristics and pressure drop in a fin with varying geometrical profiles viz. circular, square and aerofoil. Also investigation was carried out to evaluate the variation of heat transfer coefficient and friction factor with Reynolds Number.

The experimental findings provides significant amount of heat transfer enhancement in a fin with aerofoil geometrical profile compared with fins having circular and square geometrical profiles.

II. EXPERIMENTAL SETUP

A long rectangular duct is used in which fin is fitted across the duct. A blower which is connected to the other end of the duct is used to circulate the air past the fin perpendicular to the axis. An electric heater is used to heat the one end of the fin which is projected outside the duct. Thermocouples are employed at five points across the length of the fin to measure the temperature. An orifice meter is fitted on the delivery side of the blower to measure the air flow rate across the fin. The air flow rate can be varied by the blower speed regular and can be measured on the u tube manometer connected to one end of a fin. The pressure drop (range = 0.002–5 mbar) across the test part is measured with a micro-manometer having double reservoir which is to be filled with benzyl alcohol and water. The panel of the apparatus consists of voltmeter, ammeter and digital temperature indicator, heat regulator in it.

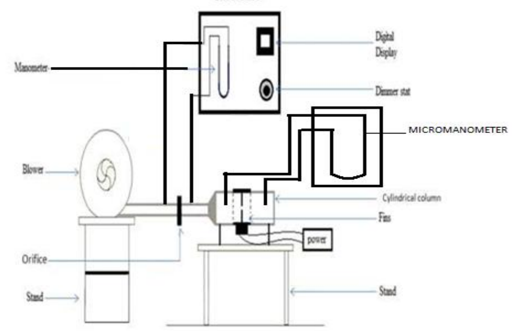

Figure 1: Experimental Setup

III. EXPERIMENTAL PROCEDURE

Experiments were conducted first on cylindrical Brass fin which is a conventional one and then on Brass fin having a square and aerofoil surfaces with constant hydraulic surface area.

A. Cylindrical surface

Initially, the experiment was carried out on cylindrical surface fin. The air flows across the fin through the pipe section with least resistance.

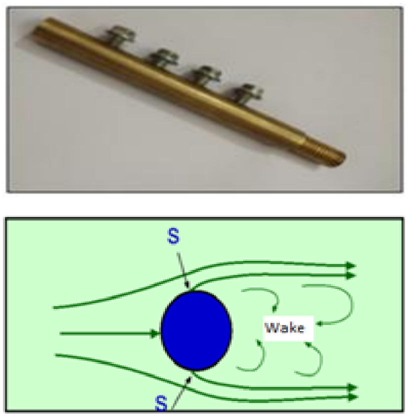

Figure 2: Flow Separation for air flowing over a Fin with Circular Profile

B. Square and Aerofoil surface

The square and aerofoil surface fins are as shown in Fig.3 and Fig.4 respectively. The two different fins with varying geometrical shapes were used for experimentation. Experiments were conducted with varying Raynold number and the heat input for all the three geometrical profile fins.

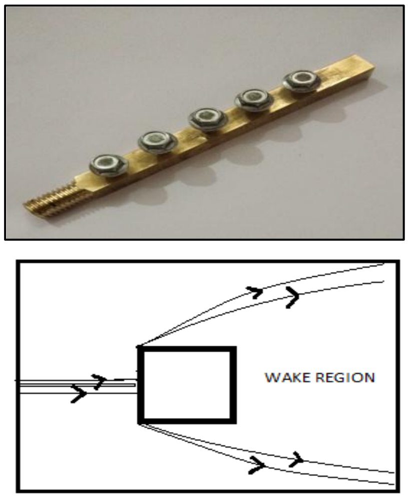

Figure 3: Flow Separation for air flowing over a Fin with Square Profile

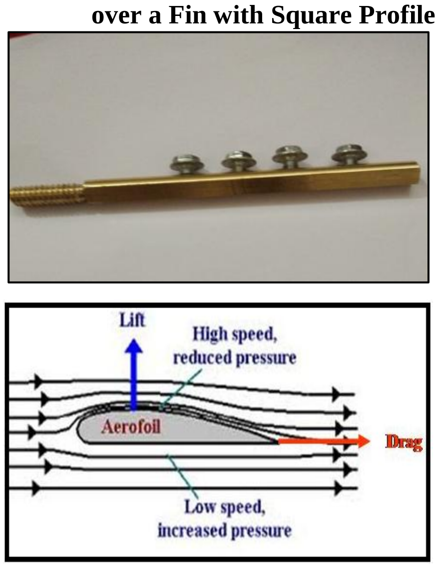

Figure 4: Flow Separation for air flowing over a Fin with Aerofoil Profile

IV. RESULTS AND DISCUSSIONS

To validate the experimental results obtained, tests were conducted over a fin with circular geometrical profile. Experimentally determined Nusselt number values for a fin with circular geometrical profile are compared with Dittus-Boelter correlation.

Figure 5 shows the comparison between Nusselt numbers obtained experimentally and by using Dittus-Boelter equation for a fin with circular geometrical profile. It is observed that the experimental value of Nusselt number is less than the numerical (Dittus-Boelter) value. This is due to the fact that only convective heat transfer is considered for experimental calculations.

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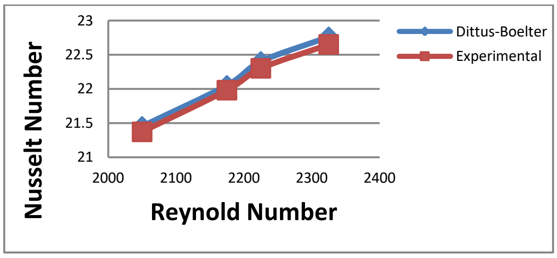

Figure 5: Comparative graph between experimental and correlation values of air for fin with circular geometrical profile

To validate the present experimental method the measured friction factor was compared with Petukhov correlation. The comparison between measured values and correlation values are illustrated in figure 6, it is observed measured friction factor decreases with Reynolds number and slightly under predicted correlated values with Petukhov around 8.2%.

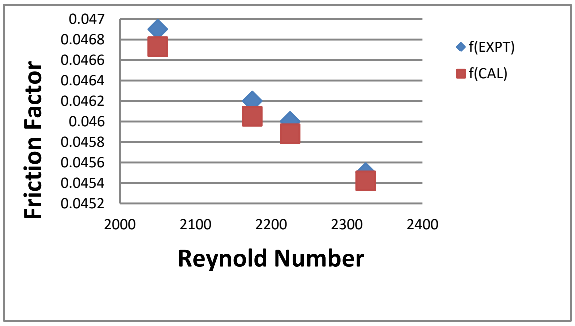

Figure 6: Comparative graph between experimental and correlation values of air for fin with circular geometrical profile

Figure 7 shows the comparison between Nusselt number and Reynolds number for fin with circular, square and aerofoil geometrical profiles. With increase in Reynolds number, the Nusselt number also increases. It is observed that for a fin having aerofoil geometrical profile, the rate of heat transfer is more than for fin having circular and square geometrical profile. Heat transfer enhancement for a fin having aerofoil geometrical profile is primarily because of separation delay of the flow because of aerofoil profile. This delayed in separation of flow is responsible to increase the contact time of air with the fin having aerofoil geometrical profile, which is responsible to increase in heat transfer coefficient. It is found that the mean Nusselt numbers for a fin having aerofoil geometrical profile is greater as compared to fin having circular and square geometrical profile which is 2.33 and 3.96 times respectively.

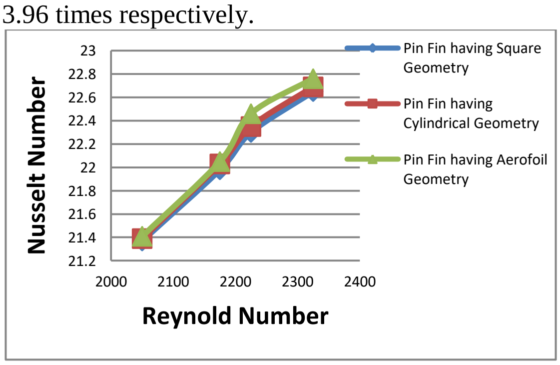

Figure 7: Comparative graph between Nusselt number Vs Reynolds number for a fin with circular, square and aerofoil profiles

Figure 8 depicts the deviation of friction factor with Reynolds number for fin with circular, square and aerofoil geometrical profiles. The friction factor for fin having circular and square geometrical profile is more than that for fin aerofoil geometrical profile. Also for all the three different test fins, there is decrease in friction factor with increase in Reynolds number. Friction factor depends on the pressure drop. It is observed that, fin having aerofoil geometrical profile has less pressure drag and more skin friction drag so the total drag for aerofoil geometrical profile is less than for fin having circular and square geometrical profile. So the overall effects on pressure drop for fin having aerofoil geometrical profile is less than for fin having circular and square geometrical profile.

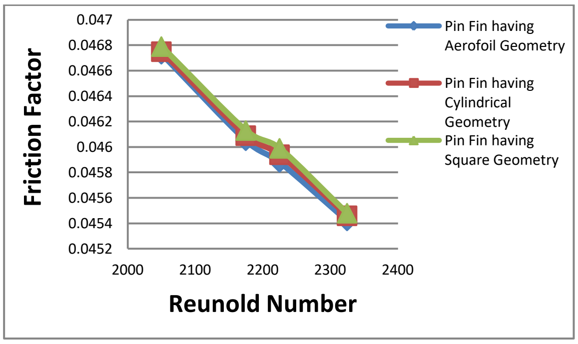

Figure 8: Comparative graph between friction factor Vs Reynolds number for a fin with circular, square and aerofoil profiles

V. CONCLUSION

The investigation on heat transfer coefficient and pressure drop of a fin with circular geometrical profile and fins having aerofoil and square geometrical profile are described in the present report. The conclusions can be drawn as follows:

1. For all the three geometrical profile of fins, the Nusselt number and pressure drop increases with increase in Reynolds number.
2. A fin having aerofoil geometrical profile, the heat transfer rates are higher than those for fin having circular and square geometrical profile.
3. The pressure drop for fin having aerofoil geometrical profile is less than for fin having circular and square geometrical profile.
4. Aerofoil geometrical profile fins can improve the heat transfer performance.

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