Forced Convection Heat Transfer through the Rectangular Fins of Different Geometry of Perforations

Ganesha B B, G V Naveen Prakash

Abstract*: All engineering systems under operations generates heat. If this heat is not removed periodically the system will fail due to overheating of components. Hence, extended surface or fin are used to remove the heat from the system. In this paper experimental study on aluminium rectangular fins with triangular, rectangular and circular perforated fins are made under forced convection mode with different voltages, air velocities and fin spacing of 8 mm. Results are compared with solid fins with perforated fins of same spacings. Results shows significant increase in heat transfer rate for perforated fins compard with solid fins under some conditions also there is a weight reduction up to 23.6% compared to solid fins.

***Index Terms*: Fins, forced convection, Heat transfer co-efficient, perforated fns**

I. INTRODUCTION

Various types of extended surfaces are commonly used to remove the heat from the engineering systems. Variety of fins like plate fins, circular pin-fins and square pin-fins are used for the purpose of removal of heat under both natural and forced convection mode. Heat transfer rate can be increased by increasing the fin surface area, increasing the velocity of fluid and using the good quality or better fluid. Practically increasing the area and usage of better fluid is not economical in many cases. Because increasing the area of fins leads increase in total weight of the system also usage of better fluid increase overall cost of the system. In many cases, increase of temperature difference between working fluid and fin surface, also increase of heat transfer coefficient on fin surfaces using better working fluids are not economical. In such situations using of fins are preferred.

II. LITERATURE SURVEY

Many investigations were made to optimize the geometric parameters of fins. Investigations on fins with different geometry of perforations were made under forced and natural convection mode. Obtained experimental results were compared with the numerical values. These works are helpful to optimize the fin geometric parameters viz., length, height, size and geometry of perforations etc.

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Basha et al [1] carried out experiment under forced convection mode with longitudinal fins. For this investigation heat flux boundary condition was considered. Aluminium and Copper base plates with trapezoidal notches and pin fins were selected for the experiment in a horizontal duct. Varying the heat input and velocity of air heat transfer coefficient were calculated. Results show that, at 9 mm spacing between the pin fins with aluminium base plate shows better results compared to trapezoidal fins on same base plate. Also at same spacing between the fins, pin fins with copper base plate shows good results compared to trapezoidal fins with same base plate.

Dhanawade and Dhanawade [2] carried out experimental analysis of turbulent heat flow also convective heat transfer of solid and perforated fin array. The enhancement in the rate heat transfer with perforated fins is observed than that of the solid fins for all heat inputs as well as for the whole tested range of Reynolds number and for all size of perforations. From the results, it is concluded that utilization of perforated fins increases the rate of heat dissipation, reduction of fin weight and fin material. And experiment showed that, it may give favorable results if perforation is added to fins of air cooled I C engines as well as many other industrial applications.

Chandrakant and Sunilkumar [3] carried out numerical and experimental analysis using two types of fin profiles i.e. Rectangular and Triangular profiles. In experimental result they observed that, heat transfer of rectangular fin profile is higher than triangular fin profile. In experimental results of both fin profile, 10% to 12% difference is observed. Similarly, in the case of simulation, it was observed that heat transfer of rectangular fin profile is higher than that of triangular fin profile. In simulation results for both the fin profiles 8% to 10% difference is observed. Amount of heat transfer increases with decreasing the surface temperature or increasing air velocity in both profiles. In comparison of both profiles, rectangular fin profile transfer large amount of heat than triangular fin profile.

Shaeri and Yaghoubi [4] carried out experiment on the heat transfer augmentation of 3-D liquid flow through the solid as well as perforated fins that are attached to a horizontal sheet. Air as effective liquid is used in the Navier Stokes equation. Reynolds number range 2×10^4 to 4×10^4 is based on fin length. Outcome shows that fins with longitudinal pores have remarkable heat transfer augmentation in addition to the decrease in weight by comparison with solid fins.

Ismail et al. [5] carried out numerical study to investigate the turbulent convection heat transfer on a rectangular plate

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mounted over a flat surface. The extended surfaces having various types of lateral perforations like rectangular, circular, hexagonal cross sections are considered. RANS based modified K-W turbulence model is used to calculate the fluid flow and heat transfer parameters. Reynolds number considered was from 2000 to 5000 based on the thickness of the fins. Shape of lateral perforation has significant effects on the heat transfer behaviour of heat sinks below turbulent flow conditions. Rectangular perforated fins have the lowest and solid fins getting higher Nu number. Triangular perforated fins have lowest skin friction coefficient.

Dhanawade et al. [6] carried out an experiment to investigate the heat transfer enhancement over horizontal flat plate surface with rectangular fin arrays with lateral square and circular perforation by force convection. The experiment was conducted for varies sizes of perforation as well as Reynolds number from $2.1x10^4$ to $8.7x10^4$. They found that average heat transfer co-efficient for square perforated fin is more than that of the fin array with circular perforations of same size. Friction factor slightly increases with increase in the size of perforation.

Ganorkar and Kriplani [7] studied performance of lateral perforated fins in a rectangular channel. Different types of perforated fins are used in the rectangular channel. Effects of perforated fins in a rectangular channel were observed for different Reynolds numbers. As Reynolds number increases the ratio of $Nu_{perforated}/Nu_{solid}$ increases. Also, increase in the number of holes increases the ratio of $Nu_{perforated}/Nu_{solid}$.

Abdullah et al. [8] examined the heat transfer enhancement from a horizontal rectangular fins with triangular perforations under natural convection. The fins heat dissipation rate is compared to that of an equivalent solid one. The results showed that the temperature drop along the perforated fin length is consistently larger than that on an equivalent non-perforated fin. For certain values of triangular dimensions, the perforated fin can enhance heat transfer. The magnitude of enhancement is proportional to the fin thickness and its thermal conductivity.

Aiessa et al. [9] conducted experiment on natural convection heat transfer from a horizontal rectangular fin embedded with rectangular perforations with aspect ratio of 2. This study showed that for certain values of rectangular perforation dimension, the perforated fin enhances heat transfer. The magnitude of enhancement is proportional to the fin thickness and its thermal conductivity.

Ganorkar et al. [10], conducted experimental investigation on an array of rectangular fins with lateral perforations in rectangular channel under forced convection. Aluminium fins was used in the experiment. By varying heat input, velocity of inlet air and by changing the diameter of the holes on the fins, Nusselt number was evaluated. Results show that, with increase in Reynolds number, the ratio of Nusselt number of perforated fin to Nusselt number of solid fin increases. Also with increase in diameter of holes, the ratio of Nusselt number of perforated fin to Nusselt number of solid fin increases.

Abdullah et al. [11], made numerical study on rectangular perforated fins under natural convection for different aspect ratio. Comparison is made with the equivalent solid fins. It is found that, fin with rectangular perforation with aspect ratio one is more efficient than that of fin with other rectangular perforations. Also the amount of heat dissipation rate for perforated fins strongly depends on the perforation geometry and the fin thermo-physical properties.

Tijani et al. [12], conducted experimental study on perforated pin fin heat sink under forced convection mode. In this study, effect of pressure drop, perforations and temperature distribution effects were studied in detail. Velocity of air considered was 1 m/s to 5 m / s and voltage of 50 W. Results show that improvement in thermal efficiency for perforated pin fins heat sink by 1 to 4 % for perforated fins.

Yasin et al. [13], made experimental and numerical study on pin finned tube heat exchanger to determine heat transfer and flow resistance. Using of perforated pin finned tube increases nusselt number and pressure drop by 22 and 26 % respectively. For numerical study, ANSYS Design modular and Fluent 18.0. Software was used. Results obtained from experiment were compared with numerical results for plain, solid and perforated finned tube heat exchanger. Correlation equations were developed for the friction factor and heat transfer.

Sonawane et al. [14], made literature review for perforated pin fins and rectangular fins. From the review it is concluded that, using of pin fin heat sink is economical compare to other types of fin geometry. Heat transfer co-efficient of perforated fins are high compared to solid fins. Also this study reveals that heat transfer co-efficient is affected by the fin geometry, number and size of perforations and thermal conductivity of the fin materials.

Mehedi et al. [15], conducted experimental study of forced convection heat transfer in a duct for perforated fins. Results were compared with solid fins. In the experiment heat transfer co-efficient, efficiency, effectiveness of fins and pressure drop were calculated for different velocities, size and number of perforations. Results showed that perforated fins give better results compared to solid fins for all velocities.

From the available literature it can be concluded that, if the spaces between the fins are too less the rate of heat transfer reduces and also the rate of convection heat transfer depends on many factors like geometry of fin, thickness of fin, height of fin, fin spacings, fin material, surface roughness and working fluid as in the case of forced convection. The rate of forced convection heat transfer can be significantly increased by using perforated fins instead of solid fins since the perforation creates turbulence flow of working fluid which carries heat. Increase in the number of fins leads to increase in the heat transfer area, resulting in the increase of convective heat transfer. If flat fins are very closer to each other, they tend to obstruct the air flow near the surface thus reducing the heat transfer rate. Increasing the number of solid fins causes part of hot air to get trapped between the fins resulting in recirculation region at downstream of the fin.

III. EXPERIMENTAL SETUP

Fig.1 shows the experimental setup used for present work. The experimental setup consists of duct of length 1500 mm and rectangular in cross section of 250 mm ×200 mm, Ammeter, Voltmeter, digital temperature indicator and Straightner inside the duct. A total of 10 k-type thermocouples are used for the investigation, in which 4 thermocouples are mounted on the fins, 2 thermocouples are fixed to base plate, 2

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thermocouples are attached to the bottom of the base and 2 thermocouples are placed at the inlet and outlet of the duct to measure inlet and outlet temperature of air. All these details are shown in Fig. 2. A total six rectangular fins of 100 x 50 x 3 mm made up of aluminium are used in this work.

Fig. 1 Experimental Setup

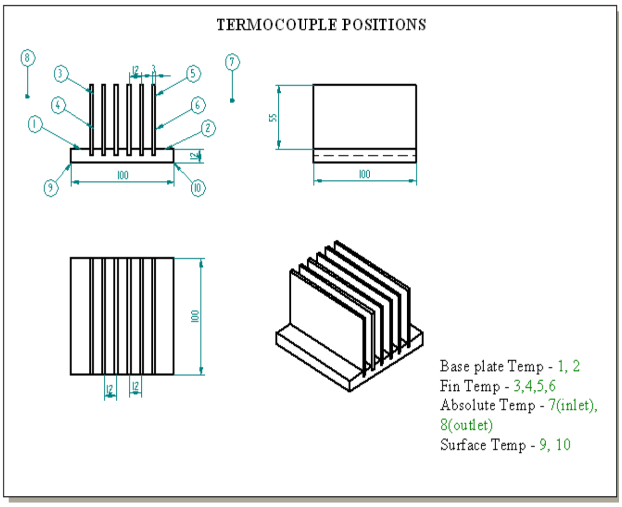

Fig.2 Thermocouple positions

IV. RESULT AND DISCUSSION

The Fig. 3 to Fig. 6 shows the variation of Reynolds number v/s Nusselt number for solid and perforated fins for different voltages viz., 60 V, 80 V,100 V, 120 V and geometry of perforations viz., circular, triangular and square. The fins used are made-up of aluminium with fin spacing of 8 mm. For circular perforations, 6 mm diameter is considered and for other geometries, 6 mm edge lengths are considered.

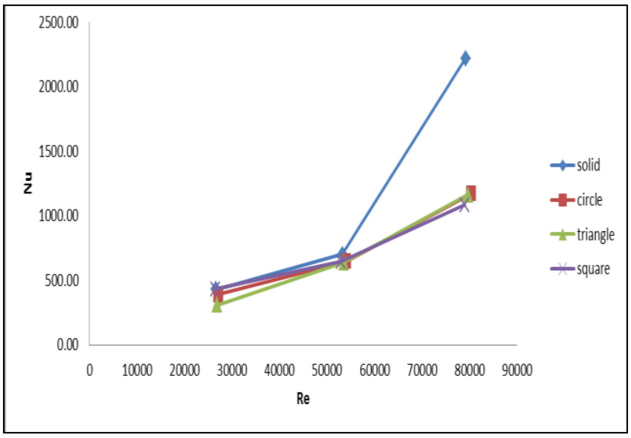

Fig. 3: Re v/s Nu for 60 Volts

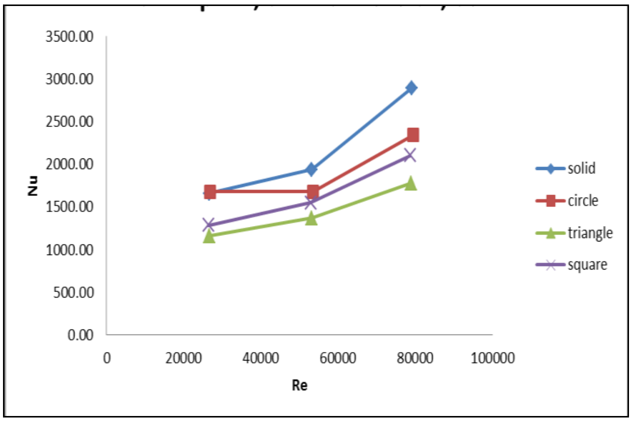

Fig. 4: Re v/s Nu for 80 Volts

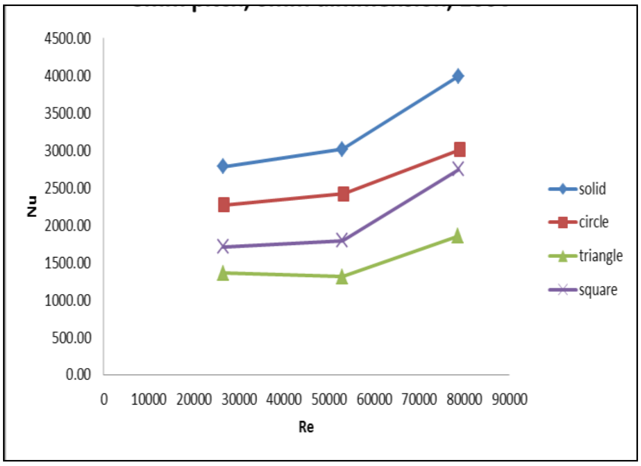

Fig. 5: Re v/s Nu for 100 Volts

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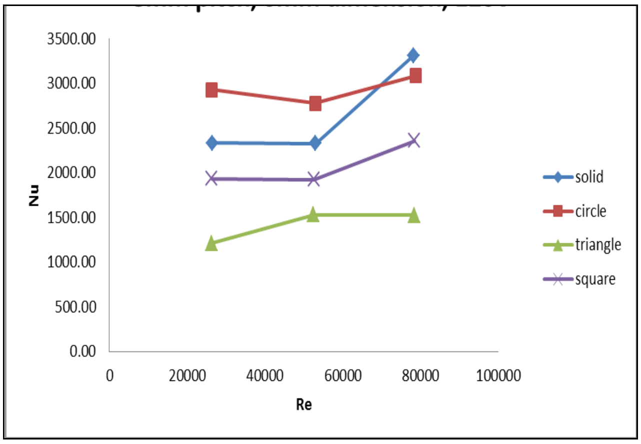

Fig. 6: Re v/s Nu for 120 Volts

From the figures it is observed that, Nusselt number increases with increase in velocity or Reynolds number. For base pitch of 8 mm and 6 mm perforations, solid fins gives better heat transfer co-efficient compared to other geometry of perforated fins. Also, circular perforated fins give high heat transfer co-efficient at 120 volts and triangular fins give very low Nusselt number at all voltages and velocities.

The Fig.7 to Fig.10 shows the variation of Reynolds number v/s Nusselt number for solid and perforated fins for different voltages and geometry of perforations. The fins used are made-up of aluminium with fin spacing of 8 mm. For circular perforations 8 mm diameter is considered and for other geometries 8 mm edge length are considered.

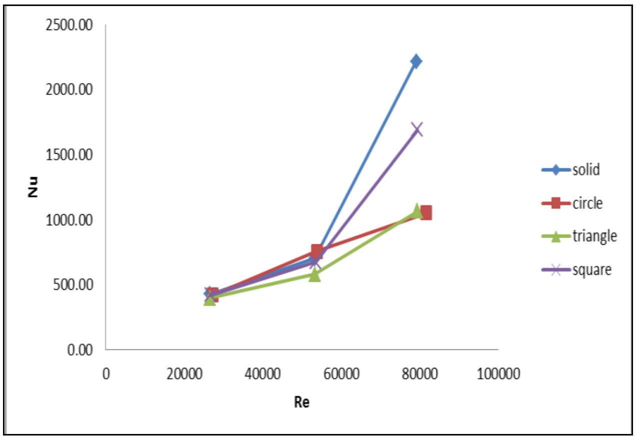

Fig. 7: Re v/s Nu for 60 V

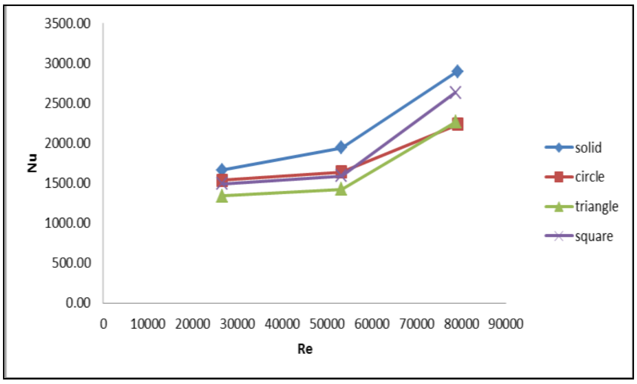

Fig. 8: Re v/s Nu for 80 V

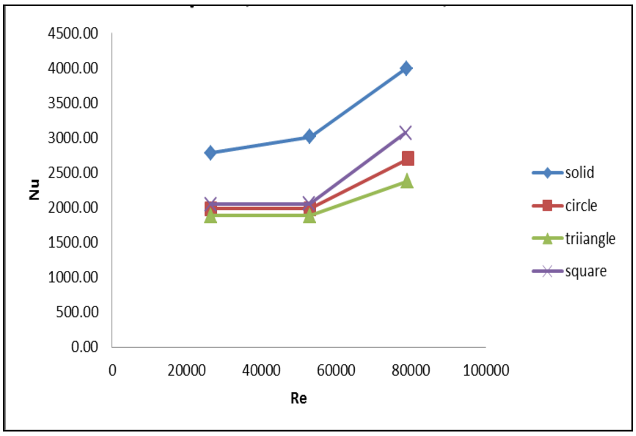

Fig. 9: Re v/s Nu for 100 V

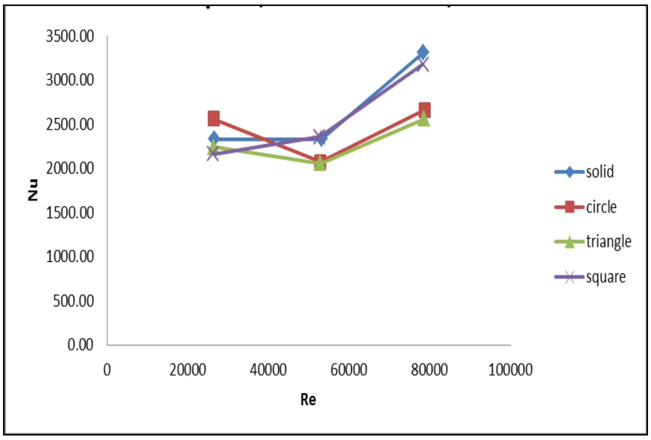

Fig. 10: Re v/s Nu for 120 V

From the figures it is observed that, for 100 V and 120 V Nusselt number increases with increase in velocity or reynolds number. For base pitch of 8 mm and 8 mm perforations, solid fins gives better heat transfer co-efficient compared to other geometry of perforated fins and triangular fins gives very low Nusselt number at all voltages and velocities.

The Fig. 11 to Fig. 14 shows the variation of Reynolds number v/s Nusselt number for solid and perforated fins for different voltages and geometry of perforations. The fins used are made-up of aluminium with fin spacing of 8 mm. For circular perforations 10 mm diameter is considered and for other geometries 10 mm edge length are considered.

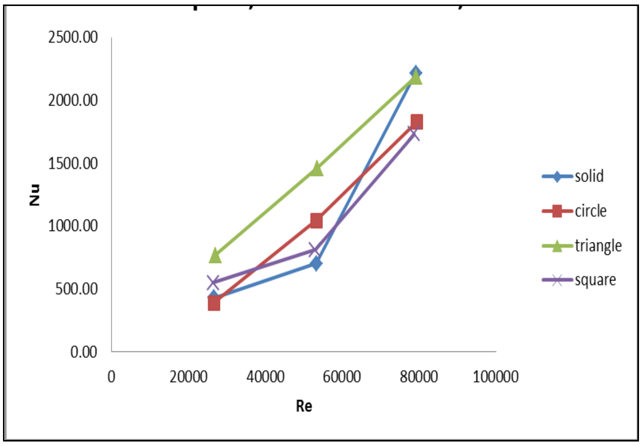

Fig. 11: Re v/s Nu for 60 V

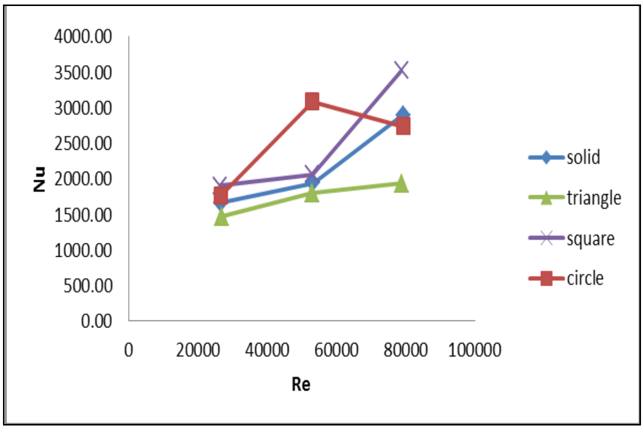

Fig. 12: Re v/s Nu for 80 V

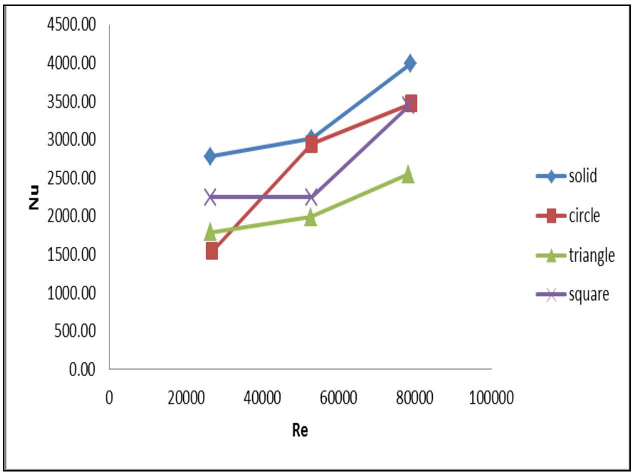

Fig. 13: Re v/s Nu for 100 V

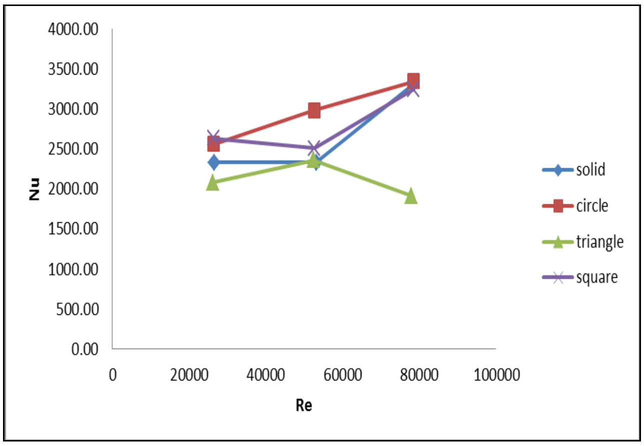

Fig. 14: Re v/s Nu for 120 V

From the figures it is observed that, Nusselt number increases with increase in velocity or Reynolds number. For base pitch of 8 mm and 10 mm perforations, circular perforated fins gives better heat transfer co-efficient compare to other geometry of perforated fins and triangular fins gives very low Nusselt number at all voltages and velocities except at 60 V.

The Fig. 15 to Fig. 18 shows the variation of Reynolds number v/s Nusselt number for solid and perforated fins for different voltages and geometry of perforations. The fins used are made-up of aluminium with fin spacing of 8 mm. For circular perforations 12 mm diameter is considered and for other geometries 12 mm edge length are considered.

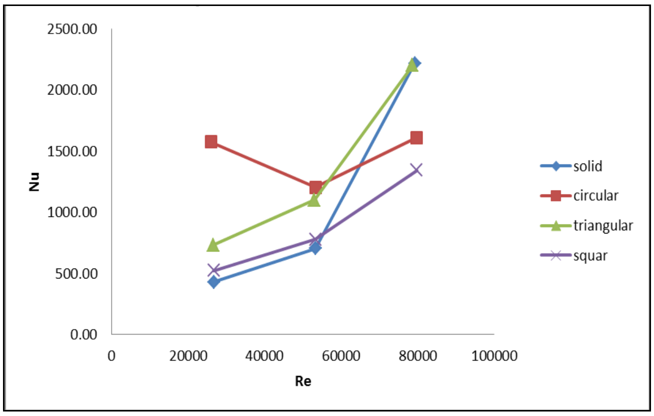

Fig. 15: Re v/s Nu for 60 V

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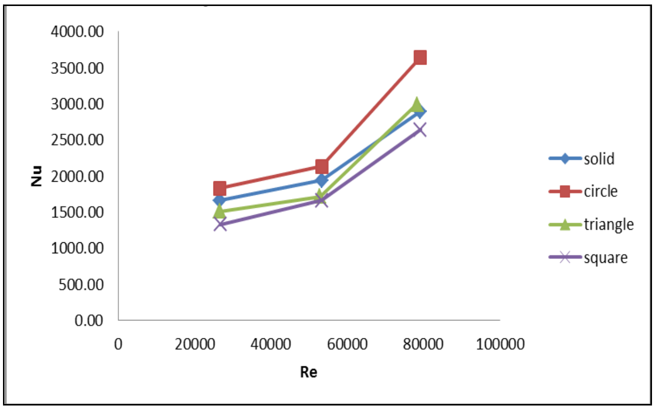

Fig. 16: Re v/s Nu for 80 V

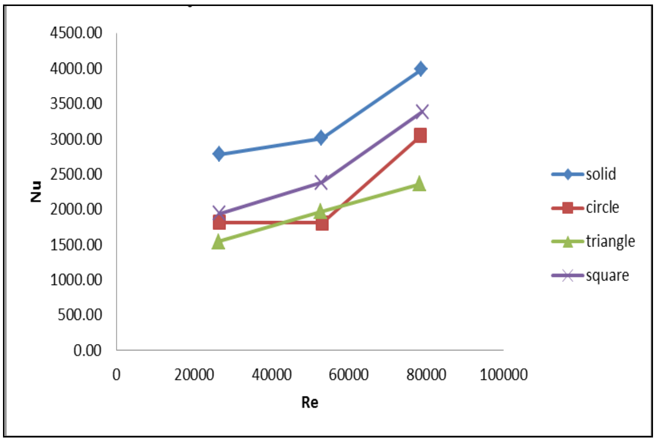

Fig. 17: Re v/s Nu for 100 V

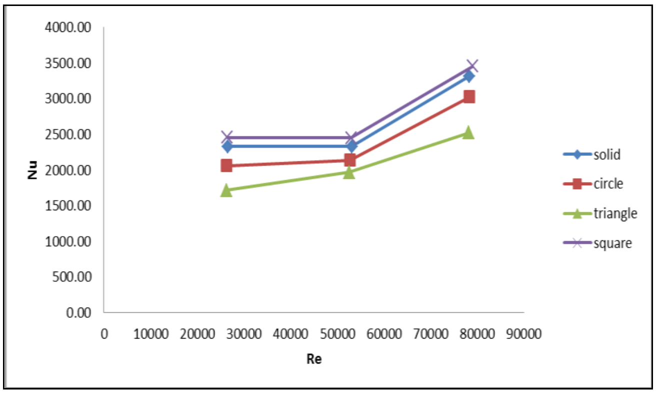

Fig. 18: Re v/s Nu for 120 V

From the Figures it is observed that, Nusselt number increases with increase in velocity or reynolds number. For base pitch of 8 mm and 12 mm perforations, circular perforated fins at 80 V, solid fins at 100 V and triangular perforated fins at 120 V give better heat transfer co-efficient.

V. CONCLUSION

From the work it is concluded that,

- As the air velocity increases the rate of heat transfer increases.
- The heat transfer rate is significantly influenced by geometry of perforations.
- Using of Square perforations of 12 mm reduces the weight by the 23.6% compare to solid fins.

For 8 mm fin spacings, under low voltages perforated fins gives almost same results as that of solid fins. Therefore solid fins can be replaced by perforated fins thereby overall weight of the system can be reduced.

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