Experimental and Numerical Investigation of Heat Transfer Enhancement Using Circular Perforated Fins

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Abstract: Experiments were done to investigate the natural and forced convection of heat transfer along a flat surface equipped with various types of rectangular aluminum fins (solid and perforated). Fins selected with dimensions of (30mm height × 30 mm width × 1mm thickness). Perforated fins have various distributed holes (2 mm dia. for 9 holes and 4 mm dia. for 5 holes). For forced convection, the air flow channel selected with a cross section area of (100×100 mm²) for (1000 mm) length. Nine Thermocouples used to record the temperature distributed from the fin base to its tip. Flow pattern included laminar and the air flow towards the fin lateral area of (30 mm × 30 mm). The effect of number, size and arrangement of perforated fins was studied. Higher heat transfer rates observed with increasing the number of circular holes also the effectiveness were increased due to the reduction into fin’s weight. Also, a numerical study was done to investigate these temperature distribution used (SOLDWORKS) simulation program. Good agreements were noted when compared between experimental and theoretical works.

Keywords: Fins, Enhancement, Perforated fin, Convection.

1. Introduction

M.R. Shaeri and M. Yaghoubi, [1], studied the thermal performance for heat transfer rate from solid and perforated fins extended from a rectangular plate using a simulation program. The number of holes was (1-8) distributed along the fin length. Calculations were done for a scope of numbers of Reynolds (100 ≤ ReD ≤ 350), dependent on blade thickness. The perforated thermal performance was higher also the effectiveness was increased with increasing the perforations number. Bayram S. and Alparslan D., [2], studying the enhancement of pressure drop and transfer of heat for the fluid flow over a square perforated fins. The efficiency of enhancement ranged between (1.1 - 1.9) with respect to the ratio of spacing between fin and the clearance ratio. The optimum experimental results founded at Reynolds number equal to (42000), height of fin equal to (50 mm) and the
distance of stream wise between fins equal to (51 mm). E. A. M. Elshafei, [3], studied experimentally the heat transfer with natural convection using pin fins of circular cross section. Reynolds number was \( 3.8 \times 10^6 \leq Ra \leq 1.65 \times 10^7 \). The diameter ratio of the hollow pin influences into the factor of augmentation which found around (1.05-1.11). Wadhah Hussein Abdul Razzaq Al- Doori, [4], studied experimentally the convection of heat transfer at natural mode from a fin of a rectangular section with perforation of circular section. The temperature dropped saw from (30°C - 25°C) while for fins with holes was (30°C - 23.7°C). it observed that with increasing of perforations diameters, the temperature drops increased. Increasing of perforation number cause to increasing in the coefficient of heat transfer and the heat transfer rate. Raaid R. Jassem , [5], investigate experimentally the thermal performance heat transfer with natural convection mode using fin plate with perforations of rectangular section. Five types of fins used in this study, those were non-perforated and four perforated with square, circle, triangle and hexagon shapes having the same cross section of (113 m²). perforations 3 columns and 6 rows, were the distributions. The temperature drop of non- perforated fins was (72°C to 57°C) while for perforated fins for the same applied power (126 W) was (72°C - 51.5°C, 72°C - 50°C, 72°C - 48°C and 72°C - 52°C) for square, circle, triangle and hexagon shapes respectively. Abdullah H. et al, [6], studied the heat transfer enhancement from a rectangular fin with square perforated fin compared with non- perforated fin for natural transfer of heat. Results show the importance of both square dimensions and the space between perforation. The increasing in fin thickness causes the increasing in heat transfer rate. Akhilesh Kumar Singh and Rajiv Varshney, [7], studied experimentally the heat transfer convection with natural mode from the rectangular perforated fins. The space between solid was 6mm, and perforated fins were (4, 6 and 8 mm). also the inclination angles were (30, 45, 60 and 90°). The results show that the increasing in diameter of perforation(reduction in fin weight) lead to increasing in the heat transfer rate. Ganesha B. B. and G. V. Naveen Prakash , [8], studied experimentally the thermal performance of the transfer of heat from different holed rectangular aluminum fins (triangle, rectangular and circular) under force convection. The space between fins was (8 mm). The results of solid fins compared with perforated fins for the same fin’s spacing show the increasing in the heat transfer rate for perforated fins and the reduction in fin’s weight was (23.6%). Ankit Vyas et al, [9], studied the shape factor of perforated fin. This study concentrated on the obtaining the maximum heat transfer rate using perforated fins with different shape factor. The shape factor achieve this purpose was the optimum shape factor for a certain condition of flow. Tarique Khan et al, [10], studied the comparing of the rate of heat transfer using solid and circular perforated rectangular fin along fin transverse axis. Fin length was specified. The main parameters were fins efficiency, effectiveness and thermal performance. The increasing of surface area exposed to convective heat transfer caused to decreasing in Nusselt number. Also high reduction in fin weight was achieved.

2. Experimental Work
The experimental schematic diagram shown in figure(1) for natural convection heat transfer. Fins taken as solid and perforate as shown in figures (2). The experimental schematic diagram shown in figure(3) for forced convection heat transfer. They include the power supply, elements of heating and data acquisition to recorded all the experiments data. One heater used to supply the constant heat flux with electrical power up to (315W). The material chosen for the fins’ base was aluminum (30 mm length × 20mm height) includes a hole of (10 mm) to place the electrical heater. Three aluminum fins extended straightly from this base. The dimensions of fins were (30mm length × 30
mm wide × 1 mm thickness). The output power was regulated and the controlled voltage set with a certain values.

**Figure 1** Schematic diagram of experimental work for natural convection heat transfer.

**Figure 2** Perforated fins: (a)(9 holes × Ø 2 mm) ; (b)(5 holes × Ø 4 mm), Solid fins
Nine thermocouples (type K) were used to record the temperatures at different positions (bottom, middle and tip of fins) for each test. Therefore the main parameters affected on heat transfer rate were the heat flux, the shape of perforation and the perforation number. The thermocouple fixed at the bottom to record fin base temperature. Also air temperature was recorded by another thermocouple. After (30 minutes) the steady state achieved and the experiments were begun.

3. Numerical Solution

The natural convection mode of heat transfer along the perforated and non-perforated fins were analyzed with the condition of steady state. Aluminum is the material of base and fins. The flow is one dimensional and incompressible, then the heat transfer using those fins are simulated by SOLIDWORKS program. The base dimensions are (30mm length × 30mm width × 1mm thickness). The fins arrangement are in perpendicular columns with distance of (2mm) between from fin to other. Heat flux remain constant for each case. It is introduce from the constant electrical power applied at the base(11.4 - 313 Watt). The continuity, energy and equation of Navier-Stokes were solved by finite volume method. The convective term was discretize. The energy flow from the base dissipated by convection. Figures (4,5) show the temperature distribution simulation model along solid (non-perforated) fin for applied power of (11.4 -313 Watt) respectively with natural convection heat transfer. Figures (6,7) show the temperature distribution simulation model along perforated fins(Ø 2 mm, 9 holes) for applied power of (11.4-313 Watt) with natural convection heat transfer. Figures (8,9) show the temperature distribution simulation model along perforated fins(Ø 4 mm, 5 holes) for applied power of (11.4-313 Watt) with forced convection heat transfer.
Figure 4 Temperature distribution for solid fins with base temperature.: (a) 33.5°C, (b) 35.3°C

Figure 5 Temperature distribution for solid fins with base temperature.: (a) 39.1°C, (b) 43.4°C, (c) 49°C.

Figure 6 Temperature distribution for perforated fins (Ø 2 mm, 9 holes) base temperature: (a) 34.1°C, (b) 35.6°C.

Figure 7 Temperature distribution for perforated fins (Ø 2 mm, 9 holes) base temperature: (a) 38.4°C, (b) 44.2°C, (c) 51.3°C.
Figure 8 Temperature distribution for perforated fins (Ø 4 mm, 5 holes) base temperature: (a) 31.2°C, (b) 33.2°C.

Figure 9 Temperature distribution for perforated fins (Ø 4 mm, 5 holes) base temperature: (a) 37.1°C, (b) 41.8°C, (c) 47.3°C.

4. Results and Discussion

In numerical analysis using (SOLIDWORKS) study perforated heated rectangular fin array. It has been carried out under natural convection for many fin types, perforated and non-perforated, multi-perforation diameter, and heater inputs. Figure (4-a, 4-b) shows temperature distribution along the non-perforated fin array at heater input (20-40 volt). It shows that heating of fin array is uniform from base to the tip for natural convection and maximum temperature happened at fin base. Figures (5-a, 5-b, 5-c) show increasing in power supply that lead to increase in temperature at base of fins for non-perforated fin at power supply (60-80-100 volt). The thermal performance affected by the distributions of temperature. When the thermal resistance decreased, the increasing in temperature values were noted. Figures (6-a, 6-b, 7-a, 7-b, 7-c) show the temperature distribution for perforated fins (Ø 2 mm, 9 holes) for different heater input. In different type of fins perforation patterns, these figures show increasing in temperature difference between base and tip of the fin due to increasing in hole diameter. Figures (8-a, 8-b, 9-a, 9-b, 9-c) shows the temperature distribution for perforated fins (Ø 4 mm, 5 holes) for different heater input. Experimentally, the distributions of temperature for both solid and perforated fin along distance are graphed in Figures (10, 11, 12). Holes play an important role in the surface area if compared with solid fins area. It was noted that the temperature differences for perforated fins higher than those for the solid fins due to the reduction in thermal resistance for perforated fins.
5. Conclusions

There are several notes can be summarized as:
1. The temperature difference between base and tip for perforated fins was greater than for those of non-perforated fins.
2. The heat transfer rate for perforated fins dependent on holes dimensions and the fin width dimension.
3. Heat transfer rate increased with the increasing of hole number.
4. The perforated fin preferred for some applications due to reduction in weight compared with those non-perforated fins.
References

[1] M.R.Shaeri and M.Yaghoubi, 2009 “Thermal Enhancement from Heat Sinks by Using Perforated Fins”, Energy Conversion and Management Vol. 50, No. 5, pp. 1264-70.

[2] Bayram Sahina Alparslan Demirb, 2008 “Performance Analysis of a Heat Exchanger Having Perforated Square Fins”, Applied Thermal Engineering Vol. 28, No. 5-6, pp. 621-32.

[3] E.A.M. Elshafei 2010 “Natural Convection Heat Transfer from a Heat Sink with Hollow/Perforated Circular Pin Fins”, 3rd International Conference on Thermal Issues in Emerging Technologies Theory and Applications, IEEE, Cairo, Egypt.

[4] Wadhah Hussein Abdul Razzaq Al-Doori, 2011 “Enhancement of Natural Convection Heat Transfer from Rectangular Fins by Circular Perforations”, International Journal of Automotive and Mechanical Engineering (IJAME), Vol. 4, pp. 428-36.

[5] Raaid R. Jassem, 2013. “Effect the Form of Perforation on the Heat Transfer in the Perforated Fins effect the Form of Perforation on the Heat Transfer in The Perforated Fins”, Academic Research International, Vol. 4, No. 3

[6] Abdullah H. and M. AlEssa, 2012 “Augmentation of Fin Natural Convection Heat Dissipation by Square Perforations”, Journal of Mechanical Engineering and Automation, Vol.2, No.2, pp. 1-5.

[7] Akhilesh Kumar Singhand Rajiv Varshney, 2017 “Performance Evaluation of Rectangular Fins with Holes in Free Convection”, International Journal for Research in Applied Science & Engineering Technology (IJRASET), Vol. 5, No. X.

[8] Ganesha B B and G V Naveen Prakash, 2019 “Forced Convection Heat Transfer through the Rectangular Fins of Different Geometry of Perforations”, International Journal of Recent Technology and Engineering (IJRTE), Vol. 8 No.1S2.

[9] Ankit Vyas , Sandeep Gupta and Sunil Gupta, 2016 “Determining Relation Among Shape of Perforation and Convective Heat Transfer from Lateral Fin Arrangement Using Simulation by Computational Fluid Dynamics”, International Refereed Journal of Engineering and Science (IRJES), Vol.5, No. 4, PP.24-31,

[10] Tarique Khan , S. A. Pande and M. R. Dharme, 2018 “Experimental Analysis of Heat Transfer Enhancement through Perforations on Rectangular Fin”, International Journal of Latest Technology in Engineering, Management & Applied Science (IJLTEMAS), Vol. VII, No. VI.

[11] Mousa, A.H. 2000". Enhancement of thermal performance of fins subjected to natural convection through body perforation". PhD. Thesis, Mechanical Engineering, Baghdad University, Iraq.

Acknowledgments
The researchers extend their thanks and appreciation to Mustansiriyah University and the College of Engineering.