ISSN 2229-5518

INVESTIGATION OF HEAT TRANSFER CHARACTERISTICS IN A RECTNAGULAR CHANNEL WITH PERFORATED DROP SHAPED PIN FINS

C. Manikandan
PG Scholar, Department of Mechanical Engineering
Adhiparasakthi Engineering College
Melmaruvathur, Tamilnadu, India
manithcae@gmail.com

S. Pachaiyappan
Assistant Professor, Department of Mechanical Engineering
Adhiparasakthi Engineering College
Melmaruvathur, Tamilnadu, India
pachaisachi@gmail.com

***Abstract*—In this study the heat transfer characteristics inside a rectangular duct with circular, rectangular, drop shaped pin fins was analyzed by using ANSYS-15.0(CFD). The heat transfer rate is increased by arranging the pin fin arrays in staggered arrangement also constant heat flux is given to get the better results. Perforated drop shape with same cross sectional area is delaying the air passes through them, it will increase the heat transfer. The heat transfer rate of perforated drop shaped pin fin was better than the circular and rectangular shaped pin fins, in terms of specific performance parameters the perforated drop shaped pin fins are promising alternative configuration to the circular and rectangular pin fins.**

Keywords—perforated drop shape; rectangular duct; staggered arrangement; constant hetflux.

I. Introduction

Extended surface heat exchangers are used to increase the heat transfer between the surface and the surrounding fluid. One of the most commonly used extended surface heat exchangers is the pin fin, different types of fins is employed with different shapes such as cylindrical, rectangular, annular, tapered, or pin fins, these fins are attached from the rectangular or cylindrical base. Fins are playing the main role to enhance the heat transfer performance in cooling of circuit boards and computer chips.

The heat transfer characteristics inside a rectangular channel attached with differently shaped pin fins of circular, elliptical and drop shaped with the same cross sectional area arranged in a staggered arrangement, drop shaped pin fins are delays the flow passing through it when compared to the circular pin fins, so drop shaped pin fins are most suitable configuration to the circular pin fins [1]. Metzger [2] et al studied the two types of pin fin array geometries used to improve the air foil internal cooling performance, one type of array uses the circular pin fin with different cross section in flow direction, second type of array uses the oblong cross section, he concludes the staggered arrangement in oblong cross section will increases the heat transfer with the pressure drop as same as the circular pin fin.

Drop shaped pin fins with internal flow has the higher heat transfer than the circular pin fins of the same pressure loss characteristics also drop shaped pin fins is delays the fluid flowing through them when compared to the circular pin fins. Chyu [3] et al studied the heat transfer improvement by using cubic pin fin array. The fin element is either cube or diamond shape. The fin arrays arranged in both inline and staggered arrangement, the results indicate that the cubic element is always gives a highest heat transfer followed by diamond and circular pin fins. The pressure drop in the diamond shape pin fins is greater when compared to the cubic pin fins, also staggered arrangement will give the highest heat transfer enhancement when compared to the inline arrangement.

Dhumme and Hemant [4] reported an experimental analysis of on heat transfer improvement and the pressure drop characteristics in a cylindrical cross section with perforated pin fins in a rectangular channel. The experimental results show that the cylindrical perforated pin fins increases heat transfer than the solid cylindrical fins, both low clearance ratio and low inter-fin spacing ratio comparatively lowers the Reynolds number is suggesting for high thermal performance. Bayram Sahin and Alparslan Demir [5] studied the heat transfer improvement and the corresponding pressure drop in the flat surface attached with square perforated pin fins in a rectangular channel. Results show that the square pin fins may increase the heat transfer. The clearance ratio and inter-pin spacing ratio are influences the heat transfer.

Giovanni Tanda [6] studied the heat transfer and pressure drop in the rectangular channel attached with an array of diamond shaped elements, both in inline and staggered arrangement were considered. The heat transfer rate is increased with the presence of diamond shaped elements when compared to the without pin fins in the rectangular channel**.** R.F. Babu's Haq et al [7] reported that the better ratio of the pin fin diameter to the inter-pin fin pitch in the transverse direction was 2.04 for all pin-fin systems. Whereas, the better ratio in the longitudinal direction was 1.63, 1.71 and 1.95 for

ISSN 2229-5518

polytetrafluroethane pin-fins, mild-steel pin-fins and duralumin pin-fins respectively.

The alternative method to improve the heat transfer rate is to provide perforations, creating a certain degree of porosity crating slots which allow the flow to pass through the blocks. As in the case of perforated pin fins, the flow rate is increased to improve the heat transfer [8]. Shaeri and Yaghoubi [9] studied numerically fluid flow and heat transfer in a solid and perforated pin fin array that is attached with the flat plate. Their results show that the rate of heat transfer in a perforated fin is higher than the solid fins due to its larger surface area to the volume ratio. The different types of shapes for perforation, it includes the small channels of triangular, circular, rectangular and hexagonal cross section. The results indicate that circular perforated fins have the best thermal and fluid dynamic performances when compared to the other types in their work [10].

II. MODELLING

PRO-E (PTC Creo-3.0 Parametric) is used to create different types of pin fin arrays. The following table shows that parameters used to create the model.

PARAMETERS	DIMENSIONS
Pitch between two adjacent fins (P_1)	10 mm
pitch between two staggered fins (P_2)	10 mm
Diagonal pitch (P_d)	12 mm
Base plate thickness (t)	5 mm
Base plate area (A)	50×50 mm^2
Diameter of the perforated hole (d)	3 mm
FOR CIRCULAR PIN FINS	
Diameter of the circular pin fin (D)	6 mm
Height of the circular pin fin (H)	20 mm
FOR RECTANGULAR PIN FINS	
Length of the rectangular pin fin (L)	8 mm
Breadth of the rectangular pin fin (B)	4 mm
FOR DROP-SHAPED PIN FINS	
Diameter of the drop-shaped pin fin (D)	6 mm
Length of the drop-shaped pin fin (L1)	6 mm

Table-1. Dimensional parameters of pin fins

A. Design of pin fins

Most of the current research are concentrated on circular pin fins because that they are easy to manufacture. However, it is clear that the perforated drop-shaped pin fins have a lower resistance to the flow and lower friction factor than the circular ones, as well as a higher surface wetted area that can increase the heat transfer.

In this study, a drop shaped pin fin is selected to improve the heat transfer and pressure loss. The configuration of the pin is shown in fig-2. Its cross section consists of a circular leading edge that extends along 90+2×Ɵ Deg and a triangle edge are tangent to the circular arc.

The distance between the canter of the circle triangle apex is L. Having the triangular portion of the pin will help to increase the wetted surface area of the heat exchanger leading to a major increase in the heat transfer and the efficiency. In addition, it delays the separation in comparison with the circular cross section which helps decreases the friction factor and the flow resistance leading to the major decrease's in the pressure loss.

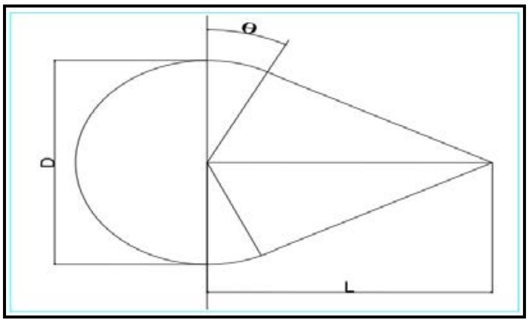

Fig-1. Drop-shaped design

The following are the models created by using PRO-E (PTC CREO-3 PARAMETRIC):

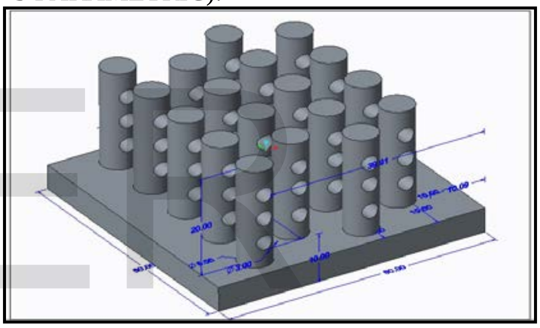

Fig-2. Perforated Circular shaped pin fin array

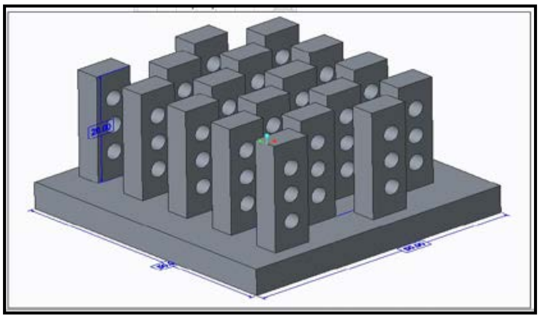

Fig-3. Perforated Rectangular shaped pin fin array

ISSN 2229-5518

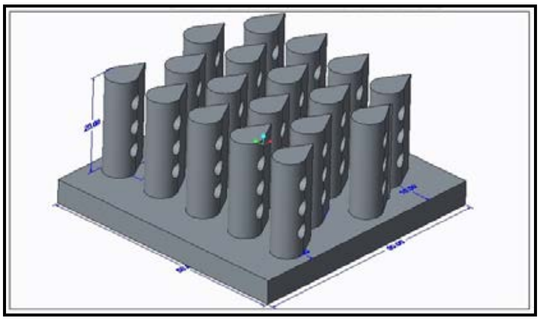

Fig-4. Perforated Drop shaped pin fin array

III. FLUENT ANALYSIS STEPS

The models created in the PRO-E (PTC CREO-3 PARAMETRIC) are imported in to the ANSYS (FLUENT) for analysing the geometries to get the effective shape of the pin fin.

A. MESHING:

A high quality mesh is very important for successful numerical simulations. The smaller the size of the element near the wall of the pin fins, the more detailed and accurate flow structure will be captured. However, a small change in the size of the element will lead a substantial increase in the number of elements for a 3D simulation. That will result in significant increases in computational time. To balance the accuracy of the simulations and solution time, an optimum size of mesh need to be chosen.

Here in fluent rectangular duct is created in the design modeller and meshing are done by FINE method to get the precise meshing for better results. The naming is given as per the following table:

MESHING	NAMING OF THE MODEL
Fine	Fin Base
Fine	Fin Wall
Fine	Inlet
Fine	Outlet

Table-2. Analysis models naming

The following are the MESH MODELS crated by the ANSYS-15 (FLUENT MESH):

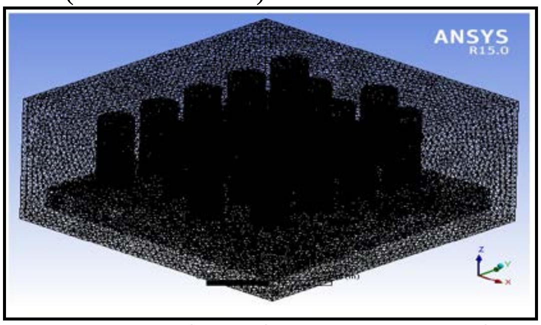

Fig-5. Mesh model for Perforated Circular pin fin array

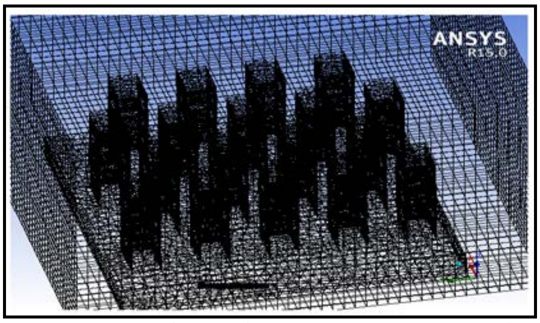

Fig-6. Mesh model for Perforated Rectangular pin fin array

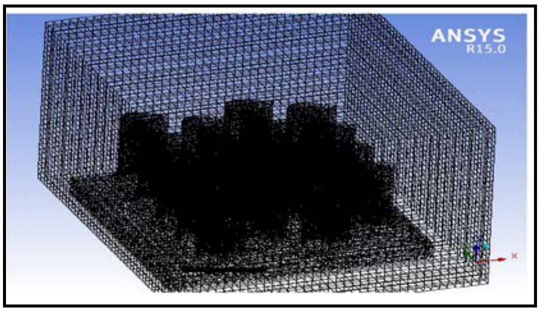

Fig-7. Mesh model for Perforated Drop-shaped pin fin array

B. SOLVER SETUP:

After meshing the analysis model, it can be solved by setting the boundary conditions it is given below:

BOUNDARY	FLOW SIMULATION	HEAT TRANSFER EQUATION
Inlet	Fully developed velocity profile	Velocity of 5m/sec, Uniform temperature at 300 K
Outlet	Zero pressure outlet	$\frac{\partial T}{\partial X} = 0$
Fin Base	Constant heat flux	Constant heat flux of 5000 w/m^2
Fin Wall	Standard no slip walls on no penetration	Adiabatic wall

Table-3. Boundary conditions

After setting the boundary conditions the model can be solved by standard initialisation up to the solution is converged then the results are analysed below.

IV. RESULTS AND DISCUSSION

A series of numerical analyses have been conducted by fluent and the results are presented in order to show the effects of heat flux in rectangular channel heat sinks.

C. TEMPERATURE CONTOUR:

For the prediction of fluid flow and thermal characteristics, contour of temperature in the fluid at the Fin pin array is shown in below fig.

ISSN 2229-5518

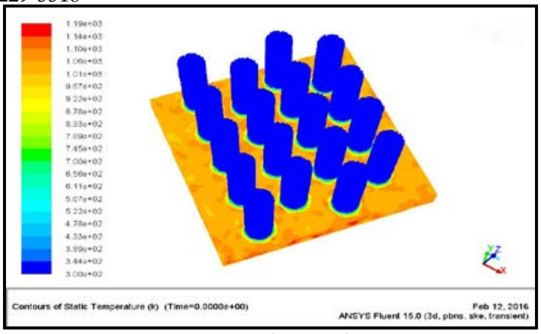

Fig-7. Temperature contour for Perforated Circular pin fin array

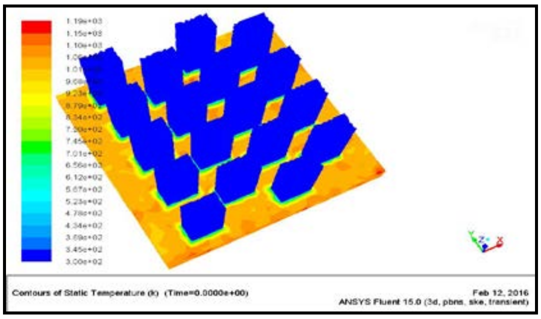

Fig-8. Temperature contour for Perforated Rectangular pin fin array

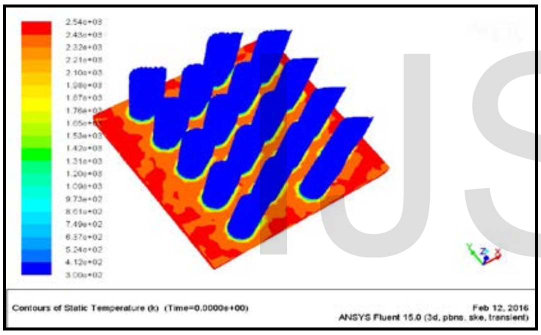

Fig-9. Temperature contour for Perforated Drop-shaped pin fin array

Above fig are the static temperature contours of Circular, Rectangular and Drop-shaped pin fin. The fig itself tells that the heat transfer in Drop-shaped pin fin array is somewhat higher than the Circular and Rectangular shaped pin fin arrays.

The temperature induced is increases in the pin fin array will causes the serious damages into the pin fin array it must be dissipated as early as possible to avoid the melting and other problems the above temperature contour will clearly tell that the temperature induced in the Drop-shaped pin fin array is somewhat lesser than the other two shaped pin fin array we are considered.

The Drop-shaped pin fin with the perforation will increase the contact between the air flow medium and pin fin arrays this will increase the heat transfer when compared to the Circular and rectangular with perforations.

The following are the pressure results obtained in Histogram plots in ANSYS for circular, drop shape and rectangular shapes in XY plot X axis is for pressure quantity and for the Y axis is for the position.

TYPE OF PIN FIN ARRAY	Circular	Rectangular	Drop shape
Maximum static temperature(K)	455	495	435
Maximum total temperature(K)	365	360	345
Static pressure difference(Pa)	92	110	95
Static pressure difference(Pa)	51	82	48

Table-4. Comparison between fins

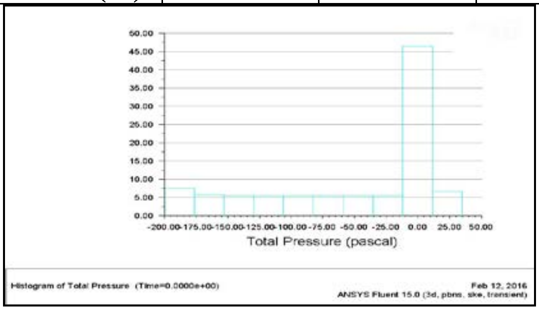

Fig-10. XY Plot for total pressure drop in a Perforated circular pin fin array

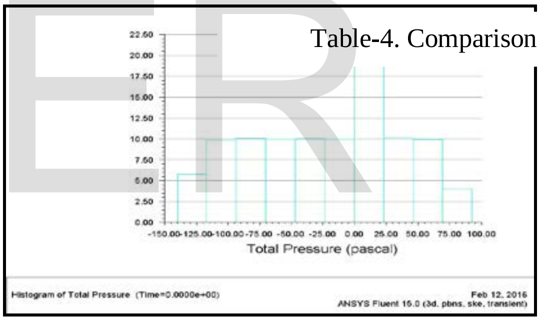

Fig-11. XY Plot for total pressure drop in a Perforated rectangular pin fin array

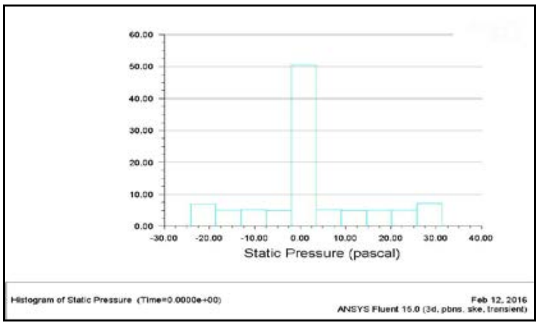

Fig-12. XY Plot for total pressure drop in a Perforated Drop-shaped pin fin array

The above fig shows the how the pressure varies with the positions of the pin fin array in rectangular duct where the forced air supply is given by the blower for heat transfer. The pin fin array is heated by using the heater with heat flux of 5000W/m2 and the heat transfer is occurred with forced convection.

The perforated round pins seem to have a wider separation region in the back, marked by a very small velocity indicating the discontinuity of the flow streamlines and the circulation of the flow downstream of the pins. This problem was solved by changing the pin geometry and using the Drop-shaped pin fins.

Heat transfer behavior alone does not provide a complete evaluation of heat exchanger performance. The increases in pressure drop, which is a measure of the energy required by the system, must be weighed against the improvements of heat transfer for each pin fin configurations.

D. COMPARISION BETWEEN FINS:

The following table is the overall comparison between perforated circular, drop shapes and rectangular shapes.

The results show that the PERFORATED DROP Fins are more reliable than the PERFORATED CIRCULAR and PERFORATED RECTANGULAR SHAPED Fins and temperature induced is varies between circular and drop fins and with appropriate equal pressure drop is this shows that temperature induced is reduced means more heat transfer rate is created in the DROP Shaped Pin Fin arrays.

V. CONCLUSION

The perforated drop shaped pin fins is increases the heat transfer when compared to circular pin fins for the same pressure drop characteristics. The main reasons are the perforated drop-shape have a higher wetted surface area leading to a higher heat flux, perforated drop-shape forces the separation to delay, the drop-shape have a considerable decrease in the friction factor in comparison with the circular and rectangular shaped pin fins.

References

[1] Fengming Wang, Jingzhou Zhang, Suofang Wang, "Investigation on flow and heat transfer characteristics in a rectangular channel with drop shipped Pin fins", Propulsion and Power Research, Vol.1, pp.64–70, 2012.

[2] D.E. Metzger, C. S. Fan, S. W. Haley, “Effects of Pin Shape and Array Orientation on Heat Transfer and Pressure Loss in Pin Fin Arrays”, ASME J. Heat Transfer, Vol.3, pp.137-142, 1984.

[3] M.K. Chyu, R. J. Goldstein, “Influence of an array of wall-mounted cylinders on the mass transfer from a flat surface ”, ASME J. Heat Transfer, Vol.34, pp.2175-2186, 1990.

[4] Amol B. Dharma, Hemant S. Facade Warnecke, “Heat Transfer Analysis of Cylindrical Perforated Fins in Staggered Arrangement ”, IJITEE, Vol.2, 2013.

[5] Bayram Sahin, AlparslanDemir, “Performance analysis of a heat exchanger having perforated square fins”, ELSEVIER, Applied Thermal Engineering, Vol.28, pp.621 -632, 2008.

[6] Giovanni Tanda, “HeatTranfer and pressure drop in a rectangular channel with diamond-shaped elements”, Heat and Mass Transfer, Vol.44, pp.3529-3541, 2001.

[7] R.F. Babus’Haq, K. Akintunde, S.D. Probert, “Thermal performance of a pin-fin assembly”, Int. J. Heat Fluid Flow, Vol.16, pp.50-55, 1995.

[8] O.N. Sara, T. Pekdemir, S. Yapici, M. Yilmaz, “Heat- transfer enhancement in a channel flow with perforated rectangular blocks”, Int. J. Heat Fluid Flow, Vol.22, pp.509-518, 2001.

[9] M.R. Shari, M. Yaghoubi, “Numerical analysis of turbulent convection heat transfer from an array of perforated fins”, Int. J. Heat Fluid Flow, Vol.30, pp.218-2228, 2009

[10] M.F. Ismail, M.N. Hasan, M. Ali, “Numerical simulation of turbulent heat transfer from perforated plate-fin heat sinks”, Heat Mass Transfer, Vol.50, pp.509-519, 2014.

[11] ANSYS Inc., ANSYS Fluent v15.0 Software User’s Gide, Lebanon, NH, 2015.