Design and Analysis of Natural Convective Heat Transfer Coefficient Comparison between Rectangular Fin Arrays with Perforated and Fin Arrays with Extension

V. Karthikeyan, R. Suresh Babu, G. Vignesh Kumar

Abstract— In this study, the Heat transfer rate of Rectangular fin arrays is analyzed by design with perforated and with extension. The effectiveness is compare to the fin arrays with extension and with perforated. The fin arrays are Perforated with various diameter and different types of extensions such as rectangular extension, trapezium extension, triangular extensions and circular segmental extensions are used. All the fin arrays are design with the help of software Solid works. Analysis is carried out using ANSYS WORKBENCH. In that steady state thermal analysis, temperature variations with respect to distance at which heat flow occur through the fin is analyzed. The Perforated and Extensions on the finned surfaces is used to increases the surface area of the fin in contact with the fluid flowing around it. So, as the surface area increase the more fluid contact to increase the rate of heat transfers from the base surface. On comparison, rectangular extensions provide on fin gives the greatest heat transfer than that of other fin arrays. The effectiveness of rectangular extensions in fin array is greater as compare to other types of fin arrays.

***Index Terms*— Heat transfer, Natural convection, Extension, Taper fin, Perforated Fin.**

I. Introduction

Extended Surface (Fin) are used to enhance convective heat transfer in a wide range of engineering applications and offer a practical means for achieving a large total heat transfer surface area without the use of an excessive amount of primary surface area. Fins are commonly applied for heat management in electrical appliances, such as computer power supplies or substation transformers and other applications include IC engine cooling, Fins in Automobile radiator. Extensions on the finned surfaces is used to increases the surface area of the fin. When the surface area increase the more fluid contact to increase the rate of heat transfers from the base surface as compare to fin without the extensions provided to it. The concept of heat transfer through perforated in fin array also one of the method to improve the heat transfer character. The efficiency and rate of heat transfer in perforated fin is compared to the fin with extension. The various types of extension provided on fin array such as (a) Rectangular extensions, (b) Trapezium extensions, (c) Triangular extension, and (d) Circular Segmental extension. The perforated in fin array diameters are 18mm, 20mm, 22mm, 24mm

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II. LITERATURE REVIEW

B. Ramdas Pradip et. al. [2] studied many industries are utilizing thermal systems wherein overheating can damage the system components and which may lead to failure of the system. To overcome this problem, thermal systems with heat exchanger effective emitters such as ribs, fins, baffles etc. are desirable. The need to increase the thermal performance of the systems, there by affecting energy, material and cost savings has led to development and use of many techniques known as "Heat transfer Augmentation". This technique is also termed as "Heat transfer Enhancement". Augmentation techniques increase the convective heat transfer by reducing the thermal resistance in a heat exchanger. Many heat augmentation techniques has been reviewed, these are (a) surface roughness, (b) plate baffles and wave baffles, (c) perforated baffles, (d) inclined baffles, (e) porous baffles, (f) channel, (g) twisted tape, (h) discontinuous Crossed Ribs and Grooves. Most of these techniques are based on the baffle arrangement. The Heat transfer enhancement techniques lead to increase in heat transfer coefficient but at the cost of increase in pressure drop.

Pardeep Singh, Harvinder lal, Baljit Singh Ubhi et al (2014). In this paper, the heat transfer performance and effectiveness of fin is analyzed by design of fin with various extensions such as rectangular extension, trapezium extension, triangular extensions and circular segmental extensions. The heat transfer performance of fin with same geometry with various extensions and without extensions is compared. The ranging 5% to 12% increase in heat transfer can be achieved with these various extensions on fin as compare to same geometry of fin without these extensions.

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Kumbhar D.G, Dr. N.K. Sane, Chavan S. T., et al (2009) In this paper, the effect of triangular perforations on rectangular fin is investigates the comparison of perforated fin with solid fin for temperature distribution along the fin and heat transfer rate. The analysis is done using software ANSYS and also by experimentation. The investigation observed that heat transfer rate increases with perforations as compared to fins of similar dimensions without perforations. It is noted in case of triangular perforations in fins achieved optimum heat transfer. It concluded that heat transfer rate is different for different materials or heat transfer rate changes with change in thermal conductivity of the material. The perforation of fins enhances the heat dissipation rates and at the same time reduces the expenditure for fin materials also. Result obtained from software Ansys and experimentation support each other. Also experimentation in rectangular fin with triangular perforations and without perforation has been done. The study shows that the heat dissipation from the perforated fin improved the heat transfer rate over the equivalent solid fin. If thermal conductivity increases heat transfer augmentation of perforated fin is also increase.

Ashok Tukaram Pise, Umesh Vandeorao Awasarmol., et al (2010). In this paper, the original engine blocks were taken for experimentation work. Modifying the solid rectangular fins as permeable fins by drilling three holes per fins inline in one half of the length of the fin of a cylinder block. The investigation observed heat transfer rates, heat transfer coefficients and percentage saving of material for solid and permeable fins are compared. The experiment shows that heat transfer rate improves with the use of permeable fins. The base temperatures profiles of solid fins are more elevated as compared to permeable fins and the tip temperatures of solid fins are more elevated as compared to permeable fins. It means that for the same heat flux the cylinder with permeable fins runs cool which shows that heat transfer rate is more in permeable fins as compared to solid fins. Also there is a net increase in heat transfer rate with permeable fins as compared to that of the cylinder block with solid fins.

III. DESIGN AND ANALYSIS OF FIN ARRAYS

3.1 DESIGNING OF FIN ARRAYS WITH SOLIDWORKS

The fin arras with various extensions and perforation in fin arrays are design with the help of design software Solidworks. The fin arras modeled using 2D and 3D commands like polyline, arc, circle, mirror, Pattern, extrude, extrude cut. There are totally 9 no. of models designed for the analysis. The array consists of 3 no. of fin.
They are listed below:

1) Rectangular Fin arrays without Extension
2) Rectangular Fin arrays with Extension
   a) Triangular Extension
   b) Trapezium Extension
   c) Circular Extension
   d) Rectangular Extension
3) Rectangular Fin arrays with Perforation
   a) With diameter 18mm
   b) With diameter 20mm
   c) With diameter 22mm
   d) With diameter 24mm

Set units in millimeter. Specifications and dimensions of different fin arrays are shown in the Fig.1 and number of extensions used on fin arrays is 30 nos.

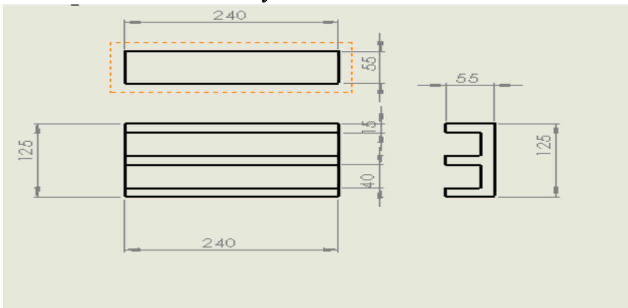

Figure 1. Rectangular fin array without extensions

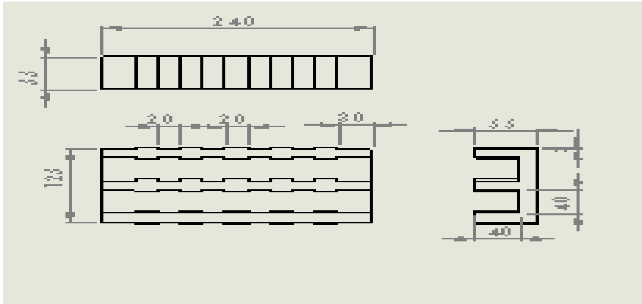

Figure 2.a. Rectangular fin array with rectangular extensions

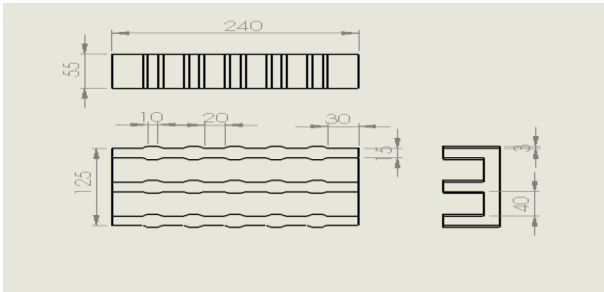

Figure 2.b. Rectangular fin array with Trapezium extensions

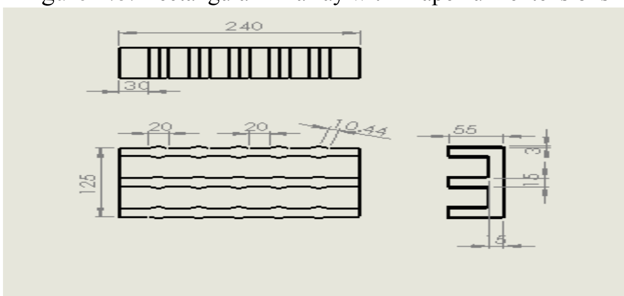

Figure 2.c. Rectangular fin array with Triangular extensions

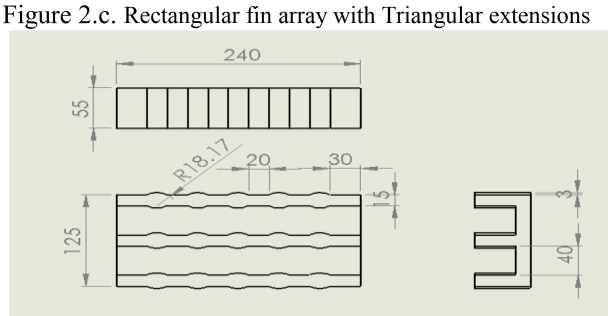

Figure 2.d. Rectangular fin array with Circular extensions

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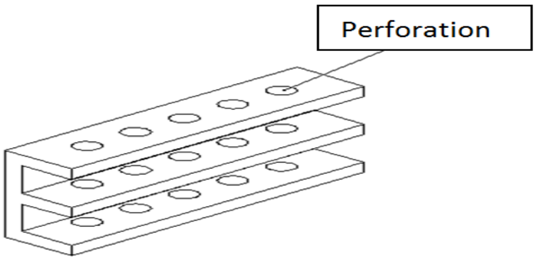

Figure 3. Rectangular fin array with perforation of 18, 20, 22, 24mm

3.2. ANALYSIS OF FIN ARRAYS FOR HEAT TRANSFER WITH ANSYS WORKBENCH

3.2.1 IMPORT THE GEOMETRY

After the creation of design the next process is to analysis the fin arrays for heat transfer by using software Ansys Workbench. The important factor is while saving the model in Solidworks it should be in ".igs" file format. So it can access through the FEA software.

Then, select the type of analysis as thermal analysis for steady-state heat transfer process. Assign unit system as customization length in mm, temperature in °C. Import the models to Ansys Workbench.

3.2.2 GENERATING THE MESH

The 3D mesh setting set mesh size towards fine the high in smooth and fast in transition. Select the model and generate the mesh for the design. Fig.4 shows that a sample meshing of the model. The meshing result shows that the solid mesh surface part having 14880 elements created, final mesh size is 3.7636 mm and surface mesh contains 72397 nodes. The mesh type is mix of brick, wedges, Pyramids.

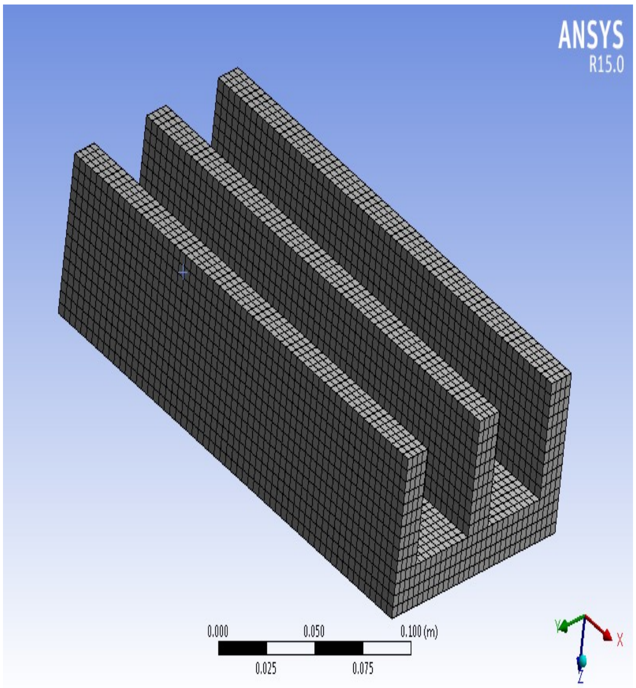

Figure 4. Meshed Rectangular fin arrays without extension

3.2.3 ASSIGNING MATERIAL AND LOADS TO THE MESHED MODEL

Aluminum (AL 6061 T6) has selected for the model due light weight and high heat transfer rate and heat dissipation in this material. The manufacturing process also simple in the aluminum and cost wise it is an economic.

The material having thermal conductivity, convection coefficient of heat transfer for air, temperature of surface and ambient temperature as:

Thermal conductivity, k = 167 W/m °C = 0.167 J/(s mm °C)
Convection coefficient of heat transfer, h = 83 W/m2 °C = 0.00083 J/(s mm2°C)
Temperature of wall surface at which fin attached, to = 55 °C
Ambient temperature, ta = 30 °C

Figure 5. Assigning the loads to Rectangular fin arrays without extension

Fig.5. Shows that loads assigning to the rectangular fin arrays without extension. "A" represents the convective coefficient of heat transfer to the model. "B" represents the Base temperature or the wall temperature.

3.3. RESULTS FROM THE ANALYSIS

After the generating the mesh, assigning of loads and constraints then next step is to run the simulation for the Rectangular models. Then proceeds for the analysis the steady-state heat transfer process and finally obtain the required result contour of temperature for Rectangular fin array models.

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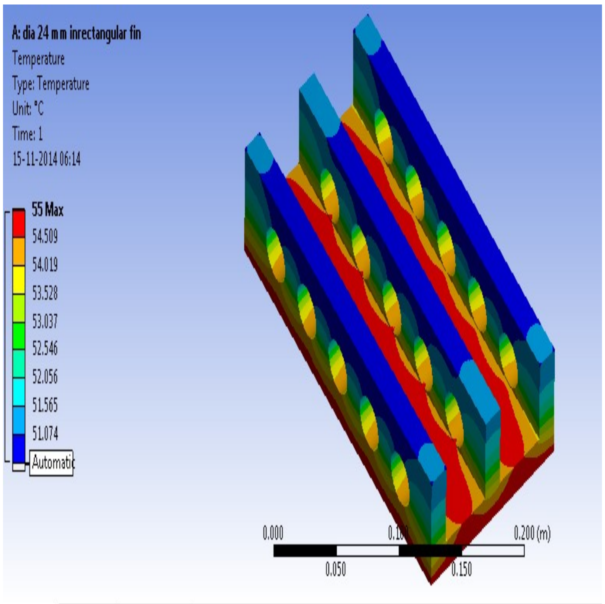

Figure 6.1.Temperature contour for Rectangular fin arrays with 24mm perforated

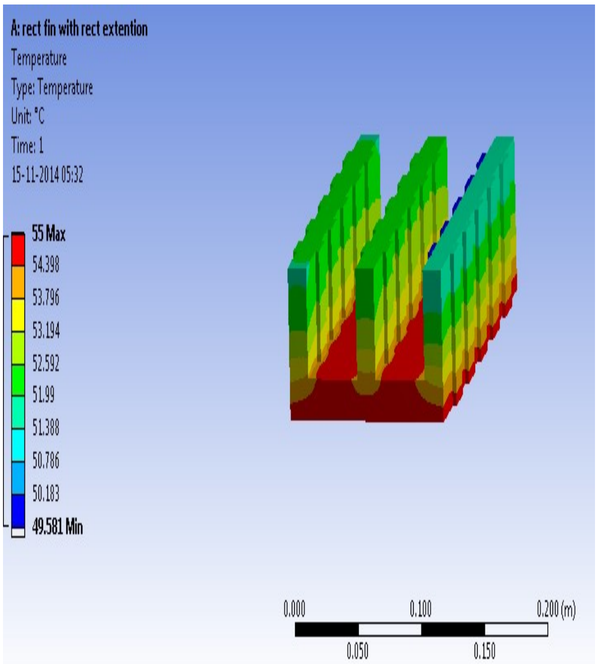

Figure 6.2. Temperature contour for Rectangular fin arrays with Rectangular Extensions.

The resultant Fig.6.1 shows that variations of temperature for 24mm perforated Fin array the temperature reduced from base at 55 °C to 50.584 °C. Fig.6.2 shows that variations of temperature for Fin arrays with rectangular extension temperature reduces from fin base at 55 °C to 49.581 °C at the tip end of the fin.

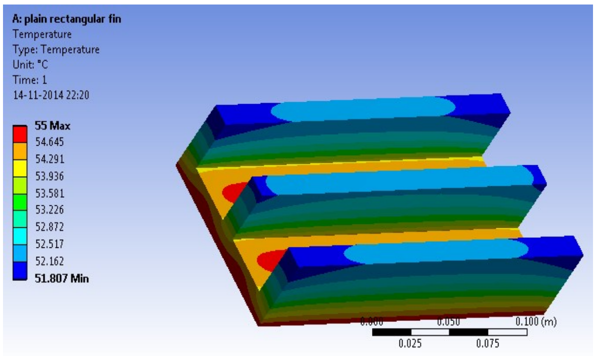

Figure 7.1. Temperature contour of fin arrays without extension

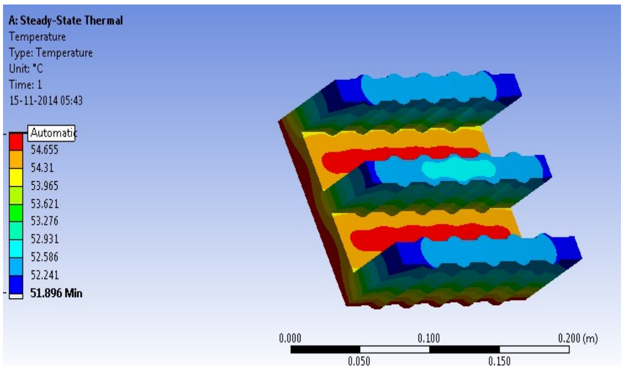

Figure 7.2. Temperature contour of fin arrays with circular extension

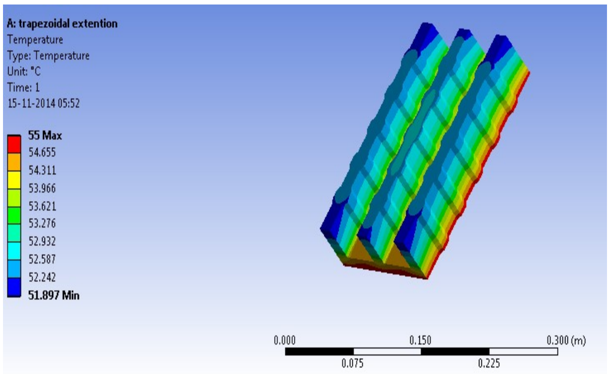

Figure 7.3. Temperature contour of fin arrays with Trapezium extension

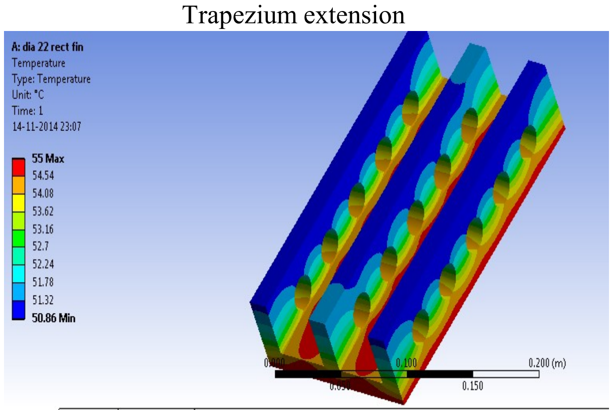

Figure 7.4. Temperature contour of fin arrays with 22mm perforated

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Similarly the resultant Fig.7 shows that variations of temperature contour of fin arrays with trapezium extensions, fin arrays with circular segmental extensions, fin without extensions that the temperature reduces from fin base to the tip end of the fin.

S.NO.	RECTANGULAR FIN PROFILES	TEMPERATURE °C	HEAT FLUX w/m^2	HEAT FLUX w/m^2
1)	Fin arrays without extension	51.807	21138	1848.5
2)	Fin arrays with Rectangular extension	49.581	37317	1629.8
3)	Fin arrays with Circular extension	51.896	20508	1860.1
4)	Fin arrays with Trapezoidal extension	51.897	20500	1860.3
5)	Fin arrays with Triangular extension	51.874	20666	1857.1
6)	Fin arrays with 18mm Perforated	51.301	23227	366.36
7)	Fin arrays with 20mm Perforated	51.097	26533	412.06
8)	Fin arrays with 22mm Perforated	50.86	25263	127.49
9)	Fin arrays with 24mm Perforated	50.584	26941	243.22

Table - 1

COMPARISON OF TEMPERATURE VARIATIONS

The Table-1 shows that comparison of temperatures variation or temperature contour and Maximum, Minimum Heat flux values of fin arrays with different types Extensions and Perforated.

IV. RESULT AND DISCUSSION

The rate of Heat transfer is calculated by using the heat transfer governing differential equation for the fin of finite length and loses heat by convection. The given length (l), thickness (y in m), width (b) are convert into meter (m), thermal conductivity of fin (K in w/m°C), coefficient of convective heat transfer (h in w/m^2°C) , temperature at base of fin (t_o in °C), temperature of the ambient fluid (t_a in °C). After the calculations of heat transfer rate of various fin geometry is compare the increase in heat transfer rate for the given geometry of fin which is shown in Table-2. The fin arrays without extension having 22.5645 W Heat transfer value.

$$Q_{fin} = (hPKA)^{0.5}(t_o - t_a)\left[\frac{\tan h\,[ml] + \frac{h}{km}}{1 + \frac{h}{km}\tan h(ml)}\right]$$

S.NO.	Types of Rectangular fin arrays	Heat transfer (in W)	Increase in heat transfer (in W)	Percentage increase in heat transfer (in %age)
1)	Fin arrays with Rectangular extension	27.3208	4.7563	21.0786
2)	Fin arrays with Circular extension	25.6313	3.0668	13.5912
3)	Fin arrays with Trapezoidal extension	25.6214	3.0569	13.5473
4)	Fin arrays with Triangular extension	25.6871	3.1226	13.8365
5)	Fin arrays with 18mm Perforated	23.8271	1.2626	5.5955
6)	Fin arrays with 20mm Perforated	23.5274	0.9629	4.2673
7)	Fin arrays with 22mm Perforated	22.9722	0.4077	1.8068
8)	Fin arrays with 24mm Perforated	22.6386	0.0741	0.3283

Table-2

S.NO.	Types of Rectangular fin arrays	Effectiveness of fins
1)	Fin arrays with Rectangular extension	5.9276
2)	Fin arrays with Circular extension	5.2769
3)	Fin arrays with Trapezoidal extension	5.7421
4)	Fin arrays with Triangular extension	5.5337
5)	Fin arrays with 18mm Perforated	3.2561
6)	Fin arrays with 20mm Perforated	3.0283
7)	Fin arrays with 22mm Perforated	2.7628
8)	Fin arrays with 24mm Perforated	2.3782

Table 3: Effectiveness for different types of fins

Table-3 shows that the effectiveness of fin arrays with rectangular extensions, without extension, with perforations.

V. CONCLUSION

Heat transfer through fin arrays with rectangular extensions higher than that of fin with other type of fins compared to it. Temperature at the end of fin arrays with rectangular extensions is Minimum as compare to fin with extensions, without extension and with Perforated. Fin arrays with rectangular extensions provide near about 13 % to 21% more enhancement of heat transfer as compare to other type of fins. This result may vary for forced convection Heat transfer.

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