ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 5, May 2014

Design and Analysis for Heat Transfer through Fin with Extensions

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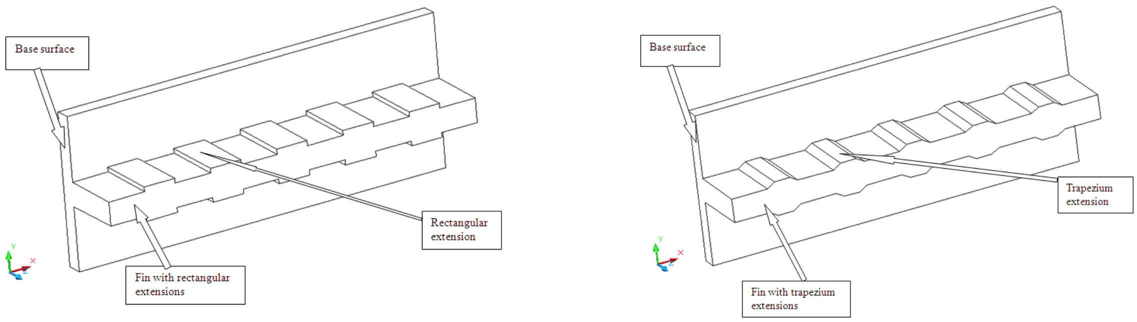
Abstract: In this research, the heat transfer performance of fin is analyzed by design of fin with various extensions such as rectangular extension, trapezium extension, triangular extensions and circular segmental extensions. The heat transfer performance of fin with same geometry having various extensions and without extensions is compared. Near about ranging 5% to 13% more heat transfer can be achieved with these various extensions on fin as compare to same geometry of fin without these extensions. Fin with various extensions design with the help of software AutoCAD. Analysis of fin performance done through the software Autodesk® Simulation Multiphysics. In this thermal analysis, temperature variations w.r.t. distance at which heat flow occur through the fin is analyzed. 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 as compare to fin without the extensions provided to it. On comparison, rectangular extensions provide on fin gives the greatest heat transfer than that of other extensions having the same length and width attached to finned surface. The effectiveness of fin with rectangular extensions greater as compare to other extensions on fin.

Keywords: Extended surface, Analysis, Extensions, Design and Heat transfer enhancement.

I. INTRODUCTION

A fin is a surface that extends from an object to increase the rate of heat transfer to or from the environment by increasing convection. 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 as compare to fin without the extensions provided to it. Types of extension provided on fin such as (a) Rectangular extensions, (b) Trapezium extensions, (c) Triangular extension, and (d) Circular Segmental extension.



(a) (b)

Fig. 1: Fin with (a) Rectangular extensions, (b) Trapezium extensions.

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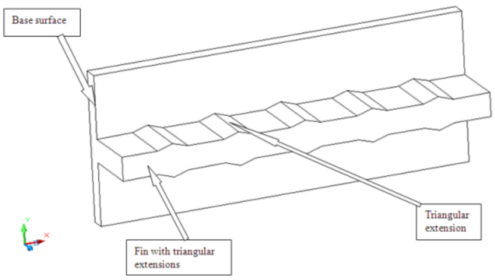
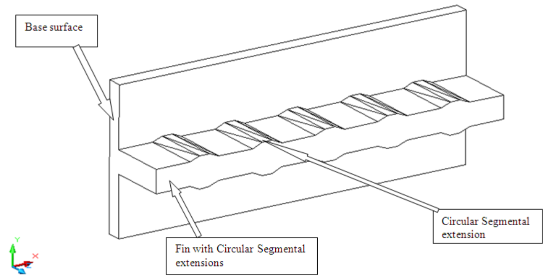


(a)



(b)

Fig. 2: Fin with (a) Triangular extensions, (b) Circular segmental extensions.

II. LITERATURE REVIEW

Abdullah, H. Alessa et. al. [1] had studied the natural convection heat transfer enhancement from a horizontal rectangular fin embedded with equilateral triangular perforations. The heat dissipation rate from the perforated fin is compared to that of the equivalent solid one. The effect of geometrical dimensions of the perforated fin and thermal properties of the fin was studied in detail. They concluded that, For certain values of triangular dimensions, the perforated fin can result in heat transfer enhancement. The magnitude of enhancement is proportional to the fin thickness and its thermal conductivity. The perforation of fins enhances heat dissipation rates and at the same time decreases the expenditure of the fin material.

B. Ramdas Pradip et. al. [2] had studied the many industries are utilizing thermal systems wherein overheating can damage the system components and lead to failure of the system. In order to overcome this problem, thermal systems with effective emitters such as ribs, fins, baffles etc. are desirable. The need to increase the thermal performance of the systems, thereby affecting energy, material and cost savings has led to development and use of many techniques termed as “Heat transfer Augmentation”. This technique is also termed as “Heat transfer Enhancement” or “Intensification”. Augmentation techniques increase 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 baffle and wave baffle, (c) perforated baffle, (d) inclined baffle, (e) porous baffle, (f) corrugated channel, (g) twisted tape inserts, (h) discontinuous Crossed Ribs and Grooves. Most of these enhancement techniques are based on the baffle arrangement. Use of Heat transfer enhancement techniques lead to increase in heat transfer coefficient but at the cost of increase in pressure drop.

Golnoosh Mostafavi [3] had investigated the steady-state external natural convection heat transfer from vertically-mounted rectangular interrupted finned heatsinks. After regenerating and validating the existing analytical results for continuous fins, a systematic numerical, experimental, and analytical study is conducted on the effect of the fin array and single wall interruption. FLUENT and COMSOL Multiphysics software are used in order to develop a two-dimensional numerical model for investigation of fin interruption effects. Results show that adding interruptions to vertical rectangular fins enhances the thermal performance of fins and reduces the weight of the fin arrays, which in turn, can lead to lower manufacturing costs.

Sable, M.J. et. al. [4] had investigated for natural convection adjacent to a vertical heated plate with a multiple v- type partition plates (fins) in ambient air surrounding. As compared to conventional vertical fins, this v-type partition plate’s works not only as extended surface but also as flow turbulator. In order to enhance the heat transfer, V-shaped partition plates (fins) with edges faced upstream were attached to the two identical vertical plates. They observed that among the three different fin array configurations on vertical heated plate, V-type fin array design performs better than rectangular vertical fin array and V-fin array with bottom spacing design. The performance was observed to improve further, with increase in the height of the V-plates (fin height).

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III. DESIGN AND ANALYSIS OF FIN WITH EXTENSIONS

A. Designing of Fin with AutoCAD

The fin with various extensions are design with the help of design software AutoCAD by using the AutoCAD 2D and 3D commands like as 2D commands polyline, arc, mirror , pedit ,& 3D commands extrude. The line draws with the Polar mode. In this mode length of the line and angle of the line is defined to draw the design. [5] The angle is measured in anti-clock direction starting from the first quadrant.
Main Fin specifications:
Length, l = 40mm = 0.04 m, width, b = 240 mm = 0.24 m and thickness, y = 15mm = 0.015 m.
Specifications of various extensions shown in the Fig. 3 and number of extensions used on main fin is 10 nos.

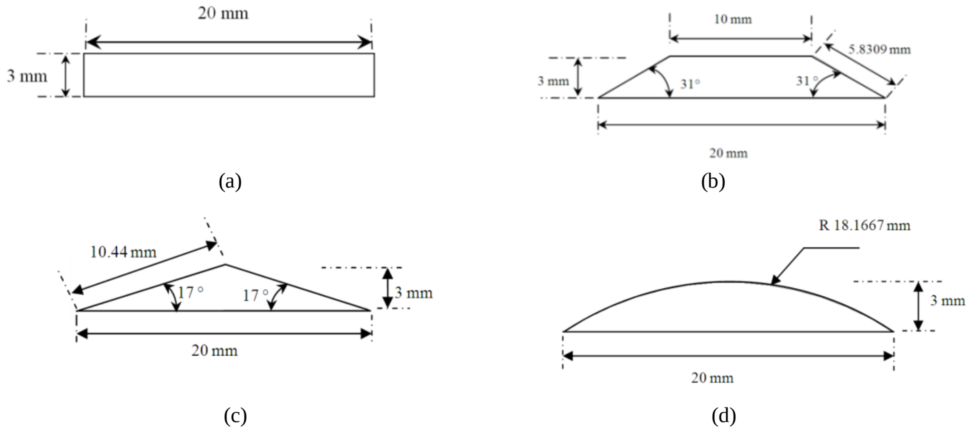

Fig. 3: (a) Rectangular extension, (b) Trapezium extension, (c) Triangular extension, (d) Circular segmental extension.

B. Analysis of Fin for Heat Transfer with Simulation Software

After the creation of design the next process is to analysis the fin for heat transfer by using software Autodesk® Simulation Multiphysics. Firstly import the design model AutoCAD DWG file (*.dwg) in the Autodesk® Simulation Multiphysics software this will make the result as Autodesk Simulation FEA model (*.fem) file format. Now, 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 and thermal energy in J. Now from the 3D mesh setting set 60% mesh size towards fine. Generate the mesh of design.

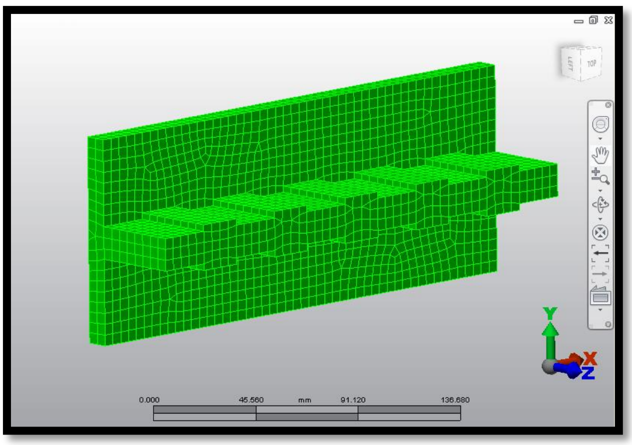

Fig. 4: Meshing of the model.

ISSN: 2319-8753

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Fig. 4 shows that meshing of the model. The meshing result shows that the solid mesh surface part having 3310 elements created, final mesh size is 4.75669 mm and surface mesh contain 3305 nodes, 9909 lines. The mesh type is mix of brick, wedges, pyramids and tetrahedra.

C. Assigning Load and Constraints to the Meshed Model

In this assign the material having thermal conductivity, convection coefficient of heat transfer for fluid, temperature of surface and ambient temperature as:
Thermal conductivity, k = 40 W/m °C = 0.04 J/(s mm °C)
Convection coefficient of heat transfer, h = 40 W/m^2 °C = 0.00004 J/(s mm^2 °C)
Temperature of wall surface at which fin attached, t_o = 55 °C
Ambient temperature, t_a = 30 °C

D. Results from the Analysis

After the generation of mesh and assigning of load and constraints next step is to run the simulation for the model. This proceeds for the analyzing the steady-state heat transfer process and finally obtain the required result contour of temperature.

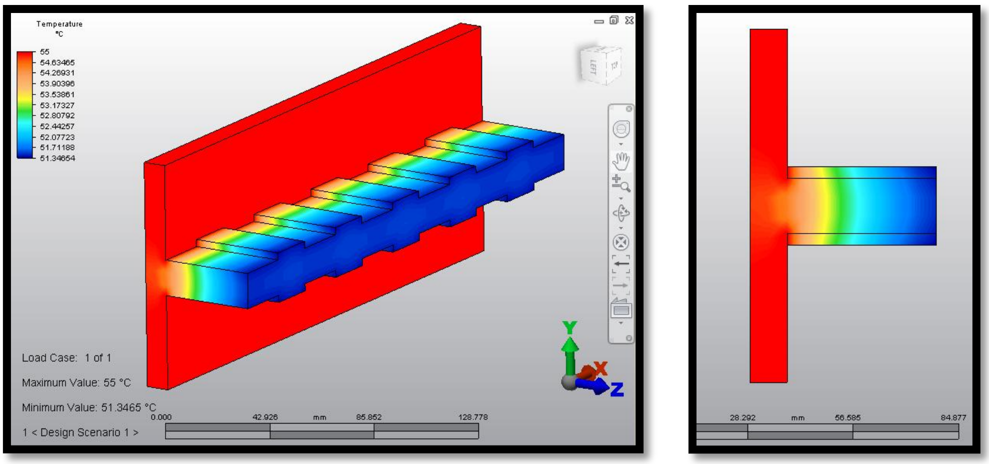

Fig. 5: Temperature contour for fin with rectangular extensions.

The resultant Fig. 5 shows that variations of temperature along length of fin with rectangular extensions that the temperature reduces from fin base at 55 °C to 51.3465 °C at the tip end of the fin.

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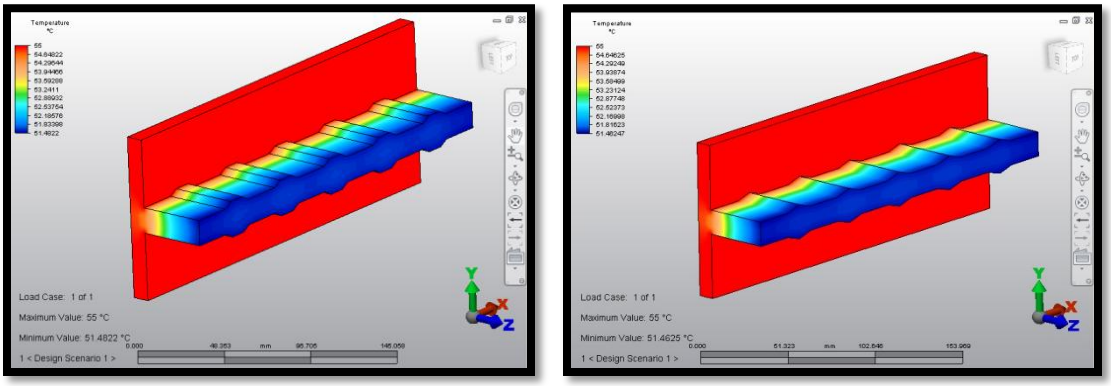
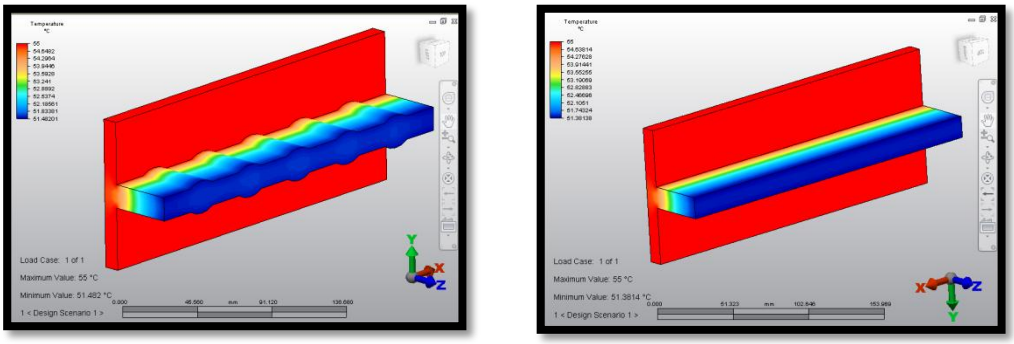


(a) (b)

Fig. 6: Temperature contour for fin with (a) Trapezium extensions, (b) Triangular extensions.

Similarly the resultant Fig. 6 & Fig. 7 shows that variations of temperature along length of fin with trapezium extensions, triangular extensions and fin with circular segmental extensions, fin without extensions that the temperature reduces from fin base to the tip end of the fin.



(a) (b)

Fig. 7: Temperature contour for fin (a) Circular segmental extensions, (b) Without extensions.

TABLE-1
COMPARISON OF TEMPERATURE VARIATIONS ALONG WITH LENGTH OF FINS

Length of fin (mm)	**Fin with different types of extensions (Temp. in °C)**				
	Rectangular	**Trapezium**	**Triangular**	**Circular**	**No Extensions**
5	53.90396	53.94466	53.93874	53.9446	53.91441
10	53.53861	53.59288	53.58499	53.5928	53.55255
15	53.17327	53.2411	53.23124	53.241	53.19069
20	52.80792	52.88932	52.87748	52.8892	52.82883
25	52.44257	52.53754	52.52373	52.5374	52.46696
30	52.07723	52.18576	52.16998	52.18561	52.1051
35	51.71188	51.83398	51.81623	51.83381	51.74324
40	51.34654	51.4822	51.46247	51.48201	51.38138

The Table-1 shows that comparison of temperatures of fin with different types of extensions corresponding to the length of fins.

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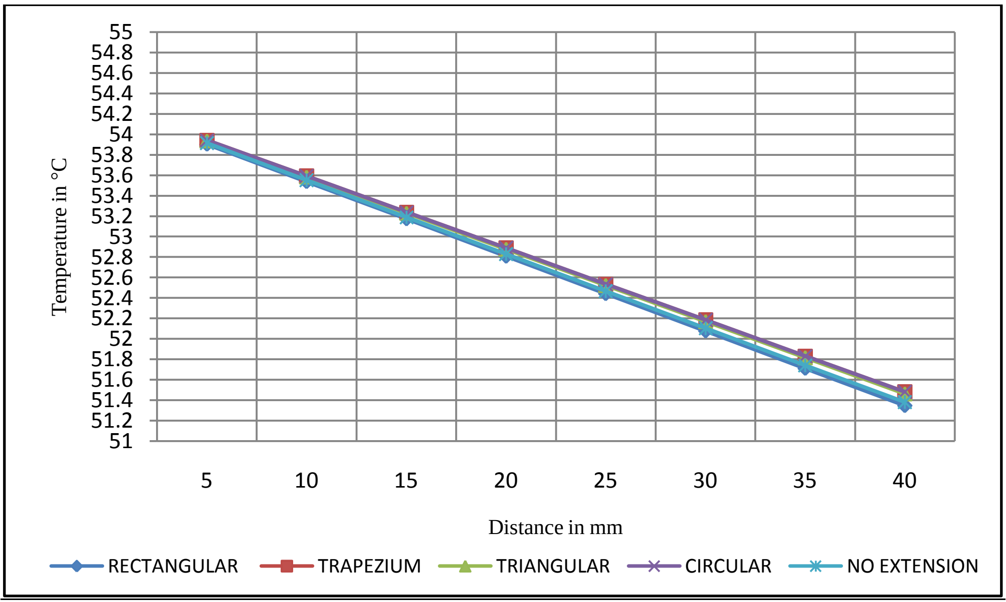

Fig. 8: Plot showing the temperature variations along with length of fin with rectangular extensions, trapezium extensions, triangular extensions, circular segmental extensions and fin without extensions.

IV. RESULTS AND DISCUSSIONS

Heat transfer calculated by using the heat transfer governing differential equation for the fin of finite length and loses heat by convection [6],

$$Q_{fin} = \sqrt{hPkA_{cs}}(t_o - t_a)\left[\frac{\tanh[ml] + \frac{h}{km}}{\left(1 + \frac{h}{km}\tanh(ml)\right)}\right]$$

for which the given length of fin (l in m), thickness of fin (y in m), width of fin (b in 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 now it is the time to compare the increase in heat transfer rate for the given geometry of fin which is shown in Table-2. The fin without extensions having 21.7665 W heat transfer value.

TABLE-2
COMPARISON OF HEAT TRANSFER FOR VARIOUS EXTENSIONS ON FIN.

Types of extensions	**Heat transfer (in W)**	**Increase in heat transfer (in W)**	**Percentage increase in heat transfer (in %age)**
Fin with rectangular extensions	24.5557	2.7892	12.93
Fin with trapezium extensions	22.9052	1.1387	5.23
Fin with triangular extensions	22.4495	0.683	3.14
Fin with circular segmental extensions	22.7155	0.949	4.36

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Now, for the discussions the heat transfer through fin with different extensions calculated by considering the changes in ambient fluid temperature from 28 °C to 18 °C as shown in the Table-3.

TABLE-3
HEAT TRANSFER THROUGH FIN AT AMBIENT TEMPERATURE 28 °C TO 18 °C

Type of extensions	Q_{fin} in W at ambient temperature					
	28 °C	26 °C	24 °C	22 °C	20 °C	18 °C
Rectangular	26.516	28.480	30.444	32.408	34.373	36.337
Trapezium	24.738	26.570	28.403	30.235	32.067	33.899
Triangular	24.246	26.041	27.837	29.634	31.429	33.225
Circular segmental	24.536	26.355	28.171	29.988	31.806	33.623
Without extensions	23.508	25.249	26.991	28.732	30.473	32.215

The use of fin with different extensions provides the increase in the heat transfer rate as compare to fin without extensions shown in the Table-4.

TABLE-4
PERCENTAGE INCREASE IN HEAT TRANSFER FIN WITH EXTENSIONS

Type of extensions	Percentage increase in heat transfer fin with extensions					
	28 °C	26 °C	24 °C	22 °C	20 °C	18 °C
Rectangular	12.796	12.797	12.793	12.794	12.798	12.795
Trapezium	5.232	5.232	5.232	5.231	5.231	5.227
Triangular	3.139	3.137	3.134	3.139	3.137	3.135
Circular segmental	4.373	4.380	4.372	4.371	4.374	4.371

Table-5 shows that the effectiveness of fin with rectangular extensions, trapezium extensions, triangular extensions and circular segmental extensions.

TABLE-5
EFFECTIVENESS OF FIN WITH EXTENSIONS

Type of extensions	Effectiveness					
	28 °C	26 °C	24 °C	22 °C	20 °C	18 °C
Rectangular	5.846	5.846	5.846	5.846	5.846	5.846
Trapezium	5.656	5.656	5.656	5.656	5.656	5.655
Triangular	5.756	5.756	5.756	5.756	5.756	5.756
Circular segmental	5.408	5.408	5.408	5.408	5.408	5.408

V. CONCLUSIONS

The use of fin (extended surface) with extensions, provide efficient heat transfer:

- Fin with extensions provide near about 5 % to 13% more enhancement of heat transfer as compare to fin without extensions.
- Heat transfer through fin with rectangular extensions higher than that of fin with other types of extensions.
- Temperature at the end of fin with rectangular extensions is minimum as compare to fin with other types of extensions.
- The effectiveness of fin with rectangular extensions is greater than other extensions.
- Choosing the minimum value of ambient fluid temperature provide the greater heat transfer rate enhancement.

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