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THERMAL ANALYSIS OF HEAT SINK WITH FINS OF DIFFERENT CONFIGURATION USING ANSYS WORKBENCH 14.0

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ABSTRACT

The effect of the pin-fin shapes on the overall performance of the heat sink with inline and staggered arrangement is studied in this paper. Six different shapes of fins rectangle, trapezoidal, rectangular interrupted, square, circular inline and staggered are subjected to study in this paper.
The optimization processes are carried out using computer simulations performed using Ansys workbench 14.0. TheHeat transfer taken in natural air and aluminum 6063 as a pin fin material. To study of thermal performance of different heat sink of the different fin profile at different velocities 5, 10 & 12 m/s and simulation is done at different heat load of 15W, 20W & 25 W and air inlet temperature is taken as 295 K. The purpose of this study is to examine the effects of the configurations of the different pin-fins design.
It is observed from the results that optimum cooling is achieved by the heat sink design which contains Circular pin fins.
After the selection of proper heat sink by CFD simulations the steady state thermal performance is carried out at different fin height of circular pin fin heat sink. The result shows that the temperature is increasing by decreasing the fin height.
At different loads the performance of all selected fin profiles is carried out and found that at & 25 W load the maximum temperature is maximum for interrupted rectangular fin and minimum for circular pin fin. And the value of Nusslet number is also maximum for circular pin fin design.

KEYWORDS: Heat Sink, Computational Fluid Dynamics (CFD), Natural convection, Thermal resistance, Surface Nusselt number, Pressure drop, Heat transfer coefficient.

INTRODUCTION

Heat sink is an electronic component or a device of an electronic circuit which disperses heat from other components (mainly from the power transistors) of a circuit into the surrounding medium and cools them for improving their performance, reliability and also avoids the premature failure of the components. For the cooling purpose, it incorporates a fan or cooling device.[10]
Extended surfaces or fins are commonly found on electronic components ranging from power supplies to transformers. The dissipation and subsequent rejection of potentially destructive self-produced heat is an important aspect of electronic equipment design. The dissipation of heat is necessary for its proper function. The heat is generated by the resistance encountered by electric current. Unless proper cooling arrangement is designed, the operating temperature exceeds permissible limit. As a consequence, chances of failure get increased. [3]

APPLICATIONS

Heat sinks are widely used in various industrial applications to cool electronic, power electronic, telecommunications, and automotive components. Those components might be either high-power semiconductor devices, audio amplifiers, microcontrollers and microprocessors. More precisely, the passive cooling heat sinks are widely used in CPU cooling, audio amplifiers and power LED cooling.

OBJECTIVE OF WORK

- To design & optimize the heat sink of the different fin profile for given heat input 15W.
- To predict velocity, Pressure and temperature profiles for heat input applied on the base of the heat sink.
- To predict the optimum value for fin width, fin spacing, no. of fins & fin height, in fin arrays for maximum heat transfer rate and minimum temperature distribution.

PREPARATION OF THE CAD MODEL

The designs of heat Sink with rectangular fins, Trapezoidal fins, Interrupted Fins, Square pin fin, Circular Pin Fins with inline Staggered arrangements is done in Auto CAD 2012 in IGES format. A flat platform of 150 X 150 X 2.5 mm [9] is common in all designs. Trapezoidal shape fins is made with a draft angle of 1° on either side. Fin height for all models is 50mm. The fin hight is decreasing from 50mm to 10 mmThe important geometric variables considered are Fin width, Fin spacing, no. of fins & fin height, base thickness.

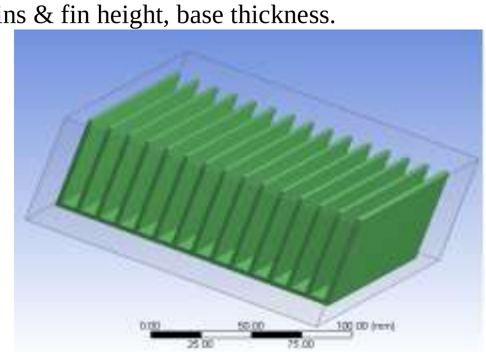

Fig. 1. Rectangular Plate Heat Sink

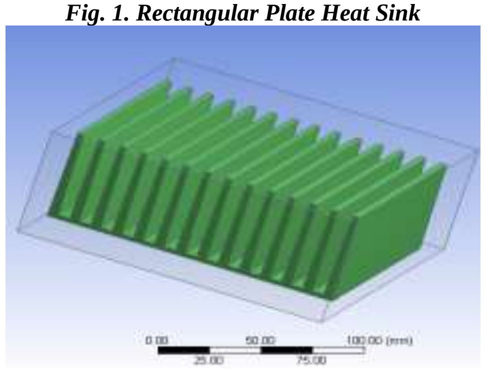

Fig. 2. Trapezoidal Heat Sink

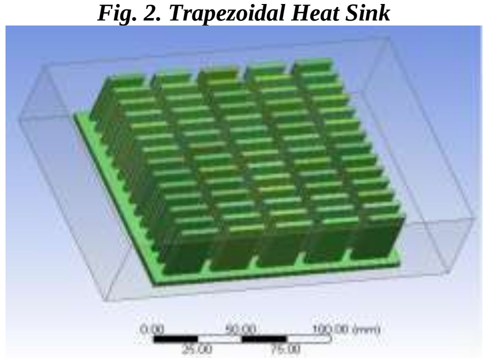

Fig. 3. Rectangular Interrupted Heat Sink

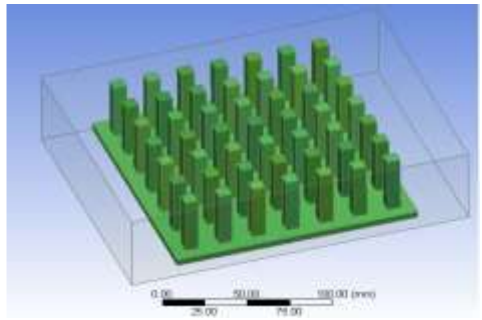

Fig. 4. Square Pin Fin Heat Sink

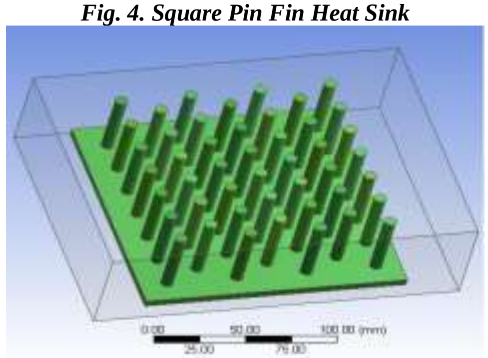

Fig. 5. Circular Staggered Heat Sink

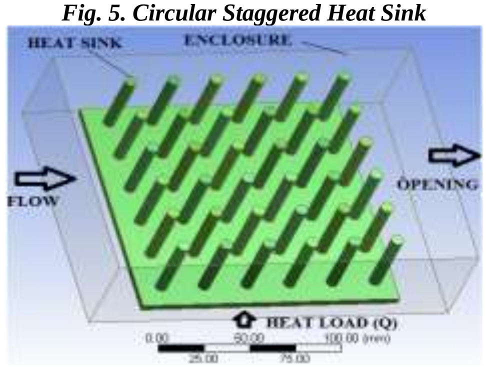

Fig. 6. Circular Inline Heat Sink Computational Model

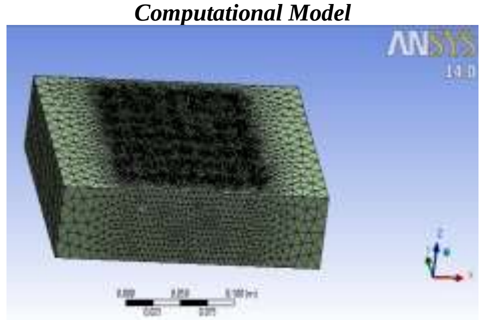

Fig. 7. Meshing of Whole domain

MATERIAL SELECTED FOR HEAT SINK

Aluminium alloy 6063 is a medium strength alloy commonly referred to as an architectural alloy. It is normally used in intricate extrusions. It has a good surface finish, high corrosion resistance, is readily suited to welding and can be easily anodized. Provide good extrudability.

CFD MODELLING

Computational Fluid Dynamics (CFD) is a branch of fluid mechanics that uses numerical analysis and algorithms to solve and analyze problems that involve fluid flows.
Certain assumptions are made for the ease of solving the models and those assumptions are given below.
1) The fins are with adiabatic tip & the airflow is normal to the axis of fins.
2) The fluid, air is assumed to be incompressible throughout the process.
3) Air properties are taken at film temperature.
4) The flow is steady, laminar.
5) There are no heat sources within the fin itself.
6) The radiation heat transfer is negligible.
7) The temperature at the base of the fin is uniform.

MESHING OF THE DOMAIN [12]

The second part of pre-processing is the mesh generation. After the model is imported to Ansys workbench it is then launched in the meshing module for the mesh generation Coarse, medium, and fine mesh types are available. In our problem CFD Tetrahedral mesher is used.

BOUNDARY CONDITIONS

- In this analysis the blocks are modeled and only heat sink is modeled as solid domain with heat source of 15W. In this case heat sink material considered as aluminum 6063. The analysis is done at atmospheric temperature of 295K.

Boundary conditions [10] are entered as follows:

- Base plate: - Heat Load of 15W & Aluminium alloy properties are assigned.
- Base top(wall): Base top is receiving heat from the chip, so heat flux is applied on the base top
- Fin bottom, Front face, Left, Right, Rear face (Walls): Heat transfer to surrounding atmosphere by convection. Inlet (velocity inlet): Air enters into the Heat sink with 5, 10 & 12m/s [11] in given direction according to the geometry.
- Outlet (Pressure Outlet): After passing through the heat sink air enters into atmosphere, so at outlet atmospheric pressure is assumed.
- After applying the above boundary conditions. Simulation is performed under steady state conditions till the convergence is reached.

MATERIAL PROPERTIES

Properties	Air	Aluminium Alloy 6063
Density (kg/m^3)	1.1965	2719
Sp. Heat (Cp) (J/kgK)	1006.43	871
Thermal Conductivity (W/mK)	0.026	202.4

RESULT & DISCUSSIONS

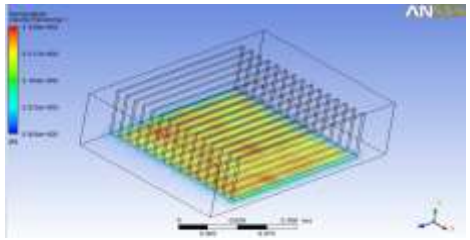

Fig. 8. Contour of minimum temperature distribution in Rectangular heat sink at 12 m/s velocity

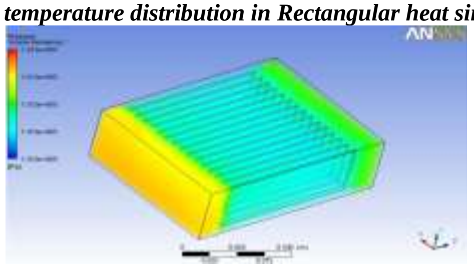

Fig. 9. Contour of minimum pressure distribution in Rectangular heat sink at 5 m/s velocity

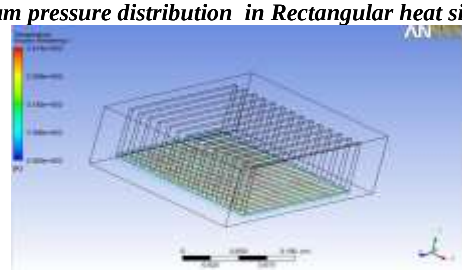

Fig. 10. Contour of minimum temperature distribution in Trapezoidal heat sink at 12 m/s velocity

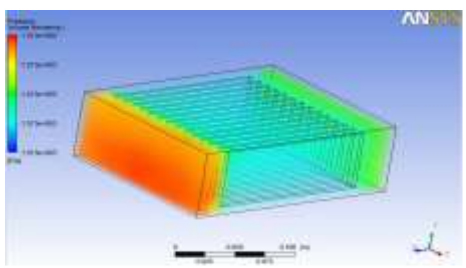

Fig. 11. Contour of minimum pressure distribution in Trapezoidal heat sink at 5 m/s velocity

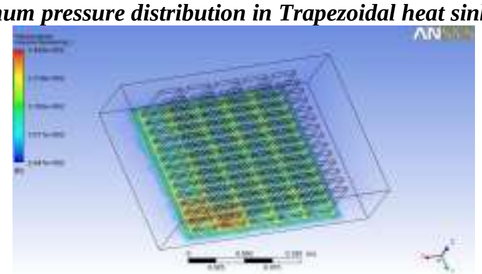

Fig. 12. Contour of minimum temperature distribution in Interrupted rectangular heat sink with 12 m/s velocity

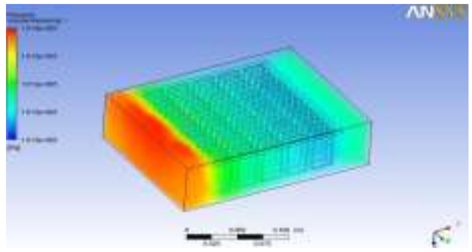

Fig. 13. Contour of minimum pressure distribution in Interrupted Rectangular heat sink at 5 m/s velocity

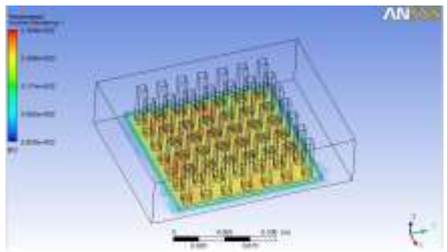

Fig. 14. Contour of minimum temperature distribution in Square pin fin heat sink at 12 m/s velocity

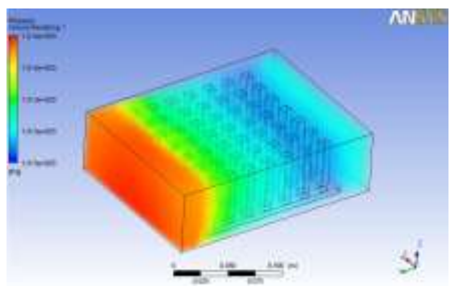

Fig. 15. Contour of minimum pressure distribution in Square pin fin heat sink at 5 m/s velocity

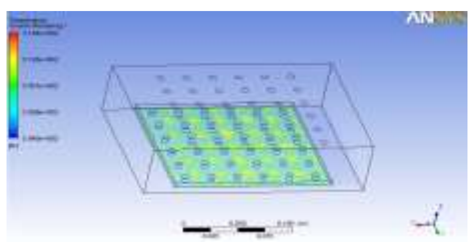

Fig. 16. Contour of minimum temperature distributio in Circular heat sink at 12 m/s velocity

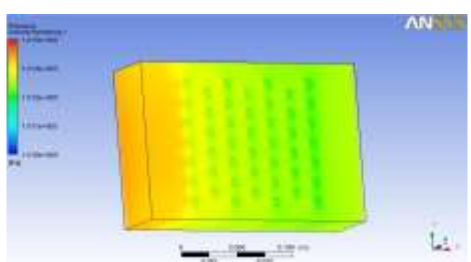

Fig. 17. Contour of minimum Pressure distribution in Circular pin fin heat sink at 5 m/s velocity

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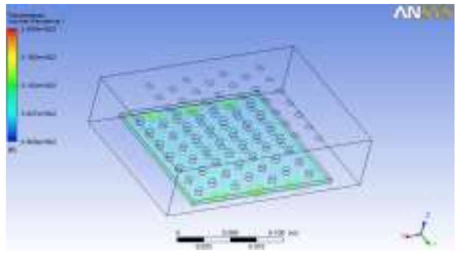

Fig. 18. Contour of minimum temperature distribution in Circular staggered heat sink at 12 m/s velocity

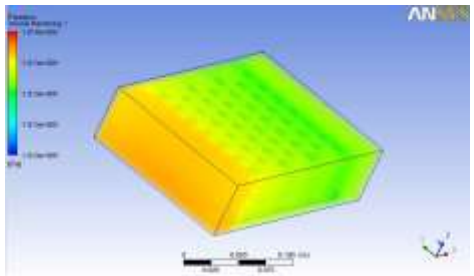

Fig. 19. Contour of minimum Pressure distribution in Circular Staggered pin fin heat sink at 5 m/s velocity

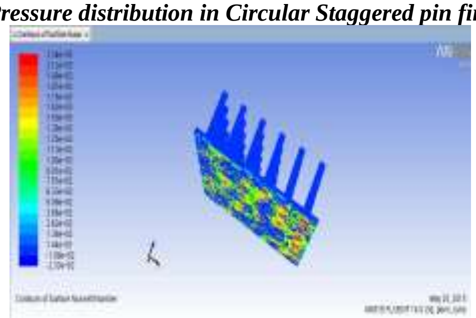

Fig. 20. Contour of Maximum Surface Nusselt Number in Circular Heat Sink at 12m/s velocity

Case No.	Fin Width (mm)	No. of Fins	Velocity (m/s)	Base Temperature (K)	R_{th} (K/W)	Nu	Pressure Drop Pa
1	2.5	15	5	347.7	3.52	629	27
2	2.5	15	10	345	3.32	654	111
3	2.5	15	12	343.9	3.26	661	148
4	3.5	14	5	342.8	3.19	1099	44
5	3.5	14	10	341.6	3.11	1157	172
6	3.5	14	12	341.4	3.1	1168	245
7	3.5	70	5	348.7	3.6	939	51
8	3.5	70	10	345	3.35	971	204
9	3.5	70	12	344.2	3.3	979	293
10	8	49	5	342.2	3.15	759	65
11	8	49	10	339.9	3	779	260
12	8	49	12	339.8	2.99	782	375
13	7	36	5	323.4	1.9	2005	78
14	7	36	10	319.2	1.62	2204	314

15	7	36	12	318.4	1.57	2242	454
16	7	46	5	329.5	2.3	1964	91
17	7	46	10	326.5	2.1	2009	368
18	7	46	12	326	2.06	2137	531

Table 1. Variation in Computation Result of Different pin fin profiles at velocity 5, 10 & 12 m/s

As it is clear from above table that the Circular pin fin heat sink has better performance than the other heat sink profiles. Represent in the table that case no. 15 has maximum Nusselt number of 2242 and minimum thermal resistance of 1.57 which is very low as compare to other profiles and geometries.

THERMAL ANALYSIS

After the selection of proper heat sink the steady state thermal performance is carried out at different fin height of selected circular pin fin heat sink. The result shows that the temperature is increasing by decreasing the fin height.

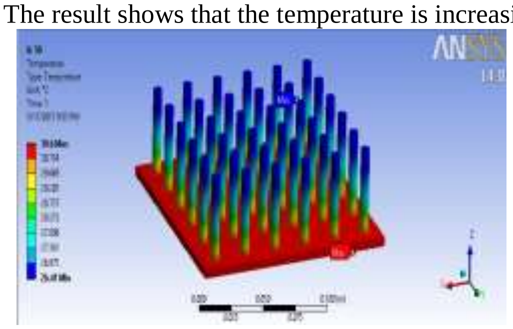

Fig. 21. Thermal analysis of selected circular pin fin heat sink at 50 mm height.

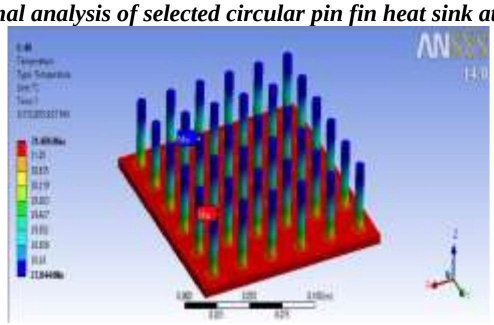

Fig. 22. Thermal analysis of selected circular pin fin heat sink at 40 mm height.

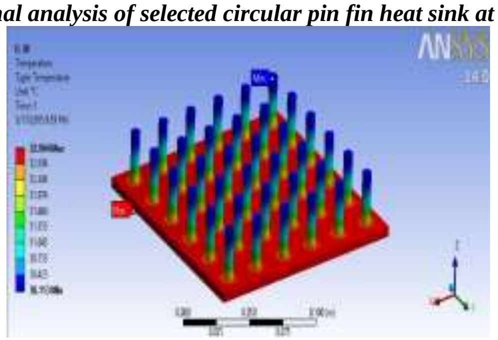

Fig. 23. Thermal analysis of selected circular pin fin heat sink at 30 mm height.

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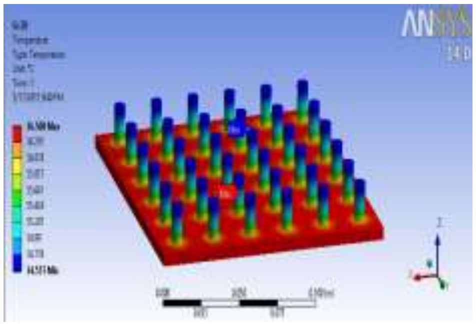

Fig. 24. Thermal analysis of selected circular pin fin heat sink at 20 mm height

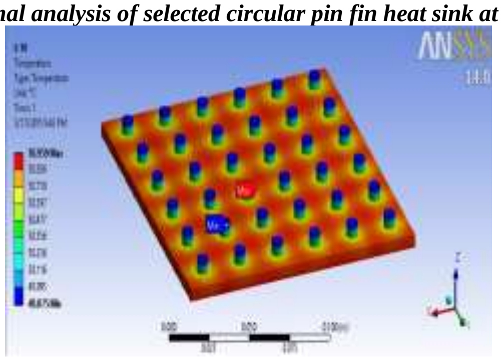

Fig. 25. Thermal analysis of selected circular pin fin heat sink at 10 mm height.

Case No.	Fin Diameter	Fin Spacing	No. of Fins	Fin Height	Maximum Temperature	Minimum Temperature
1	7	18	36	50	30.6	26.41
2	7	18	36	45	30.971	27
3	7	18	36	40	31.406	27.844
4	7	18	36	35	32	28.829
5	7	18	36	30	32.904	30.113
6	7	18	36	25	34.257	31.888
7	7	18	36	20	36.508	34.557
8	7	18	36	15	40.733	39.22
9	7	18	36	10	50.959	49.875

Table 2. Maximum temperature of selected circular fin profile at different fin height.

Table 2. Represent the variation of temperature and Nusselt Number of selected different fin profile at different loads.
As represented in the table no. 2 that the value of maximum temperature obtained is different for all heat sink profiles. It shows that at & 25 W load the maximum temperature is maximum for interrupted rectangular fin and minimum for circular pin fin. And the value of Nusslet number is also maximum for circular pin fin design.

PERFORMANCE AT DIFFERENT HEAT LOADS

We have selected the circular pin fin profile for the heat sink at 15 W heat load as represented in the table number 1. But if the heat input is increased, the maximum temperature obtained is different for all heat sink profiles.

SNo.	Fin profile	Fin width/ Diameter (mm)	Fin spacing (mm)	No. of Fins	Fin Volume (mm^3)	Weight (kg)	Fin Area A_{fin} (mm^2)
1	Rectangular	3.5	7	15	393750	1.07	230000
2	Trapezoidal	3.5	7.634	14	275373	0.901	212450
3	Interrupted Rectangular	7	22	70	269500	0.885	178500
4	Square	8	13	49	156800	0.579	78400
5	Circular Inline	7	18	36	69272	0.34	40000
6	Circular Staggered	7	43	46	88514	0.393	52300

Table 3. Represent the total volume, weight and fin area of different fin profiles heat sink

Profile	Heat Load (W)	Maximum Temperature (K)	Nusselt Number (Nu)
Rectangular	15	343.914	661
	20	360.285	690
	25	376.606	708
Trapezoidal	15	341.447	1167.5
	20	356.992	1264.5
	25	372.49	1331
Interrupted Rectangular	15	344.239	978.52
	20	360.72	1063.6
	25	377.151	1119
Square	15	339.758	782.46
	20	354.736	828
	25	370	860
Circular	15	318.447	2242
	20	326.304	2608
	25	334	2892
Circular Staggered	15	325.984	2137
	20	336.344	2468
	25	346.6	2720

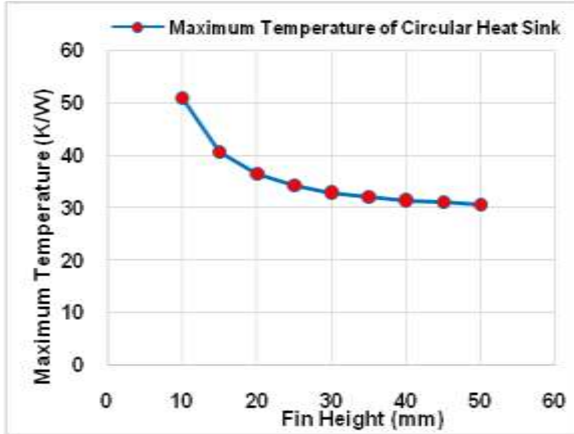

Figure 24 Represent the decrease in temperature of selected Circular heat sink configuration with respect to fin height.

It represent in the table that after selection of proper heat sink configuration from different profiles as result is mentioned in the Table 3. The volume and weight of selected heat sink is calculated and found that the Circular inline pin fin has lowest volume and weight than the other selected heat sink gives better thermal performance and reduction in cost due to reduction in material.

CONCLUSIONS

The overall performance of the six different profile heat sinks was studied in this paper for different velocities varying from 5, 10 & 12 m/s. The paper presents computer simulation and thermal analysis of different shape fins heat sink for an electronic system cooled by natural convection.
From computational result it is clear that circular pin fin with 7 mm fin dimeter, 36 no. of fins and 18 mm fin spacing has better performance than the other one and the maximum temperature obtained is 318 K ans maximum Nusselt number is 2242 at 12 m/s.
The steady state thermal performance of selected circular pin fin design shows in the graph 4 that the maximum temperature is increasing by decreasing fin height.
As represented in the table no. 5.9 that the value of maximum temperature obtained is different for all heat sink profiles. It shows that at & 25 W load the maximum temperature is maximum for interrupted rectangular fin and minimum for circular pin fin. And the value of Nusslet number is also maximum for circular pin fin design.
It represent that the total volume of selected fin profile from different configurations is minimum i. e. 69272.11 mm^3 in case of circular pin fin design.

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