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Performance Evaluation of Inverted Triangular Notch and Trapezoidal Plate Fins with Natural Convection

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Abstract - **The purpose of the present study is to compare notch and un-notch fin array and to investigate thoroughly the possibility of performance improvement. Extensive experimental investigations are performed for various fin numbers, power supply, and fin geometry. These present results are applicable when the Rayleigh number, fin-height-to-cylinder-diameter ratio, fin number, and power supply are in the range 180000-623000, 1/2, 32-44, 5-30 watt with an increment of 5 watts respectively. This research examined the effect of a cylindrical heat sink used to cool an LED light bulb. The setup has been kept vertical and horizontal. From Investigation of Horizontal Setup, vertical setup, notched, un-notched and trapezoidal plate fin it is found that overall there is a change in heat transfer rate and thermal resistance. Effect of change in weight of heat sink is also discussed. Comparison of Fin efficiency and the Nusselt number is been done for notched, un-notched, trapezoidal plate heat fin.**

Keywords — Fin efficiency, Heat transfer coefficient, Notch, Nusselt number, Thermal resistance, Un-Notch Fin.

I. INTRODUCTION

Fin arrays on vertical and horizontal surfaces are used in a variety of engineering applications to dissipate heat to the surroundings. Studies of heat shifted and fluid flow associated with such arrays are therefore of considerable engineering significance. The important controlling variables generally available are the orientation and the geometry of the fin arrays. In the case of short horizontal arrays, it is observed that the air entering symmetrically from both the ends gets heated as it shifts towards the center of the fin channel, as well as it rises due to decrease in density. So, the middle portion of the fin becomes ineffective because hot air stream passes over that part and therefore it does not bring about large heat shipted. This area is removed at the centre from fins and they became inverted notched fins. Between 10% to 40% area removal increases the heat shifted rate. This modified geometry increase in heat shifted rate reduces material cost and material weight.

The main objective of this work is to compare heat transfer rates of heat descends with un-notched plate fins, inverted triangular notched plate fins and trapezoidal shaped fins having different fin numbers(32 to 44), power supply (5 to 30 W) and fixed fin height (30mm) and to obtain heatsink with better heat transfer rate. Recently, cylindrical heat sinks with vertical plate fins, as shown in figure 1 are being used widely for cooling LED lightings. However, to the best of our known information, there has been no investigation on the Nusselt number for the natural convection from these vertical cylinders with vertically oriented plate fins. Therefore, there is no general correlation by which one can obtain the Nusselt digits for the natural convection from vertical cylinders with vertical flat fins.

Fig. 1 . Cylindrical heat sink with vertical plate fins For LED cooling [10]

II. LITERATURE REVIEW

The aim of the survey is to study the ongoing work in the field of LED cooling using the heat sinks. Various fin geometries are studied and the brief is presented hereafter.

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Table 1. Literature Survey

Author, Journal & Year	Parameters Studied	Outcome
Kim et al, Experimental Thermal, and Fluid Science, 2014 [1]	• Compared the thermal performance of vertical cylindrical sink with Branched fins with conventional plate fins. • The proposed correlation for estimating Nu.	• R_{th} for branched fins was 36 % lower. • Correlation shows agreement with experimental data.
Lee et al, International Journal of Heat and Mass Transfer, 2014 [2]	• Studied Orientation effect for a cylindrical heat sink with conventional plate fins. • A numerical model considering natural convection and radiation heat transfer was developed and validated experimentally. • Correlation to predict the Nu around an inclined cylindrical heat sink was proposed.	• With the increase in angle of inclination, the drag coefficient increased and the Nu decreased. • The best thermal performance was obtained for vertical orientation. • Orientation effect was intensified by increasing the number of fins or the fin length. • The influence of fin height on the orientation effect was insignificant.
Kim et al, Journal of Mechanical Science and Technology, 2013 [3]	• Investigated natural convection from horizontal cylinders with longitudinal plate fins. • The suggested correlation for estimating Nu.	• R_{th} has an optimal value at a specific fin number. [R_{th}= 1.88 C/W for 36 fin no.] • Correlation shows agreement with experimental data. • R_{th} decreases continuously as the fin height increases.
Kim et al, Experimental Thermal and Fluid Science, 2012 [4]	• Investigated natural convection from vertical cylinders with longitudinal plate fins. • The proposed correlation for estimating Nu.	• Correlation shows agreement with experimental data.
Lee et al, Applied energy, 2014 [5]	• The heat sink of LED lighting was optimized with respect to its fin-height profile. • Optimization was conducted to simultaneously minimize the thermal resistance and Mass.	• The cooling performance of the optimized design (pin–fin array with the tallest fins in the outer region) showed an improvement of more than 45%.
Lee et al, International Journal of Heat and Mass Transfer, 2012 a [6]	• Radiation effect on total heat transfer for radial heat sink was studied by varying ε. • Optimization was carried out for R_{th}, with and without considering a change in mass.	• Maximum radiation heat loss was found to be 27 % of the total loss. • For optimized model, R_{th} was found reduced by 12.3 5 with an increase in mass by 24 %. • For optimized model without changing mass, R_{th} reduced by 8.7 %

The important findings of literature survey are as follows: Thermal performance of fins is better for vertical orientation of the base surface, thermal resistance decreases with increase in fin height, thermal resistance for branched fin is lower as compared to conventional plate fins, in previous studies, correlations was developed to study thermal performance of fins and in many cases, correlation shows agreement with experimental data, orientation effect can be intensified by increasing the number of fins or the fin length, thermal resistance has optimism value at particular fin number etc.

III. Experimental Investigation

In presently, in order to suggest the Nusselt number correlation, the thermal resistances of natural convective heat sinks are measured for various fin numbers, fin heights, and base temperatures. The schematic diagram of the tested heat

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sink is shown in Fig. 2 and the dimensions of the heat descends are listed in Table 1. Four different heat sinks are used to cover the same range of fin heights and a wide range of fin numbers. The heat descend consist of fins and an annular cylinder base, which are created by aluminum alloys 5052 (k = 138 W/mK).The heat sinks are assembled by the interference fit of the fins and the base. A cartridge heater is then inserted into the inner hole of the base (Fig. 3). A thermal interface material (Anabond 652-C) is used to reduce the contact thermal resistance between the heat descend and the heater. The helping cylindrical blocks, whose length is 150 mm and a diameter of 60mm, are made of Bakelite in order to reduce the heat loss from the top and bottom sides of the base. Power is supplied to the heater from a power supply. The power supplied to the heater is in the range 5–30 W. In order to calculate the net heat transfer rate to the heat descend, the heat loss through the supporting blocks is measured and subtracted from the electric power supplied to the heat. In order to measure the base temperature, four J-type thermocouples are circumferentially attached to the cylinder, as shown in Fig. 4. A control panel is used to acquire the signals from the thermocouples and convert them into temperature data with the help of temperature indicator. The experiments are performed in an isolated and quiescent room. Set up in horizontal and vertical position is shown in Fig. 5 and Fig 6.

Table 2. Geometric configuration of tested heatsinks

No	N_{fin}	H (mm)	D (mm)	L (mm)	t (mm)
Heat sink 1	32	30	60	50	1
Heat sink 2	36	30	60	50	1
Heat sink 3	40	30	60	50	1
Heat sink 4	44	30	60	50	1

The derived results are based on the formulas made by An et Al.[4].

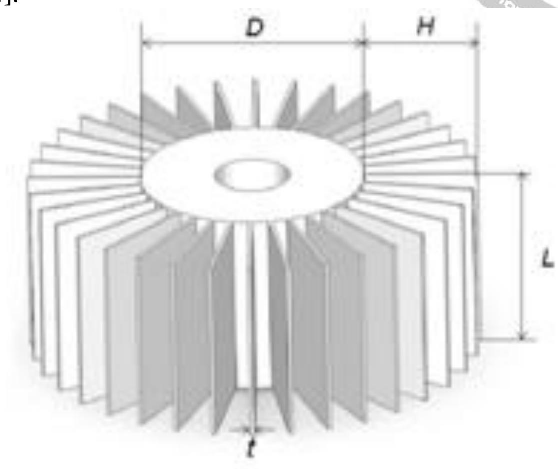

Fig. 2. Tested heat descend

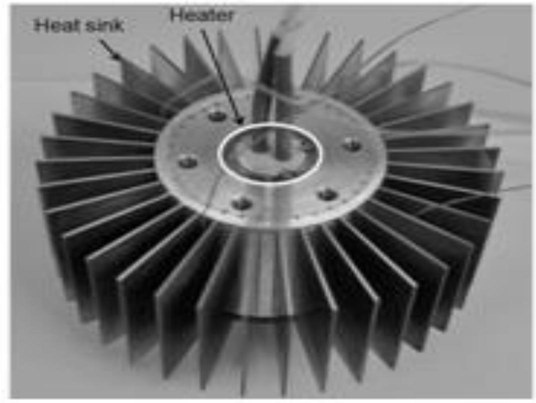

Fig.3. Tested heat descend with heater

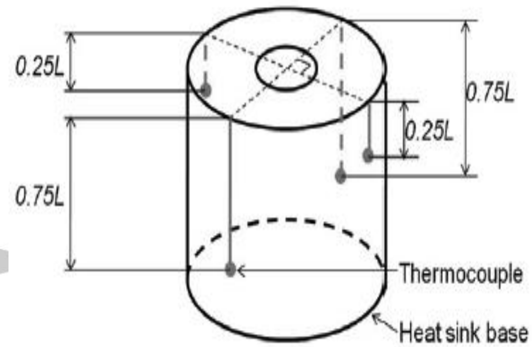

Fig. 4. Position of Thermocouple

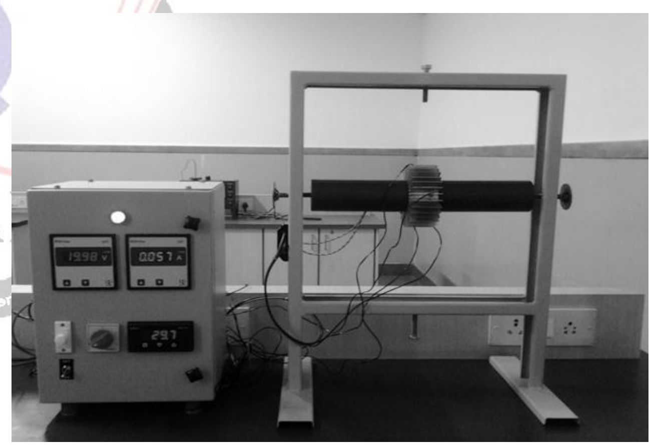

Fig. 5. Horizontal Setup

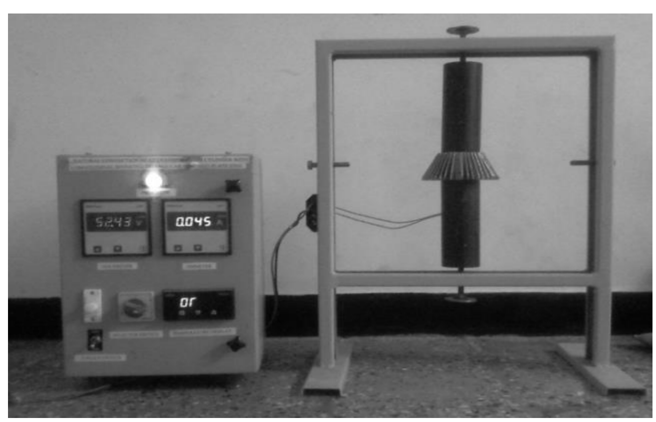

Fig. 6. Vertical Setup

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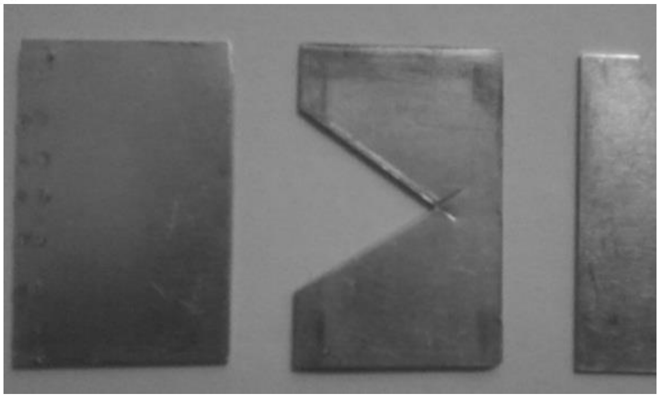

Fig. 7. Different shapes of fins

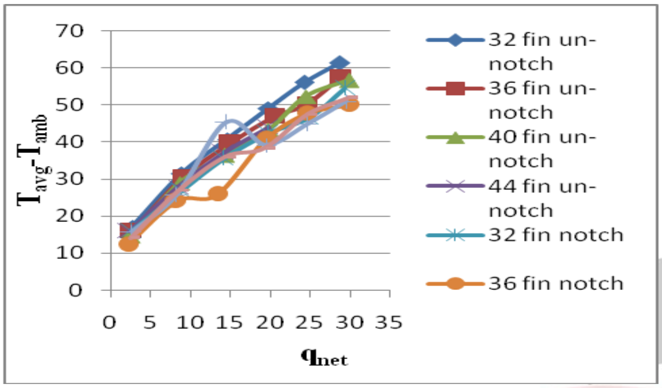

Fig. 8. Tavg-TambVsq$_{net}$ (Horizontal Orientation)

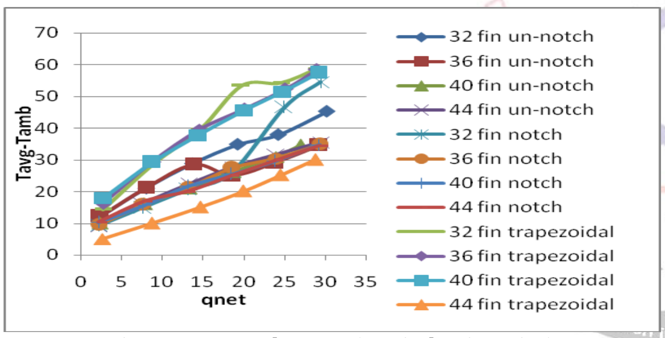

Fig. 9. Tavg-TambVsqnet (Vertical Orientation)

IV. RESULT AND DISCUSSION

From graphs and table 3 we can say that

- With the increase in power supply Rth decreases.
- Rth is minimum for each power supply for notch and un-notch heat sink.
- No significant change in Rth at the higher power supply.
- Thermal resistance for 36th and 40th notch fin heat sink are very close.
- Increment in thermal resistance for a 36th notch fin heat sink with respect to 40th notch fin heat sink is 0.5%.

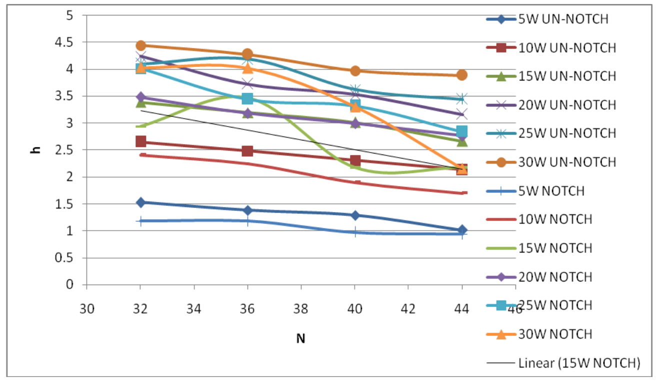

Fig. 10. h Vs N (Horizontal Set-up)

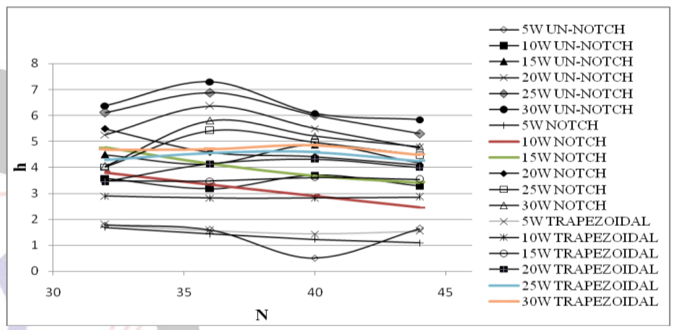

Fig. 11. h Vs N (Vertical Set-up)

From Figure 10 and 11 important findings are, i) heat transfer coefficient h increases with increase in power supply for both notch and un-notch and trapezoidal heat sink ii) for individual power supply, heat transfer coefficient is higher for notch heat sink as compared to un-notch heat sink and iii) by providing notch overall increment in heat transfer rate for horizontal orientation is 11% and for vertical orientation comparing between trapezoidal and un-notch plate fin increment heat transfer rate is 29%.

Table 3. Result and Discussion

Sr. No	H	N	Types of fins	Orientation	q (watt)	T_{avg}-T_{amb}	Rth	h	Nu
1	30	32	Un-notched	Horizontal	5.12	17.1	6.12	1.527	2.93
					10.07	31.62	3.54	2.649	5.09
					15.03	40.8	2.78	3.39	6.51
					20.09	49.12	2.78	4.241	8.15
					25.18	56.1	2.31	4.097	7.88
					30.15	61.45	2.13	4.442	8.54
2	30	36	Un-notched	Horizontal	5.06	15.97	6.07	1.832	2.66
					10.27	30.32	3.36	2.483	4.78

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					15.52	39.85	2.65	3.192	6.14
					20.67	46.95	2.28	3.719	7.15
					25.07	50.15	2.03	4.185	8.05
					30.01	57.85	1.99	4.271	8.21
3	30	40	Un-notched	Horizontal	5.02	14.57	5.89	1.29	2.48
					10.06	28.97	3.32	2.31	4.43
					15.02	36.37	2.55	3.01	5.79
					20.04	43.35	2.18	3.53	6.79
					25.09	52.32	2.13	3.62	6.95
					30.1	56.72	1.94	3.97	7.65
4	30	44	Un-notched	Horizontal	4.77	15.9	6.82	1.013	1.94
					10.01	27.92	3.26	2.13	4.1
					14.88	37.25	2.62	2.66	5.12
					19.98	4397	2.21	3.16	6.08
5	30	32	Notched	Horizontal	5.05	16	6.08	1.18	2.27
					10.39	26.72	3.02	2.41	4.63
					15.05	35.65	2.5	2.94	5.65
					20.05	42.47	2.15	3.48	7.69
					25.2	46.6	1.87	4.01	7.71
					30.14	54.55	1.86	4.03	7.75
6	30	36	Notched	Horizontal	4.99	12.32	5.42	1.18	2.27
					10.4	24.12	2.91	2.24	4.3
					15.05	25.87	1.92	3.47	6.67
					19.98	40.85	2.08	3.18	6.11
					24.88	47.75	1.93	3.44	6.61
					30.29	50.06	1.67	4.02	7.73
7	30	40	Notched	Horizontal	5.8	15.8	5.98	0.97	1.86
					10.05	25.72	3.1	1.9	3.65
					15.11	45.43	2.71	2.17	4.17
					20.12	39.2	2	2.99	5.75
					24.81	44.9	1.81	3.32	6.38
8	30	44	Notched	Horizontal	5.11	14.03	5.56	0.94	1.81
					10.17	27.05	3.12	1.7	3.27
					15.3	36.07	2.48	2.17	4.17
					20.04	38.32	1.97	2.76	5.31
					24.92	47.63	1.92	2.84	3.46
					30.3	51.95	1.74	2.15	6.06
9	30	32	Un-notched	Vertical	5.04	12.05	5.26	1.78	3.42
					10	21.08	2.64	3.58	6.88
					15	28.85	2.11	4.49	8.63
					20.1	34.83	1.81	5.25	10.09
					24.83	37.9	1.56	6.12	11.76
					30.19	45.3	1.5	6.37	12.25
10	30	36	Un-notched	Vertical	5.06	12.3	5.27	1.59	3.05
					9	21.17	2.66	3.18	6.12
					15.19	28.52	2.06	4.13	7.94
					20.23	25.1	1.35	6.36	12.23
10	30	36	Un-notched	Vertical	25.10	29.75	1.25	6.88	13.23
					30.10	34.65	1.18	7.3	14.04
11	30	40	Un-notched	Vertical	5.18	10	4.42	0.51	0.98
					10.15	16.07	2.08	3.7	7.12
					15.21	21.07	1.59	4.86	9.36
					20.18	26.23	1.41	5.5	10.58
					25.10	30.97	1.29	6.01	11.56
					27.87	34.6	1.28	6.08	11.69
12	30	44	Un-notched	Vertical	5.13	9.03	4.22	1.64	3.6
					10.06	16.28	2.13	3.28	6.31
					15.13	22.27	1.68	4.17	8.03
					20.10	27.63	1.48	4.75	9.14
					25.08	31.75	1.33	5.3	10.19
					30.21	35.55	1.21	5.84	11.23
13	30	32	Notched	Vertical	5.13	9.2	4.27	1.69	3.25
					10.12	14.9	1.96	3.81	7.32

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					15.06	20.72	1.59	4.77	9.17
					20.09	25.97	1.4	5.48	10.53
					25.02	46.6	1.87	4.01	7.71
					30.14	54.55	1.85	4.05	7.79
14	30	36	Notched	Vertical	5.09	9.5	4.46	1.44	2.76
					10.04	15.8	2.07	3.34	6.42
					15.08	21.2	1.62	4.15	7.98
					20.03	27.5	1.48	4.58	8.8
					25.12	30.5	1.27	5.41	10.4
					30.16	34.87	1.19	5.8	11.53
15	30	40	Notched	Vertical	5.07	10.25	4.72	1.23	2.36
					10.10	15.65	2.05	2.91	5.6
					15.05	21.7	1.65	3.67	7.06
					20.03	25.5	1.39	4.41	8.48
					25.04	29.52	1.24	4.98	9.58
					30.1	34.8	1.19	5.21	10.02
15	30	40	Notched	Vertical	5.07	10.25	4.72	1.23	2.36
					10.10	15.65	2.05	2.91	5.6
					15.05	21.7	1.65	3.67	7.06
					20.03	25.5	1.39	4.41	8.48
					25.04	29.52	1.24	4.98	9.58
					30.10	34.8	1.19	5.21	10.02
16	30	44	Notched	Vertical	5.06	10.37	4.8	1.1	2.12
					10.08	17.02	2.2	2.46	4.73
					15.03	20.09	1.61	3.42	6.58
					20.03	24.97	1.36	4.1	7.88
					25.04	29.85	1.25	4.48	8.81
					30.01	34.5	1.17	4.81	9.95
17	30	32	Trapezoidal	Vertical	5.04	14.27	5.24	1.79	3.44
					10.13	28.53	3.25	2.9	5.58
					15.14	39.8	2.71	3.49	6.71
					20.1	53.4	2.74	3.45	6.63
					25.3	54.23	2.21	4.29	8.25
					30.14	58.92	2.03	4.68	9.00
18	30	36	Trapezoidal	Vertical	5.13	16.25	5.97	1.57	3.02
					10.13	29.48	3.35	2.82	5.42
					15.02	29.58	2.72	3.48	6.69
					20.03	46.05	2.3	4.13	7.94
					25.62	52.33	2.09	4.55	8.75
					29.96	58.43	2.02	4.71	9.06
19	30	40	Trapezoidal	Vertical	5.02	18.03	6.55	1.44	2.77
					10.06	29.53	3.36	2.82	5.42
					15.01	37.8	2.63	3.61	6.94
					20.06	45.65	2.27	4.32	8.31
					25.27	51.55	2.08	4.59	8.83
					30.08	57.45	1.97	4.85	9.33

V. CONCLUSION

From the investigation, it is found that by providing notch overall increment in heat transfer rate for horizontal orientation is 11%. And for vertical orientation comparing between trapezoidal and un-notch plate fin increment in heat transfer rate is 29% and an overall decrease in thermal resistance for Horizontal orientation is 21%. And for vertical orientation decrease in thermal resistance is 27.5 %. Results show that 36 notch fin heat sink gives maximum heat transfer rate which is 35% higher compare to 36 un-notch fin heat sink in a horizontal orientation and for vertical orientation it about 36%. Thermal resistance for 40 notch fin heat sink is minimum as compare another heat sink. Thermal resistance for 36 notches and 40 notch fin heat sink are very close, this arises a problem in selection of best heatsink So by considering weight parameter we can compromise between thermal resistance and weight.The increment in thermal resistance for 36notch fin heat sink with respect to 40 notch fin heat sink is 0.5% but there is 10% weight reduction. Weight reduction for 36 un-notch and notch heat sink is 19%. So the outcome of experimentation shows that 36 notch fin heat sink gives the best performance in all sense.

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