

Factors Affecting on Thermal Performance of Fins & Analysis of Fins with ANSYS Icepak

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ABSTRACT: In this paper, various factors affecting on thermal performance of fin are studied. Factors to be considered while designing of pin fin array are investigated. By changing parameters it's performance on array such as maximum temperature, pressure and velocity are comparatively studied. From the results obtained we suggested best solution according to the requirement.

KEYWORDS: Fins, Ansys icepak, Electronics cooling.

I. INTRODUCTION

Now days number of chips on transistor are increasing also size of devices becomes compact i.e. amount of heat dissipation from available surface are increasing i.e. power density increasing. Cooling of electronics devices become major issue.

According to the Moore's law "the no. of transistor on a chip increases double after each 18 months" so we have to maintain temperature below specific temperature (e.g. 85°C) of the electronic component so that reliability will increase & chances of failure of that part will be minimized.

There are various option for cooling of electronics device such as heat sink, heat pipe, thermoelectric coolers but heat sink is mostly used in the electronics cooling due to it's heat transfer capability and ease of use.

II. BACKGROUND & RELATED WORK

Initially we have read different research papers, understood which are factors affecting on pin fin array its effects on performance of pin fin array & used this knowledge for improving performance of fin array by changing design of array & results are obtained with the help of ANSYS Icepak software. The summary literature review of research paper as following.

Now day's researchers are trying to maximise the heat transfer from heat sink of minimum size. Waqar ahmed khan obtained heat transfer coefficient for the heat sink and the average temperature of the fluid by an energy balance & optimise overall performance of fin geometry for combined effects of thermal resistance & pressure drop also studied effects of various parameters on pin fin array [1]. While Tzer-ming Jeng & Shene-Chung Tzeng compared the performance of the square pin-fins with that of the circular pin-fins & find out optimal pitches for inline & staggered arrangement.[2] P.A.Deshmukh & R.M.Warkhedkar investigated effects of design parameters air side thermal performance under mixed convection for elliptical pin fin heat sink & found out optimum aspect ratio & void fraction for fin & compared results with circular fin.[3] T.J.John, B.Mathew & H.Hegab studied overall performance of a micro pin fin heat sink with single phase liquid flow & different pin fin geometries operating under similar conditions, square & circular fins selected axial pitch, transverse pitch, aspect ratio, hydraulic diameter changed alternately and results are compared.[4] Jaideep pandit, Megan Thompson, Srinath V.Ekkad, & Scott T.Hextable studied pin fin arrays of circular, triangular, hexagonal, & diamond shapes having fin length of constant size & varied channel height and found that heat transfer performance is better for diamond shape fin at ratio of pin height to channel height 0.5.[5] Naser Sahiti

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investigated analytical, experimental, & numerical investigation of various aspects of single phase convective heat transfer enhancement & comparison of the heat transfer rate with the required pumping power of heat transfer surfaces under comparison [6].

III. RESEARCH METHODOLOGY

3.1 Principle of operation.

The principle of operation is to provide larger area over which convective heat transfer can occur than original surface area.

3.2 Factors to be considered while designing heat sink.

- Power that needs to be dissipated.
- Maximum allowable component temperature.
- Available space/volume for heat sink.
- Power density.
- Air Flow parameters.
- Pressure Drop.
- Manufacturability.
- Cost.

3.3 Factors which affect the performance heat transfer.

- 1) Arrangement of pin fin array.
- 2) Shape of pin fin (cross-section of fin).
- 3) Geometric parameters (diameter, length, aspect ratio, void fraction).
- 4) Pitch between adjacent fins (transverse & longitudinal).
- 5) Number of fins.
- 6) Material of pin fin.
- 7) Shroud clearance (bypass factor).
- 8) Nature of fluid flow (natural or forced).
- 9) Location of fan/Blower in case of forced convection i.e. velocity of flowing fluid.
- 10) Type of flowing fluid.
- 11) Surface finish of the fins.
- 12) Inclination of fins.

1) Arrangement of pin fins -

According to arrangement of pin fins they are classified as -

- a) Inline pin fin array – in these, each pin fins are in straight line horizontally & vertically in a rectangular channel.
- b) Staggered pin fin array – in these, pin fins are not in straight line they are randomly oriented in rectangular channel.
- c) Radial pin fin array- in these, pin fins are along radial direction in circular channel.

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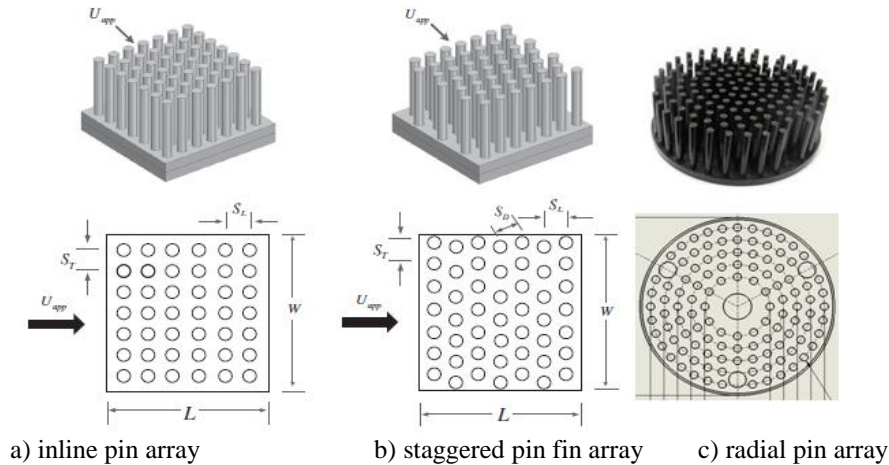


Fig.1 Type of pin fin array.

Heat transfer performance of the staggered arrangement is better than in-line arrangement because in staggered arrangement of pin-fins increases turbulence around the pins, which increases the cooling rate significantly. [1]

2) Geometry of fins (cross section of the fins) -

There are various geometries of the fins such as circular, Elliptical, square, NACA, Dropform, Lancet etc.

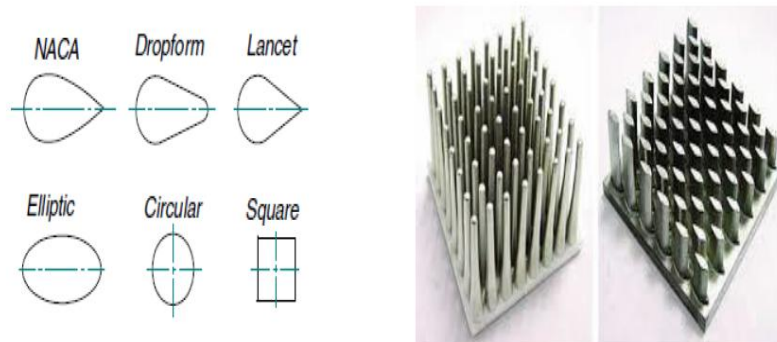


Fig.2 Shape of the pin fins.

The heat transfer performance is better in circular array in in-line arrangement but there is large pressure drop & in staggered arrangement elliptical fin has better performance.

The elliptical fin has heat transfer rate 20% more than circular pin fins but it has reduction in pressure 100%.

The pressure drop is maximum in circular in in-line arrangement while square in staggered arrangement. [2]

3. Geometric parameters (diameter, length, aspect ratio, void fraction) -

The change in diameter does not large effect on heat transfer performance change in diameter by 25 % has only 6% change in thermal performance but change in length has significant effect on the heat transfer performance. [3]

Aspect ratio- it's ratio of the height of the fin to the length of the fin. Longer fins i.e. Aspect ratio more than 4 has better heat transfer performance. Fins that are too short cannot be modeled with an adiabatic tip which may lead to poor performance and overheating of the sink surface. Fins that are too long will have Compromised fin efficiency

since fin efficiency is a strong function of fin height. Therefore, the variation in aspect ratio was done by varying the height of the pin fin with fin efficiency close to 90%. Generally as void fraction & hydraulic diameter increases heat transfer performance increases. [3]

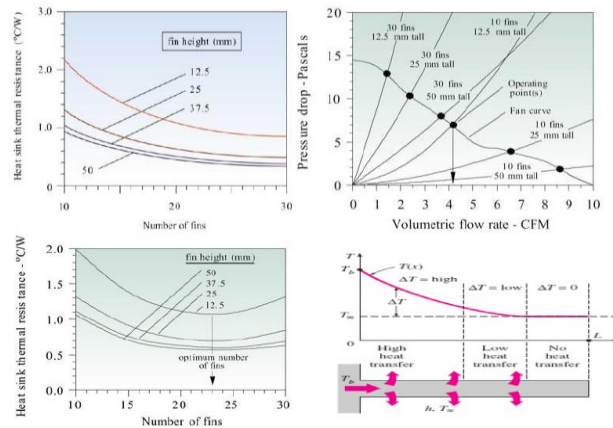


Fig.3 Effects of the geometrical parameters on the pin fin.

4) Pitch between adjacent fins (transverse & longitudinal) -

Generally heat transfer increase with decrease in streamwise pitch (X_L) & Spanwise pitch (X_T). Streamwise spacing (X_L) had a larger effect than spanwise spacing (X_T) on array heat transfer. Spanwise spacing (X_T) had a larger effect than Streamwise spacing (X_L) on array pressure drop. The heat transfer can be maximized & pressure drop can be minimized by reducing streamwise spacing (X_L) & increasing spanwise spacing (X_T) between pin fins. The results of streamwise pitch (X_L) & spanwise pitch (X_T) for pressure drop of array are controversial than heat transfer results.

The variations of axial pitch between structure does not have much effect on thermal resistance & pressure drop for square heat sink but for circular heatsink thermal resistance decreases & pressure drop increases as axial pitch decreases. For square & circular heat sink as transverse pitch decreases thermal resistance decreases & pressure drop increases. [4]

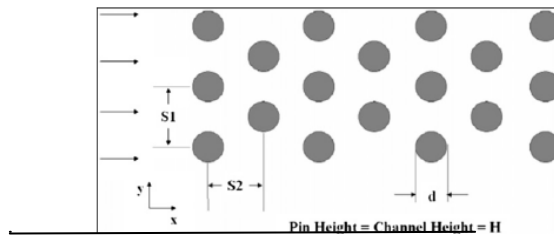


Fig.4 Effects of streamwise & spanwise spacing.

5) Number of pin fins –

Generally increasing no of fins on array (fin density) increases heat performance reaches maximum & again decreases due to increase in conduction resistance over convection resistance so we have to choose optimum no of fins on pin fin array. So we have to select optimum no of fins so that thermal performance of fins will increase.

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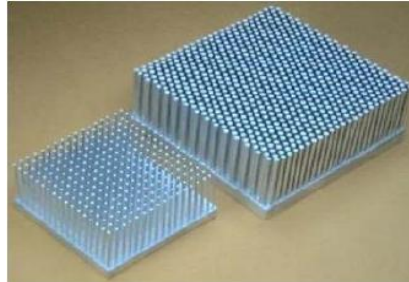


Fig.5 Effects of fin density on pin fin array.

6) Material used for pin fin -

Generally material which are good conductor of heat are used for pin fin heat sink such as copper ($k= 398$ w/mk) but sometimes aluminum ($k= 238$ w/mk) is preferred due to it's low cost & weight. Thermal performance is better in case of copper but it has high cost compared with aluminum so copper is used when temp is reduced in large amount otherwise aluminum fins are used.

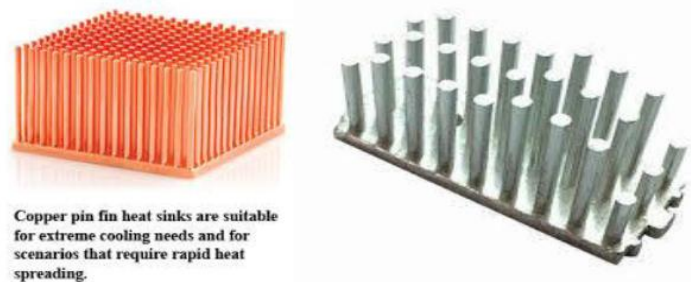


Fig.6 Material used for pin fin (copper & aluminum).

7) shroud clearance (bypass factor) -

It's found that performance is maximum when the ratio of height of fin to the height of channel (h/H) is 0.5.

[5]

8) Nature of fluid flow (natural or forced) -

Generally force convection has better performance than natural convection. In natural convection the buoyancy effect forces hot air to flow to the top and cold air to come to the bottom. The typical velocity is 0.2 m/sec & in forced convection Air is forced over the components with a fan or blower. The velocity of air depends on the fan and the local conditions.

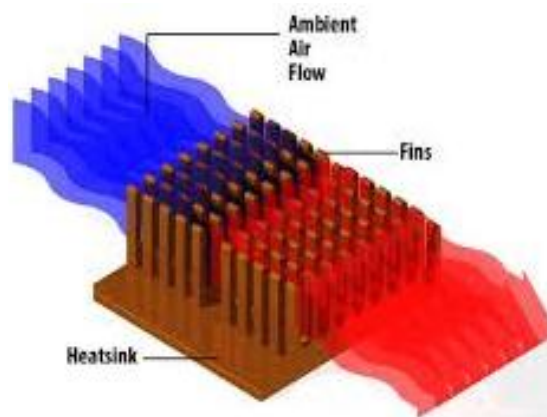


Fig.7 Nature of the fluid flow.

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9) Location of fan /Blower in case of forced convection i.e. velocity of flowing fluid -

Location of the fan from the fin array & velocity of fluid plays very important roll increase in velocity performance increases riches to the peak & further increases in velocity performance reduces .The location of fan affects the performance of heat sinks. The angles of intake and exit of flow of air decides which type of fan/blower is to be selected. Location of fan/blower is selected in such a way that flow of air will be free from obstructions or will have minimum obstructions. Design of electronic equipment is done with considering the effects of location of fan. [6]



Fig.8 Location of the fan &velocity of fluid.

10) Type of flowing fluid -

The type of the fluid used (e.g. air, gas etc.) effects the performance of the array.generally air is used as fluid due to its available at free of cost but sometimes special heat absorbing gases are used to improve performance of heat sink.

11) Surface finish of the fins -

Surface finish of the fins also effects thermal performance of the pin fin. Generally smooth surface finish has less heat transfer performance. Because the friction between air & smooth fin is less as compared with friction between air & rough fins.

12) Inclination of the pin fins -

Splayed pin fins has inclined fins inclination of the fins also affects the performance of the pin fin.due to inclined fins flow of air disturb and air comes contact with fin for more time so inclination of fins affects thermal performance of fin.



Fig.9 Splayed fins.

IV. EXPERIMENTAL ANALYSIS.

Problem statement-

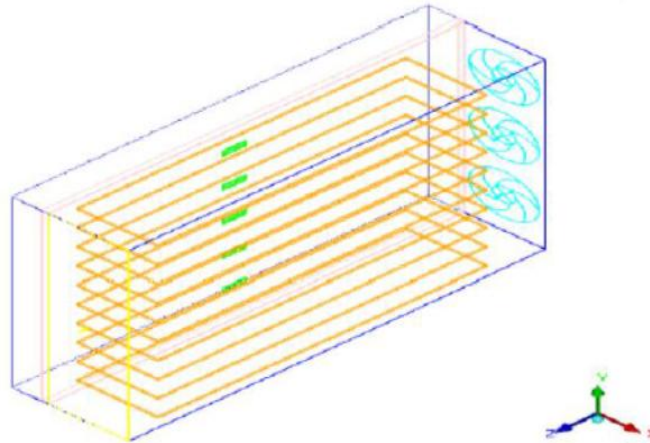
The cabinet contains an array of five high-power devices, a backing plate, ten fins, three fans, and a free opening, as shown in Figure. The fins and backing plate are constructed of extruded aluminium. Each fan has a total

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volume flow rate of 18 cfm and each source dissipates power at the rate of 33 W. According to the design objective, the base of the devices should not exceed 65°C when air sweeps the fins at an ambient temperature of 20°C.



INPUTS:

1. Cabinet.

$X_S : 0$	$X_E : 0.075$
$Y_S : 0$	$Y_E : 0.25$
$Z_S : 0$	$Z_E : 0.356$

2. Backing Plate: (block): The backing plate is 0.006 m thick and divides the cabinet into two regions: the device side and the fin side.

$X_S : 0$	$X_E : 0.006$
$Y_S : 0$	$Y_E : 0.25$
$Z_S : 0$	$Z_E : 0.356$

3. Opening: (on the $_n$ side of the backing plate.)

$X_S : 0.006$	$X_E : 0.075$
$Y_S : 0$	$Y_E : 0.25$
$Z_S : 0.356$	$Z_E : --$

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4. Fan (set of 3):

Xc : 0.04	Ext. Radius : 0.03
Yc : 0.0475	Int. Radius : 0.01
Zc : 0	

Fan type of intake. Under Fan flow, select Fixed and Volume.
For 3 copies offset distance is 0.0775.

5. High-power device: (source)

X _S : 0	X _E : --
Y _S : 0.0315	Y _E : 0.0385
Z _S : 0.1805	Z _E : 0.2005

For four copies offset distance is 0.045m.

6. Fins (plates):

To create the array of ten fins, you will build a single rectangular plate as a template, and then create nine copies, each with a specified offset in the y direction.

X _S : 0.006	X _E : 0.075
Y _S : 0.0125	Y _E : --
Z _S : 0.05	Z _E : 0.331

Conducting thick thermal model with thickness of 0.0025m.
For nine copies offset distance is 0.025m.

We have used fine meshing, no of iteration 200, convergence criteria 10^{-3} for all variables & 10^{-7} for energy. For problem setting we have used force convection due to fan is present, flow is turbulent, solved zero equation of turbulence. Ignored heat transfer by radiations, exclude solar radiations, variables are not changing with time (steady state) & neglected effect of altitude.

V. RESULT DISCUSSION

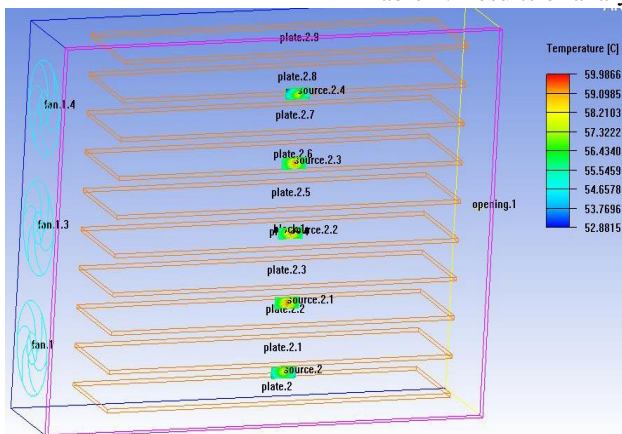
(Results Obtained After Changing Parameters)

Following are the results of some analysis that were obtained by changing different parameters on the thermal performance of pin fin heat sinks with the help of ansys icepak software.

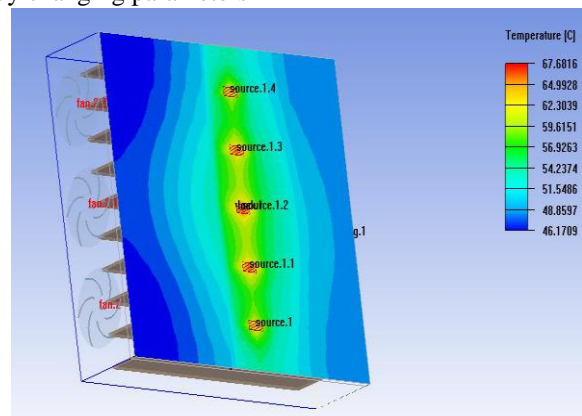
In particulates, First word indicates type of fin (plate/inline/staggered). second word indicates cross-section of fin. Third material of fin & in bracket quantity of fins in pin fin in array.

Sr. No.	Particulars	Temp.(°C)	Pressure (N/m ²)	Velocity (m/s)
1	Plate	59.9866	1.16879	3.3968
2	Inline circular Al (100)	50.9459	29.3409	4.93267
3	Staggered circular Al (95)	51.6377	23.6823	4.45972
4	Inline elliptical Al (100)	50.9631	28.9734	4.89959
5	Staggered elliptical Al (95)	51.6377	23.6823	4.45972
6	Inline circular Cu (100)	43.8775	29.3409	4.93267
7	Staggered circular Cu (95)	50.703	23.6823	4.45972
8	Inline circular Al (81)	55.1483	21.5501	4.20616
9	Staggered circular Al (77)	55.6362	18.0161	3.85801
10	Change in diameter 25%(increased)	49.499	49.114	6.51376
11	Reduced height by 10%	53.0419	22.9588	4.42714
12	Uneven height	53.3591	19.1422	4.47029
13	Failure of middle fan in plate fin analysis	67.6800	3.38008	1.25738

Table 1: Results of analysis by changing parameters



Temp contours on five devices



Temp contours on backing plate after failure of fan

Details of problems by sequence as that are in above table

- 1) Plate dimensions described in problem input. For next analysis only dimensions of fins are changed that are following.
- 2) For analysis 3,6,7,8 & 9
Diameter = $d=0.0115\text{m}$, Height = $h=0.069\text{m}$
- 3) For analysis 4 & 5
Major diameter = $a=0.00708\text{m}$, Minor diameter = $b=0.00468\text{m}$, Height = $h=0.069\text{m}$
- 4) For analysis 10
Diameter (D) = 0.014375m & height (h) = 0.069m
- 5) For analysis element 11
Diameter = 0.0115m & height (h) = 0.0621m
- 6) For analysis no. 12
Diameter = $D=0.0115\text{m}$ for all fins.

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Following are the heights (m) of different fins for analysis no-12.

Height																					
0.045	0					9					90						99				
0.048	1	10				8	19				91	80					98	89			
0.051	2	11	20			7	18	29			92	81	70				97	88	79		
0.054	3	12	21	30		6	17	28	39		93	82	71	60			96	87	78	69	
0.057	4	13	22	31	40	5	16	27	38	49	94	83	72	61	50		95	86	77	68	59
0.060		14	23	32	41		15	26	37	48		84	73	62	51			85	76	67	58
0.063			24	33	42			25	36	47			74	63	52				75	66	57
0.066				34	43				35	46				64	53					65	56
0.069					44					45					54						55

Table 2: Values of Uneven Height of fins in analysis no-12 according to icepak.

7) For analysis no-13, problem is same as per plate fin, except middle fan is failed and it is given free area ratio as 0.3

VI. CONCLUSION

The given cabinet contained an array of five high-power devices dissipating power at the rate of 33W, 3 fans were provided with 18cfm flow rate to cool the heat sink. It was required to maintain the temperature below 65°C when ambient temperature is 20°C.

We created geometry of given dimensions and modelled with Icepak and following results were obtained.

Sr. No.	Particulars	Results
1	Maximum Temperature on the Five Devices	59.9866°C
2	Maximum Velocity on the Fin Side of the Enclosure	3.39680 m/s
3	Maximum Pressure on the Fin Side of the Enclosure	1.16879 N/m ²
4	Maximum Temperature on the Fin Side of the Enclosure	59.9202°C
5	Maximum Temperature on the Backing Plate	59.9202°C
Results After Fan Failure :		
6	Maximum Temperature on the backing plate.	67.6816°C
7	Maximum Velocity on the fin side of enclosure	3.38008 m/s
8	Maximum Pressure on the Fin Side of the Enclosure	1.25738 N/m ²

Table3: Final Results of given problem

1. The given geometry was analysed for different plane cuts like temperatures, velocities etc. & the given geometry is suitable for maintaining the base temperature of heat sink below 65°C as required.

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2. after failure of fan maximum temperature increases up to 67.6816°C which is not desirable. Hence for safe working conditions failure of fans should be avoided.
3. For obtaining the minimum temperature at the heat sink, it is better to use Copper pin fins which give 43.8775°C temperature. But Copper is costly hence one can prefer the cheaper & lighter material like Aluminium heat sink with elliptical pin fins which offers the temperature reduction up to 50.9631°C. But for minimum pressure drop it is better to go with Plate fin heat sink which gives lowest pressure drop.
4. The velocity is lowest at the two extreme side regions of heat sinks & it is maximum at the fan blades. There is isolated region of high pressure immediately downstream of the fans and local maxima at the upstream tips of fans.
6. Also some other geometry which was modelled with the help of Icepak has reached to the following conclusions:
 - Heat transfer performance is better in staggered arrangement for elliptical pin fins & for In-Line arrangement circular pin fins are better.
 - In-line arrangement gives higher heat sink resistance and lower pressure drop than the staggered arrangement. Also circular pin fins gives more heat transfer than elliptical pin fins but the pressure drop is more.
 - The Length of Fin affects more than it's Diameter. The Pin Array having more height at centre has better performance.
 - Heat transfer increases with the increase in approach velocity, number of pins &, Reynolds's No.

VII. ACKNOWLEDGMENT

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BIOGRAPHY



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