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CFD Analysis of Various Height of Pin Fin Heat Sink in Inline Arrangement

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ABSTRACT

The electronic device became the part in a daily life, hence it is our responsibility to increase the life of such electronic devices by providing efficient cooling to the heat producing systems, else it causes permanent failure of hard disks,cpu, chipset, graphic cards etc. the heat sink is the major part that produces heat energy continuosly results in decrease the life of such devices very rapidly this produced heat can be removed by adopting various heat dissipation techniques like providing fans for air cooling , liquids for liquid cooling and with the help of heat sink to keep the temperature within the permissible safe range.
In the present paper the work has been carried out on efficient heat sink for cooling of electronic devices. The modification of existing heat sink depends on various geometric parameters like, fin length, fin height, fin thickness, number of fins, base plate thickness, space between fins, fin shape or material etc. and based on the concept of standard pin fin, splayed pin fin and hybrid pin fin heat sinks the new model with various heights of fin, the heat sink is developed which is observed as a pyramid structure and also obtained the result with increasing heat dissipation rate. The analysis is done by using CFD, ansys fluent.

Keywords: *CFD Analysis ,Hardware, Cooling Of Electronic Devices, Heat Transfer .*

1. INTRODUCTION

The hardware that is used in the electronic devices as a heat managing system is Heat sink. By increasing the surface area called fins,they are used to control the heat that is producing from all modules or assemblies of device.Now-a-days the demand of heat management in the electronic devices has been tremenduosly increased by increasing the usage of electronic devices, that generates heat enormously. continuos usage of the device results in heat producing equipment decreases the performance and life of device.Hence it is the challenging task for the design engineers to design effective heat sink to improve the life of devices.

Pin fins are available with variety of materials,different sizes and shapes.It has been studied from the pervoius references that round pinfins are giving better performance when compared to the flat fins.Also pinfins with copper and aluminium is giving the high performance than other materials.The general heat sink is standard heat sink that is shown below with rectangular base plate and having the pinfins are arranged in normal or

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perpendicular to the base plate.

Fig.1. Standard pin fin heat sink

But beyond the standard pin fin heat sink it requires greater cooling power ,hence the design of standard pinfin heatsink is modified to splayed pinfin heatsink and hybrid pinfin heat sink as shown belo fig2. and fig3.performance.

Fig.2. Splayed pin fin heat sink

The splayed pin fin heat sink and hybrid pin fin heat sink are the models which are similar to the standard pi fin heat sink whose fins are in round structure but due to difference in materials and their geometrical parameters like its orientation etc there is difference in the performance The splayed pin fin heat sink is the sink consists of a rectangular base plate with round fins are mounted on it .From the centre the fins are splayed or oriented with different inclinations. Hence its structure is looking like splayed.

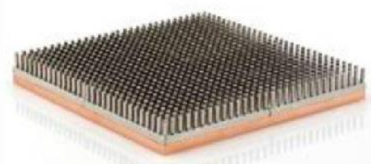

Fig.3. Hybrid pin fin heat sink

Hybrid heat sinks are designed for devices that feature small and focused heat sources. It consists of two different materials are used for the base plate as copper and for the pinfins the materials used is aluminium.

By applying the above designs the heat dissipation rates was improved and also by applying the foot prints of standard dimensions the new model was obtained with various fin heights as shown below in fig4 which is in U shape called hyoid structure.As the structure is with decreased fin heights appears as inverted V structure called pyramid structure as in fig5 of heat sink and gives better performance when compared to splayed and hybrid pinfin heat sinks.

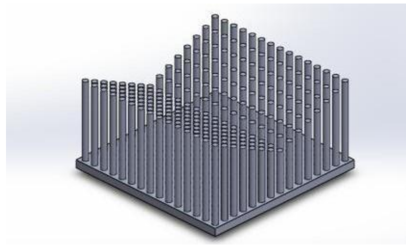

Fig 4.hyoid sturcture of pin fin heat sinkwith copper as base plate and aluminium as fins

Fig 5.pyramid structutre of pinfin heat sink with copper as base material and aluminium as a fin material.

2. LITERATURE REVIEW

O.A.sharma ,from his paper it is concluded that the splayed heatsink with round pinfins are giving better performance than the standard heat sink.[1]

Jonsson and Bjorn they conducted various experiments on different shapes of pin fins and finally concluded that elliptical pinfins are giving better thermal performance at high velocities and cylindrical pinfins at midrange velocities[2]

Md. Abdul Raheem Junaidi, Raghavendra Rao, S. Irfan Sadaq, Mohd Moinuddin Ansari,from this paper . It is observed from the results that optimum cooling is achieved by splayed & hybrid pin fin heat sinks. These heat sink designs promises to keep electronic circuits 20 to 40% cooler than standard pin-fin.[3]

Wirtz, R. A., Sohal, R., and Wang, H it is observed from this paper the heat transfer coefficient is maximum under fan i.e with forced covection

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and minimum at the corners of arrays.by increasng the fan power or fin height the overall thermal resistance is decreases.[4].

Tahat, M. A., Babus'Haq, R. F., and Probert, S. D., from this paper the experimental results were found to various pin-fin assemb,the effects of variiying profiles of pin fins and air flows have been obtained.[5]

T.Therisa,B.srinivas and A.Ramakrishna[6],they concluded that hyoid structure is giving better heat transfer coeffiecient from numerical analysis and also on simulation.[6]

3. ASSUMPTIONS

The modelling of pin fin heat sinks are made by GAMBIT 2.4.6 software.

1.air is incompressible.

2.air flow is perpendicular to fins.

3.air propeties are taken at film temperature.

4.flow is steady,laminar and 2D.

5.temperature at base is uniform.

6.fin material is homogenous and isotropic.

3.1 Geometry

Heat sinks, used in electronic devices, usually consist of arrays of pin-fins arranged in an in-line manner as shown in Fig 6

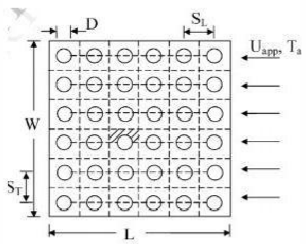

Fig 6 schematic of inline pinfin heat sink

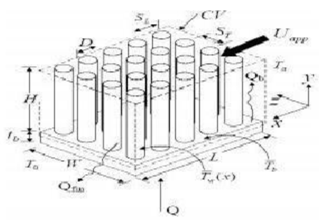

Fig 7.arrangement of heatsink

The pins are attached to a common base and the geometry of the array is determined by the pin dimensions, number of pins and pin arrangement. Fig 4: Schematic of in-line pin-fin heat sinks The geometry of an in-line pin-fin heat sink is shown in Fig 5.The dimensions of the base plate are L × W × tb, where L is the length in the stream wise direction, W is the width, and tb is the thickness. Each pin fin has diameter D and height H. The longitudinal and transverse pitches are SL and ST respectively. The approach velocity of the air is Uapp. The direction of the flow is parallel to the x-axis. The base plate is kept at constant heat flux and the top surface (y = H) of the pins is adiabatic. The average local wall temperature of the pin surface is Tw(x). The heat source is idealized as a constant heat flux boundary condition at the bottom surface of the base plate. The mean temperature of the heat source is Ts transfer coefficient across bank of tubes Reference Velocity The mean velocity in the minimum free cross section between two rows, Vmax, is used as a reference velocity in the calculations of fluid flow and heat transfer for inline arrangement, and is given by

Vmax= [ST/(ST-D)] Uapp (5)

Table 1 Dimensions of heat sink from footprint

Quantity	Dimension
Footprint (mm^2)	52×52
Base plate thickness (mm)	3
Overall height of fin(mm)	30
Approach velocity (m/s)	3
Thermal conductivity of solid aluminium(W/m•K) for aluminium	237
Thermal conductivity of solid copper(W/m•K)	401
Thermal conductivity of air (W/m•K)	0.0284
Density of air (kg/m3)	1.086
Specific heat of air (J/kg•K)	1007
Kinematic viscosity (m2/s)	18.15×10^{-6}
Absolute viscosity (Ns/m^2)	19.70×10^{-6}
Prandtl number (Air)	0.6976
Heat load (W)	130
Ambient temperature (K)	297
Base plate temperature (K)	353

3.2 Calculations

To form an appropriate model for calculations, the following assumptions are made.

1. The contact resistance between the heat sink and processor would be negligible when using a high quality thermal paste.

2. The average temperature of the air flowing through the heat sink would be 325 K, and used

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the values of material properties at 325 K.

3. The Intel, core i7-970 processor is selected as heat source of 130W, to evaluate the pin fin heat sink performane

3.2.1 Heat transfer coefficient over flate plate

Reynolds's number (Re_L) = $(\rho v L)/\mu$ (1)

$Nu = 0.332 Re_L^{0.5} Pr^{0.333}$ (2)

$Nu= h_1 L/k$ (3)

$h_1 = Nu\, k/L$ (4)

3.2.2 Heat transfer coefficient across bank of tubes Reference Velocity

The mean velocity in the minimum free cross section between two rows, Vmax, is used as a reference velocity in the calculations of fluid flow and heat transfer for inline arrangement, and is given by

$V_{max}= [S_T/(S_T-D)] U_{app}$(5

where Uapp is the approach velocity, SL, and ST are the dimensionless longitudinal and transverse pitches,

$Re_{Dmax}= \rho v_{max} D$ (6)

$Nu= C (Re_{Dmax})^n$ (7)

For the values of C and n from data book

$Nu= h_2 D/k$ (8)

$h_2 = Nu\, k/D$ (9)

4. CFD SIMULATION APPROACH

The ANSYS FLUENT 15.0 CFD code was used for the simulations. The simulation procedure was started with pre-processing.

The computational mesh was generated using tetrahedral elements. In order to accurately resolve the solution fields in the high gradient regions, the grid was stretched. The discretization scheme was first order upwind scheme. A SIMPLE algorithm was used. For the simulations presented here, depending on the geometry used, fine mesh of up to 3, 33,998 elements were used. The flow field and heat transfer were determined by iteratively solving the governing momentum and energy equations. The under-relaxation factors were first set at low values to stabilize the calculation process, and were increased to speed up the convergence.

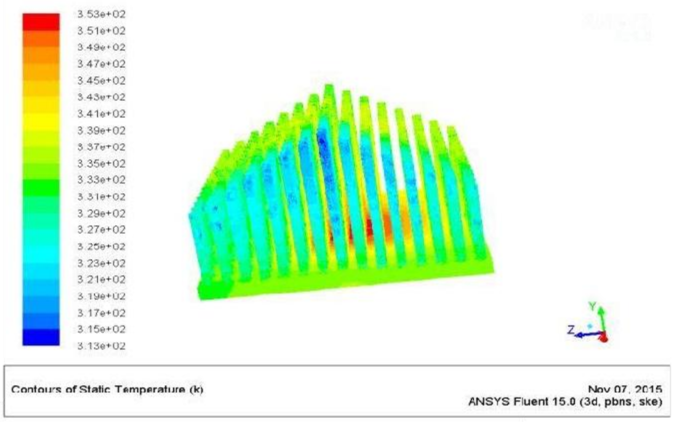

Fig 8. :Temperature Contours of pyramid Pin Fin Heat sink velocity (copper base plate with aluminium heat sink)with 3 m/s velocity

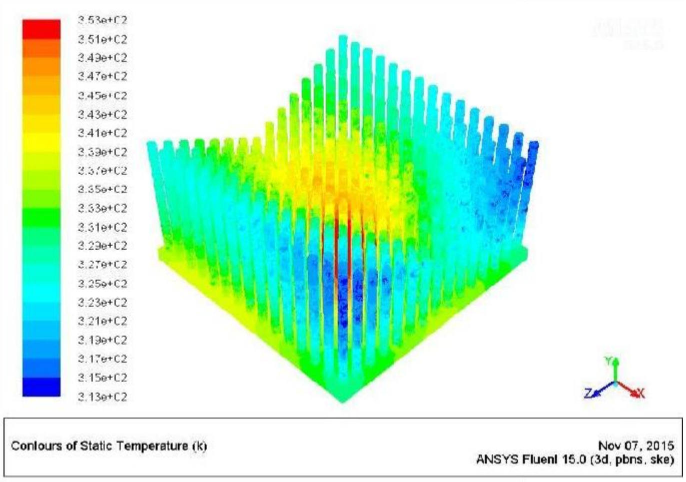

Fig 9:Temperature Contours of hyoid(U-shaped) Pin Fin Heat sink velocity (copper base plate with aluminium heat sink)with 3 m/s velocity

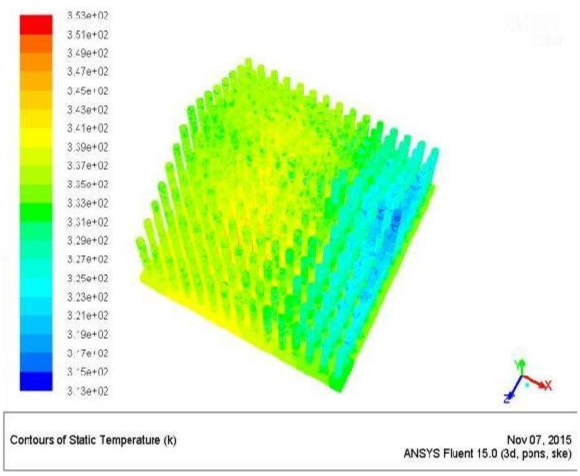

Fig 10 :Temperature Contours of pyramid Pin

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Fin Heat sink velocity (copper base plate with aluminium heat sink)with 3 m/s velocity

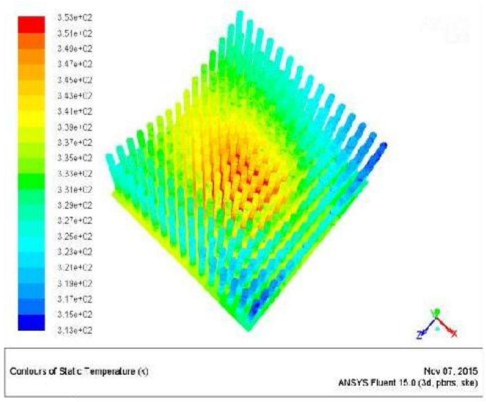

Fig 11:Temperature Contours of hyoid Pin Fin Heat sink velocity (copper base plate with aluminium heat sink)with 3 m/s velocity

5. RESULTS & DISCUSSION

from the fig 7 to 11 it is observed that as discussed earlier from the previous papers the copper base plate is of high heat spreading capabilities when compared to the aluminium but here the hyoid and pyramid sturcutre with copper base plate is giving better performance when compared to standard and splayed pin fin heat sinks

Table.2

	Al	Cu	hybrid	hyoid	pyramid
Standard	342	337	330	317.916	320.127

6. CONCLUSION

The analysis is done in CFD ansys 15.0 version with ,solid works modelling the component.and the following conclusions were made

from the cfd simulation it is observed that the standard pin fin heatsinks gives the result.

but splayed pinfins given more heat transfer beyond this hybrid heat sink performed well[1]. but from this investigation the hyoid[6] and pyramid structures are giving better performance than standard,splayed and hybrid pinfin heatsinks.[1]

.Also weight is less and reduces materials consumption when compared to other heatsinks

7. FUTURE SCOPE

The work can be carried with various profiles also with different material compositions.

8. NOMENCLATURE

Ab = area of the base plate, m2

AC=Area of the Micro processor chip, m2

tb=Thickness of the base plate, m tc=Thickness of the Microprocessor chip, m Ta =Ambient Temperature, K

Ts = Surface Temperature, K Tf =Film Temperature, K

D = pin diameter, m H = pin height, m

k = thermal conductivity

N = total number of pins in heat sink

L = length of heat sink in flow direction, m

NL = number of pins in the longitudinal direction NT = number of pins in the transverse direction NuD = Nusselt number based on pin diameter

Q = total heat transfer rate, W

ReD = Reynolds number based on pin diameter

SLlongitudinal distance between two consecutive pins,m

ST = transverse distance between two consecutive pins, m

Uapp = approach velocity, m/s

Vmax = maximum velocity in minimum flow area, m/s

W = width of heat sink, m

Subscripts

a = ambient

b = base plate f = film

app = approach Greek

μ = absolute viscosity of fluid [kg/ms] ν = kinematic viscosity of fluid [m2/s]

ρ = fluid density [kg/m3]

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