Numerical Simulation and Investigation of an Electronic Cooling System Utilizing Extended Surfaces

Minesh Vohra[1], Sanjeev Kumar[2]
[1,2] Assistant Professor, Lovely Professional University, Phagwara, India.

Abstract: In the present paper the work has been carried out on efficient heat sink for cooling of electronic devices. For this purpose, A numerical simulated model has been the analyzed in order to choose the suitable fin geometry for maximum heat dissipation from the microchip surface. The ANSYS Fluent module was used to produce a CFD heat transfer simulation. In the fin array region of the heat sink, a thermal gradient system was introduced. An effective grid consistency model has been developed and validated based on Grid Independence. The simulated investigation with variable fin geometries i.e. Fin 1, Fin 2, Fin 2, Fin 4; showed that the water was adequate to cool the CPU with the specified fin configuration, i.e. Fin 2 having elements (1.25E+06) and the maximum surface temperature of the Microchip obtained is 291.167K which is minimum in comparison to rest of the fin geometries.

Keywords: Fins, Heat Transfer Rate, *CFD Analysis, Hardware, Cooling of Electronic Devices*

1.1 INTRODUCTION:

Owing to exponential growth within modern technology, modern appliances including computers are now necessity in our everyday live and for the optimum utilization of the processors integrated with in the hardware requires optimum cooling on the microchip of Processors. Teertstra et al (1999) concluded that methods, are useful for simplistic architectures, but also, they fell short for real-world implementations. Copeland (2000) concluded that the conventional method of characterization of the heat sink was the topic of much disagreement as the vendors presented various measures or definitions to assess the behavior of the heat sink. Analytical and empiric methods for fin output. Stewart and Stiver (2004) concluded that optimal configuration of the computer heat sink is highly time-consuming. Culhamand J. R et.al. (2001) proposed a method that permitted the simultaneous optimization of the design parameters of the heat sink. Iyengar M and Bar-Cohen A (2001) developed an analytical model, in which thermal efficiency of side-inlet & side-out (SSE) heat sink has been presented, and the heat capacity for number of operating variables has been calculated. Bar-Cohen and Iyengar M (2002) investigated the ability for least utilization of energy by natural & forced convection. Cohen and Iyengar (2002) hypothesized that cooling with conventional heat sinks would be the favored approach for heat dissipation having high efficiency and low cost. Chen et al (2004) also predicted that future cooling in computers and software devices would require more effective portable heat exchanger using active heat transfer with ambient air. Hsien-Chie Cheng t al (2004) provided a statistical description of the chip interfacial w.r.t chip spatial position & scaled it for successful characterization based on temperature. The mathematical term does not only accurately describe the relationship between thermal efficiency and architecture parameters. John Parry et al (2004) defined a sequential optimization approach which results in design optimization and demonstrated its use by optimizing heat sink configuration for a simple device. The findings revealed the requirement for a regional solution, the knowledge that could be obtained from automatic product optimization, and also highlighted the feasibility of the solution. Yu-Tang Chen (2004) et al have investigated the fluid flow characteristics with heat transfer behavior study in micro-channeled Sink and results suggested that forced convection in the micro-channel heat sink showed excellent cooling efficiency, especially in the PCM. Seri Lee (2004) has developed an empirical modeling model for forecasting and maximizing the thermal efficiency of bi-directional fin heat sinks. The optimization of heat sink architectures and standard parametric behaviors was addressed on the basis of the effects of the sample simulation. The author proposed a basic method for calculating the flow velocity of the fin and also defined the evolution of the flow velocity of the fin. Park et al (2006) carried out numerically the optimization in the structure of form plate heat sink with integrated air deflector in order to mitigate the loss of pressure under the desired optimum temperature and geometric constraints. In their analysis, the Cryging Method, which is one of the metamodels associated with computational fluid dynamics (CFD), was used to achieve optimal solutions. The commercial software ANSYS Fluent 14.2 was used to produce a CFD heat transfer simulation. An effective grid consistency model has been developed and tested. The tests obtained showed that the water was sufficient to cool the CPU.

1.2 METHODOLOGY

1.2.1 Modeling and Design: Geometry and Mesh Structure

The commercial package ANSYS 14.2 was employed to generate the CFD Simulation of heat flow in the microchannel heat sink. The cut-off cell mesh used in the measurements was provided by Ansys Mesher.

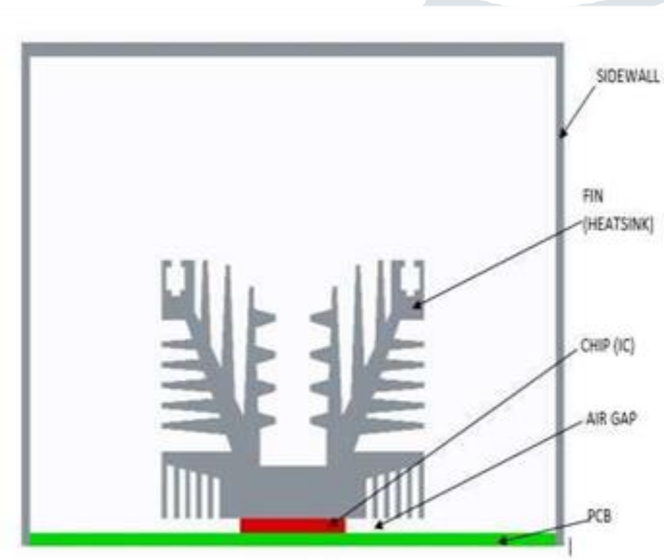

Fig. 2: Fin 1

Fig. 3: Fin 2

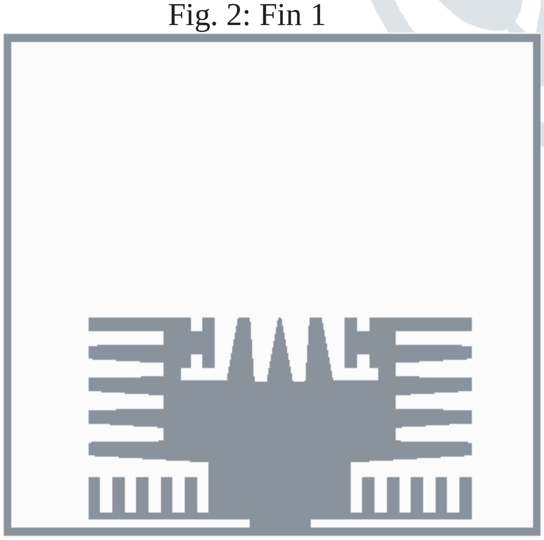

Fig. 4: Fin 3

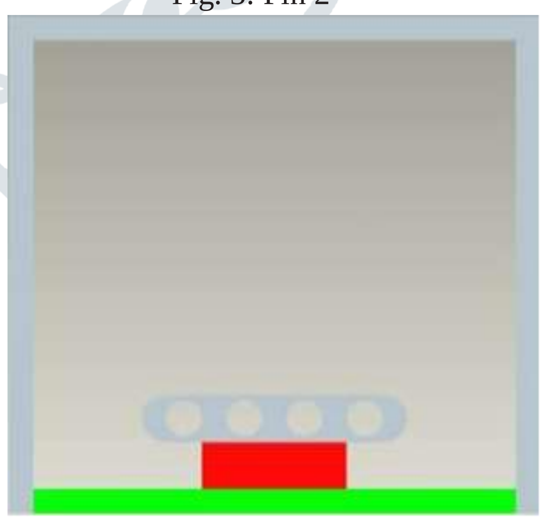

Fig. 5: Fin 4

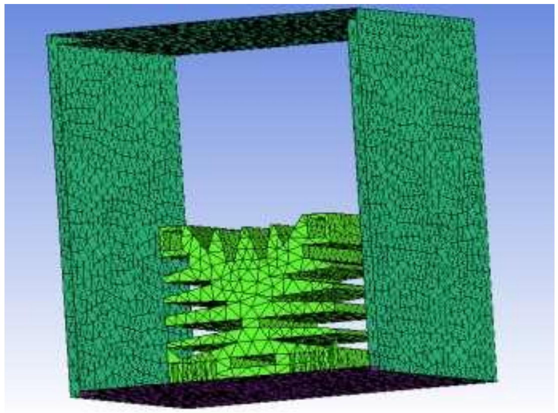

Fig. 6: Meshing

The chip (IC) is installed on printed circuit board (PCB). A finned heat sink is attached to the top of the chip to cool it. Air can flow between the fins of the heat sink as well as in the narrow gap between the heat sink and PCB. The PCB is fitted into a rectangular casing. Based on the Grid Independence test considering one of the property variations as constant i.e. Temp, the following grid sizes were taken into consideration for final simulations

Sr. No.	Fin Type	Element Size
1	Fin1	1.34E+06
2	Fin 2	1.25E+06
3	Fin 3	1.30E+06
4	Fin 4	1.20E+06

1.2.2. Boundary Conditions

The boundary conditions for fluid dynamics and heat transfer in the CFD module (CFX)) have been described. At the inlet, the flow rate of the fluid was set as constant. The direction of the flow was defined as normal to the boundary. For all situations, a constant heat flux of 115 W was defined at the bottom wall of the heat exchanger. A fully defined flow (pressure drain) condition was imposed at the outlet. At all the walls, a no-slip boundary condition was proposed. Single phase model with laminar flow regime was assumed for all cases.

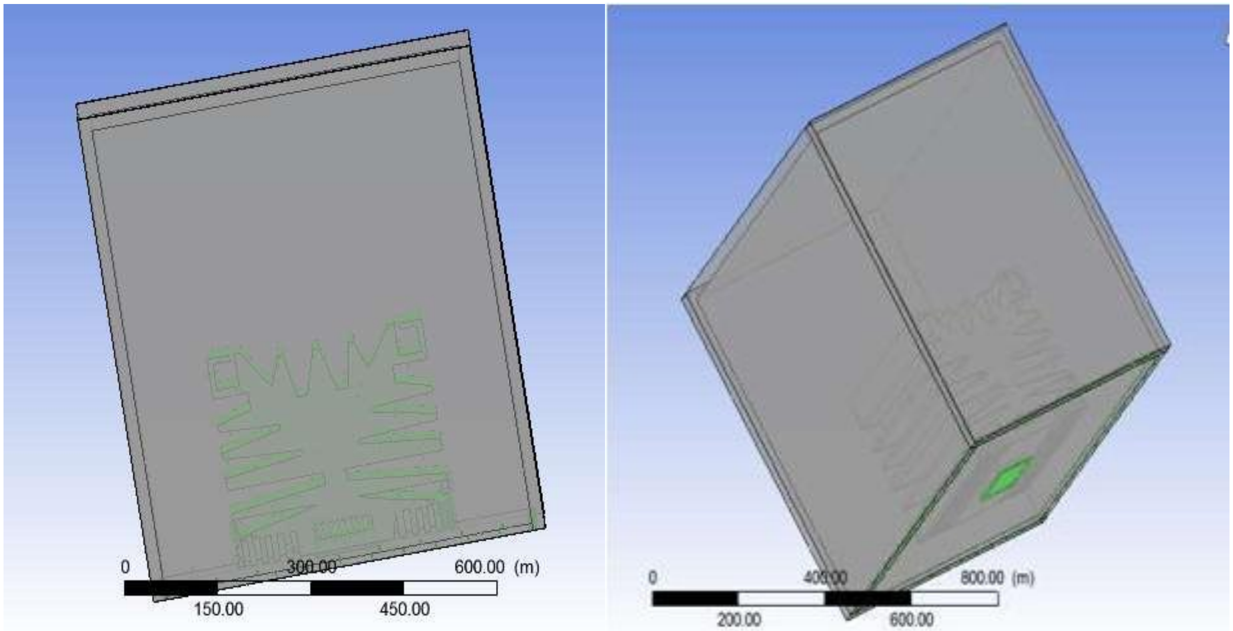

Fig. 7: Solid and Fluid Domains

The pressure-based solver was used for calculations. In addition, First-order upwind scheme has been used and the solution initialization has done. Least-Squares Cell-Based method and the SIMPLE algorithm were chosen for gradients and for the pressure-velocity coupling, respectively. Convergence of the numerical solution was achieved by controlling the scaled residuals at a constant point below 10^{-3} for each component, except for the residual energy for which the criterion was 10^{-6} with the surface monitor of average static temperature at the outlet was used as an indicator of convergence. Moreover, the mass and heat balances were monitored during CPU Heat Sink Cooled by Water

1.4 RESULT & DISCUSSION

Convergence Criterion:

When we are using different type of geometry for heat transfer for the same boundary condition the result vary in each geometry.

Representation of Curves for Momentum and Mass Transfer for Various Fins:

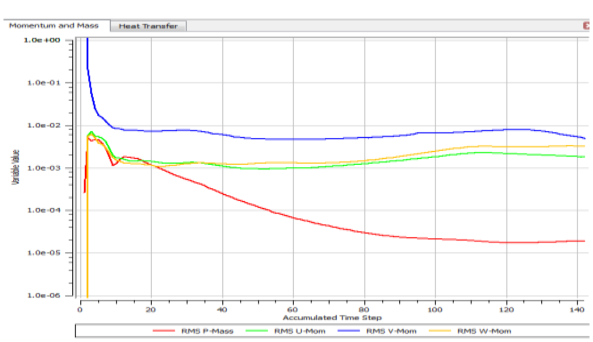

Fig 8: Momentum and Mass for Fin 2

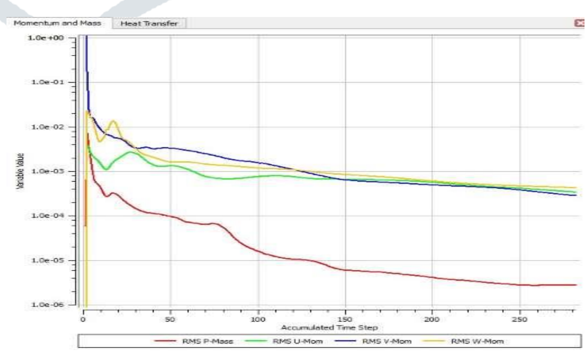

Fig 9: Momentum and Mass for Fin 1

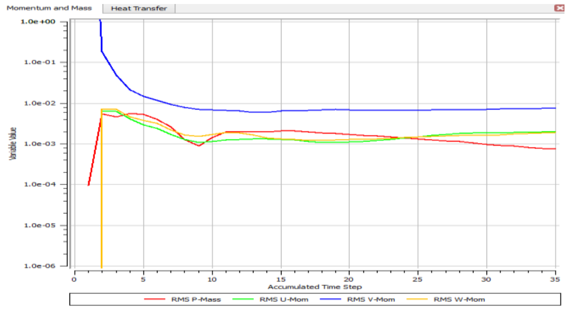

Fig 10: Momentum and Mass for Fin 3

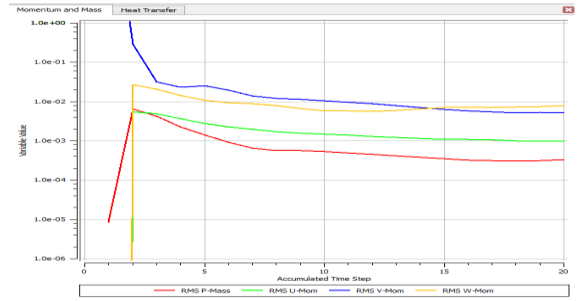

Fig 11: Momentum and Mass for Fin 4

Representation of Curves for Heat Transfer Rate for Various Fins

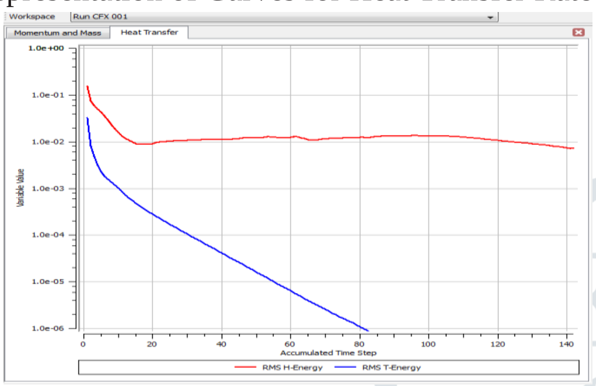

Fig 12: Heat Dissipation for Fin 2

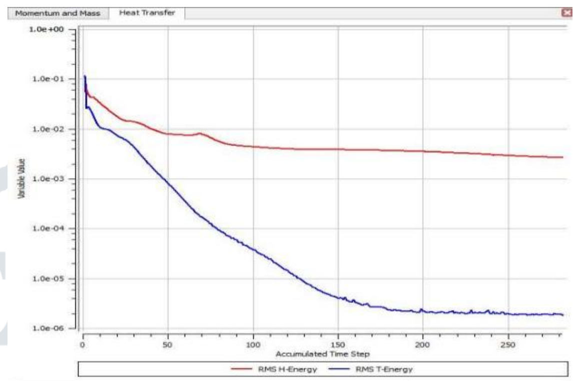

Fig 13: Heat Dissipation for Fin 1

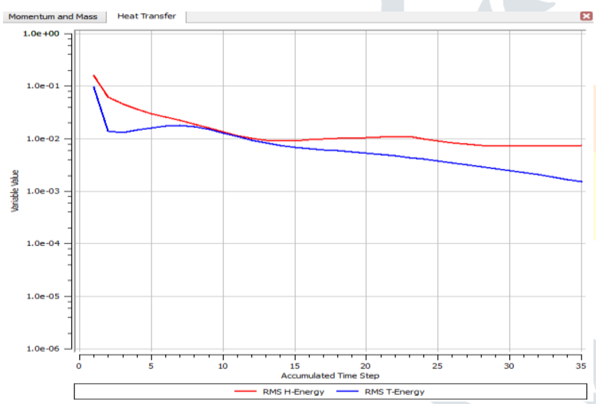

Fig 14: Heat Dissipation for Fin 3

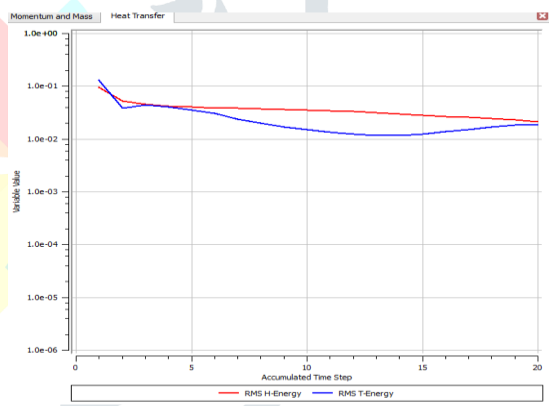

Fig 15: Heat Dissipation for Fin 4

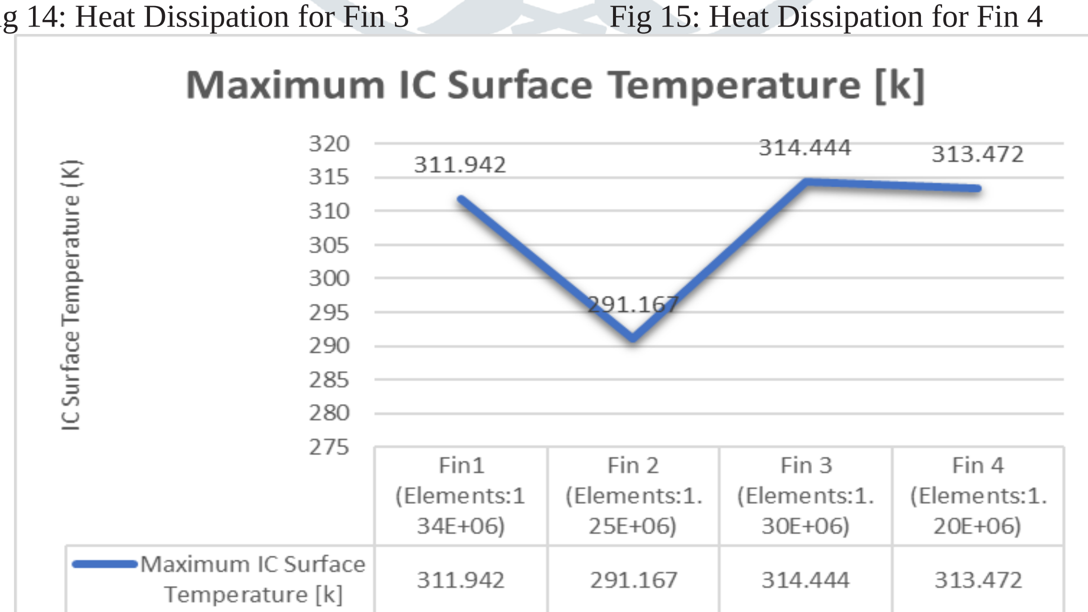

Fig 16: Micro Chip (IC) Surface Temperature

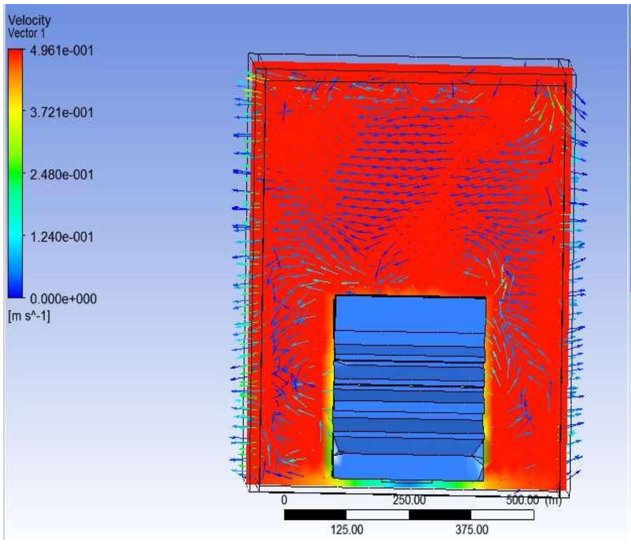

Fig 17: Temperature Contour for Fin 2

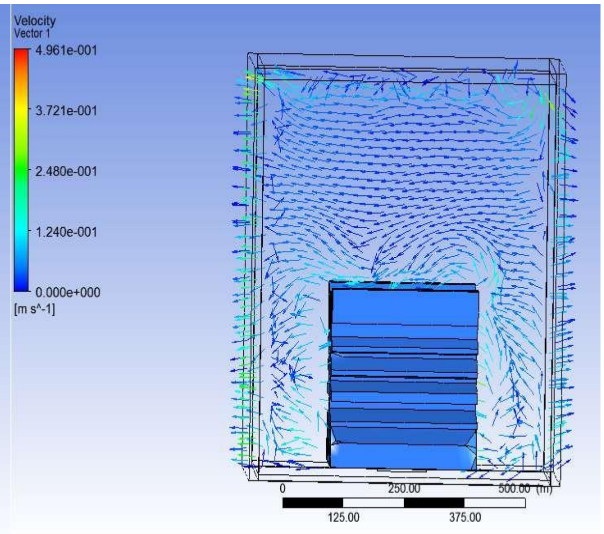

Fig 18: Velocity Vector for Fin 2

The presents a numerical and experimental study on water as a coolant in a CPU heat sink. An appropriate grid quality model was developed and validated. The obtained results showed that water was sufficient enough for CPU cooling. Also, the overall performance of the heat sinks with different shaped fin has been investigated and it seems that the fin geometrical structure number2 having elements (1.25E+06) gives the best results in comparison to rest of the fin geometrical structures within the defined flow domain as the surface temperature on the IC seems to be minimum as per the simulation and hence fin geometry 2 promoted the better heat transfer or heat dissipation from the surface of Microchip (IC) in combination with the water as a cooling medium.

REFERENCES

1. Chen,Y-T., Kang, S-W., Tuh, W-C., and Hsiao T-H (2004). "Experimental investigation of fluid flow and heat transfer in micro channels", *Tamkang Journal of Science and Engineering,*
Vol. 7(1), pp 11-16.
2. Bar-Cohen, A. and Iyengar, M. (2002). "Design and optimization of air-cooled heat sinks for sustainable development", *IEEE transactions on components and packaging technologies*, Vol. 25(4), pp 584-591.
3. Teertstra, P., Yovanovich, M.M., Culham, J.R., and Lemczyk, T. (1999). "Analytical forced convection modeling of plate fin heat sinks", *IEEE Semiconductor thermal measurement and management symposium*, San Diego, USA, March, pp 34-41.
4. Lee, S. (1995). "Optimum design and selection of heat sinks", *IEEE Semiconductor thermal measurement and management symposium,* San Jose, USA, February, pp 48-54
5. Copeland, D. (2000). "Optimization of parallel plate heat sinks for forced convection", *IEEE Semiconductor thermal measurement and management symposium*, San Jose, USA, March, pp
266-272.
6. T. Stewart and D.W. Stiver (2004). "Thermal optimization of electronic systems using design of experiments based on numerical inputs", *IEEE Semiconductor thermal measurement and management symposium*, San Jose, USA, March, pp 135-142.
7. C.W. Leung and S. D. Probert (1988). "Optimal Length of an array of uniformly spaced vertical rectangular fins protruding upwards from a horizontal base", *Applied Energy*, Vol.
30, pp 29-35
8. Hsien-Chie Cheng, Wen-Hwa Chen, and I-Chun Chung (2004) "Integration of Simulation and Response Surface Methods for Thermal Design of Multichip Modules", *IEEE transactions on components and packaging technologies,* vol. 27, no. 2, June, PP 359 – 372

9. Park, Park-Kyoun Oh, Hyo-Jae Lim (2006), "The application of the CFD and Kriging method to an optimization of heat sink", *International Journal of Heat and Mass Transfer* 49 3439–3447

10. Yu-Tang Chen, Shung-Wen Kang, Wen- Chian Tuh and Tsung-Hsin Hsiao (2004), Experimental Investigation of Fluid Flow and Heat Transfer in Microchannels", *Tamkang Journal of Science and Engineering*, Vol. 7, No. 1, pp. 11-16

11. Bar-Cohen A and Iyengar M (2002), "Design and Optimization of Air-cooled Heat Sinks for Sustainable Development", *IEEE transactions on components and packaging technologies*,
Vol. 25, No. 4, December, PP: 584 – 591 12. Iyengar M and Bar-Cohen A (2001)**,** "A Design for manufacturability of SISE parallel plate forced convection heat sinks", *IEEE transactions on components and packaging technologies*, vol. 24, no. 2, June PP 150 – 158

13. Culhamand J. R and Muzychka Y. S (2001), "Optimization of Plate Fin Heat Sinks Using Entropy Generation Minimization", *IEEE transactions on components and packaging technologies*, vol. 24, no. 2, June PP 159 – 165

14. Parry J, Bornoff R.B, Stehouwer P, Driessen L T, and Stinstra E (2004), "Simulation-Based Design Optimization Methodologies Applied to CFD", *IEEE transactions on components and packaging technologies*, vol. 27, no. 2, June PP 391– 397