CFD ANALYSIS OF HEAT SINK FOR PCM

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ABSTRACT

Heat dissipation techniques are the prime concern to remove the waste heat produced by Electronic Devices, to keep them within permissible operating temperature limits. Heat dissipation techniques include heat sinks, fans for air cooling, and other forms of cooling such as liquid cooling. Heat produced by electronic devices and circuitry must be dissipated to improve reliability and prevent premature failure. Integrated circuits such as CPUs, chipset, graphic cards, and hard disk drives are susceptible to temporary malfunction or permanent failure if overheated. As a result, efficient cooling of electronic devices remains a challenge in thermal engineering.

The main objective of this paper is to reduce the temperature distribution of the heat sink. The CFD analysis is carried out for the heat sink to predict the temperature distribution. Paraffin Wax is used as a Phase Change Material (PCM) due to its latent heat storage capacity. The CFD analysis is carried under two cases, one is heat sink with using PCM another one is without using PCM. The comparative values of temperature is predicted for both the cases.

Keyword: - *Heat dissipation, Heat sink, Fan, Air cooling, Temperature distribution*

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1. INTRODUCTION

Electronics devices and equipment now permeate virtually every aspect of our daily life. Among the most ubiquitous of these is the electronic computer varying in size from the hand held personal digital assistant to large scale mainframes or servers. In many instances a computer is embedded within some other devices controlling its function and is not even recognizable as such. For example in automobiles, space crafts, missiles, satellite etc. The applications of computers vary from games for entertainment to highly complex systems supporting vital heath, economic, scientific, mobile phones, and defense activities.

The dimensions of the instruments also decreasing day by day but simultaneously the number of functions increases as a result the functions per unit volume are increasing hugely, this is most visible in portable electronic component, such as laptops, cell phones, digital cameras and other items around us, where an increasing number of functional components are squeezed into an ever shrinking system box. In a growing number of applications computer failure results in a major disruption of vital services and can even have life threatening consequences. As a result, efforts to improve the reliability of electronic computers or electronics chips are as important as efforts to improve their speed and storage capacity.

Recently the developments concerned with the VLSI technology and MEMS demand the fabrication of electronic chips on a single silicon wafers for which microchannels are to be embedded with these silicon based micro systems. Hence, understanding the heat and fluid flow phenomena through the microchannels are the major thrust area of electronic packaging engineers. The thermal energy developed during the relentless operation of electronics chips is to be dissipated by incorporating efficient heat sinks on the chips. It has been observed that the chip failures are caused primarily due to the temperature rise in the circuits because of accumulation of heat. Hence, microchannel embedded chips are the possible solution to ultra compact electronics gadgets.

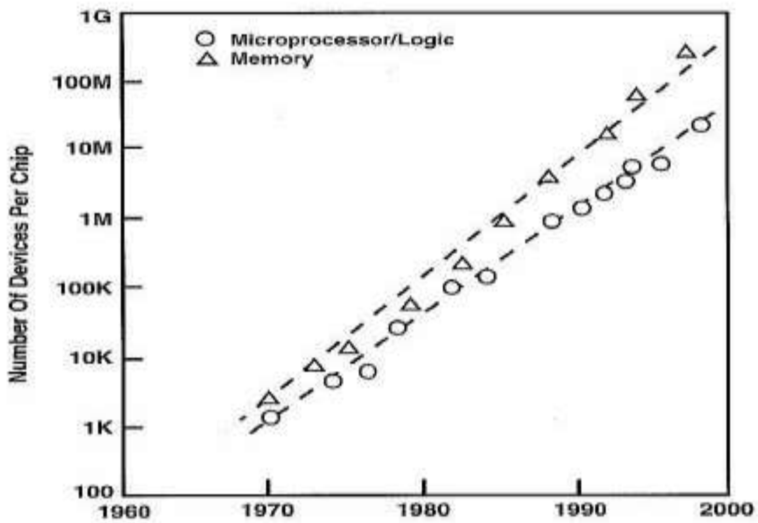


Fig 1.1 Increase in circuit complexity.

Since the development of the first electronic digital computers in the 1940s, the effective removal of heat has played a key role in ensuring the reliable operation of successive generations of computers. The ENIAC, has been described as a ‘‘30 ton, boxcar - sized machine requiring an array of industrial cooling fans to remove the 140 KW dissipated from its 18,000 vacuum tubes’’. As with ENIAC, all early computers used vacuumtube electronics and were cooled with forced air. As a replacement for vacuum tubes, the miniature transistor generated less heat, was much more reliable, and promised lower production costs. For a while it was thought that the use of transistors would greatly reduce if not totally eliminate cooling concerns. This thought was short lived as packaging engineers worked to improve computer speed and storage capacity by packaging more and more transistors on printed circuit boards, and then on ceramic substrates

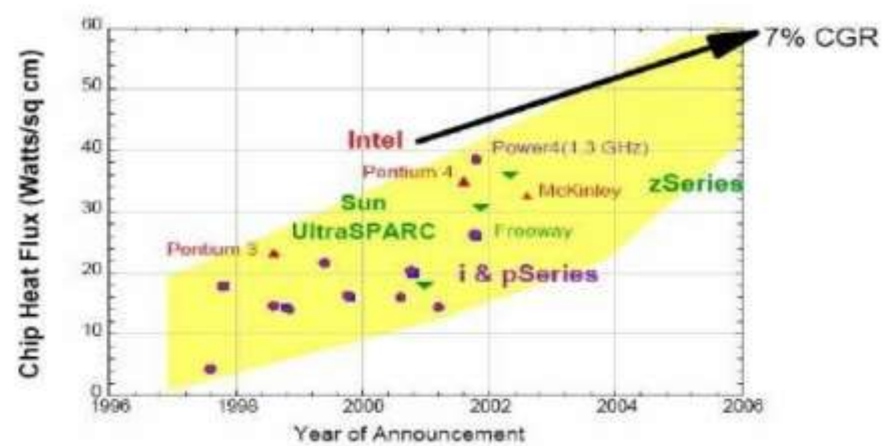


Fig 1.2 The chronological evolution of chip level heat flux.

The trend toward higher packaging densities dramatically gained momentum with the invention of the integrated circuit. During the 1960s SSI and then MSI led from one device per chip to hundreds of devices per chip. The trend continued through the 1970s with the development of LSI technologies offering hundreds to thousands of devices per chip, and then through the 1980s with the development of VLSI technologies offering thousands to tens of thousands of devices per chip. In many instances the trend toward higher circuit density has been accompanied by increased power dissipation per circuit to provide reductions in circuit delay (i.e., increased speed).

The need to further increase packaging density and to reduce signal delay between communicating circuits led to the development of multi chip modules began in the late 1970s and is continuing to this day. It represent the chip heat flux and module heat flux. It can be seen that the chip heat flux increases at a CGR of 7 % per year, and heat flux associated with bipolar circuit technologies steadily increased from the very beginning and really took off in the 1980s.

1.1 NEED FOR ELECTRONIC COOLING

Traditional Thermal Design Requirements

- Design for Performance
- Design for Reliability
- Design for Serviceability
- Design for Extensibility
- Design for minimal Cost
- Design on minimal Impact on User

New Thermal Design Requirement

- Design for improved cool ability at the package level via optimized internal thermal conduction paths.
- Design for direct air cooling at the product level via enhanced convection process over the packages.
- Design for special cooling needs at the module level via spot cooling devices attached to the packages.
- Design for low temperature applications-Sub ambient to cryogenic.
- Design for low cost via CATE and improved manufacturability.

2. DESIGN OF HEAT SINK

Heat sinks, used in electronic devices, usually consist of arrays of pin-fins arranged in an in line manner. 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.

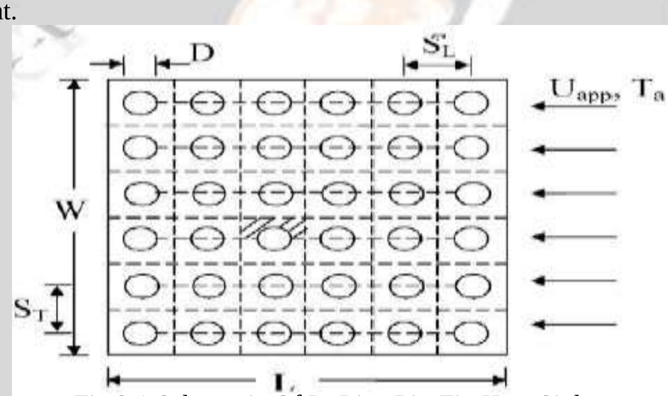


Fig 2.1 Schematic Of In-Line Pin-Fin Heat Sinks

The geometry of an in-line pin-fin heat sink is, 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 xaxis. 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. It is assumed that the heat sink is fully shrouded and the heat source is situated at the centre of the base plate.It is assumed that the fluid temperature is averaged over the height of the heat sink, with Tf = Tf (x), so the fluid temperature Tf (x) is the bulk mean fluid temperature. Fully developed heat and fluid flow are assumed in the analysis, and the thermo physical properties are taken to be temperature independent.

2.1 CALCULATIONS

To form an appropriate model for calculations, the following assumptions are made. The contact resistance between the heat sink and processor would be negligible when using a high quality thermal paste. The average temperature of the air flowing through the heat sink would be 325 K, and used the values of material properties at 325 K. The Intel, core i7970 processor is selected as heat source of 80W, to evaluate the pin fin heat sink performance. Heat transfer coefficient over flate plate

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

Nu = 0.332 ReL0.5 Pr 0.333

Nu= h1L/k; h1 = Nu k/L

2.2 PERFORMANCE ANALYSIS OF HEAT SINKS

The modelling of pin fin heat sinks are made by ANSYS software. This analysis is based on the following assumptions:

- The fins are with adiabatic tip.
- The fluid, air is assumed to be incompressible throughout the process.
- The airflow is normal to the fins.
- Air properties are taken at film temperature.
- The flow is steady, laminar and two dimensional.
- There are no heat sources within the fin itself.
- The radiation heat transfer is negligible.
- The temperature at the base of the fin is uniform.
- The heat flow in the fin and its temperatures remain constant with time. The fin material is homogeneous and isotropic.

The geometry cleanup and surface mesh is done by using ANSA 15.0. The surface mesh count is about 4,337. Then output file is saved for importing to the solver.

Fig.2.2 CAD model of a heat sink

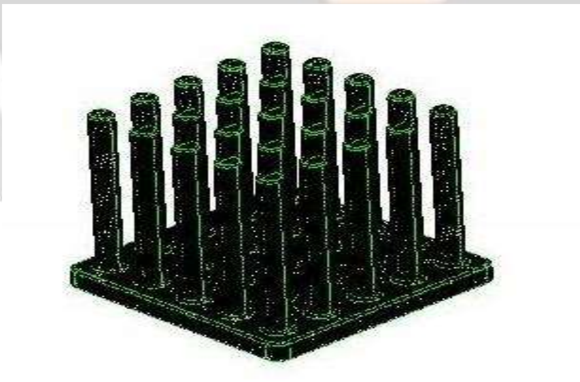


Fig.2.3 Meshing Of Heat Sink

The ANSYS FLUENT 14.5 CFD code was used for the simulations. The simulation procedure was started with preprocessing. 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 underrelaxation factors were first set at low values to stabilize the calculation process, and were increased to speed up the convergence. The normalized residuals were set at 10^4 for velocity components and at 10^7 for energy equation, which proved to be adequate.

3. SECTION MODEL

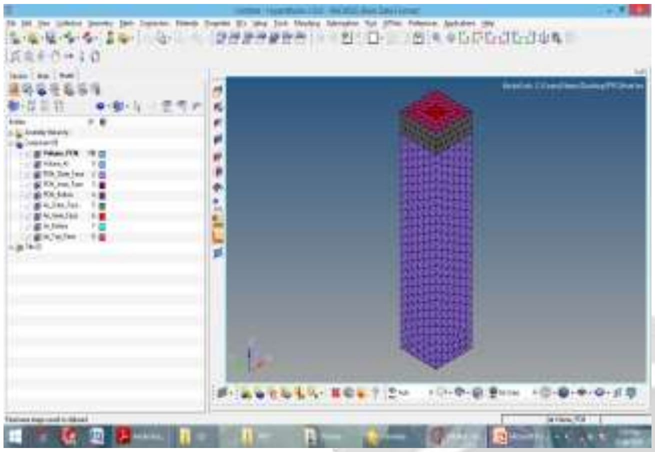


Fig. 3.1(A) Section Model

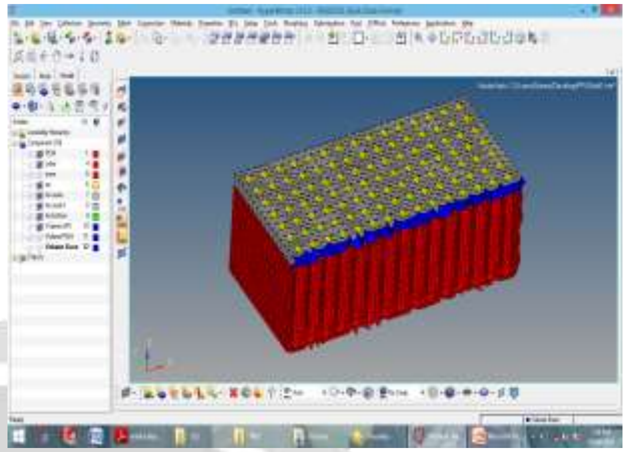


Fig. 3.1 (b) section model

3.1 PROPERTIES OF MATERIALS

Material (kgm3)	Density (kg/m3)	K (w/mk)	Cp (j/kg K)	T (ºC)
Paraffin RT44	760	0.2	2000	43
Aluminium	2719	202.4	871	660
Air	1.225	-	-	-

3.2 GEOMETRICAL DETAILS

- Base Size 70*70
- Fin Height 25 mm
- Fin Width 2 mm
- No Of Fins 100
- Side wall Thick 2 mm

3.3 STATIC PRESSURE

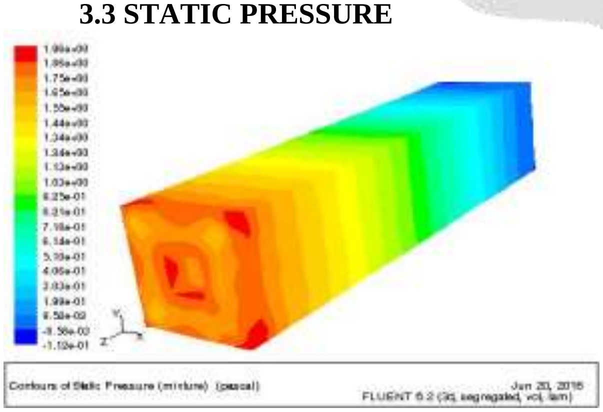


Fig. 3.2(a) static pressure

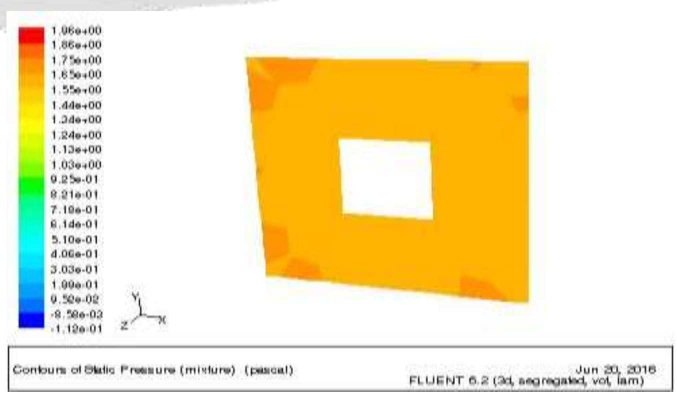


Fig. 3.2(b) static pressure

3.4 STATIC TEMPEATURE

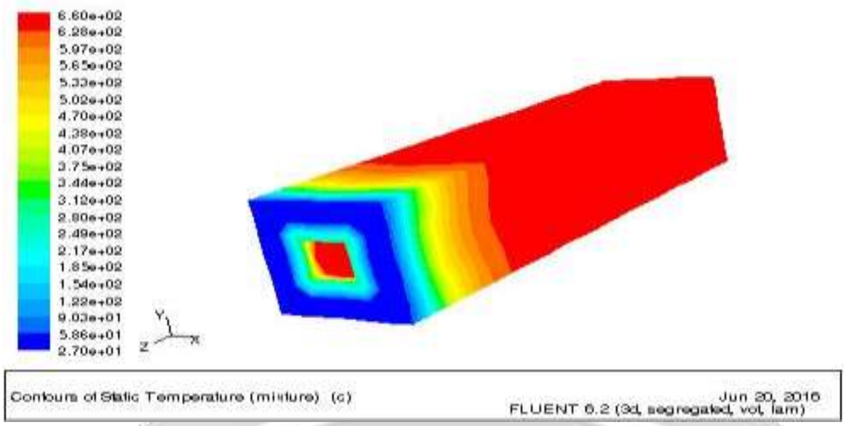


Fig.3.3 Static Temperature

3.5 VELOCITY MAGNITUDE

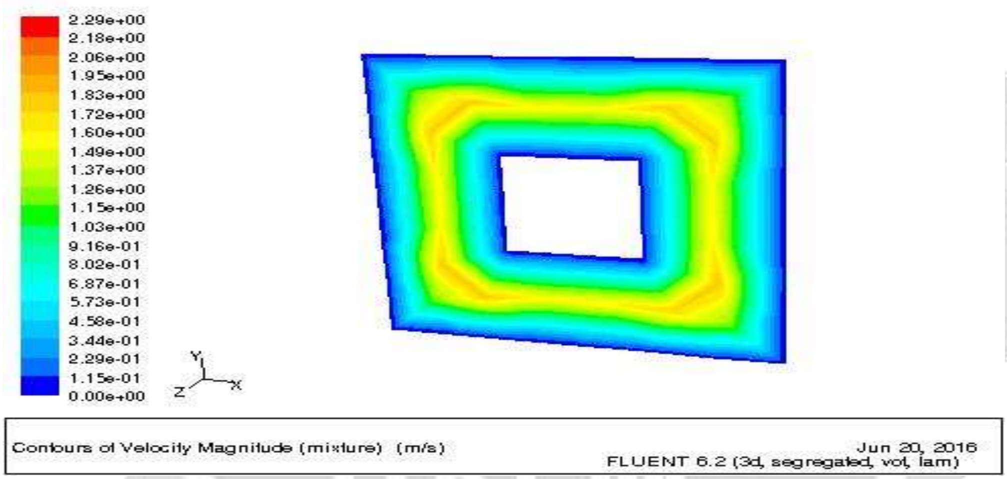


Fig. 3.4 velocity magnitude

3.6 VELOCITY VECTOR

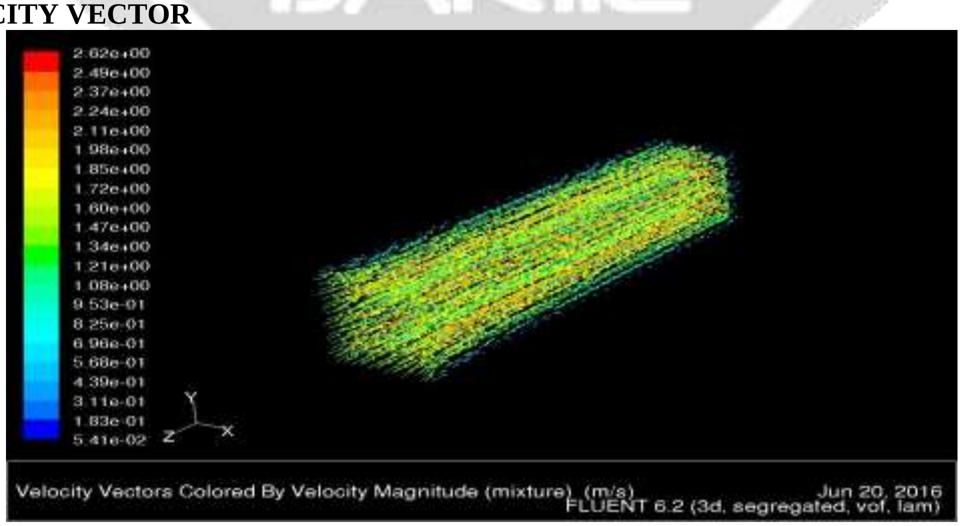
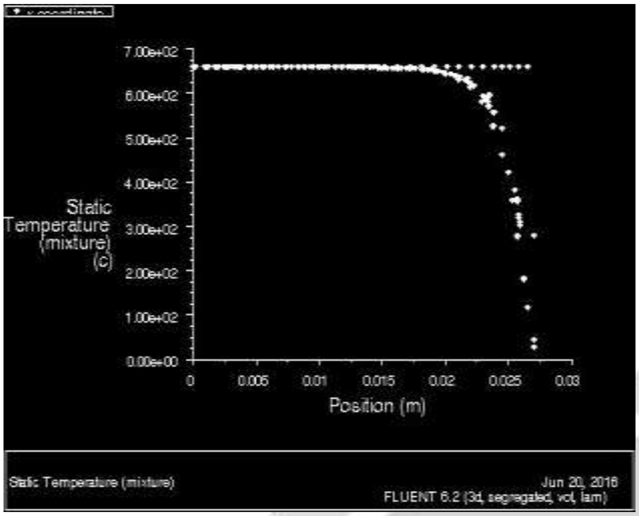


Fig.3.5 Velocity Vector

3.7 STATIC PRESSURE FOR PCM



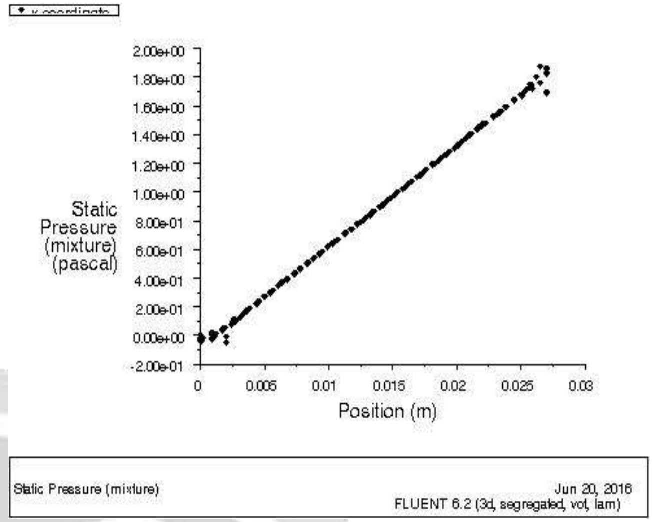


Fig.3.6(a) static pressure for PCM Fig 3.6 (b) static pressure for PCM

3.8 VELOCITY MAGNITUDE FOR PCM

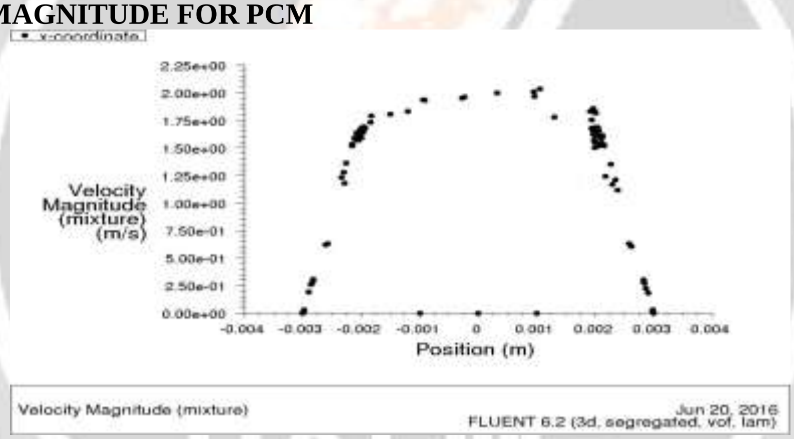


Fig. 3.7 Velocity Magnitude for PCM

The CFD analysis of the heat sink is made for both the cases and the results are shown above. From the result it came to know that heat sink with using Phase Change Material has very low temperature distribution along the heat sink comparing to the another case, because of the Latent Heat Storage capacity of the PCM. Therefore by using the Phase Change Material the temperature can be easily maintaned in the electronic devices.

4. CONCLUSION

In this thesis the CFD analysis is made for a heat sink under two cases, one is without using PCM material and another one is with using PCM material. based on the result obtained a comparative study is made. In both the cases the base plate is made of Copper and the fins are made up of Aluminum. The copper material is used for a base plate is due to the reason that the ability of copper to spread heat rapidly through the base of the heat sink becomes a necessity to ensure the effectiveness of the fins located far away from the heat generating device. The result obtained from the CFD analysis illustrates that, by placing the PCM material inbetween the processor and the base plate, due to the latent heat storage capacity, the PCM material obsorbs the heat generated by the processor. as a final result the heat transfer is limited in the heat sink by placing PCM. The heat sink with out placing PCM material have a normal temperature distribution across the heat sink.

This material is selected due to its thermal conductivity and other physicalproperties which suits for the thermal management system. Finally from the result itcame to know that heat sink with using Phase Change

Material has very lowtemperature distribution along the heat sink comparing to the another case, because ofthe Latent Heat Storage capacity of the PCM.

5. REFERENCES

1. Chen, Han-Ting.,Jenn-Tsong, Horng., Chen, Po-Li. and Hung, Ying-Huei., (2004), "Optimal design for PPF heat sinks in electronics cooling applications", ASME Journal of Electronic Packaging, Vol. 126, pp. 410-422.9. Phillips, R.J., (1990), "Microchannel Heat Sinks", ASME .
2. Cheng, Y.P., Lee, T.S. and Low, H.T., (2006), "Numerical analysis of mixed convection in three-dimensional rectangular channel with flush mounted heat sources based on field synergy principle", International Journal for Numerical Methods in Fluids, Vol. 52, pp. 987-1003.
3. Culham, J.R. and Yovanovich.,(2000), "Thermal characterization of electronic packages using a three-dimensionalfourier series solution", ASME Journal of Electronic Packaging, Vol. 122, pp. 233-239.
4. Haider, S.I., Joshi, Y., Nakayama, K. and Wataru., (2002), "A natural circulation model of the closed loop two phase thermosyphon for electronics cooling", ASME Journal of Heat Transfer, Vol. 124, pp. 881-890.
5. Hung, T.C., Wangi S.K. and Tsai, F.P., (1997), "Simulation of passively enhanced conjugate heat transfer across an array of volumetric heat sources", International Journal for Numerical Methods in Engineering, Vol. 13, pp. 855- 866.
6. Jung, H. H., and Maveety, J. G., "Pin Fin Heat Sink Modeling and Characterization," Sixteenth IEEE Semi-Therm Symposium, IEEE Publications, Piscataway, NJ, March 2000, pp. 260–265.
7. Jung, J.Y. and Kwak, H.Y., (2008), "Fluid flow and heat transfer in microchannels with rectangular cross-section", Heat and Mass Transfer, Vol. 44, pp. 104-1049.
8. Kumara, K.S., Tulapurkaraa, E.G., Biswasb, G. and Gowdac, B.H.L., (2005), "Reverse flow in channel with obstruction at entry", Fluid Dynamic Research, Vol. 37, pp. 387- 398.
9. Wong, H. and Peck, R.E., (2001), "Experimental evaluation of air-cooling electronics at high altitudes", ASME Journal of Electronic Packaging, Vol. 123, pp. 356-365.
10. X.Q. Wang, A.S. Mujumdar, "Transient cooling of electronics using phase change material (PCM)-based heat sinks", Applied Thermal Engineering(2008) 1047–1057.
11. Zhao, C.Y. and Lu, T.J., (2002), "Analysis of microchannel heat sinks for electronics cooling", International Journal of Heat and Mass Transfer, Vol. 45, pp. 4857-4869.