Analysis of Thermal Resistance and Pumping Power of Rectangle Micro Channel Heat Sink for upper Flow with Different Coolant

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Abstract
In this paper we optimise the performance of microchannel heat sink with upper flow arrangement of flow at entrance and exit. The performance of micro channel heat sink is directly affected by the pumping power and the thermal resistance. Here we flow from the upper section and optimise to be very low pumping power and thermal resistance. The aspect ratio and the hydraulic diameter of the microchannel are same for flow arrangement. Fluid flow and heat transfer are investigated on the basis of the simulation of the micro channel with number of channel in rectangular shapes. The aim of this work is to get an impression of the physical behaviour in small elements that enable the development of new liquid cooling systems with higher cooling ability and higher effectiveness.

Index terms— upper flow arrangement, micro channel, very low pumping power and thermal resistance.

1 Introduction

ince the pioneering work of Tuckerman and Pease [1] in 1981, many studies have been conducted on micro-channel heat sinks as summarized by Phillips [2] and more recently, by Morini [3]. The need for cooling in high power dissipation (100 W/cm 2) systems in several scientific and commercial applications such as microelectronics requires something beyond the conventional cooling solutions. A number of studies have investigated the thermal design optimization of micro-channel heat sinks to determine the geometric dimensions that give optimum performance. For the heat transfer study purpose, the channel walls were assumed to behave as fins. With the increasing heat production of electronic devices, the air cooling technology reaches its limits, whereas liquid cooling represents a promising opportunity to develop cooling devices with much higher heat transfer coefficient. Today's rapid IT development requires high PC performance capable of processing more data and more speedily. To meet this need, CPUs are assembled with more transistors, which are drawing more power and having much higher clock rates. This leads to an ever-larger heat produced by the CPU in the computer, which will result in a shortened life, malfunction and failure of CPU. The reliability of the electronic system will suffer if high temperatures are permitted to exist. Therefore, removal of heat has become one of the most challenging issues facing computer system designers today. However, conventional thermal management schemes such as air-cooling with fans, liquid cooling [4], thermoelectric cooling [5][6][7][8][9], heat pipes [10], vapour chambers [11], and vapour compression refrigeration [12] have either reached their practical application limit or are soon become impractical for recently emerging electronic components. Therefore, exotic approaches were regarded as an alternative to these conventional methods in sufficient for cooling further high power processors.

As the fluid is passing through the different section of the micro channel the distribution of the fluid in the passage is disturb the flow condition of the fluid that affect the velocity and thermal boundary layer of the flow. As flow is reached fully developed there is no change in the velocity of the fluid layer. The thermal and velocity boundary layer are playing an significant role in the fluid flow in micro channel. The different shapes of micro channel are used to dissipate the large amount of heat from the system or electronic circuit. As a practical cooling fluid, the liquid metal must satisfy the following requests: non-poisonous, non-caustic material, low viscosity, high thermal conductivity and heat capacity. Most studies in this approach employed the classical fin theory which models the solid walls separating microchannels as thin fins. The heat transfer process is simplified as one-dimensional, constant convection heat transfer coefficient and uniform fluid temperature. However, the nature of the heat transfer process in MCHS is conjugated heat conduction in the solid wall and convection to the cooling fluid. Using a nano fluid as the heat transfer working fluid has gained much attention in recent years. Xuan and Roetzel (2000) proposed two theoretical models to predict the heat transfer characteristics of nano fluid flow in a tube. Li and Xuan (2002), Xuan and Li (2003) and Pak and Cho (1998) experimentally measured the convection heat transfer and pressure drop for nano fluid tube flows. Their results indicated that the heat transfer coefficient was greatly enhanced and depended on the flow Reynolds number, particle Peclet number, particle size and shape, and particle volume fraction. These studies also indicated that the presence of nano particles did not cause an extra pressure drop in the flow. Recently, Yang et al. (2005) carried out an experimental study attempting to construct a heat transfer correlation among the parameters that affected heat transfer. For a laminar flow regime in a circular tube, they indicated that the heat transfer effective for the nano fluid flow had a lower increase than predicted by either the conventional heat transfer correlation for the homogeneous or particle-suspended fluid. Ding et al. (**??**006) reported heat transfer effective data for the force convection in circular tubes using carbontube (CNT) nano fluid. In most of the studies mentioned above, the nano fluid heat transfer flow characteristics were carried out in macro-scale dimensions. Only a few studies addressed the nano fluid flow and heat transfer in micro-scale dimensions. CHEIN AND HUNAG (2005) EMPLOYED a macro-scale correlation to predict micro channel heat sink performance. In experimental aspect, Chein and Chuang (2007) studied the general behaviour heat sink performance and particle deposition effect when nano fluid is used as the working fluid. In the study of lee and mudawar (2006), al2o3-h2o nanofluid was used as working fluid. They pointed out that the high thermal conductivity of nano particles can enhance the singlephase heat transfer coefficient, especially for the laminar flow. Due to complicated heat transfer phenomena and large variety in nano fl uids further studies on nano fluid flow and heat transfer characteristics in micro-scale dimensions are still necessary. In this study, thermal resistance characterizing MCHS performance using nano fluids as coolants are investigated. We particularly focus on the microchannel geometry effect on the MCHS performance when nano fluid is used as the working fluid. Although micro -channel heat sinks are capable of dissipating high heat fluxes, the small flow rate produces a large temperature rise along the flow direction in both the solid and cooling fluid, which can be damaging to the temperature sensitive electronic components. Therefore, more sophisticated predictions of the temperature field are essential for an effective micro-channel heat sink design. A more accurate description of the heat transfer characteristics can only be obtained by direct numerical simulation of three dimensional fluid flow and heat transfer in both the solid and cooling fluid.

2 II.

3 Analysis Procedure

The micro Channel heat sink modelled in this investigation consists of three arrangement of fluid flow. The fluid is flow through the front, upper and the side of the channel there are two shape of micro channel heat sink are used. One is the rectangular shape and another is the trapezoidal shape are used. The aspect ratio and the hydraulic diameter for the rectangle and trapezoidal micro channel heat sink are assumed to be same. The arrangement of fluid flow is from the different sections are the front, upper and the side of the micro channel. The two different fluids are used one is the water and another is nano fluid with thermal conductivity 10 times of water. This investigation has to be carried out for the high performance of the micro channel.

These studies can help to clarify some of the variations in the previously published data and provide a fundamental insight into thermal and fluid transport process occurring in the microchannel heat sinks designed for electronic cooling and other application.

The analysis is based on the following assumptions:

To simplify the analysis, the following assumptions are made in modelling the heat transfer in micro channels of the present study:

? Steady state flow.

? Incompressible fluid.

? Laminar flow.

? Constant properties of both fluids and solid.

? Effects of viscous dissipation are negligible.

4 III.

5 Mathematical Formulation

The combination of the thermal resistance models and the optimisation algorithm served as useful tool in the design of the micro channel heat sink. The thermal resistance in the heat sink arises from three sources: conduction resistance in the heat sink, including the fin effects; convection resistance between the micro channel surfaces & the coolant & the resistance due to the temperature arise of the cooling fluid.

6 Rth= Rcond+Rconv+Rcap

(1)

The total thermal resistance is calculated:Rth=Tmax-Tmin/Q (2) ? = v.Î?”p**(3)**

IV.

7 Computational Domain

A schematic of the rectangular micro channel heat sink is illustrated with upper flow arrangement.

8 Results and Discussion

9 Conclusion

This all analysis is done on the basis of simulation for the rectangular shape of micro channel heat sink for upper flow arrangement to investigate the role of thermal resistance and pumping power.

? In this investigation concluded that comparisons between the water and custom nano fluids having thermal conductivity 10 times more of water for rectangular shape of micro channel heat sink for upper flow to predetermining the effect of pumping power and thermal resistance. ? Thermal resistance and pumping power are the parameters that are depend upon the geometrical and flow parameters. ? In this investigation water shows most predominant results as compare to the custom nano fluid. ? From this investigation we conclude that there is very low value of thermal resistance and a low pumping power is required for the coolant used as water.

VII.

10 Nomenclature

A Area exposed to heat transfer c p Specific heat (J kg? 1 K? [1]

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Figure 1: Fig. 1 :

[1] Analysis of Thermal Resistance and Pumping Power of Rectangle Micro Channel Heat Sink for upper Flow with Different Coolant

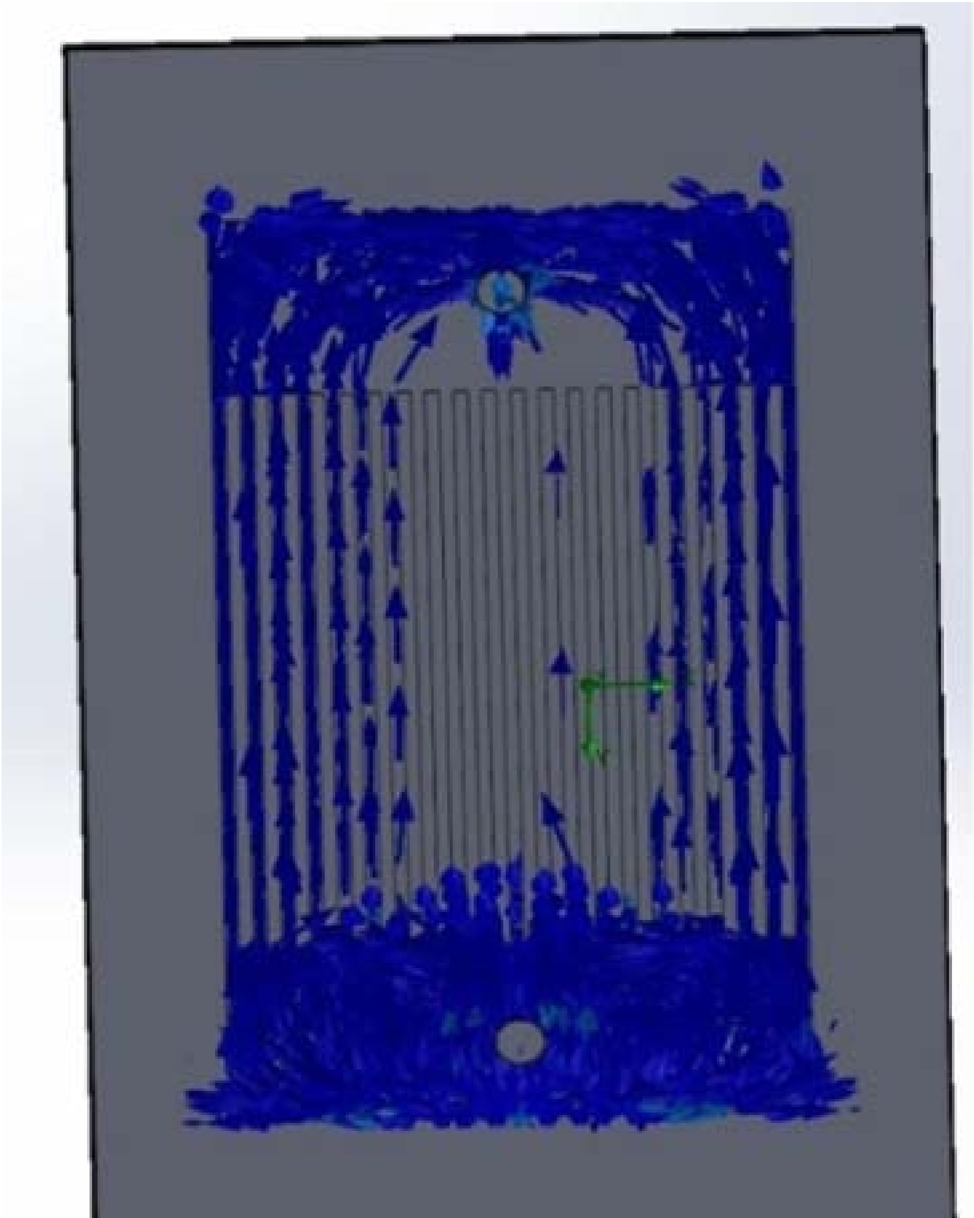

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Figure 2: Fig. 2 :Fig. 3 :Fig. 4 :Fig. 5 :

[Yang et al. ()] , Y Yang , Z Zhang , E A Grulke , W B Anderson . 2005. (Heat transfer properties)

[Koo and Kleinstreuer ()] 'A new thermal conductivity model for nano fluids'. J Koo , C Kleinstreuer . *Journal of Nanoparticle Research* 2004. 6 p. .

[Simons and Chu ()] 'Application of thermoelectric cooling to electronic equipment: a review and analysis'. R E Simons , R C Chu . *Annual IEEE Semiconductor Thermal Measurement and Management Symposium* 2000. p. .

[Lee and Mudawar ()] 'Assessment of the effectiveness of nano fluids for single -phase and two-phase heat transfer in micro-channels'. J Lee , I Mudawar . 10.1016/ijheatmasstransfer.2006.08.001. *International Journal of Heat and Mass Transfer* 2006.

[Xuan and Roetzel ()] 'Conceptions for heat transfer correlation of nanofluids'. Y Xuan , W Roetzel . *International Journal of Heat and Mass Transfer* 2000. 43 p. .

[Li and Xuan ()] 'Convective heat transfer and flow characteristics of Cu-water nano fluid'. Q Li , Y Xuan . *Science in China E* 2002. 45 p. .

[Strassberg ()] *Cooling hot microprocessors*, D Strassberg . 1994. 39.

[Qu and Mudawar ()] 'Experimental and numerical study of pressure drop and heat transfer in a single-phase microchannel heat sink'. W Qu , I Mudawar . *International Journal of Heat and Mass Transfer* 2002. 45 p. .

[Lv et al. ()] 'Experimental validation of a conceptual vapour-based air-conditioning system for the reduction of chip temperature through environmental cooling in a computer closet'. Y G Lv , Y X Zhou , J Liu . *J Basic Sci Eng* 2006. (preliminarily accepted)

[Phillips ()] *Forced Convection, Liquid Cooled, Micro channel Heat Sinks*, R J Phillips . 1987. Cambridge MA. Massachusetts Institute of Technology (M. S. Thesis)

[Wang and Mujumdar ()] 'Heat transfer characteristics of nano-fluids: a review'. X Wang , A S Mujumdar . *International Journal of Thermal Sciences* 2007. 46 p. .

[Tuckerman and Pease ()] 'High-performance heat sinking for VLSI'. D B Tuckerman , R F W Pease . *IEEE Electron Device Letters* 1981. 2 p. .

[Pak and Cho ()] 'Hydrodynamic and heat transfer study of dispersed fluids with submicron metallic oxide particles'. B C Pak , Y L Cho . *Experimental Heat Transfer* 1998. 11 p. .

[Xuan and Li ()] 'Investigation on convective heat transfer and flow features of nanofluids'. Y Xuan , Q Li . *ASME Journal of Heat Transfer* 2003. 125 p. .

[Koo and Kleinstreuer ()] 'Laminar nano fluid flow in micro heat sinks'. J Koo , C Kleinstreuer . *International Journal of Heat and Mass Transfer* 2005. 48 p. .

[Lundquist and Carey ()] 'Microprocessorbased adaptive thermal control for an air-cooled computer CPU module'. C Lundquist , V P Carey . *Annual IEEE Semiconductor Thermal Measurement and Management Symposium*, (San Jose) 2001. p. .

[Semeniouk and Fleurial ()] 'Novel high performance thermoelectric micro coolers with diamond substrates'. V Semeniouk , J P Fleurial . *Proceedings of the 1997 16 th International Conference on Thermo electrics*, (the 1997 16 th International Conference on Thermo electricsDresden) 1997. 1997. p. .

[Morini ()] 'Single-phase convective heat transfer in micro-channels: overview of experimental results'. G L Morini . *Int. J. Thermal Sci* 2004. 43 p. .

[Wang et al. ()] 'Thermal conductivity of nanoparticle-fluid mixture'. X Wang , X Xu , S U S Choi . *Journal of Thermophysics and Heat Transfer* 1999. 13 p. .

[Disalvo ()] 'Thermoelectric cooling and power generation'. F J Disalvo . *Science* 1999. 285 p. .

[Li et al. ()] 'Threedimensional analysis of heat transfer in a micro-heat sink with single phase flow'. J Li , G P Peterson , P Cheng . *InternationalJournal of Heat and Mass Transfer* 2004. 47 p. .

[US) Guidelines Handbook Global Journals Inc ()] 'US) Guidelines Handbook'. `www.GlobalJournals.org` *Global Journals Inc* 2015.

[Nquyen et al. ()] 'Use of heat pipe/heat sink for thermal management of high performance CPUS'. T Nquyen , M Mochizuki , K Mashiko , Y Saito , L Sauciuc . *Annual IEEE Semiconductor Thermal Measurement and Management Symposium* 2000. p. .

[Xie et al. ()] 'Use of heat pipes in personal computers. Thermo mechanical Phenomena in Electronic Systems'. H Xie , A Ali , R Bhatia . *Proceedings of the Intersociety Conference*, (the Intersociety ConferenceSeattle) 1998. p. .