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A Review of Microchannel heat sink

[1]Vedulla Manoj Kumar, [2]Sk. Farooq, [3]B Nageswara Rao

[1]*VFSTR University, Department of mechanical engineering,PG Scholar, VFSTR University, Guntur-522213, AP, India.*
[2]*VFSTR University, Department of mechanical engineering,Assistant Professor, VFSTR University, Guntur-522213, AP, India.*
[3]*VFSTR University, Department of mechanical engineering,Associate Professor, VFSTR University, Guntur-522213, AP, India*

Address For Correspondence:
Vedulla Manoj Kumar, Department of mechanical engineering, PG Scholar, VFSTR University, Guntur-522213, AP, INDIA
Mobile no: 9985651441, E-mail: manojlike225@gmail.com

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ABSTRACT

Background: The interest in micro-technologies has increased in the last decades, because of the low volumes and high performance granted by their application. Today's electronic components are required to perform tasks at a faster rate, and so high-powered integrated circuits have been produced in order to meet this need. In order to solve this problem, microchannel heat sinks were introduced in 1981 by Tuckerman and Pease and have since been the study of many researchers in the field of fluid mechanics. Objective: The research work summarized in this paper presents aanalytical investigation of various aspects of heat transfer enhancement by the use of microchannel heat sink is presented. Results: A review article is presented for determining optimum microchannel heat sink conditions by the consideration of both heat transfer characteristics and fluid dynamics. In this paper we discussed about the possible future directions of research that may be followed in order to obtain greater understanding of microchannel heat sinks.

INTRODUCTION

Microchannel heat sinks constitute an innovative cooling technology for the removal of a large amount of heat from a small area. Heat sinks have long been used for cooling of electronic components to maintain them under the maximum allowed operational temperature. Forced air cooling with heat sink is suitable and enough efficient for low power applications cooling. The spacing for housing the heat sink is often limited in electronic devices, and the air flow rate is also limited by the maximum allowable acoustic noise and fan power consumption. Therefore, the main design concern is to find the best heat transfer medium (or heat sink) which can maximize the heat dissipation with the volume of heat sink and operating condition of the cooling fan fixed. The heat dissipation of a heat transfer medium is a complex function of many factors, e.g., available heat transfer area, heat conduction, interstitial heat transfer coefficient, and flow resistance characteristics. The importance of heat transfer enhancement has gained greater significance in such areas as microelectronic cooling, especially in central processing units, macro and micro scale heat exchangers, gas turbine internal airfoil cooling, fuel elements of nuclear power plants, and bio medical devices.

Currently, researchers emphasize on theheat transfer enhancement of microchannel heat sink. It is due to microchannel heat sinks have many advantages including automotive and stationary fuel cells as well as electronics cooling (Rao T., 2001), The implementation of microchannel heat sinks in a notebook computer was discussed by (Pokharnaetal *et al.*, 2004), Recent research work is going about the developments on incorporating flow boiling in microchannels for cooling of electronic devices (Satish G. Kandlikar., 2014).

The main objective of this work is to investigate various aspects of heat transfer enhancement by the use of microchannel heat sink is presented.

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2. Geometry of microchannels:

The proposed design consists of a manifold system with lateral fluid supply-and-return which feeds an array of parallel microchannels where the heat transfer is performed (seeFig.1).

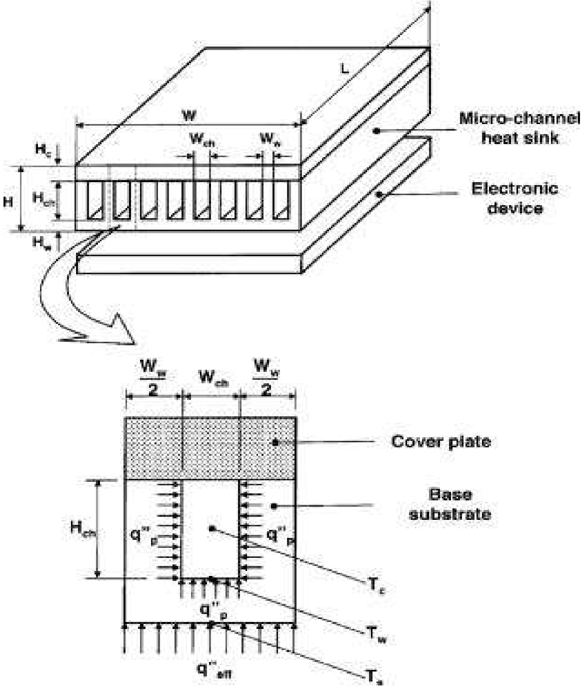

Fig. 1: Schematic diagram of microchannel heat sink

Fluid enters the inlet manifold channels from the side. Along the inlet manifold channels the flow uniformly branches into the subsequent heat transfer structures through slit nozzles at the bottom wall of the manifold channels. The parallel micro-channels are orthogonal to the manifold channels. Hence, the flow direction after impingement on the hot surface at the bottom of the heat transfer channels is perpendicular to the one of the manifold system. While traveling along the heat transfer micro-channels the fluid removes the heat, leaves the heat transfer micro-channel structure upwards, through slit nozzles and merges into the outlet manifold channels which guide the fluid to a lateral return (see Fig. 1). The entire chip area can be cooled by just one of these systems.

3. Literature Review of microchannels:

The challenge of heat removal is very prevalent in nature and usually crucial in many engineering applications. With the advance of the modern micro-electronics industry, efficient removal of ever increasing heat flux has become a major challenge for the thermal engineers. Heat flux of several electronics devices have already reached 100 W/cm2 (Bar-Cohen, A., *et al.*, 2007), which once was thought to be too high. The trends to miniaturize the electronic devices and to increase packaging density are increasing very fast specially for the defense equipment related electronics, i.e. radar, laser weapons, etc. where 1000 W/cm2 becomes a reasonable heat removal target (Mudawar, I., *et al.*, 2009). which exceeds capability of the most advanced cooling solutions. To keep pace with the current growth trend of the microelectronics devices, efficient, reliable and user level applicable thermal management solution is necessary which is capable of dissipating large amount of heat load from a nanometer size chip with surface temperature less than a prescribed value; i.e. 1250C for defense application (Jaeseon, L. and I. Mudawar, 2008) and less than 1000C for general microelectronics. Micro-channel heat sinks constitute a powerful means for dissipating large amounts of heat from small surfaces. They possess several unique attributes that make them prime contenders for the next generation of coolers for high performance computer processors and laser diodes. A typical heat sink contains a large number of small diameter coolant channels. Liquids such as water and fluorochemicals are two types of coolant that are favored with micro-channel heat sinks. Heat sinks are classified into single-phase or two-phase according to whether boiling of liquid occurs inside the micro channels.

Microchannel heat sink introduced in early 1980s by Tuckerman and Pease (Tuckerman, D.B. and R.F.W. Pease, 1981) can enhance single-phase heat transfer rate significantly compared to the conventional channel by increasing surface area to volume ratio and reducing convective heat transfer thermal resistance, their pioneering work has motivated many researchers to focus on the topic and micro channel flow has been recognized as a high performance heat removal tool ever since. However dissipation of increased heating load in single-phase convective flow in microchannel is limited by its cost, high pressure drop and high temperature gradient along the flow direction and sometimes become impractical to implement. Thermal and fluid performance for micro channel heat sinks can be modeled with Reynolds numbers, apparent friction factors, Nusselt numbers, and parameters that describe the thermal and fluid performance of the coolant. The thermal performance depends, in part, on whether the coolant flow is laminar or turbulent. The Reynolds number, Re, which is the ratio of inertial to viscous fluid forces, Can be used to estimate the transition between laminar and turbulent flow (Richard j. Phillips, 1988). The flow dynamics and heat transfer characteristics of a microchannel heat sink were investigated numerically. The key findings from the study are Pressure drop increases with increase in Reynolds number and pressure drop along the channel is linear with the assumption of constant viscosity. Maximum temperature in the heat sink is encountered at the bottom of the sink immediately below the channel outlet. Temperature of the heat sink can be reduced by increasing the flow rate of coolant. The heat flux and Nusselt number is much higher near the channel inlet and varies around the channel periphery approaching zero at the corners of rectangular microchannel (Md. Emran and Mohammad Ariful Islam, 2014). The heat transfer and pressure drop a flat tube in a cross flow of air have been experimentally study. This paper examines the impact of two parameters on the average heat transfer coefficient and friction factor for air flow over single flat tube. It can be summarized that the experimental results are drawn the heat transfer coefficient increase almost linear with increase heat flux supply for all free stream velocity. The average Nusselt number increase with increase Reynolds number with any heat flux supply tested. The pressure drop increased and friction factor decrease with increasing of free stream velocity (Tahseen Ahmad Tahseen, M.M. Rahman and M. Ishaka, 2015). These experimental studies sought to : i) develop Nusselt- Reynolds number correlations so that convective heat transfer coefficients could be defined for individual modules, ii) highlight the sensitivity of component heat transfer to module position relative to the PCBs leading edge, iii) quantify the effect of introducing channel flow disturbances on module temperature, and iv) mea- sure the adiabatic temperature rise of passive neighboring or downstream modules for different PCB configurations and air velocities (Lohan, J., M. Davies and R. Cole, 1997). Khan *et al*. (2004) Investigated experimentally of the heat transfer by forced convection of air cross flow over one in-line elliptical tube configuration with the minor-to-major axis ratio of 0.33 and at the horizontal plane of attack. The results indicated that the increased heat transfer rate with an increase of both air and water flow. Chang and Mills (Ishak, M., *et al*., 2013) have experimental studies of the impact of aspect ratio on heat transfer by forced convection from a circular tube in the air cross-flow. The result of the study shows that the mean heat transfer coefficient raises with reduction the aspect ratio. The heat transfer and pressure investigation experimental both in-line and staggered flat tube configuration by Tahseen *et al*. (2012), Ishak *et al*. (Tahseen, T.A., M. Ishak, M.M. Rahman, 2012). From the studies shows the effect of heat flux supply, the front free-stream velocity of air flow on the heat transfer coefficient. In the other hand, show the effect of Reynolds number on the pressure drop of cross flow. The results indicate the Nusselt number increase always with an increase of Reynolds number. Tahseen *et al*. (2012,2012) have 2–D numerical studies incompressible, steady state flow and using the body fitted coordinate (BFC). The first study heat transfer over a two flat tube staggered and second study the heat transfer over series in-line flat tube between parallel plate channel. The two studies show effects of the Reynolds number on the heat transfer coefficient. The results revealed that the heat transfer coefficient increase with an increase of Reynolds number always. This paper presents recent advances in a number of novel, high-performance cooling techniques for emerging electronics applications. Critical enabling thermal management technologies covered include microchannel transport and micropumps, jet impingement, miniature flat heat pipes, transient phase change energy storage systems, piezoelectric fans, and prediction of interface contact conductance (Kim, S.J., D. Kim, 1999). This study describes the demonstration and analysis of a platform for thermal management studies of microelectronics cooling methods. The platform consists of an aluminum base with a heater cartridge inserted to simulate the microelectronics heat source. In this study, the platform is first demonstrated for testing of phase change materials as a cooling method for microelectronics. The results of the analysis indicate the applicability of a lumped parameter model for platforms of the type presented in this study. Furthermore, the results quantify the applicability of the zero flux boundary condition often assumed for thermal management studies and also show that, as the area of the insulated portion of the platform increases, the thermal response time increases due to the decrease in the surface area for heat transfer (SeokPil Jang, Sung Jin Kim, 2005).

In this study, four heat sinks with various microchannel structures are designed and heat-flow coupling is investigated in electronic chip cooling to search for the heat and flow peformence of microchannel structure. It is testified that the microchannel’s structure has a significant influence on electronic chips cooling via the theoretic analysis and numerical computation of flow and heat exchange characteristics. The heat sink with tree-like microchannel can take away the most heat at the same inlet flow rate. The temperature of electronic chip cooled by it is the minimum and uniform. The minimum heat flux of the fluid is at the center of channel. The heat flux of the fluid linealy increases with the location varies from the channel center to channel wall, which is more than 500%. Comparison with other structures, the temperature of chip cooled by tree-like heat sink is lower. But it will lead to higher flow pressure drop than that of paralell and reticular structure, 90kPa and 97kPa, expectively. Another factor of enhancing heat dissipation is to increase the average flow speed of microchannel heat sink in the condition of the same pump power. Hence, we may refer to these conclusions in designing the structure of microchannel heat sink by using the objective function of the uniform and maximum flow rate or minimum flow pressure drop (Khalil AzhaMohdAnnuar, *et al*., 2015). experiments have been performed to show that conventional correlations for fluid flow and heat transfer adequately predict the behavior in microchannels of hydraulic diameters as small as 250 µm. Pumping requirements of microchannel heat sinks have been analyzed, and the size of the microchannels have been optimized for minimum pumping requirements (Suman Kumar Jha, S. *et al*., 2016). In this paper, analytical solutions for velocity and temperature distributions through microchannel heat sinks are presented by modeling the microchannel heat sink as a fluid-saturated porous medium. The analytical solutions are obtained based on the modified Darcy model for fluid flow and the two-equation model for heat transfer (Sivapragasam, A., *et al*., 2014]. In this paper, we study heat transfer and fluid flow in a micro- channel heat sink subject to an impinging air jet. This type of heat sink retains the high heat transfer coefficient associated with the typical microchannel heat sink and experiences a low pressure drop compared to the microchannel heat sink with a parallel flow (Shugata Ahmed, *et al*., 2014).

The advancement of microelectronics technology in producing high clock speed and power density's central processor unit (CPU) indirectly related to thermal management issue (Mehdi Nafar and Mohammad Tavassoli, 2011). Electronic devices are very sensitive to heat and the temperature above the limit would harm the system very badly (Irfan AnjumBadruddin, *et al*., 2014). It is possible to design a new heat sink with a suitable base plate which has better thermal performance and uses less material using CFD simulations (Mustafa Koz, *et al*., 2011). Simulation of flow boiling in double-layer microchannel heat sink has been performed and they concluded the two-phase heat transfer coefficient augments with applied heat flux. However, a decreasing trend has been observed after achieving critical heat flux (CHF). For the considered channel, it is observed that CHF is $550 \times 104Wm-2$. Two-phase heat transfer rate also increases with wall temperature rise until CHF is achieved. Highest heat transfer rate is 6.4 W (Fangjun Hong', Ping Cheng, 2009). Actual convection flow velocity through fins is usually unknown to designers. By input of the Biot number Bi, heat transfer coefficient ratio, H and the shape parameter, the heat transfer equation which is expressed in implicit form can be solved by iterative method to calculate the optimum fin length and fin thickness (Zeighami, R., *et al*., 2000). From this analysis they addressed that the increased length of heater increases the fluid velocity inside the medium and found that the Nusselt number increases with increase in the length of the heater (Adewumi, O.O., *et al*., 2000).

Micro heat sinks have a broad applicability in many fields such as aerospace applications, micro turbine cooling, micro reactors, electronics cooling, and micro biological applications. Among different types of micro heat sinks, those with micro pin-fins are becoming popular due to their enhanced heat removal performance. However, relevant experimental data in current literature is still scarce to adequately explain their differences from their macro size counter parts. In previous studies in literature, it was shown that thermal and hydrodynamic characteristics of micro pin-fin heat sinks are strongly affected by height over diameter (H/D) ratio of pin-fins. To address the lack of information about this subject, the objective of this work is to show how velocity boundary layer around pin-fins and consequently, the thermal and hydrodynamic characteristics are affected when H/D ratio and local Reynolds number (Re) vary. In this paper, the pin-fin height over diameter ratio, H/D, varies from 0.5 to 5, while Reynolds number and heat flux provided from the fluid interacting surfaces of the micro pin-fin are in the range of $20 \leq Re \leq 150$ and $100 \leq q_{in}(\mathrm{W/cm^2}) \leq 500$, respectively. In this research, micro pin-fin heat sinks are three dimensionally modeled on a one-to-one scale with the use of commercially available software COMSOL Multiphysics 3.5a. Full and temperature dependent Navier–Stokes equations subjected to compressibility and energy equations are solved under steady state conditions (Rahman, M.M.,). This paper presented a numerical study on laminar forced convection of water in offset strip-fin micro channels network heat sinks for microelectronic cooling. A 3-dimensional mathematical model, consisting of N–S equations and energy conservation equation, with the conjugate heat transfer between the heat sink base and liquid coolant taken into consideration is solved numerically. The heat transfer and fluid flow characteristics in offset strip-fin micro channels heat sinks are analyzed and the heat transfer enhancement mechanism is discussed. Effects of geometric size of strip-fin on the heat sink performance are investigated. It is found that there is an optimal strip-fin size to minimize the pressure drop or pumping power on the constraint condition of maximum wall temperature, and this optimal size depends on the input heat flux and the maximum wall temperature. The results of this paper are helpful to the design and optimization of offset strip-fin microchannel heat sinks for microelectronic cooling (Steinke, M.E and S. G. Kandlikar, 2006). Zeighami *et al*. (Lee, P.S. and S.V. Garimella, 2006) studied transition from laminar to turbulent flows for water in microchannel heat sinks. Previous work indicates that flow transition occurred at a transition Reynolds number lower than 2200, which is the transition Re at the macroscale. Low transition Reynolds numbers could be due to surface roughness, viscous heating, and/or the electric double layer. Until now, analytical work has not been able to determine the transition Reynolds number at the microscopic level. This transition number can only be studied experimentally. Using microresolution particle image velocimetry, Zeighami *et al*. generated vector fields in a microchannel measuring 150 µm × 100 µm × 1 cm. Velocity fields at Reynolds numbers of 200, 720, 1200, and 1600 were generated. Except for the case where Re = 1600, all fields seemed steady and parallel. When Re = 1600, the flow began to show some turbulent behavior. The velocity fields temporally fluctuated and became more asymmetric. This paper presents a three-dimensional numerical study of steady, laminar, incompressible flow and forced convection heat transfer through a microchannel heat sink with micro pin fin inserts for both fixed and variable axial lengths. The objective of the study was to optimise the geometric configuration of an integrated microchannel and micro pin fins for different solid volumes so that the peak temperature in the configuration was minimised. The geometric optimisation of the integrated microchannel and micro pin fin was carried out using a computational fluid dynamics (CFD) code with a goal-driven optimisation tool subject to global constraints. The optimisation procedure was carried out in two steps. Firstly, the microchannel configuration was optimised without the micro pin fins inserted and the results were compared with similar work found in the open literature. This optimisation was carried out for both fixed and relaxed lengths. Thereafter, the integrated design of the microchannel and micro pin fins was optimised. Results showed that as the Bejan number increased, the minimised peak temperature decreased. Also, the maximum thermal conductance increased with the optimised microchannel structure with three to six rows of micro pin fin inserts. Diminishing return set in when the number of rows of micro pin fin inserts was greater than three for the fixed length but for the relaxed length, as the number of rows increased, the results improved but when it exceeded six diminishing returns set in for a fixed solid volume of 0.9 mm^3. For each Bejan number used in this study, there was an optimum channel hydraulic diameter and aspect ratio, solid volume fraction and pin fin aspect ratio that satisfied the global objective (Mishan, Y., *et al.*, 2007). Rahman (Xu, J.L., Y.X. Song, 2008) experimentally determined the pressure drop and heat transfer in two different geometries of microchannel heat sinks. The two configurations are I-channels, where the working fluid flows through parallel channels, and U-channels, where the fluid passes through numerous bends in a single channel. The width of the individual channels was 1 mm and the depths ranged from 176 to 278 µm. Using water as the coolant, he measured the pressure and temperature of the coolant along the microchannel. Rahman’s results showed that the Nusselt number is always greatest at the entrance for any value of Reynolds number. This was expected since the boundary layer is beginning to form at the entrance. In addition, it seemed that the flow transitions from laminar to turbulent are very gradual because of the microscopic dimensions. He concluded that the average Nusselt number in microchannels is higher than in larger channels because the velocity boundary layer breaks down due to the surface roughness of the microchannel walls.

A few investigators have studied optimization of plain and enhanced microchannel geometrical parameters and modeling of plain microchannels to provide practical design guidelines.

Steinke and Kandlikar (Sabbah, R., M.M. Farid, S. Al-Hallaj, 2008) confirmed the validity of the continuum theory and showed the entrance region effects, entrance and exit losses, and experimental uncertainties as the major reasons for the discrepancy in the earlier data reported in the literature. They also presented a detailed analysis of the uncertainties associated with fluid flow and heat transfer data available in the literature. Lee and Garimella (Rosa, P., *et al.*, 2009) studied the effect of entrance region on heat transfer under circumferentially uniform wall temperature condition and axially uniform wall heat flux thermal boundary conditions. Mishan *et al.* and Xu *et al.* (Kim, S.J. and D. Kim,1999; Knight, R.W., *et al.*, 1992) confirmed that the conventional theory is applicable for water flow through microchannels including the entrance effects. They developed a method for the measurement of fluid temperature distribution which provides the fluid temperature distribution inside the channel. Sabbah *et al.* (Wen, Z. and K.F. Choo, 1997) observed that the prediction of heat transfer in micro-channels becomes difficult with increase in complicacy of the geometry of the micro-channels, which requires three-dimensional analysis of heat transfer in both solid and liquid phases. Despite the small width of the channels, the conventional Navier-Stokes and energy conservation equations still apply to the microchannel heat exchanger due to the continuum of the working fluid where the channel width is much larger than the mean free path of liquid molecules (water). Rosa *et al.* (Ryu, J.H., *et al.*, 2003) reported that heat transfer in microchannels can be suitably described by the standard theory and correlations. But the scaling effects which includes entrance effects, conjugate heat transfer, viscous heating, electric double layer (EDL) effects, temperature dependent properties, surface roughness, rarefaction and compressibility effects (which are often negligible in macro-channels) may have a significant influence and these should be accounted. Furthermore, measurement uncertainties may be more important, due to the reduced characteristic dimensions. Heat transfer experiments were conducted to investigate the thermal performance of air cooling through mini-channel heat sink with various configurations. Two types of channels have been used, one has a rectangular cross section area of 5 × 18 mm2 and the other is triangular with dimension of 5 × 9 mm2. Four channels of each configuration have been etched on copper block of 40 mm width, 30 mm height, and 200 mm length. The measurements were performed in steady state with air flow rates of 0.002 - 0.005 m3/s, heating powers of 80 - 200 W and channel base temperatures of 48°C, 51°C, 55°C and 60°C. The results showed that the heat transfer to air stream is increased with increasing both of air mass flow rate and channel base temperature. The rectangular channels have better thermal performance than triangular ones at the same conditions. Analytical fin approach of 1-D and 2-D model were used to predict the heat transfer rate and outlet air temperature from channels heat sink. The predicted values for outlet air temperatures using the two models agree well with a deviation less than ±10%. But for the heat transfer data, the deviation is about +30% to –60% for 1-D model, and –5% to –80% for 2-D model (Chien-Hsin Chen, 2007). Knight *et al*. (Guodong Xia, *et al*., 2015) presented a fin model to redesign the previous investigators microchannel heat sink and reduced thermal resistance from 10 to 35 %. Wen and Choo (Joseph Dix, Amir Jokar, 2010) set up a thermal resistance model to study an optimum thermal design of the heat sink under three types of flow constraints: the constant coolant volume flow rate, constant pressure drop, and constant pumping power. The lowest total thermal resistance was 0.054 °C/W when the channel aspect ratio was 15 and the pumping power was fixed at 7.5 W. Ryu *et al*. (PaisarnNaphon', OsodKhonseur, 2009) adopted an optimization scheme based on the steepest descent method to optimize a manifold microchannels heat sink. For given pumping power, the optimal design variables that minimize the thermal resistance are obtained iteratively. Among various design variables, the channel width and depth are more crucial than others to the heat-sink performance. The optimal microchannel width and depth are 16 mm and 140 mm, respectively, and the corresponding thermal resistance is 0.031 °C/W. This paper presents an analysis of forced convection heat transfer in microchannel heat sinks for electronic system cooling. In view of the small dimensions of the microstructures, the microchannel is modeled as a fluid-saturated porous medium. The velocity field in the microchannel is first solved by a finite-difference scheme, and then the energy equations governing the solid and fluid phases are solved simultaneously for the temperature distributions. Also, analytical expressions for the velocity and temperature profiles are presented for a simpler flow model, i.e., the Brinkman-extended Darcy model. This work attempts to perform a systematic study on the effects of major parameters on the flow and heat transfer characteristics of forced convection in the microchannel heat sink. The velocity profiles of the fluid in the microchannel, the temperature distributions of the solid and fluid phases, and the overall Nusselt number are illustrated for various values. It is found that the fluid inertia force alters noticeably the dimensionless velocity distribution and the fluid temperature distribution, while the solid temperature distribution is almost insensitive to the fluid inertia. Moreover, the overall Nusselt number increases with increasing the values of α_s and ε, while it decreases with increasing k_r (Xia, G.D., *et al*., 2015).

In this paper, experiment is used to perform temperature and pressure drops and numerical simulation is used to understand and interpret the complex thermal behavior by presenting the flow field in the current complex corrugation microchannel heat sink. The comprehensive performance is evaluated by total thermal resistance and thermal enhancement factor. Compared with the equivalent rectangle microchannel heat sink, the average temperature and maximum temperature is reduced obviously and temperature distribution is more uniform albeit with higher pressure penalty for flow rates larger than 100 ml/min. It is observed that the vortex becomes bigger and moves to the middle of channel with increasing of flow rate. The enhance heat transfer mechanisms can be contributed to the heat transfer area enlarged, thermal boundary interrupted and redeveloped, chaotic advection, hot and cooling fluid better mixed by vortex formed in the reentrant cavity. The pumping power is reduced 18.99% when total thermal resistance equals to 0.446 K/W, compared with rectangle microchannel heat sink. The thermal enhancement factor can reach 1.24 for Reynolds number of 611. Therefore, complex corrugation microchannel heat sink is more economical for chip cooling system (Lei Chai, *et al*., 2016). Fluid flow and heat transfer of a microchannel electronics cooler is analyzed using computational simulation and experimental validation. The microchannel cooling technique appears to be a viable solution to high heat rejection requirements of today’s high-power electronic devices, such as diode lasers. The thermal design of these small electronics cooling devices is a key issue that needs to be optimized in order to keep the system temperatures at certain levels. However, this optimization should balance the heat transfer with pressure drop through the system by modifying the geometrical design. This technique is used in optimizing the performance of a microchannel cooler for high-power semiconductor diode laser applications in this study. The results show that symmetrical design modifications improve both pressure drop and heat transfer significantly, while resizing the channels may affect slightly (Md. Emran, Mohammad Ariful Islam, 2013). Experiments have been performed to investigate the heat transfer characteristics and pressure drop in the micro-channel heat sinks under constant heat flux conditions. The experiments are performed for the Reynolds number and heat flux in the ranges of 200–1000 and 1.80–5.40 kW/m^2, respectively. The micro-channel heat sink with two different channel heights and two different channel widths are accomplished by wire electrical discharge machine. Effects of different geometrical configurations parameters of the micro-channel and heat flux on the heat transfer characteristics and pressure drop are considered. The micro-channel geometry configuration has significant effect on the enhancement heat transfer and pressure drop. The results of this study are expected to lead to guidelines that will allow the design of the micro-channel heat exchangers with improved heat transfer performance of the electronic devices. In the present study, fluid flow and heat transfer in microchannel heat sinks with different inlet/outlet locations (I, C and Z-type), header shapes (triangular, trapezoidal and rectangular) and microchannel cross-section shapes (the conventional rectangular microchannel, the microchannel with offset fan-shaped reentrant cavities and the microchannel with triangular reentrant cavities) are numerically studied with computational domain including the entire microchannel heat sink. Detailed three-dimensional numerical simulations are useful in identifying the optimal geometric parameters that provide better heat transfer and flow distribution in a microchannel heat sink. Results highlight that flow velocity uniformity is comparatively better for I-type and poor for Z-type. The flow distribution is found to be symmetrical for I-type. It is seen from the header shapes analysis that the rectangular header shapes provides better flow velocity uniformity than the trapezoidal and triangular headers. The fluid flow mechanism can be attributed to the interaction of the branching of fluid and the friction offered by the walls of the header. Effects of microchannel cross-section shapes emphasize that the microchannel with offset fan-shaped reentrant cavities and the microchannel with triangular reentrant cavities of the heat sinks enhance the heat transfer compared to the conventional rectangular microchannel. The heat transfer mechanism can be attributed to the jetting and throttling effect, the additional flow disturbance near the wall of the reentrant cavities and the form drag of the reentrant cavities. The heat sink C has better heat transfer characteristic for $q_v = 150$ ml/min and is able to prolong the life of the microelectronic devices. A numerical investigation has been carried out to examine the characteristics of laminar flow and heat transfer in microchannel heat sink with offset ribs on sidewalls. The three-dimensional equations considering entrance effect, conjugate heat transfer, viscous heating and temperature-dependent properties are solved for the fluid flow and heat transfer in the microchannel heat sink. Five different shapes of offset ribs are designed, including rectangular, backward triangular, isosceles triangular, forward triangular and semicircular. Results show that the offset ribs result in significant heat transfer enhancement and higher pressure drop. Depending on the different offset ribs and Reynolds number ($190 \le Re \le 838$) studied in the present work, Nusselt number and friction factor for the microchannel heat sink with offset ribs are 1.42–1.95 and 1.93–4.57 times higher than those for the smooth one, leading to performance evaluation criteria of 1.02–1.48. Further, as a consequence of significant pressure drop, the microchannel heat sink with offset ribs gradually loses its advantage as an effective heat transfer enhancement method at higher Reynolds number. In this study, a three-dimensional numerical simulation is performed in order to investigate the flow dynamics and heat transfer characteristics in a microchannel heat sink. A unit cell containing a single microchannel of a width of 231 μm and a depth of 713 μm with surrounding solid is used for simulation. Water at 15 °C is used as the cooling liquid with Reynolds number ranging from 225 to 1450 and a constant heat flux is applied at the bottom of the heat sink. A commercial CFD code employing finite element method is used for the numerical simulation. Mesh independence test is performed for the accuracy of results. The pressure drop in the microchannel obtained from the simulation agrees well with experimental results. The highest temperature is found at the bottom of the heat sink immediately below the channel outlet and the lowest is at the channel inlet. The heat flux is high near the channel inlet due to thin thermal boundary layer in the developing region and varies around the channel periphery with lower values at the corners. These findings demonstrated that the conventional Navier–Stokes and energy equations can adequately predict the fluid flow and heat transfer characteristics of microchannel heat sinks.

Conclusions:

A review article is presented for determining optimum microchannel heat sink conditions by the consideration of both heat transfer characteristics and fluid dynamics. The effects of approach velocity and heat sink thermal conductivity are examined with respect to its role in influencing optimum design conditions and the overall performance of the heat sink. Based on the papers reviewed, it revealed the research needs to be focused to investigate advanced cooling technology. The challenges of cooling electronic equipments may be expected to continue through the remaining of this decade. As the size of semiconductor is reducing day by day and power dissipation is increasing rapidly, so a breakthrough is needed in advanced cooling to reduce cost without sacrificing effectiveness of cooling. Anyhow, the analysis conducted in this review confirmed that the understanding of fluid flow and heat transfer mechanisms in microchannels.

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