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Simulation of Heat Transfer Enhancement in Micro-channels and Its Application in Electronic Devices - A Review

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ABSTRACT

So many studies have been investigated to enhance heat transfer in microchannels. In this paper, a review of available studies conducted on heat transfer enhancement in wavy microchannel, Converging-Diverging microchannel and non-uniform wavy microchannels was presented. Enhancement of heat transfer in electronic devices has always been an issue to reduce the average downtime.This review looked into the numerical simulation of heat transfer in microchannels aimed in optimization the overall performance of microchannel systems. M icrochannels with different geometries were examined in each study. Also the effect of changing wavelength and amplitude on heat transfer enhancement in microchannels was studied in a research. The review showed that the geometry of microchannel is an effective factor in heat transfer enhancement along other factors studied in the presented investigations.

Keywords: Heat transfer enhancement, Wavy microchannel heat sink, Converging-Diverging, Non-Uniform, Cooling methods, Electronic devices

1. INTRODUCTION:

The Microchannel heat sink developed by Tuckerman and Pease [1] has become one of the most promising cooling methods for microelectronic devices. In the last two decades, due to prominent advantages such as high heat transfer coefficient, low coolant requirements, small size, and large surface area-to-volume, it has attracted a lot of attention [2]. Many studies have examined the performance of microchannel heat sink theoretically [3,4], numerically [2,5]. These studies have shown that microchannel heat sinks can perform much better than conventional heat sinks. However, more progress is still needed to meet the increasing cooling needs of microelectronic devices. Microchannel heat sink usually uses direct channels with very poor mixing of fluid, because the coolant flow is almost straight [6]. At the same time, regular flow in these channels due to the thickening of the thermal boundary layer, inevitably leads to a decrease in heat transfer along the direction of coolant flow [7]. The idea of using wavy microchannels instead of straight channels was proposed in order to improve the performance of heat sinks [8]. The results have shown that with the same cross section, the corrugated design has a much better heat transfer performance than the straight one. [9] The concept of MCHS cooling was at the first has been proposed by Tuckerman and Pease [1] in 1981. They hinted that decreasing the dimensions of the fluid cooling channel to a micron scale leads to an increase in the rate of heat transfer and demonstrated a forty-fold amelioration in ability of heat-sink practically using Si-based microchannels anodically bonded to Pyrex cover plates. An extensive research on MCHS after that has been pursued and much research has been done to investigate the heat transfer and characteristics of fluid flow at MCHS. Harms [10] and Harms et al. [11] Provided experimental data for a single-phase forced-convection in deep rectangular microchannels. They showed that when the width of channel and the Reynolds number are kept constant and these silicon-substrate channels are made in a 2 mm thickness and also deionized water was used as working fluid, the pressure drop is inversely proportional to the channel depth. Ambatipudi and Rahman accomplished the numerical simulations for conjugate heat transfer in a silicon-substrate rectangular microchannels [12]. They examined the geometric parameters -the depth and width of channel-, the number of channels and the amount of flow through the channel. They realized that the coefficient of heat-transfer increased with the enhancement of fluid velocity inside the channel. The Nusselt number varies along the length of channel. They realized that enhancement of the number of channels along the entire length of channel, increases the local number of Nusselt.[12]The microchannels are in fact widely used in the hydrogen production reactor's heating chamber [13-15] and the bipolar plate of the fuel cell [16,17]. The Studies and researches have in the meantime proved that the microchannels improve the efficiency of the hydrogen production reaction and the power density of the fuel cell by highly efficient heat and mass transfer. In order to increase the heat-transfer performance of microchannels many methods exist [18,19]. However, the first requirement that was discussed [1] was to enhance the microchannels to meet high heat flux cooling. By the way, they suggested that increment methods should be attentively evaluated by penalties of increasing the pressure drop in a given system. These methods have been approved to increase heat transfer in single-phase flow in micro-channels and mini-channels [20]. Outcomes has shown that increasing the performance of heat transfer by these techniques puts a single-phase fluid system in competition with a two-phase system. Cooling limitations of single-phase cooling media in plain channels have been evaluated [21] and the use of various microstructures into the channels to increase heat transfer has been investigated. In addition, they investigated the pressure drop and heat transfer in a microchannel reinforced with an off-set strip fins for single-phase liquid flow [22]. Experimental results show excellent improvement in heat transfer through plain or traditional microchannels with penalty pressure drop. On the other hand, polymer microchannels with corrugated walls were analyzed for flow control and mixing [23]. The effect of surface roughness on heat transfer in a rectangular microchannel was investigated experimentally [24]. This article provides a review of various studies that have examined various factors to increase heat transfer in micro channels.

2. NUMERICAL SIMULATION OF HEAT TRANSFER ENHANCEMENT IN WAVY MICROCHANNEL HEAT SINK

The result of Wavy flow on MCHS thermal performance, coefficient of shear stress and friction of the wall and pressure drop was investigated and reported. The higher heat transfer performance of wavy microchannels was proved and it is much better than straight microchannels with the same cross section. The pressure drop of Wavy microchannels is much lower than the achievement of increased heat transfer. Both shear stress and friction of the wall increase proportionally with increasing domain of wavy microchannels. In the so called Wavy microchannel heat sink (WMCHS) with rectangular cross section, the water flow characteristics and Heat transfer was studied and the different wavy ranges from 125 to 500 μm were investigated numerically in this study [25]. This investigation covers the Reynolds number in the range of 100 to 1000. The governing equations of constant flow and three-dimensional heat transfer were concluded using the finite volume (FVM) method. The water flow field and heat transfer phenomena inside the heated WMCHS were simulated and the results were compared with straight microchannels. By comprehensive investigation of the effect of different wavy amplitudes in WMCHS on thermal and streamflow, the gained results were compared with straight MCHS. It was clarified that the MCHS temperature increases with decreasing wavy amplitude and is always lower than the straight microchannel. By the way, the said trend is not applicable to MCHS with a 0.25 dimensionless corrugated domain [25].The shear stress of the wall and heat transfer coefficient increase with increasing amplitude of Wavy microchannels. With increasing Wave amplitude, the friction coefficient and pressure drop across the corrugated MCHS proportionally increase and they are always higher than typical straight MCHS. The 0.25 wave amplitude is not able to increase the cooling efficiency of MCHS and is even weaker than the straight MCHS performance. Generally, the optimal overall thermal performance of wavy microchannels is proved in the range of 0.0625 to 0.21875. Therefore, Wavy microchannels can be proposed as the next generation cooling devices to eliminate high heat flux instead of using conventional straight microchannels [25].

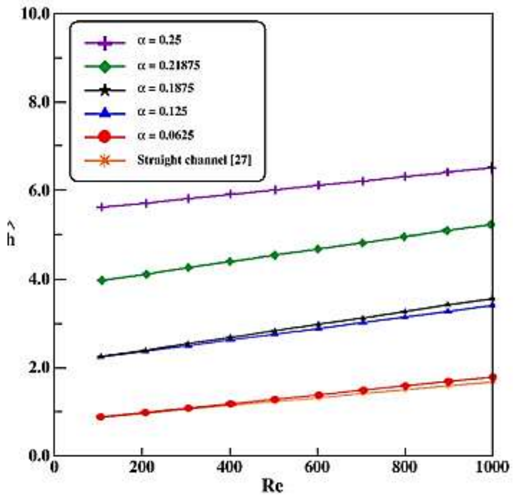

Fig. 1. Pressure drop variation versus Reynolds number for both wavy and straight micro-channels.

Figure 1 Shows the linearly increment of pressure drop along with increasing Reynolds number. α represents dimensionless wavy amplitude (α=A/L). A is wavy amplitude and L is straight wavy length (μm).There is similar behavior for all cases studied. That is notable that the in the numerical simulation does not exist the connections and pipes between the pressure transducers where have been used in the actual design of a heat sink. Increment of the kinetic energy of the fluid increases the partial losses. That is proportional to the square of the Reynolds number [25]. As reported by Sui et al. [8], It's clearly observed that the pressure drop for all cases of wavy microchannels increases with increasing wavy domain.

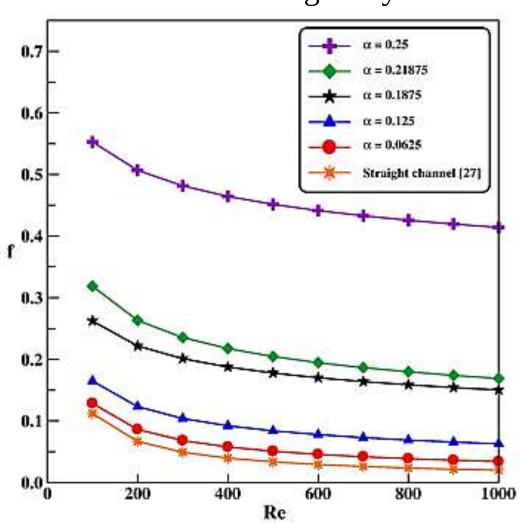

Fig. 2. Friction factor variation versus Reynolds number for both wavy and straight micro-channels.

Figure 2 has shown that the friction factor decreases with the increase of the Reynolds number for all cases. As the result shows the increasing Reynolds number for all cases caused the decreasing of coefficient of friction. As reported by [26,27,28], the coefficient of friction is significantly increased over the straight microchannels in the large corrugated range of 0.25. The results show that changing the patterns of Dean vortices along the direction of flow through corrugated microchannels causes only a slight increase in friction factor, especially at small Wavy domain [25].

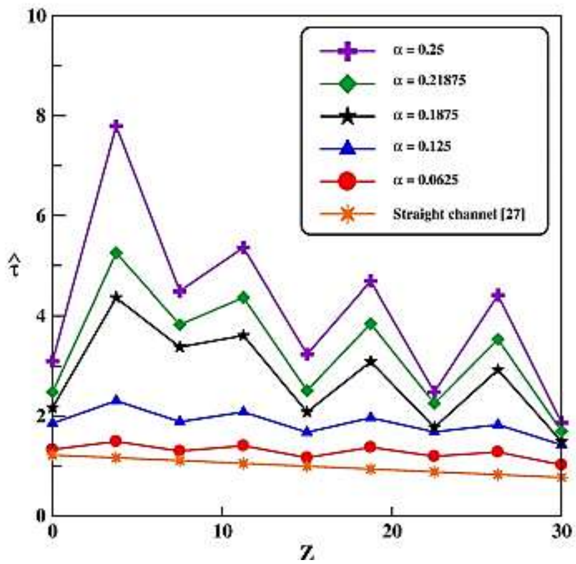

Fig. 3. Dimensionless wall shear stress variation along the length of flow direction for both wavy and straight micro-channels.

As shown in Fig. 3, it has been also the effect of using wavy microchannels on the local dimensionless wall shear stress investigated. As shown the shear stress of the wall increases with increasing wavy amplitude. Generally, for all the cases investigated, the highest shear stress in the wall at a larger value of 0.25 wave amplitude is due to the greater pressure drop discussed in the previous section. It is also shown that the shear stress of the wall along the flow direction decreases in oscillation for all corrugated microchannels, while the shear stress of the wall of straight microchannels decreases linearly along the flow direction [25].

3. NUMERICAL SIMULATION OF HEAT TRANSFER ENHANCEMENT IN PERIODIC CONVERGING-DIVERGING MICROCHANNEL

The performance of heat transfers and fluid flow in the convergent-divergent circular cross-sectional three-dimensional microchannel has been investigated numerically. Three different types of microchannels with a diameter of 100 µm and a length of 6.125 mm have been used for simulation of Reynolds numbers in the range of 50 to 1000. In proposed microchannels the

Reynolds Number effect, converging-diverging angle, converging-diverging cross-section length on pressure drop and heat transfer have been evaluated. In the study shown in Figure 4, the typical microchannel configuration with converging-diverging cross-section has been used [29]. The thermal performance (convection) and Hydrodynamic of proposed channels have been compared with conventional microchannels having same diameter and length (straight microchannels). The fluid amplitude in this numerical study has been kept under constant heat flux, fixed temperature and boundary conditions. In the microchannel the cold water has entered with the constant temperature of 300K and has obtained the heat from the wall. In this study three micro-channels with a diameter of 100 micrometers have been used and two of them have been the proposed wave microchannels as shown in Figure 5. A & B type micro-channel has 24 converging-diverging cross sections and all the microchannels have similar length of 6.125 mm. The main purpose of this study was to analyze the effects of converging-diverging cross sections on overall microchannel performance [29].

Fig. 4. Schematic of microchannel with periodic converging-diverging cross-section.

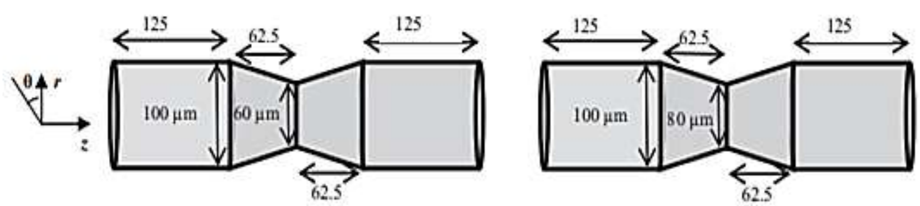

Fig. 5. Computational amplitude of one module of converging-diverging cross-section of type A and B channel.

Numerical Scheme: The classical continuity, Navier-Stokes and energy equations are solved along with the prescribed boundary condition using the finite volume based solver Fluent (ANSYS 15). The channel geometries are meshed using structured hexahedral cells [29]. The result of study has clarified that the flow at the converging-diverging cross-section causes recirculation and separation of the more intense flow, that decreases with decreasing convergence and divergence angles and increases with increasing aspect ratio. The performance of local and global heat-transfer in channels was improved by the way with in a converging-diverging cross-section at a higher pressure drop in comparison with a straight channel with the same cross section [29]. Studies proven that a straight microchannel with a diameter of 100 μm has a less pressure drop than the proposed wavy microchannel with a diameter of 100 μm. Moreover, the pressure drop in type A microchannels is much higher than in type B. The heat transfers by the intermittent converging-diverging cross-sections in the newly proposed microchannel is significantly increased. The heat transfer coefficient of 100 μm of the newly proposed channel in the range 192.66 <Re <796.17, is 46.8% –160.2% greater than the straight microchannel [29].

The responsible system for such a behavior are as follows:

- Fluid mixing and velocity in converging section caused increment in heat transfer
- Manipulation in the formation of the boundary layer caused increment of heat transfer.
- Enhancement of heat transfer surface caused increasing heat transfer.

In the proposed wavy microchannel the heat transfer has been significantly increased in comparison with the straight channel. Also the average Nusselt number of channels was 2 times higher for type A channels, 1.5 times higher for type B channels than for straight channels [29]. Higher recirculation and separation of the flow in the converging-diverging section helps to increase the heat transfer but also enhancement of the pressure drop. The effect of converging-diverging cross-section on heat transfer of microchannels type A was weaker than type B, but the total efficiency of microchannels type A was better than type B [29].

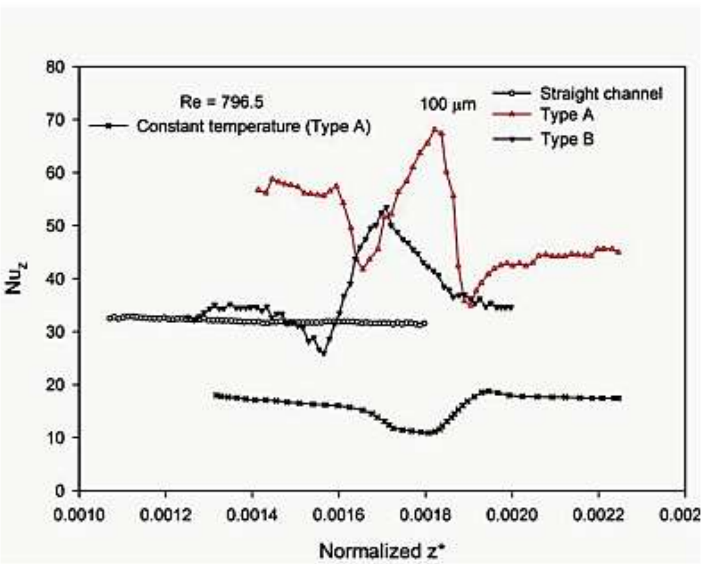

Fig. 6. Local Nusselt number along the flow direction in the one of the converging–diverging cross-section.

Fig. 6 has shown the distribution of local Nusselt number along the one of the converging-diverging cross-section for Re = 796.5. Under the constant heat flux conditions, following trends have been seen [29]: (1) Because of the weak effect of the thermal input, The Nusselt numbers at the input of microchannels type A have been higher than the straight microchannels. (2) A positive gradient of the Nusselt number due to the sudden contraction at the cross section has found in the converging region. (3) The local Nusselt number has been decreased at the diverging cross-section and increased at the converging cross-section, and the amplitude of the oscillation has been approximately similar to that of local friction coefficient.

4. EXPERIMENTAL AND NUMERICAL INVESTIGATION OF HEAT AND MASS TRANSFER IN NON-UNIFORM WAVY MICROCHANNELS

The mass and heat transfer performance of the non-uniform wavy microchannels have been evaluated by a numerical method. In accordance with principle of entropy generation and the performance evaluation criteria (PEC), the effects of the Reynolds number, Re, and the peak deviation position on the thermal-hydraulic efficiency of the microchannels have been analyzed [30]. Numerical analysis has clarified that the heat transfer performance of the diverging wavy microchannels (shown as MCH-41) has shown better heat transfer performance than the uniform Wavy microchannels (MCH-05) and micro Converging Wavy channels (MCH-14). The MCH-41 has been lower thermal resistance and entropy generation than MCH-05 and MCH14. In addition, a platform of flow visualization was created to observe the periodic pulsation characteristics of the fluid at Re 693. The mechanism of heat transfers and enhanced mass of diverging Wavy microchannels have been further analyzed. The experimental results have been consistent with the numerical simulation results [30]. Fig. 7(d) has shown the performance evaluation criteria (PEC) values as a function of the Reynolds number for different types of wavy microchannels. As shown in Fig. 7(d), the PEC values for different types of wavy microchannels have been all greater than 1.0 and their maximum value has been1.9, which has indicated that the wave grooves have been important in the improvement of the thermal performance of the microchannel. All PEC values of MCH-41, MCH-14, and MCH-05 have been increased by increasing in Re number, and the PEC of MCH- 14 has been less than that of MCH-41.

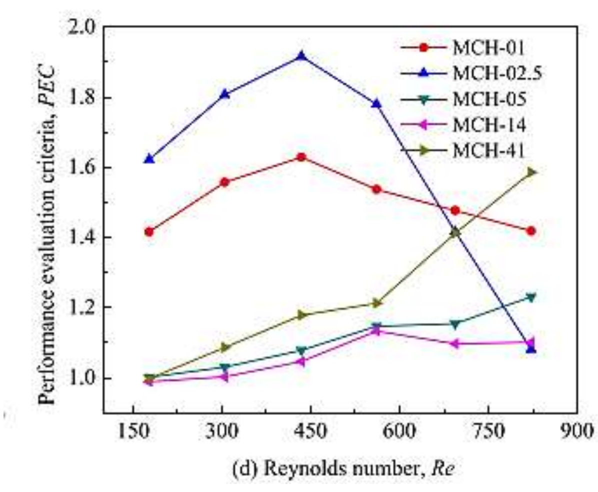

Fig. 7. Heat transfer performance of microchannels with different types performance evaluation criteria, PEC, as a function of Re.

Fig. 8(e) has shown a magnified image of the streamline of the sixth and seventh wavy units of MCH-41. As can be clearly seen, the fluid is not trapped in the Wavy groove and is sucked to the top of the microchannel. This "suction" of the liquid from the Wavy cavity upwards has leaded to the flow of hot liquid near the heating surface to the cold liquid on the top surface, which has created a flow in the direction of the temperature gradient. It has been known from the synergistic theory [31,32] that this flow has been caused efficient convection heat transfer. Figure 8 (f) has shown that the liquid is trapped in the Wavy groove of MCH-14 and forms transverse vortices that have been unfavorable for mass transfer.

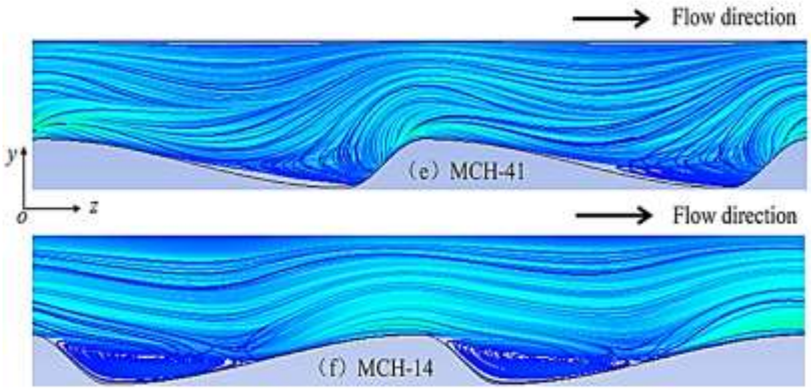

Fig. 8. Streamlines of microchannels with different types at Re=693 by numerical simulation. Magnified images of wavy units of MCH-41 and MCH-14.

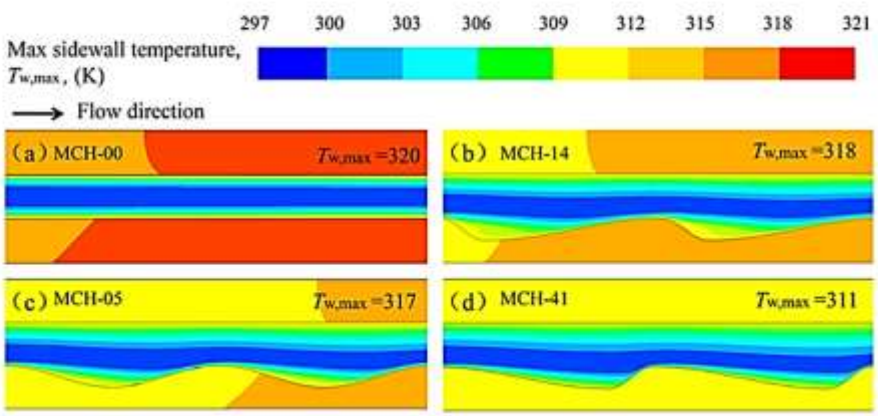

Fig.9. Temperature profiles of the sixth and seventh wavy units of the smooth and wavy microchannels at Re=434.

Figure 9 has shown the wall temperature T_W as a function of Reynolds number Re of smooth and wavy microchannels. The T_W value of MCH-41 was the lowest, followed by MCH-14 and MCH-05, and the T_W value of smooth microchannel was the highest [30].

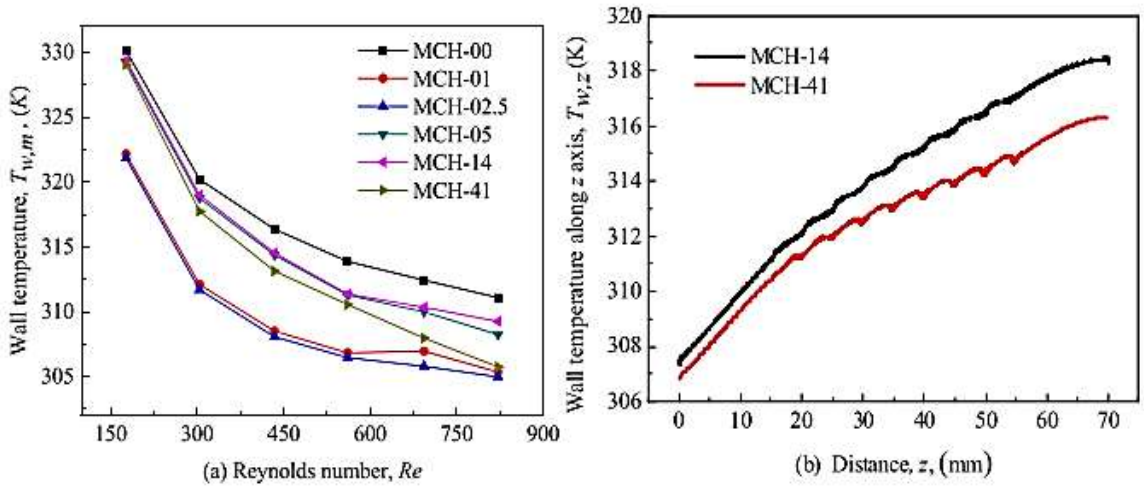

Fig. 10. Analysis of Wall temperature:
(a) average wall temperatures of microchannels with different types as a function of Reynolds number
(b) wall temperature of the heating surface of MCH-41 and MCH-14 along the flowing direction at Re 434

Figure 10(a) has shown the average wall temperature $T_{w,\,m}$ of the different wavy heating surfaces as a function of Reynolds number Re. The $T_{w,\,m}$ value has been decreased with the increase in Re. The $T_{w,\,m}$ value at low Re has been decreased faster than that at high Re values. In addition, the $T_{w,\,m}$ value of MCH-41 has been lower than that of MCH-14, and the $T_{w,\,m}$ values of MCH01 and MCH-02.5 have been lower than that of the microchannel with wavelength of 5.0 mm. Figure 10 (b) has shown the $T_{w,\,z}$ values of MCH-41 and MCH-14 along the flow direction at Re = 434. The $T_{w,\,z}$ value of MCH-41 has been noticeably lower than that of MCH-14 along the flowing direction, which has been consistent with the result of wall temperature analysis shown in Figure 10(a) [30].

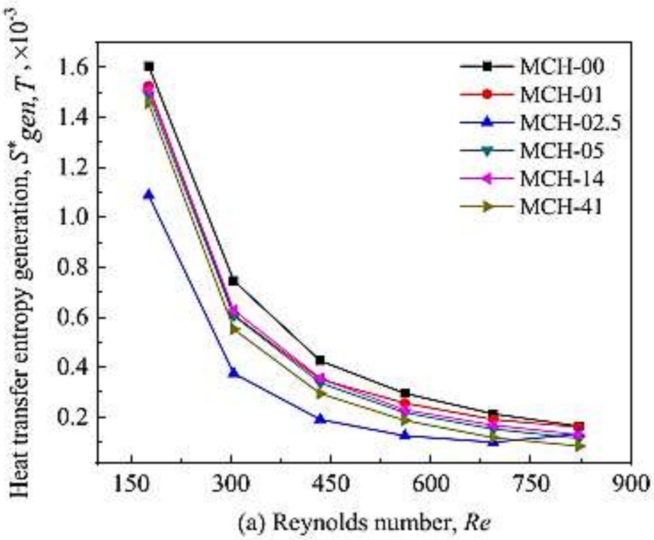

Fig. 11. Non-dimensional entropy generation analysis of microchannels with different types as a function of Reynolds number. (a) heat transfer entropy generation $S^*_{gen, T}$

In figure 11, By increasing Re number the $S^*_{gen, F}$ value has been increased, which has been indicated that the $S^*_{gen, T}$ value strongly has determined the S^*_{gen} value at Re values in the range of 177–822. This has been due to the simultaneous decrease in the thermal resistance and increase in the pressure drop with the increment of the Re [30]. The main results of this study have been as follows [30]:

(1) Diverging Wavy cavity has been very important in heat and mass transfer processes. Based on a combination of simulation analysis and visualization experimental results, a mass and heat transfer mechanism has been presented. The impinging jet flow and fluid oscillation in divergent corrugated cavities have been lead to increased mixing and improved heat and cold convection.

(2) However, the heat transfer effects of long-wavelengths microchannels have been worse than short-wavelength, but the pressure drop also in long-wavelengths microchannels have been decreased. Additionally, it has been discovered that the pressure drop of long wavelength microchannels was less than that of smooth microchannels (MCH-00) with 5.0 mm wavelength, 0.5 mm amplitude and 1.0 mm hydraulic diameter. Therefore, the long Wavy microchannel have had lower flowing resistance. However, the divergent wavy microchannel pressure drop (MCH-41) has been increased dramatically, when the Reynolds number exceeded 693.

(3) By the increasing Reynolds number, the thermal resistance, $R_{T,}$ and average wall temperature, $T_{w, m}$ has been decreased. At Reynolds number in the range of 177–822, the $R_{T,}$ $T_{w,}$ and $T_{w, z}$ values of the convergent (MCH-14) and uniform (MCH-05) microchannels have been higher than MCH-41. On average, the $R_{T,}$ value of MCH-41 has been 11.8%

lower than that of MCH-14 and 21.3% lower than that of the MCH-00. The temperature of MCH-41 has been more uniform than that of the MCH-14, MCH-05, and MCH00.

(4) By increasing the Reynolds number, the Nu and PEC wavy microchannels with a wavelength of 5.0 mm have been increased. Both Nu and PEC of microchannel MCH-41 have been larger than MCH-14 and MCH-05, respectively. The heat and mass transfer performance has been effectively increased by divergent Wavy cavity.

(5) Based on the principle of entropy generation Ns,a , the energy efficiency of microchannel heat sink has been evaluated. The Ns,a values of wavy microchannel heat sink have been all lower than 1.0, and the Ns,a value of MCH-14 and MCH-05 have been higher than MCH-41. The heat transfer performance of the wavy microchannel in accordance to PEC, R_T, Tw and Ns,a parameters, has been much better than that of the smooth one. It has been concluded that the designed MCH-41 can efficiently improve the heat and mass transfer performance and temperature uniformity of microchannel heat sinks, which maybe a good application in the heating chamber for hydrogen production or fuel cell bipolar plate.

5. HEAT TRANSFER ENHANCEMENT IN MICROCHANNEL HEAT SINK BY WAVY CHANNEL WITH CHANGING WAVELENGTH/AMPLITUDE

An improved scheme of Wavy microchannel heat sink by changing the wavelength and / or amplitude along the flow direction has been proposed. Under a constant pumping power, the thermal resistance R and the maximum bottom temperature difference of the lower wall for the new design have been compared with those for the straight and the original wavy design. The results has proven that the performance of the new design wavy microchannel increases remarkably with lower R and smaller $\Delta T_{b,max}$ when the amplitude of wavy units increases or wavelength decreases[33]. This increase has become more significantly when the absolute value of the $\Delta ʎ$ wavelength difference or the ΔA amplitude difference between two adjacent wavy units have been increases. By simultaneously increasing the absolute values of $\Delta ʎ$ and ΔA, performance could have been further improved. In addition, the reductions in R and $\Delta T_{b,\ max}$ has been found more remarkable for the new design heat sink with a smaller channel aspect ratio, as has been compared to the straight and new design wavy microchannel heat sink. The increase in heat transfer is attributed to the formation of vortices in the channel cross-sections due to the curved walls, which promotes the coolant mixing and increase the convective heat transfer between the coolant and channel walls [33]. The studied microchannel heat sink Figure 12 (a) has been consisted of 50 channels and 50 ribs with a rectangular cross section and has had a bottom surface of $L_X \times L_y$= 1410 mm2. As shown in Figure 12 (b), which consists of one channel and two vertical half-fins, based on geometric symmetry, only one unit has been modeled as the computational amplitude. The channel height and width have been respectively denoted by H_C and Wc, while vertical fin width has been denoted by W_f. The thickness for the bottom horizontal fin has been d. The wavy microchannel in the current work has been produced by two parallel wavy vertical fins. Figure 13 (a) has shown an original design wavy channel with constant wavelength l and amplitude A, consisting of seven wavy units. The characteristics of each wavy unit has been represented by two circular arcs. It has been noted that a circular arc is to be uniquely determined by three given points. However, the values of l and A have been specified, and the profile of the wavy units have been obtained [33]. Figure 13 (b) has shown a new design wavy channel with variable amplitude and / or wavelength, which also consists of seven wavy units. As with the original design, the index of each wavy unit for the new design has been represented by two circular arcs; however, the wavelength and / or amplitude for each wavy unit has been varied along the direction of the flow in the form of arithmetic progression, i.e. λ_{i+1}-λ_i= Δλ or / and A_{i+1} -A_i= ΔA (i = 1, 2, 3,…, 6) has remained constant, where li and Ai have represented the wavelength and amplitude of its wavy unit.

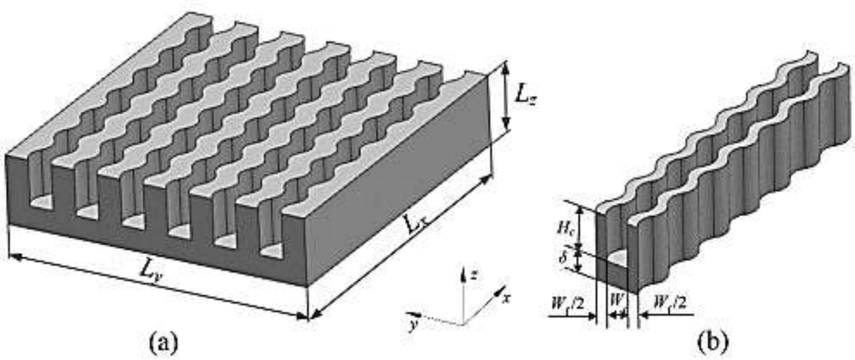

Fig. 12. The schematics of (a) wavy microchannel heat sink and (b) its periodic unit.

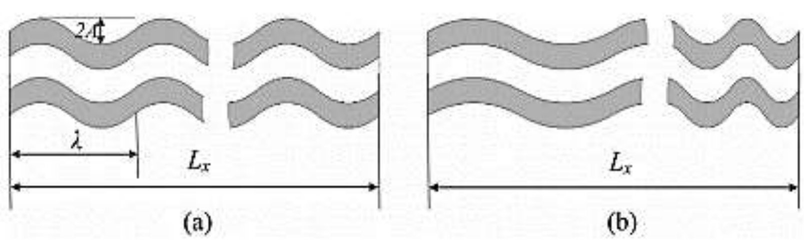

Fig. 13. The top view of the wavy channel: (a) original design and (b) new design.

In Figures 14 and 15 have been shown respectively the thermal resistance and the temperature difference on the bottom wall as the function of Δλ and ΔA. The better performance of the new designs MCHS has been again proven over the straight and the original wavy channel design [33]. In addition, a better performance by increasing the absolute value of Δλ or ΔA has been obtained and the thermal resistance of the heat sink has been decreases and the temperature on the bottom wall has been uniformly distributed. This increasing of performance has been attributed to the enhanced vortices in outlet region of the channel which has been caused by small wavelengths and large amplitudes [33]. Previous studies [8,34,35] have proven that small wavelength or/and large amplitude consequently leads a high pressure drop penalty. However, the average wavelength or amplitude in the current designs has been equal to that in the original wavy design. The large wavelength or small amplitude in the inlet region has been compensated by the small wavelength or large amplitude in the output region. Therefore, the penalty for pressure drop has greatly been reduced. The cooling performance in present design has been better than the original wavy design micro channel under the same pumping power, and also as results have shown, its performance will be increased by decreasing the wavelength or increasing the amplitude along the coolant flow direction [33].

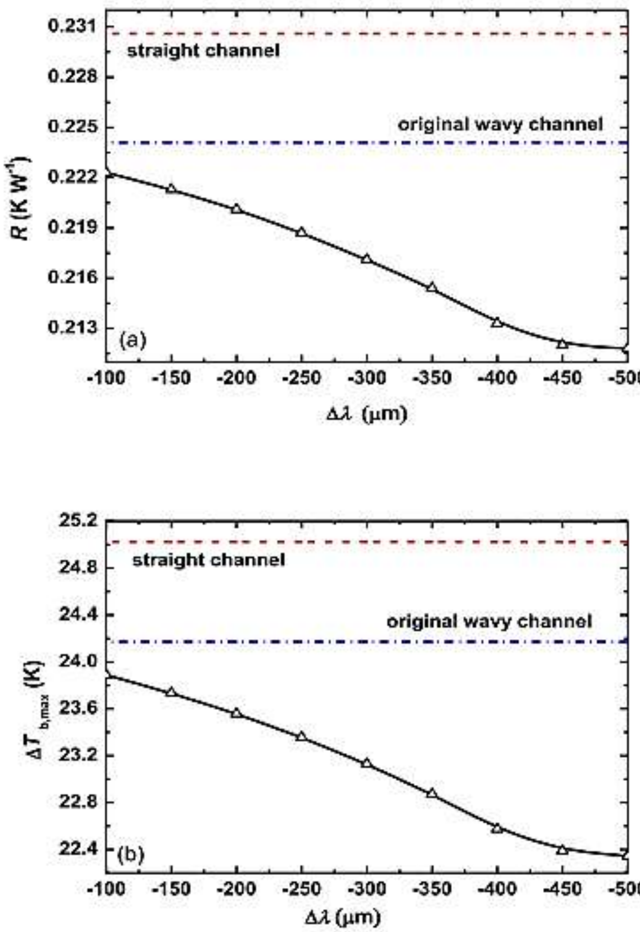

Fig. 14. (a) Thermal resistance R and (b) temperature difference on the bottom wall $\Delta T_{b, max}$ as a function of Δʎ.

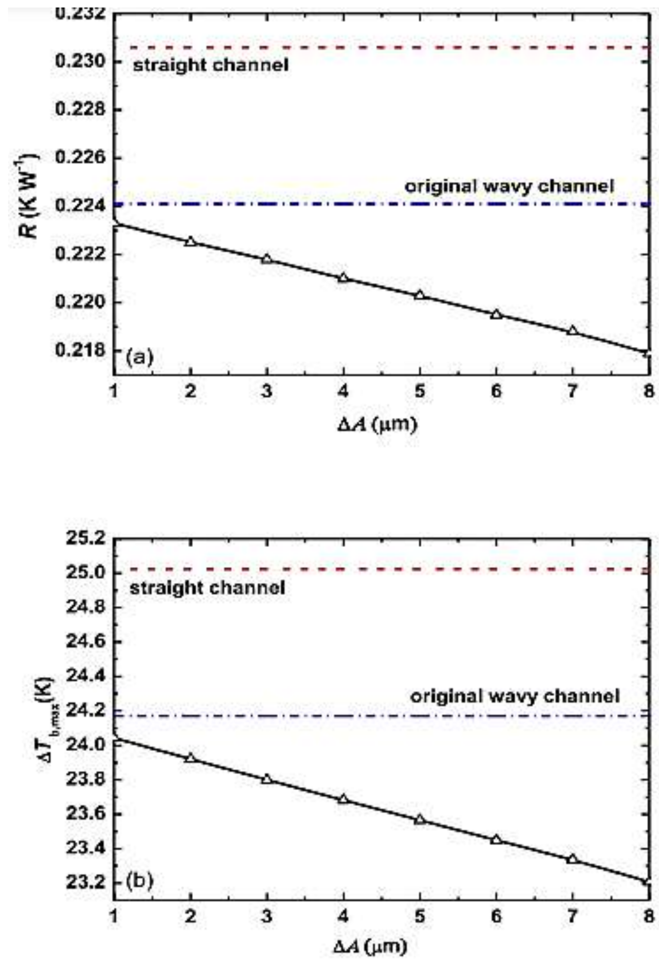

Fig. 15. (a) Thermal resistance R and (b) temperature difference on the bottom wall $\Delta T_{b, max}$ as a function of ΔA.

Three kinds of new wavy channel designs have been adopted. In first design, the amplitude has been kept constant and the only wavelength of the wavy units has changed. In the second scheme, only the amplitude with a constant wavelength has changed. In the third design, both the amplitude and wavelength has change simultaneously [33]. in the new designs, in order to keep the average wavelength and / or amplitude constant, the wavelength and / or amplitude of the fourth wavy unit has been assumed to be the same as the original design. An improved new design of wavy microchannel heat sink with changing the wavelength and / or amplitude along the flow direction has been proposed. The flow and heat transfer characteristics of this new design has been checked numerically under a constant pumping power Ω= 0.1 W. The main conclusions have been as follows [33]:

(1) In comparison to the original wavy design, the heat sink has created less thermal resistance and smaller temperature difference in the bottom wall by decreasing the wavelength or increasing the amplitude along the flow direction. The formation of vortices in cross section of the channel has been responsible for improving performance, which not only has increased the coolant mixing but also has increased the convective heat transfer between the coolant and channel walls by Dean vortices.

(2) By increasing the absolute value of the Δʎ wavelength difference or the ΔA amplitude difference between two adjacent wavy units, the performance of the new design has been increased. In order to achieve the best heat sink performance when the wavelength and amplitude changing simultaneously, there has been an optimal combination of Δʎ and ΔA. The results again have shown that the new design wavy microchannel with small channel aspect ratio is more effective for the heat sink.

6. COOLING SYSTEM OF ELECTRONIC DEVICES USING MICROCHANNEL HEAT SINK

Accelerating the operation of micro or macro electronic devices have been required the production of microprocessors with large numbers of transistors. As far as, in the electronic devices increases the heat production, therefore the thermal issues have always been the key elements that limit the maximum performance of the processor. This issue has always been the main problem in the development of advanced electronic products. Increasing the temperature will reduce the average downtime in electronic devices if no precautions are taken to develop more effective and innovative cooling methods. As has been reviewed in this article, a promising solution to this issue is to cool the liquid using a new design microchannel heat tank. Therefore, having the efficient cooling systems is really necessary to the micro or macro electronic devices [36]. For various heat transfer purposes as microchannel heat sinks, the channels with different cross sections and sizes have been used. As per following, these channels have been classified based on their hydraulic diameters [36]:

Table1: Classification of channels

Channels	Hydraulic diameter (Dh)
Conventional channels	Dh > 3mm
Minichannels	3mm ≥ Dh ≥ 200μm
Microchannels	200μm ≥ Dh ≥ 10μm
Nanochannels	10μm ≥ Dh ≥ 1μm

The heat fluxes that an electronic component produces, causes it to exceed its allowable temperature limit. However, as has been investigated and proven, at 55% of electronic chips failure the main cause had been due to temperature increase in comparison with other factors that accounts for 20% vibration, 19% humidity and 6% dust (as shown in Figure 1). So it has been a big challenge to the engineers to remove the heat of electronic chips very efficiently. Microchannel heat sinks have improved the heat transfer removal 50 times more efficiently than conventional methods [36].

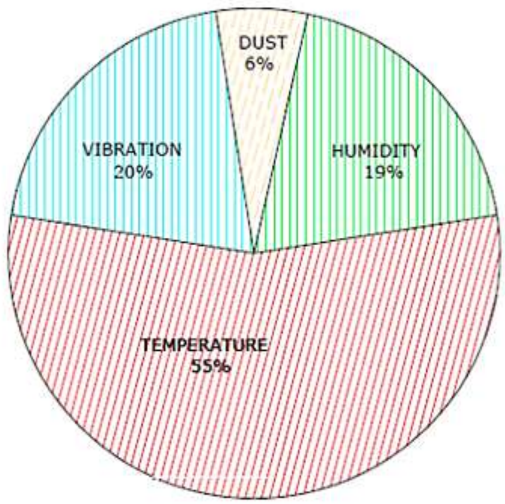

Fig. 16. Major causes of electronics failure

7. APPLICATIONS:

Many high-flux cooling applications make effective use of the high heat transfer capacity of these microchannels. These microchannels and minichannels have been developed and applied in many biological applications which provide very high rates of heat and mass transfer in organs such as the kidneys, liver, brain and lungs. i. For rapid isolation and detection of pathogens. ii. For research about drug delivery (1) Cooling with very high heat flux in lasers and digital microprocessors. (2) In the aerospace sector, in which microchannel heat sinks devices are frequently used to control the temperature in avionics. (3) For biomedical applications and displays. (4) Biosensors: Fast and sensitive detection of specific biological molecules such as specific proteins or DNA presents in biological fluids. (5) Controlled systems of drug control. (6) For inkjet printing and electronics applications. (7) Paper drying, process, air / refrigeration separation industries, heat treatment of metals, automotive [36].

The performance, effectiveness and longevity of electronic devices have been increased because of using microchannels in these devices and it will increase even more. It has shown from the diagram that, by decreasing the dimensions of the channel, the heat transfer coefficient accordingly has been increased. Also, the heat generated in the devices has been reduced due to using these microchannels in electronic devices. As the input power has been increased, more and more heat flux has been given by the heat sink. The flow rate has been increased, the speed of the molecules has also been increased so that the friction between them has been increased and the pressure drop has been increased. The temperature of the chip has been increased because of conductivity through copper, and more heat has been transferred to water through convection. Heat transfer has also been enhanced. The thermal resistance is proportional to the flow, so it has decreased with increasing flow. The Nusselt number is a function of the length of the thermal inlet, the Prandtl number has increased linearly by increasing flow velocity [36].

8. CONCLUSIONS:

Many studies have examined various factors to increase heat transfer in microchannels in recent years. Different experimental configurations and theoretical studies have been used to investigate and enhance the overall performance of microchannels. Different microchannel geometries, coolant types, structural materials and different wavelength, amplitude have been used to improve heat and mass transfer in microchannels. Any improvements in the overall performance of the systems have been analyzed using different analysis methods. The optimization of microchannel heat sinks has been conducted using different optimization designs.

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