GEOMETRIC ANALYSIS AND SCOPE OF NANOFLUID IN MICRO CHANNEL HEAT SINKS FOR ELECTRONIC COOLING APPLICATION - A REVIEW

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ABSTRACT

With a technological advancement and electronic devices miniaturization, use of liquid coolants increasing continuously into the servers, laptops, and computers. Expanding the efficiency of the system is one of the technique by which sustainability of energy might be guaranteed, for which miniaturization has effectively given arrangements. Micro channel heat sinks (MCHS) are extensively utilized for enhancement of the cooling rate. MCHS seems a trustworthy cooling technology because of its higher control on heat conveying ability. A smaller size of micro channels and capacity of dispersing heat made finest decision for electronic cooling systems. The proposed examination gives a comprehensive review of available studies regarding the various parameters like geometry, pattern, manifold and nanofluid for MCHS which are helpful for cooling enhancement of the system. Also the effects of above mentioned parameters on the performance of MCHS were analyzed. The primary objective behind the study is covering a research gap into the review of various parameters effect upon a performance of MCHS. From this review, execution of micro-channel into electronic devices is greatly suggested because of its capability of protection and extension in an electronic devices lifespan.

KEYWORDS: Micro-Channels, Cooling Techniques, Heat Sink, Pattern, Nanofluid, Heat Transfer

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1. INTRODUCTION

One of significant worries of a 21st century is a protection of energy and the journey of advancement for optional energy sources. Conventional resources of energy, being persistently misused, are relied upon to getting depleted into an upcoming decade (Omer 2008). Researchers, specialists and mechanical associations are unendingly flourishing to address this essential concern with the goal of innovative product accomplishments (Waghmare et al. 2020). Technological advancement early in the 1960s caused it conceivable for mounting incorporated to accumulate circuits upon the silicon chip. After 1968s, microchips sizes have decreased by 100 to 1 micrometer and a quantity of sections into the chips have expanded by 1 to 10⁵ (Kakaç et al. 2012). In ongoing decades, broad improvements have been accomplished into the micropumps, micro fuel cells (Islam et al. 2004), micro heat exchangers, micro bio-chips (Kakac 2012) and micro channel for cooling of a solar system (Di Capua et al. 2018). On the other hand, a fundamental issue into decreasing a chip sizes is an expansion into a delivered heat (Tullius et al. 2011).

The authors, (Tuckerman 1981) primarily clarified an idea of micro channel heat sinks (MCHS) and anticipated that single-phase cooling into micro channels might expel heat around the rate $10 \times 10^6 \text{ W/m}^2$. Forced

convection and fluid injection in channels have been utilized for quicker and bigger scope of cooling into the industries for quite a long time. Micro channel transfer of heat has famous and intriguing due to higher coefficients of heat transfer and lower to medium pressure drops compared to other cooling systems (Phillips 1988). For instance, MCHS have been exhibited for higher power laser diode cluster at heat flux evacuation rate upto $5 \times 10^6 \text{ W/m}^2$ (Beach et al. 1992).

When a necessity of cooling is more than $1 \times 10^6 \text{ W/m}^2$, a cooling unable to be effectively met either by basic air/water cooled systems. Within numerous applications, wherever higher heat flux of devices must be scattered, a necessary heat sinks should be bigger than a devices themselves (Mundinger et al. 1988). The heat flux and temperature of the electronic device below 348.15 K is desirable for optimal device functioning (Taylor and Solbrekken 2008). Heat losses in the range of $6 \times 10^6 - 10 \times 10^6 \text{ W/m}^2$ is the latest challenge of a current decade. However, the heat flux of numerous superior electronic devices is currently a lot high than predictions (Murshed and Castro 2017; Waghmare et al. 2020; Mahmoud et al. 2013). Air is (Kleiner et al. 1995) utilized a type of coolant as per accessibility and stability into traditional cooling, like fins and fan, unable to expel in excess of 10^6 W/m^2 from electronic devices because of low coefficient of heat transfer (Dix et al. 2008). As survey carried out at various electronics shop in central and western India, atmospheric temperature in summer season approaches around 321 K. At that working condition, heat flux and temperature of electronic devices reached upto 375-385 K. This higher temperature is very much harmful for the working device which may further causes damage to the internal parts. As several researchers suggested a utilization of MCHS having a liquid as a coolant medium, particularly water due to higher capacity of heat transfer and simpler availability (Arani et al. 2017). The greater surface-volume proportion and higher decrease into thickness of the thermal boundary layer can prompt the decrease into the thermal resistance (Baru et al., 2015; Mohamad Noh and Che Sidik 2014). Various examinations have been done previously for the optimized performance. By altering the different factors like reducing hydraulic diameter, superior heat elimination would be accomplished by an expansion into a quantity of channels and accessible surface of heat transfer into a similar space. Altering the various geometry of different parameters like shape of cross section, manifold, pattern, and nanofluid would result in optimization of various dependent parameters. Besides, in a MCHS, consideration of various factors like thermal-hydraulic performance, capability of fabrication, reliability, compatibility, and mostly commercialization is essential.

In current work, a quality research articles are reviewed and the impact of alteration into various geometric variables upon pressure drop and performance of heat transfer for MCHS as far as shape, pattern, and manifolds are concerned. The fundamental explanations behind is to provide all aspects of geometry variables and a background to researchers who need to begin investigating in current area. At the end, reviews have been carried out on some of the commercialized models, which prove that the vast majority of results from scientifically investigation are applied to commercialized ones. In any case, development and cost are two fundamental variables which ought to be thought of.

2. VARIOUS MANUFACTURING TECHNIQUES AND EFFECTIVE PARAMETERS FOR COOLING ENHANCEMENT IN MCHS

Another key concern seems to be the microchannel manufacturing of a desired shape and size on a required material. Studies used various manufacturing techniques of microchannel fabrication. Figure 1 shows the various manufacturing techniques used for MCHS.

Figure 1: Manufacturing techniques for MCHS

Table 1 shows some of the popular manufacturing techniques and the form of micro - channels that was created. Kandlikar and Grande revealed that microchannels manufacturing technology had evolved rapidly by miniaturization of conventional machines technologies to a implementation of recent methodologies used for the manufacturing of semiconductors. Such technologies modified the micro - channel heat sink field scenario, many number of reputed industries have approaches in dealing associated with microchannels.

Table 1: Typical manufacturing techniques of microchannel

Author	Shape of MCHS	Material	Dimensions (H, W) mm	Manufacturing Techniques
(Papautsky et al. 1998)	Rectangular	Glass and Si	H = 50 to 100, W = 300 to 1500	Electroplating
(Lee et al., 2005)	Rectangular	Cu	H = 5*W, W = 194 to 534,	Micro-milling
(Wu et al., 2005)	Trapezoidal	Si	H = 56.5, W ₁ = 251, W ₂ = 155.7	Photolithography method
(Mei et al. 2008)	Rectangular	Cu and Al	H = 400, W = 137 to 174	Micro-moulding
(Wu et al. 2010)	Rectangular	Si	H = 50, W = 483.4	Deep reactive chemical etching
(Chen and Garimella 2011)	Rectangular	Si	H = 389, W = 100	Saw- Cutting
(Lee et al. 2011)	Rectangular	Si	H = 100, W = 100	Dry Etching

The efficient factors considering rate of cooling are microchannel geometry, working fluid, irregularity, and inlet/outlet circumstances (Hussien et al., 2016). The appropriate choice of these factors mentioned is a major element in the removal of the heat generated (Almoli et al. 2012).

2.1 Various Geometries of MCHS

Various geometries of microchannel, such as rectangular, triangular, trapezoidal, diamond, circular, and sometimes hexagonal forms, were used into the effort for improvement in all thermal performance (Perret et al., 1998). The different geometries of the microchannel such as (a) rectangular, (b) trapezoidal, (c) triangular, (d) circular, (e) hexagonal, & (f)

diamond are as shown in figure 2

Figure 2: Various microchannel geometries

The prime reason of the use of various geometries by researcher was a need to increase the efficient heat transfer area allowed and minimize convective thermal resistance. Lowering total thermal resistance is among the most major aspects of most research. In order to increase surface area, heat transfer augmenters like cavities (Chai et al. 2013) and ribs (Husain and Kim 2009) were utilized. The augmenters results in negligible thermal efficiency gains or lowering thermal resistance. These improvements however comes at cost of high pumping power demands (Mohammed et al., 2011b). The microchannel dimensions ranged between 10 mm and 1500 mm. Most often, the large number of studies employing rectangular microchannel heat sinks demonstrated that this was the best option according to scientists. This was probably due to its ease of machining, it's own stability (Hetsroni et al. 2005) as well as its exceptionally high thermal performance (Perret et al., 1998).

2.2 Various Patterns of MCHS

In recent years, examination of various flowing path patterns as into the heat sinks had drawn considerable attention. A heat sink's performance could improved through adjusting channel pattern to irregular geometries, wherein supplementary flows or mixing of liquid are being created, often followed through charge of a pressure drop. Hence, achieving the equilibrium among pressure drop penalties and heat transfer performance is indeed the extremely important for obtaining an appropriate pattern. Above condition implies that certain situations lead heat transfer to increase whereas pressure drop to reduce. So researchers need to explain the items are relevant in the design (Rakhsha et al. 2015). Patterns are broadly divided into the four types as shown in Figure 3

Figure 3: Various types of Patterns in MCHS

2.3 Various Structures and Headers of manifolds in MCHS

While considering the distribution of flow, structures of manifold can be separated as below,

(i) Consecutive type manifold and (ii) Bifurcation type manifold

2.3.1 Consecutive type manifold

As shown in Figure 4, a consecutive manifold consisting with one primary inlet port as well as some ports branched from its primary port. Consecutive manifolds are classified into four categories depending on the configuration of the primary port and branch ports, i.e. (i) Dividing flow, (ii) Combining flow, (iii) Reverse flow (U- type) and (iv) Parallel flow (Z- configuration) (Bajura and Jones 1976; Datta and Majumdar 1983; Tomor and Kristóf 2017; J. Wang and Wang 2015).

Figure 4: Consecutive type manifolds

2.3.2 Bifurcation type manifold

Figure 5 shows the bifurcation type manifold which is a structure as good as tree in having primary inlet and divided into several branches. An explanation for both the rise within that form of pressure drop was its presence of several branches that are reduced in length by these diameters. Bifurcation manifolds at low velocities have strong flow uniformity (P. Li, Coopamah, and Ki 2008; Liu and Li 2013). Their dynamic nature nevertheless makes them unconventional (Wang 2011). Using nanofluids as a coolant, (Bahiraei and Heshmatian 2017) utilized this manifolds for achieving optimized effectiveness into the cooling applications. One of key element of this type of manifolds is a uniformly distributing the flow into branches that could result in uniform CPU temperature.

Figure 5: Bifurcation type manifolds

2.3.3 Different shapes and architectures of Headers in MCHS

Xia et al., studied an impact of various shapes of header (triangular/rectangular/trapezoidal) as in figure 6 (Ebrahimi et al. 2016). Deionized water was being utilized in experiment, and 2 M W m^{-2} heat flux were transferred to a base of its sink. Experimental study revealed how geometric shape influence on a microchannel has an essential role to play into the influencing heat transfer efficiency. Compared with trapezoidal and triangular configurations, the rectangular head shape appears having greater uniformity of flow. Then the optimized microchannel shape is experimentally tested.

Figure 6: Various header shapes

(Manikanda Kumaran et al., 2013) investigated five positions of inlet and outlet, five rectangular outlet header inlet header shapes, and four outlet header shapes with a rectangular inlet header. To evaluate different configurations and different header types, authors utilized pressure drop and mal-distribution factor. They noticed the presence of MLD flow in the inlet header which is the outcome of the fluid recirculation and separation.

Figure 7: Various header locations

2.4 Nanofluid for MCHS

Nanofluids have been used as a substitute to replacing ethylene glycol or a water mixture. One or two step processing is the popular process utilized for nanofluid processing. The nanoparticle material and the base fluid are essential aspects for the creation of nanofluids. Nanofluids like oxide ceramics (Al_2O_3 and CuO), nitride ceramics (AlN and SiN), carbide ceramics (SiC and TiC), metals (Cu , Ag , and Au), carbon nanotubes, semiconductors (TiO_2 and SiC), and composite materials have been used for various nanoparticles. This products are widely used with a liquid base like ethylene glycol, water, and oil (Ghale et al., 2015).

One of the techniques used only to manufacture nanoparticles by one-step process is the physical vapor deposition (PVD) technique or liquid chemical process. However, owing to the difficulties of removing the nanoparticles from the liquid, PVD did not earn the attention. Recent advances in nanofluid technology have led to the development of a direct evaporation device in which liquid ethylene glycol flows under low vapor pressure. Copper vapor can condense in the nanoparticles that raises ethylene glycol's thermal conductivity to 40 percent by addition of 0.3 percent of concentration of Cu nanoparticles. This technique can be utilized with lower pressure vapour. The other approach used into nanoparticles processing is the use of chemical synthesis. This method will give up a stable nanofluid of Copper-in-Ethylene glycol (Ahmed et al. 2016). Compared to PVD method this technique is well identified for its ease and lower price.

Another approach is the two-step processes that use nanoparticles that must first be generated and then combined with the base fluids. The process is commonly used in the development of nanofluids. The key explanation is that nanopowders are easy to get. Some of the nanoparticles in the form of dried agglomerates are used which have greater dimensions than single particles. Sedimentation approach is widely employed to assess nanofluid stability. Comparing engineered nanofluids to traditional solid-liquid suspension, engineered nanofluids have improvements into intensifying heat transfer between the particles and fluids from their high surface area, offering greater surface of heat transfer (Ebrahimi et al. 2016). In addition, main Brownian particle movement provides higher dispersal constancy and decreases pumping strength, blockage problems with particles, and simple properties adjustment to meet the requirement. Such are

the widely recognized nanofluid benefits.

3 EFFECT OF VARIOUS PARAMETERS ON PERFORMANCE OF MCHS

3.1 Effect of Geometries of MCHS

Several of the major works are reviewed in this section where descriptions of the heat sinks are given into Table 2, and critical cases are discussed below.

Table 2: Description of the different cross section articles

Reference	Heat sink dimensions (mm)	Geometry	Heat flux/Heat	Re/ Flow rate	Outcome
(Gunnasegaran et al. 2010)	22×12×1.5	RC, TZ, TR		100-800	In rectangular shape decrement in liquid temperature about 45 to 0 K was noted.
(F. Zhou and Catton 2011)	51×3	SQ, CR, EL, NACA, Drop-form	10 W		
(Alfaryjat et al. 2014)	22×12×1.5	HX, RH, CR		100-1000	
(Alfaryjat et al. 2014)	16×6	CR, SQ, TR	1W		
(Duangthongsuk and Wongwises 2015)	Dh =1.2	CR, SQ	20000 and 50000 W/m ²	700-3700	Circular shape performance was 6% to 9% superior than the square
(Abdoli et al., 2015)	2.45×2.45	CR, HD, modified HD, and symmetric convex	$10 \times 10^6 - 20 \times 10^6$ W/m ²		The convex pumping power was less than the CR shape, HD, and modified HD.
(Wang et al., 2016)	10×7.62×44.8	RC, TZ, TR	10^6 W/m ²	100-1000	$R_{TR}/R_{RC}=11.82\%$, $R_{TZ}/R_{RC}=1.01\%$
(Hua et al. 2016)		CR, EL, SQ, DD, TR		100-1000	Re>600 f reduced rapidly with increase in Reynolds number.
(Zhang et al., 2017)		RC, TZ, CR		0.5 to 4 cm ³ /s	$R_{COV,RC}/R_{COV,TR}=69.5\%$, $R_{COV,CR}/R_{COV,TR}=39.5\%$
(Yang, Jin, et al. 2017)	10.3×10.3	RH, HD, sine	144×10^4 W/m ²		
(Yang, Wang, et al. 2017)	6×0.2	TR, SQ, PT, HX, CR	72 W	100ml/min	Heat sink highest temperature was for the 326.726 K for TR, 324.752 K for SQ, 325.796 K for PT, 324.203 K for HX, and 326.347 K for CR shape of pin-fin cross-section.
(Sakanova and Tseng 2018)		CR, Cone, HD		312-1562	Heat transfer coefficient found same after 0.03m/s of inlet velocity of CR and HD shape.

Note: CR-Circular, DD-Diamond, EL-Elliptical, HD-Hydrofoil, HX-Hexagonal, PT-Pentagonal, RC-Rectangular, RH-Rhombus, SQ-Square, TR-Triangular, TZ-Trapezoidal

Several authors (Gunnasegaran et al. 2010; Wang et al., 2016) conducted numerical research into the impacts of multiple geometric parameters upon heat transfer characteristics of MCHS. In terms of heat transfer, rectangular have the

dominance of a rectangular shape according to the results; whereas worst efficiency had found in triangular shape. (Alfaryjat et al. 2014) studied numerically the thermal hydraulic efficiency of MCHS at numerous aspect ratios which were investigated in different forms compared to other researchers. Researchers found better in temperature distribution in circular shape, and the temperature of top wall was greater than those another situations. In addition, the lowest pressure decrease and the highest heat transfer coefficient, belong to the circular and hexagonal form respectively. On the empirical analysis, (Abdoli et al., 2015) found that the circular and rectangular shapes have a highest and minimum pressure drops, respectively. Trapezoidal shapes also have lower thermal resistance to complete convection, while the rectangular form had the highest.

3.2 Effect of Patterns of MCHS

Lists of all papers studied are provided into the Table 3 and are discussed in depth as follows, some of them requiring further information.

Table 3: Few articles regarding patterns of MCHS

Reference	Heat sink Material	Pattern	Channel dimensions	Heat flux /Power input	Re/ Flow rate	Outcome
(Mohammed et al., 2011b)	Aluminum	WV	430×280×1000 μm	100 W/m ²	100-1000	Increment in the amplitude of wave not essentially increases the heat sink performance.
(Mohammed, et al., 2011a)	Aluminum	ZZ, CV, and ST	430×280×1000 μm	100 W/m ²	100-1000	Dean vortices formation into curly and wavy patterns with resulting secondary flows and boundary layer in disturbed form.
(M. Khoshvaght-Aliabadi et al. 2017)	Aluminum	TR, TZ and SN	1×1×100 mm		650-3000	More heat transfer effect on trapezoidal heat sink considered to triangular and sinusoidal heat sinks.
(Aliabadi et al., 2016)	Aluminum	ZZ with TR, RC, and CR nooks in both positive and negative direction	1×1×100 mm		100-900	Heat transfer performance was improved due to messy advection and boundary layers disruption.
(M. Khoshvaght-Aliabadi et al., 2017a)	Aluminum	Plate fins and plate-pin fins: TR, SN, and TZ	1×1×100 mm	50 W	100-900	Lower pressure drop and higher coefficient of heat transfer observed in heat sinks for plate-pin fins compared to heat sinks for plate fins.
(M. Khoshvaght-Aliabadi et al., 2017b)	Aluminum	Interrupted-inline, Integral-interrupted, , and interrupted-staggered of straight and WV	1×1×100 mm	25000 W/m ²	100-900	The spread out configurations outcomes considerable decrease of base temperature compared to inline arrangements.
(Sui et al., 2011)	Copper	WV	404×205×25000 μm	5×10 ⁵ W/m ²	300-800	An increase in the heat transfer coefficient and friction factor were equal to

						149% and 211%, and 41% and 76%, respectively.
(Al-Neama et al. 2017)	Copper	Serpentine: SPM, DPM, and TPM	2×1.5×25 mm	100 W	0.1-1 l/min	The SPM performed better thermally. In DPM and TPM, the pressure drop and the velocity were less than in SPM.
(Al-Neama et al. 2018)	Copper	Serpentine: SMPF, SMCF	2×1.5×25 mm	6.2×10^5 W/m ²	0.053-318 l/min	
(Sui et al. 2010)	Silicon	WV	150 μ m	1.5×10^6 and 3×10^6 W/m ²	100-800	The heat transfer enhancement in the wavy microchannels was much higher than the pressure drop limit.
(L. Lin et al. 2017)	Silicon	wavelength of 2000 μ m and amplitude of 30 μ m	250×80×14000 μ m	10^6 W/m ²		Rising the amplitude to wavelength relation with direction of flow and reducing an aspect ratio of the channels may increase the performance of wavy microchannels.
(Chai et al. 2013)	Silicon	Interrupted channel with RC ribs	200×100×10000 μ m	1.22×10^6 W/m ²	187-715	With $s = 1.3$ mm, the microchannel heat sink had the maximum PEC in the range observed.
(Jawalekar and Shelare 2020)	Silicon	Interrupted channel with RC, BTR, FTR, DD, and EL ribs	200×100×10000 μ m	10^6 W /m ²	187-715	With rib length increment, the hydrothermal output of the disrupted microchannel heat sink decreases.

Note. BTR: Backward-Triangular, CR: Circular, CV: Curvy, DD: Diamond, DPM: Double path serpentine microchannel, EL: Ellipsoidal, FTR: Forward-Triangular, ID: Interdigitated, MTC, MSC: Multiple serpentine with two, three and six channels respectively, RC: Rectangular, SMCF: Serpentine MCHS with chevron fins, SN: Sinusoidal, SP: Straight parallel, SPM: Single path serpentine microchannel, SS: Single serpentine, ST: Step, TPM: Triple path serpentine microchannel, TR: Triangular, TZ: Trapezoidal, WV: Wavy, ZZ: Zigzag.

Mostly, choosing a right pattern relies upon factors like geometric requirements and flow rate, and cannot be described for general. Overall interpretation of reviewed articles discussed is offered in this section, and where possible finest geometries have been introduced. Heat transfer rate and pressure drop in the oblique patterns was improved compared to traditional ones. Additionally, the rate of heat transfer into the MCHS is increased with angle of oblique fins and rising pitch. Also, studies shows that hydrothermal performance of these patterns could be improved by staggered arrangement and increased fine porosity.

3.3 Effect of Structures and Headers of Manifolds of MCHS

Work on the transfer of heat and pressure drop was conducted theoretically and experimentally in this area. Some variations were found in the multiple microchannels between theoretical and experimental results of friction factor and pressure drop, whereas no variation found into any microchannels (Wang and Peterson 1994a; Harley 1995). This is because of subsistence of maldistribution (MLD) resulting by microchannel separation (Webb 2003; Manikanda et al., 2013), that brings a uneven distribution of temperature in microchannels edges (Nielsen et al. 2012; Nielsen et al., 2013). (Kim et al., 1995) studied an effect of shape of header and suggested triangular header form for better flow distribution as

compared to other. Moreover, the flow rates in the rectangular header of the last channels were greater than the primary channels that amplified MLD. Rectangular header however improved MLD at higher flow speeds. (Xia et al. 2015) examined microchannel fluid flow having various headers form and different outlet / inlet arrangements. Because of the symmetrical flow distribution they remarked that I-type had greater flow uniformity compared with another cases. In addition, influence of friction in walls reduced the static strain that eventually contributed for a velocities uniform distribution. (Bogojevic et al. 2009) studied an impacts of outlet / inlet opening, and blockage of channel was the product of particle sediment or manufacturing processes that affect the MLD flow, environmental impact and system life (Jensen 2001). The location of the outlet / inlet opening is outside or inside and the location of the channel blockages is top, middle or bottom. Outcomes suggested that less MLD could be generated within position. The overall area of the products is reduced whenever the inlet / outlet is regarded within, and hence the production cycle is increased.

Table 4: summarized all effective parameters for optimizing the design of the manifolds

Reference	parameters	Inlet & Outlet type	Minimum MLD	Maximum MLD	Outcome
(Datta and Majumdar 1983)	U/Z/Mixed-type	H×H×H	Mixed	N.A.	Rising heating charge causes boiling liquid that generates steam which leads to increase MLD flow.
(Kim et al., 1995)	TZ / TR /RC header shape	H×H×H	TR	RC	RC header shape's final channel flow rate is greater compared to primary channel, this causes to rise in MLD flow.
(Delsman et al. 2004)	E c/s, /F c/s, /G c/s, H c/s, I c/s shape	H×H×H H×H	I into lower flowing rate & H in higher flowing rate	G in lower flowing rate & E in higher flowing rate	E: Distribution region is triangle shape. F: 45 ° angle outlet and inlet region. G: inlet / outlet region matched to channels. H: outlet / Inlet area with more outlet space put in line to channels. I: outlet / Inlet region built on both sides in line with extra space channels.
(Chein and Chen 2009)	D/I/N/S/U/V -type	H×H×H H×V×V	U & V type	S-type	V-type is more suitable for manifold design among other cases.
(Shelare et al., 2020)	Right/obtuse /acute TR Manifold	V×V×V	Right, TR	N.A	Singular in-flow loop pressure drops are smaller than those of the drops in frictional pressure which cause the singular losses to be overlooked.
(Sehgal et al., 2011)	P/U/S-type	V×H×H	S-type	N.A.	Nu figures for U-type are 2 to 8 percent higher compared to P-type and 13 to 19 percent higher than S-type. P-type has a minimum friction factor that makes the use of microchannel heat sink in the industry.
(Wang et al. 2011)	U/Z-type	H×H	U-type	Z-type	The pattern of jet flow is important in MLD flow while gravity effect has no roles in MLD.
(Zeng et al., 2012)	Right TR /Oblique TR Manifold	V×V	Right, TR	Oblique TR	Right, TR Manifold crate narrow velocity distribution.
(Manoj Siva et al., 2014)	I/U-type	V×V ×V	I-type	U-type	By reducing the hydraulic diameter the flow better distribution obtained. Increase in flow MLD as number of

					channels increases and the multiple area decreases.
(Manikand a et al., 2013)	I/C/V/Z/U- type & RC / TR /3 type TZ inlet header shape & RC / TR /2 type TZ inlet header shape	V×V ×V ×H×H	C-type & TR (inlet) & TZ (outlet)	V-type & TZ No.2 (inlet) & TR (outlet)	I-type and Max have a symmetrical distribution. · P belongs to the Z-type during min. Four outlet and five inlets headers, set respectively by RC inlet and outlet.
(Wang and Wang 2015)	U/Z-type	H×H	U-type	Z-type	Z-Type approaches flow propagation as quickly as U-Type which is awfully useful for efficient design.
(Xia et al. 2015)	TR / TZ / RC header shape & C/I/Z-type	V×V ×V	RC & I- type	TR & Z-type	Branching fluid increases static pressure, and friction factor impact reduces the Rec header pressure which results in consistent velocity.
(Anbumee nakshi and Thansekha r 2016)	Rec. / TZ /TR header shape	H/H/H & V/V/V	RC in high flow rat & TZ / TR in low flow rate	RC in low flow rat & TZ / TR In high flow rate	From all situations the vertical flow configuration produces fewer MLD leaking than that of the (Horizontal) inline configuration.

Ultimately, to conclude for this segment the I-type may be most suitable for achieving symmetrical flow. In addition, minimum MLD was observed in rectangular header a shape that increases the heat transfer coefficient. In general, Re number, form of inlet / outlet and heat sink size need these parameters to be consider in order to achieve header shapes and optimum arrangements for decreasing MLD.

3.4 Effect of Nanofluid for MCHS:

Table 5 provides a description of the microchannel geometric parameters, the working fluid and the operating conditions used by numerous investigators,

Table 5: Summarized geometric parameter of microchannels and working fluid

References	Working fluid	Material of heat sink	Particles
(B. X. Wang and Peterson 1994b)	Water	Stainless steel	
(Choi and Cho 2001)	Water	Cu	5% Paraffin slurry as PCM
(Jang and Choi 2006)	Water	Si	copper nano particles and diamond nano particles
(Nguyen et al. 2007)	Water	Cu	Al ₂ O ₃
(Lin et al., 2011)	Water		Al ₂ O ₃
(Escher et al. 2011)	Water	Si	Silica (SiO ₂)
(Mo et al. 2012)	Water		TiO ₂
(Raveshi et al. 2013)	Water and ethylene glycol	Cu	Alumina
(Yiamsawas et al. 2013)	Ethylene glycol and water		TiO ₂ and Al ₂ O ₃

(Fan et al. 2013)	Paraffin-based nanocomposite		Carbon nanofillers
(M. Li 2013)	Paraffin		Nano-graphite
(Mahmoud et al. 2013)	paraffin wax PCM	Al T6- 6061	
(Suganthi et al., 2014)	Ethylene glycol and water		ZnO
(Marcinichen et al. 2014)	R134a	Cu	
(Bayomy et al., 2016)	Water	Al	
(N. Zhou et al. 2017)	Water	Cu	
(Mowade et al., 2020)	Water	Cu	Multi-walled carbon nanotubes
(Bahiraei et al. 2019)	Water	Cu	Green ecofriendly nanofluids
(Hadavand et al. 2019)	Water	Si	Silver (Ag)

From Table 5 it can be concluded that the number of research were conducted on test sections based on copper and silicon substrates. Due to its high thermal conductivity, copper is a very common material in thermal process equipment and silicone is a strong semiconductor widely utilized in the electronics and VLSI industry. Also from Table 5, that the majority of studies were conducted by refrigerant or water as working fluid.

4 CONCLUSIONS AND FUTURE SCOPE

Various liquid cooling techniques was used for heat transfer efficiency improvement into electronics equipments. Heat sinks geometry and nanofluids assumes a crucial role while enhancing cooling system capacity. Critical parameters which can be impacted due to the thermal-hydraulic efficiency are pressure drop, mean temperature, and coefficient of heat transfer, flow and temperature uniformity, as well as Nusselt number. Important data are extracted at the end of each part of paper. Parameters of geometry are broken down into three significant parts that are summed up beneath.

- Cross-section shape in microchannels has been addressed in section 2.2. According to Table 5, in microchannels heat sinks, rectangular shapes have more significance. It means that the rectangular form absorbs extra heat which causes less pressure rises, while in some situations the efficiency of the rectangular shape was greater than that of other shapes by about 50 percent.
- By analyzing a number of different papers, it is noted that geometric parameters assume to have an imperative role in heat sinks efficiency within each of the patterns studied. In periodic patterns, for example, the amplitude and length of the periodic pattern, periodic pattern shape, number of spiral channels, and the spiral patterns, may influence performance of those heat sinks. Therefore effectual parameters for efficiency of heat sink should be investigated in the design for optimized performance of patterns discussed.
- In Manifold study, it was concluded that maldistribution along the microchannel should be minimized to achieve a specific hot spots and an optimal design for achieving optimum performance. Various parameters are important in performing on MLD into the microchannel such as inlet / outlet arrangements, header shape, inlet configurations, inlet / outlet position, and corner curvature radius. U-type, however, provides better distribution; sometimes, a maximum drop in pressure is produced. I-type have a symmetrical type of flow therefore can be proffered to use.
- One of the major drawbacks is the microchannel-based liquid cooling that, despite its supremacy, is not yet

commercialized for compact devices like laptops but most studies have been conducted for estimation of the microchannel performance index alone. Research on a composite output index was also not much seen by performing an accelerated analysis with micropump, flow losses, and head losses.

- Continuous developments in microfabrication further inform us that microchannel heat sinks are a desirable substitute for heat pipes and fins in compact electronic cooling systems. This is only feasible in conceptual terms when related functional tools of the microchannels are also taken into consideration in the analysis as a single entity. Cooling with microchannels throughout a single phase holds good but addition of nanoparticles like Al_2O_3 , SiO_2 or TiO_2 an effective option for dissipating high-power systems.
- Most of experiments on microtubes or microchannels of rectangular section has been done. Also few studies on various cross sections such as hexagonal, V-shape, trapezoidal etc has been done. It would be important to aware channel geometry impact on the characteristics of heat transfer, and particularly on instability. In addition, refrigerants such as R600a and R290 were not explored as microchannel working fluid.
- Finally, researchers will think about an implementation of MCHS primarily to improve the design of the MCHS. That means they have to specify which parameters are more important than other things, i.e. the pressure drops, coefficient of heat transfer, thermal resistance, MLD, and PEC. After define chip types (microchannel or micropin-fin). Researchers then select which sequence, manifold and cross-section they are concerned, respectively. The designer would also think about the manufacturing limitations prior to carrying out information design.

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