© 2019 IJSRSET | Volume 6 | Issue 6 | Print ISSN: 2395-1990 | Online ISSN : 2394-4099
Themed Section : Engineering and Technology
DOI : https://doi.org/10.32628/IJSRSET196618

An Experimental Analysis of Microchannel Heat Sink using Novel Geometry with Nano Fluid and Water

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ABSTRACT

Oblique fins with sectional cuts are used in place of continuous straight fins to better mix the fluid because of secondary flow in tilted cut oblique channels. The other factor is the re initialization of thermal as well as hydrodynamic boundary layer at the noted line of each fin which decline the density of boundary layer. These breakages of continuous fins resulted in secondary flow generation which enhances the heat transfer rate with reasonable pressure drop. Wavy channel novel geometry is also studied which utilises the length wise blend due to curvy geometry. For laminar region, the amount of convective heat transfer is a function of span wise fluidic mixing. Dean vortices which are cajoled due to centrifugal fluctuation increases the heat transfer capabilities. By clubbing the benefits of both novel geometries i.e. Dean vortices with secondary channel mixing a further better novel geometry branched wavy structure is developed whose fluid movement and heat transfer behaviors were examined numerically. Secondary branches are combined in an alter manner at 45^0 at the trough of the wavy channel to provide cross channel mixing. All the 3 geometries are studied at different range of Reynolds number which ranges from 240 to 600. An increase in heat transfer coefficient as compared to oblique and wavy channel was observed after the addition of secondary branches with decrease in pressure drop penalty. For simulating different geometries in ANSYS 2 methods are implemented which resulted in discrete phase modelling being the better method. The temperature, pressure, velocity contours from simulations were obtained to explain different behaviours.

Keywords : Microchannel Heat Sink, Novel Geometry, Nano Fluid And Water, Hydrodynamic Boundary Layer, ANSYS, MCHS

I. INTRODUCTION

After the boom in electronics industry since past four to five decades, the no. of transistors which can be embedded cheaply on the specified circuit has increased to twice or thrice in approximately two to three years after the Moore's law patented by Gordon E. Moore. This drift has paved a roadmap to ground-breaking changes in micro-level technology after the invention of integrated circuit in the early 1950. Now transistors and electronic gadgets are fabricated smaller than before, while integrated chips have higher clocking frequency than before. But, the dissipate heat composed all along the computation is proportional to the clocking frequency. But the Waste heat that is generated from chips must be evacuated to assure that the working temperature is in the optimum area. When the temperature exceeds the area, the work of the gadget would either deteriorate or life would shorten. This problem worsens as the product miniaturization makes the effective area lesser for waste heat removal, which leads to thermal management challenges. After 1975, Keyes presented the thermal management threat posed by the continuous miniaturization of the electronics chips and circuits. In past it was considered as the temporary issue after performance of product; however, things have changed now. Jenkins & Bennet pointed that now thermal management has become the most essential thing for advance designs. According to few researchers like Ramsey in 2004, more than 50%of failure that occurred in electronic systems was because of heating issues, prompting the importance of integrating thermal management considerations in the intial phase of device construction to ensure the maximum productivity of whole system. Over the years, there has been broad analysis performed to extend the heat removal capability of air- cooled heat sink to meet the fierce cooling requirements.

Micro channel heat sink manufactured by Pease and Tuckerman is now became the most viable cooling option for micro-electronic industrial gadgets. It has fascinated huge consideration in the past 20 to 30 years due to certain specific advantages such as large value of h, less requirement of coolant, compact structure. There are many numerical studies done related to micro channels which has indicated that they are far better in many ways correlated to traditional straight finned geometries. But with the exponential growth in electronics industry the continuous innovation and improvement is the need of the hour.

In the past few years micro channel heat sinks have also been effectively used in cryogenics as well as in refrigeration and cooling industry. The major problem with straight channels is of continuous hydrodynamic as well as thermal boundary layer generation which causes poor mixing which decreases the rate of heat transfer. Oblique fins with sectional cuts are used in place of continuous straight fins to better mix the fluid because of secondary flow in tilted cut oblique channels. The other factor is the re initialization of thermal as well as hydrodynamic boundary layer. There are several proposed methods for heat transfer increment in literature given by various research scholars and scientists. Basically, there are two methods among the proposed theory which shows promising signs and one among these involves the generation of Dean vortices because of centrifugal instability. It is known that when fluids flow through wavy passages, it experiences a centrifugal force which in turn generates Dean vortices. Because of the formation of the vortices the fluid suffers a rapid shearing as well as stretching action leading to better fluidic mixing which in turn enhances the heat transfer rate. This mechanism is involved in wavy and branched wavy micro channels. Wavy channel novel geometry is also studied which utilizes, the area wise blend due to curvy geometry.

There is various other mechanism to increase heat transfer rate for better cooling of devices for increasing its efficiency as well as lifespan; reducing the thermal boundary layer, rise in flow interruptions and rise in the velocity gradient adjacent to the facial of the heated surface. To accomplish such, a slanted cut diagonal finned heat sink configuration was proposed. Corner to corner cuts at general interims empowered cross-channel blending which converted into an expanded degree of traverse astute blending. Interferences forward the barrier, as the outcome of cuts, disturbed the hydrodynamic boundary layer, compelling it to intials after regular period of time. This added up to a slenderer boundary layer and a steeper slope nearer to the surfaces of heat exchange. That together with improved extent of span-wise flow resulted in better performance, which neglected the minuscule pressure drop occurred. The inspiration for this investigation is to additionally improve the act of wavy channel heat sinks by adding the advantages of dean vortices and secondary channel mixing. That prompted the proposition and investigation of the branched wavy channels. It was proposed that the introduction of the secondary branches to the places of higher pressure built-up develop would decrease the pressure drop occurring in the channel. This process happened because the high pressure was provided secondary passage to bleed-off, thereby reducing the comprehensive resistance to the flow of fluid. Other than that, due to secondary branches also disrupts the hydrodynamic boundary layer developed. For laminar region, the degree of convective heat transfer is a function of span wise fluidic mixing. Dean vortices which are cajoled because of centrifugal instability increases the heat transfer capabilities. By clubbing the benefits of both novel geometries i.e. Dean vortices with secondary channel mixing a further better novel geometry branched wavy structure is developed whose fluid movement and heat transfer behaviours were examined numerically. Secondary branches are combined in an alter manner at 45^0 at the trough of the second wavy channel to provide secondary channel mixing.

During starting stages straight micro channel is used but the problem with straight channel is that there is no span-wise mixing of fluids due to parallel streamline flowing of fluids. Other problem is that boundary layer is continuous which deteorates the heat transfer capabilities. For laminar region, amount of convective heat transfer is directly dependent on area-wise fluid mixing. One method for solving this problem is to design wavy micro channel. When fluid passes through wavy channel dean vortices will be cajoled due to centrifugal instability. Due to cajoled vortices span wise mixing takes place. Other novel geometry is oblique channel and in it better fluid mixing because of secondary flow. Breaking continuous fin into oblique section will break the boundary layer formation. In this channel significant local and global heat transfer enhancement was achieved with very less pressure drop. Problem with oblique geometry is that Due to the large hydraulic diameter heat transfer coefficients are relatively low. The next novel geometry which comes into picture is branched wavy. It combines the advantages of both benefits of dean vortices with cross channel mixing mechanisms. The induced dean vortices and cut allows cross channel mixing better than both. The cut is made at the highest pressure built up surface so that pressure drop penalties can be reduced. In this high-pressure fluid was provided to bleed off and hydrodynamic boundary layer assembled up is disrupted.

II. LITERATURE REVIEW

2.1 BACKGROUND DETAILS

Since last few decades many researchers are trying to find new cooling methods & a method to advancein the heat transfer rate using micro channel sink. In present scenario many novel geometries are used to attain the required objectives. Among these geometries few are Oblique micro channel, wavy micro channel and branched-wavy micro channel. Nano fluids are also used to boost the heat transfer rate.

In this review focus is towards certain areas which is as follows : -

- A thorough study of heat transfer characteristics in micro-channel
- Nanofluid as working fluid
- Study on various geometries like oblique, wavy and branched wavy geometries

To design a novel micro channel heat sink the basic understanding of the characteristics of the heat transfer and fluid flow in micro-channel is essential. In the initial stages the designs and relationship of macro scale fluid motion and heat transfer are given. The advantage of numerical simulation on ANSYS software is that it has the ability to investigate small phenomenon that are taking place in geometry which is impossible to observe and investigate in experiments.

The break-through work related to heat transfer enhancement using microchannel heat sink for cooling of electronic devices was first investigated and demonstrated by 2 great researchers **Tuckerman & Pease in 1981** by clear away high heat flux of the order 80 W/cm^2 with micro-channels. As the characteristics length which is hydraulic diameter of the passage reduces then heat transfer coefficient rises. This innovative work paved the way for future research in micro channel heat transfer.

Copeland et al. investigated and exposed the application problems for the conventional micro-channel which resulted in high pressure drop as well as high temperature gradient.

Chang and Prasher shown that flux can be extracted of the range of 250 W/cm^2.

Wang and Peng investigated experimentally that the heat transfer characteristics of water and methanol movement through micro-channels with rectangular random section.The outcome of the experiment signifys a great change into the behavior pattern of the forced-flow convection in micro-channels.

Chen and Chang proposed a bifurcation at 90^0 in rectangular heat sink

Pence proposed a smaller intersection angle (less than90^0) in disk type shaped heat sink.

Peng and Peterson experimental results shows that small change in geometry or cross section area had a great effet on the single-phase forced convective heat transfer.

W. Qu and I. Mudawar have done research on ΔP and heat transfer characteristics of single-phase laminar flow in micro-channels. De-ionized water was used as cooling fluid and a pair of heat flux elevation, 100 W/cm^2 and 200 W/cm^2, defined relative to the plan form area of the heat sink were tested.

Jung et al has analysis the heat transfer coefficients & friction factor of aluminium oxide in a rectangular micro channel. Great outcome comes out as a result of advancement in the convective heat transfer coefficient of the nano fluids without any large scale friction loss.

W. Qu and I. Mudawar conducted 3D fluid flow movement and analysied similar to that of **Kawano et al.** and **Fedorov and Viskanta**. This model considered the hydrodynamic and thermal developing flow along the channel and found that the Reynolds number would effect the dimension of established circulate region.

J. Koo et. al. has considered two types of nano fluids, i.e., copper oxide nano spheres at low volume concentrations in water or ethylene glycol He studied. the impact of nano particle concentrations in these two mixture flows on the micro channel pressure gradients, temperature profiles and Nusselt numbers are computed, in light of aspect ratio, viscous dissipation, and enhanced temperature effects. Based on these outcomes,he recommended it for micro heat-sink work advancement.

Tsung-Hsun Tsai et.al. analysed MCHS work using copper–water (Cu–H2O) and carbon nano tube–water (CNT–H2O) nano fluids as coolants in the study. The velocity and temperature distributions were obtained by modeling the MCHS as a porous media. The result were then used to evaluate the thermal resistance that characterizes MCHS performance. It was found that the nano fluid reduced the temperature difference between to a great extend as compared to that of pure fluid.. This temperature difference produces a reduction in conductive thermal resistance.

Jie Liet. al. examined two effective thermal conductivity models for nano fluids in detail, where he employed the commercial Navier–Stokes solver CFX-10 and user-supplied pre- and post-processing software. The outcome clearly defines that nanofluids add to the thermal performance of microchannel mixture flow with a minimal rise in pumping power.

Lee et. al. created oblique fins in a micro channel heat sink to modulate the flow, resulting in heat transfer enhancement. Mathematical investigation of laminar flow and heat transfer in altered micro channel heat sink showed that significant enhancement of heat transfer can be attain with slightly pressure drop penalty. The combination of the entrance and secondary flow effect results in a much improved heat transfer performance (the average and local heat transfer coefficients are enhanced approximately as 80%). Both the maximum wall temperature and temperature gradient are substantially decreased as a result.

Several researches **Masuda et al., Lee et al., Xuan and Li, and Xuan and Roetzel** stated that with low nano particles concentrations (1–5 Vol%), the thermal conductivity of the suspensions increased by more than 20%.

Eastman et al. at Argonne National laboratory showed with some primary experiments with suspended nano particles, the thermal conductivity of approximately 60% can be obtained with 5 vol% CuO nano particles in the based fluid of water.

Based on the above scholars and professors review, it can be observed that the effect of oblique channel, wavy channel and branched wavy channel with nano fluid on heat transfer performance has never been investigated. Thus, the ambition of this project is to perform the full domain heat transfer and fluid motion analysis for oblique channel, wavy channel and branched wavy channel with nanofluid.

III. OBJECTIVES

The basic aim of my work is development a geometry which has highly effective heat transfer augmentation technique for micro channel heat sink. This solution should enhance heat transfer performance and eliminate the temperature mal distribution across the heat source surface while preventing significant pressure drop penalty. The major objectives of this research are:

- The intent of this project is to show the heat transfer performance using oblique-finned, wavy & branched wavy channel with the use of nano fluid and water
- A comparative study is to be presented for oblique and wavy & branched wavy channel
- To design a novel geometry with the aim of better cooling solutions
- To perform full domain simulation in oblique finned, wavy and branched wavy micro channels while considering edge effect as well as migration effect
- To examine and explore the influence of edge effect on flow and temperature uniformity

IV. METHODS AND MATERIAL

MATHEMATICAL MODELING

For numerical study, full domain of Oblique, Wavy and Branched Wavy novel geometry is designed in SOLID WORKS 15 and the simulation along with meshing is done in ANSYS 15.0 and ANSYS 16.0. The full geometry along with simulation domain is meshed using different elements mostly hexahedral volume elements using proximity and curvature option in ANSYS Meshing.

The following assumptions which are made to remove the complexity of the process are

- ✓ Steady state
- ✓ Incompressible laminar flow
- ✓ Constant fluid properties
- ✓ No viscous dissipation
- ✓ No radiative and natural convective heat transfer
- ✓ Negligible net migration of the fluid through channels in the way perpendicular to the fluid flow were made in the design model simulation setup.

SOLUTION METHOD

In this study, the 3-dimensional domain was used in the simulations. The simulation domain consisted of the aluminium (base and fins), and the fluid domain (water and nanofluid).Navier–Stokes equations have been solved with the help of the finite volume method on ANSYS Fluent 15.0 and ANSYS FLUENT 16.0.

The basic standard method is used for pressure discretization, and the SIMPLE scheme is employed for pressure–velocity coupling. The second order upwind scheme is used to calculate the momentum and energy equations. The Standard initialization option has been used for initializing solution.

For the boundary conditions, a constant heat flux was equipped from the base of the heat sink model and an adiabatic condition is enforce on the top of the fins, side base walls of the sink and few surfaces of fluid domain region. Periodic conditions are employ on the side walls. Constant velocity and constant pressure boundary conditions are employ at the inlet and outlet respectively.

The solutions are considered to have converged once the residues for energy, continuity and momentum equation reaches 10^{-06} and 10^{-04}.

V. CONCLUSION

1. The outcome from numerical simulation shows a clear comparison of oblique-finned microchannel, wavy finned microchannel and branched wavy microchannel using nanofluid having 1%,2% and 3% concentration (alumina-water mixture) and water as working fluid.
2. The results show rise of pressure drop in oblique, wavy and branched wavy channel with increase in the nanoparticle concentration.

3. In discrete phase modeling, the result shows highest pressure drop in wavy channel followed by branched wavy and oblique channel.
4. The mean value of h is much higher in branched wavy finned channel when compared to oblique and wavy channel.
5. The results shows higher in discrete phase modeling as compared to mixture rule which suggest DPM is better.
6. So, branched wavy-finned microchannel can be a potential alternative to microchannel heat sink application.

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Cite this article as :

Tushar Singare, Mohd. Shahnawaz Ansari, "An Experimental Analysis of Microchannel Heat Sink using Novel Geometry with Nano Fluid and Water", International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), Online ISSN : 2394-4099, Print ISSN : 2395-1990, Volume 6 Issue 6, pp. 49-66, November-December 2019. Available at doi : https://doi.org/10.32628/IJSRSET196618
Journal URL : http://ijsrset.com/IJSRSET196618