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Computational Heat Transfer Analysis in Spiral Micro-Channel Heat Sink

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Abstract

Objectives: The research work studied so far doesn't involve much work on Spiral Micro-channel so the concept of spiral micro channel was proposed. To determine pressure drop and temperature drop with varied flow-rate at constant heat source in spiral micro channel. **Methods:** The computational heat transfer analysis on Spiral Micro-channel Heat Sink (SMCHS) has been performed with varied mass flow rate of 1-3 kg/hr in two different flow arrangements. One when the fluid Entry at Inner Spiral (IS) and another when the fluid Entry at Outer Spiral (OS). Both the cases are compared at the constant heat input, which was given at the bottom surface of the SMCHS. The CFD analysis determined the point parameters at inlet and outlet of Spiral micro channel. **Findings:** The computational fluid dynamics analysis shows the less pressure drop and temperature drop results when fluid entry at IS as compared to OS for every flow rate; which is an innovation. The computational results show that pressure drop decreases by 2.39% and temperature drop decreases by 6.99% when fluid entries at IS as compared to OS. **Applications:** The spiral micro channel has a wide application in the area of electronic cooling; futuristic application is to cool the armor, spot welding etc.

Keywords: Heat Sink, Spiral Micro-channel, Spiral Eye

1. Introduction

In oday's era the micro channel is being widely used in many areas in the field of thermal engineering. Micro-channel heat exchanger, micro channel heat sink, micro channel in micro-fluidics devices, etc. are some of the major areas where micro channel is used. Assume of all the places where air is perfectly cooled; at home, at the office, at industries, at a restaurant, etc. It's all about the heat generated by the electronic components and cooling these systems is the main focus. One of the key components to cool these systems is micro channel. Many researchers are doing exciting things in the world of cooling systems. Micro-channel is completely changing the things in performance of cooling the systems. By using the micro channel the rate of heat transfer can be augmented, thus reduce the energy consumption and significantly improve environmental performance.

In[1] set as pioneers in the successful application in high heat flux electronics cooling and micro-fluidic devices. The concept of six topics related to transport phenomena in micro-channels: single-phase gas flow, enhancement in single-phase liquid flow and flow boiling, flow boiling instability, condensation, electronics cooling and micro scale heat exchangers. Micro-channels are defined as flow passages that have hydraulic diameters in the range of 10 to 200 micrometer[3]. The phenomenon of conduction through heater takes place at first place while convection takes place later in a fluid. Free convection flow may be classified according to whether the flow is bounded by a surface[4]. For experimental purposes a device used to measure pressure is called a manometer and it is commonly used to measure small and moderate pressure differences. To keep the size of manometer to manageable level, heavy fluid such as mercury is used if large pressure differences are anticipated[5]. The experimental work

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involves the choosing the best material for the research[6]. Solid materials have been conveniently grouped into three basic classifications: metals, ceramics and polymers. Material like metal are composed of one or more metallic elements (such as iron, Aluminum, copper, etc.). The material for the micro channel can be chosen depending on the thermal conductivity. The material which has high thermal conductivity offers a much high rate of heat transfer, as it conducts heat at much faster rate from one place to another. Thermal conductivity (of a material) depends essentially upon following factors:

i) Material Structure
ii) Moisture Content
iii) Density of material
iv) Pressure and Temperature (operating conditions)[7].

If particularly good pressure drop data[8] are to be obtained, it may be desirable to make use of a piezo meter ring that is an interconnected set of static pressure holes around the perimeter of the duct in a plane normal to the direction of flow. The pressure drop across the micro channel can be measured directly with a manometer or a differential pressure gauge[8].

In[9] have experimentally studied the impact of channel and plenum aspect ratios with different flow arrangements P, U and S kind Micro-channel Heat Sink for various Reynolds number at different heat inputs. In[10] studied the pressure drop in two types of square mini-channel heat sink. Both types of square mini-channel one with spiral geometry and the other with straight geometry, which has 90-degree bend has 30 mm x 30 mm base plate with 1mm square channel.

2. Design of Spiral Micro-channel

The Spiral Micro-channel is a passage for the fluid to flow with 0.8 mm x 0. 5 mm as the cross-section area and 358 mm as its length. In first step the 3D extruded part having dimensions 50 mm x 50 mm x 5 mm is made. The 3D extruded part is assigned the material Aluminum 6061. The inner circle of 5 mm is made at mid of Aluminum 6061 and spiral with a pitch of 5mm, revolution of 4.25 and start angle 135 degree is made by taking the inner circle as a reference. The spiral is offset with a distance of 0.25 mm in a bilateral direction. The outer circle is drawn at a point where the spiral ends i.e. at corner of Aluminum 6061 as shown in the Figure 1. The next step deals with the extrude cut command in order to get the passage for the fluid to flow. The inner circle, located at mid of spiral which has been made extrude cut is called as inner spiral eye while the outer circle, located at the corner of the spiral which has been made extrude cut is called as the outer spiral eye. Table 1 shows the dimensions of Spiral Micro-channel. In the second step the 3D extrude boss part is made and assigned the material as acrylic. The 'through all' 5mm diameter extrude cut is made on acrylic exactly at the position where inner and outer spiral eye is manufactured on Aluminum 6061. In the third step both the parts are assembled by keeping the acrylic on the Aluminum 6061. The forth step deals with the attachment of 'lid' on the opening of acrylic which helps in closing of inner and outer spiral eye as shown in the Figure 2.

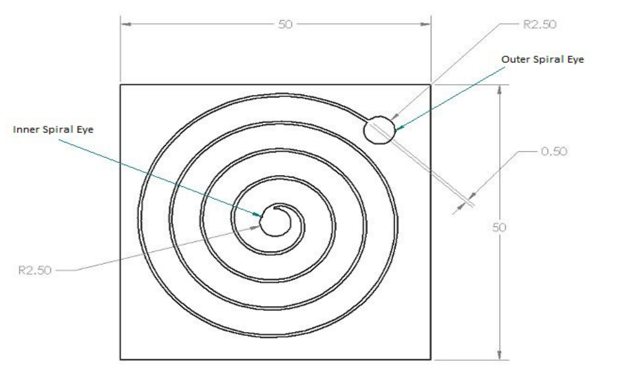

Figure 1. Two-dimensional design of spiral micro-channel with dimensions. All dimensions in mm.

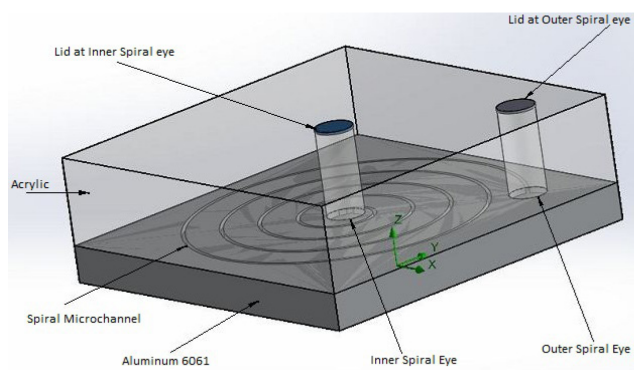

Figure 2. Three-Dimensional design of spiral micro-channel packed completely by acrylic. This 3-D design has been made in Solid Works 2012 x 64 Edition software.

Table 1. The dimensions of spiral micro-channel

Pitch of Spiral Micro channel	**5mm**
Revolution of Spiral Microchannel	4.25
Start Angle	135 degree
Length of Spiral Microchannel	358mm
Width of Spiral Microchannel	0.5mm
Height of Spiral Microchannel	0.8mm

3. Computational Analysis

Case 1: Inner Spiral eye is kept as inlet or (Entry at IS)

Case 1.1

The boundary condition at inlet is given as mass flow rate of 1 LPH (Liter Per Hour) or 1 kg/h. While at outlet the atmospheric temperature and pressure is given as boundary condition. While the heat source of 25 Watt is given at the bottom face of the Spiral Micro-channel heat sink as shown in Figure 3 and Figure 4.

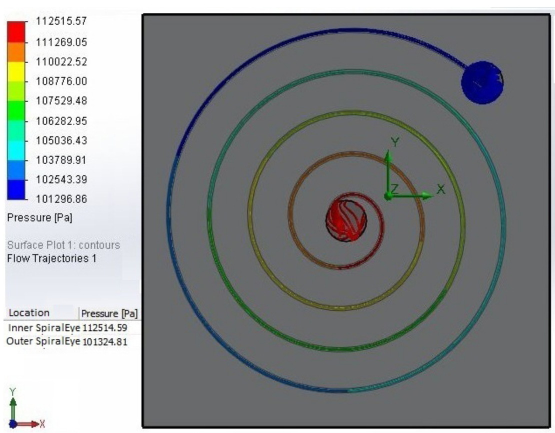

Figure 3. Pressure contours at 1LPH and 25 W (When Inner Spiral eye is kept as inlet).

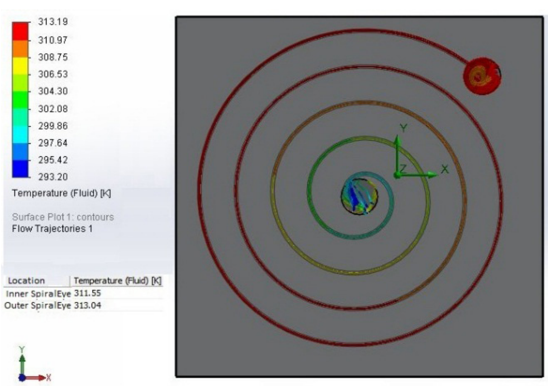

Figure 4. Temperature contours at 1LPH and 25 W (When Inner Spiral eye is kept as inlet).

Case 1.2

The boundary condition at inlet is given as mass flow rate of 1.5 LPH (Liter per hour) or 1.5 kg/h. While at the outlet the atmospheric temperature and pressure is given as a boundary condition. While the heat source of 25Watt is given at the bottom face of Spiral Microchannel Heat Sink as shown in Figure 5 and Figure 6.

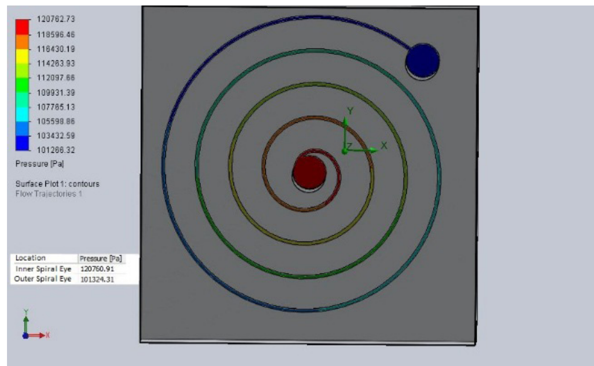

Figure 5. Pressure contours at 1.5LPH and 25 W (When Inner Spiral eye is kept as inlet).

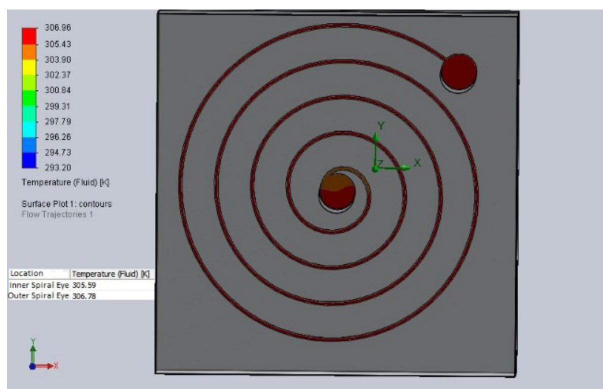

Figure 6. Temperature contours at 1.5LPH and 25 W (When Inner Spiral eye is kept as inlet).

Case 1.3

The boundary condition at inlet is given as mass flow rate of 2 LPH (Liter per hour) or 2 kg/h. While at the outlet the atmospheric temperature and pressure is given as a boundary condition. While the heat source of 25Watt is given at the bottom face of Spiral Micro-channel Heat Sink as shown in Figure 7 and Figure 8.

Case 1.4

The boundary condition at inlet is given as mass flow rate of 2.5 LPH (Liter per hour) or 2.5 kg/h. While at the outlet the atmospheric temperature and pressure is given as a boundary condition. While the heat source of 25Watt is given at the bottom face of Spiral Microchannel Heat Sink as shown in Figure 9 and Figure 10.

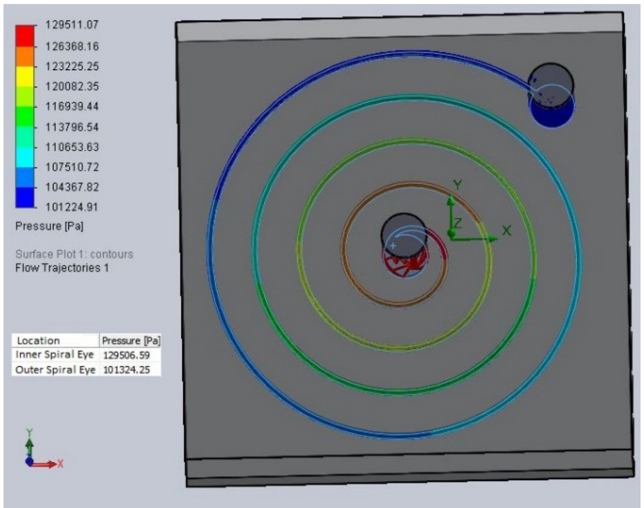

Figure 7. Pressure contours at 2LPH and 25 W (When Inner Spiral eye is kept as inlet).

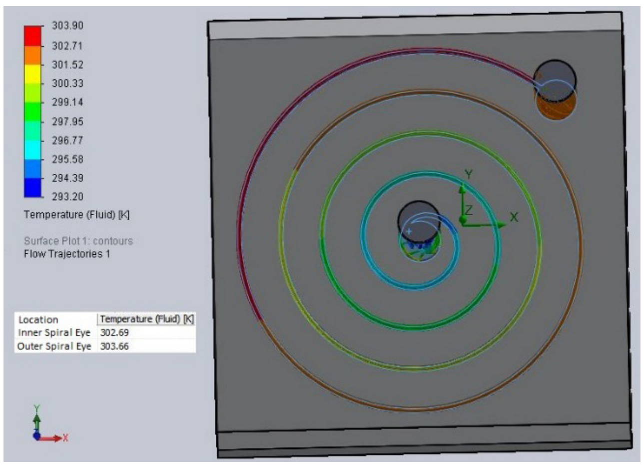

Figure 8. Temperature contours at 2LPH and 25 W (When Inner Spiral eye is kept as inlet).

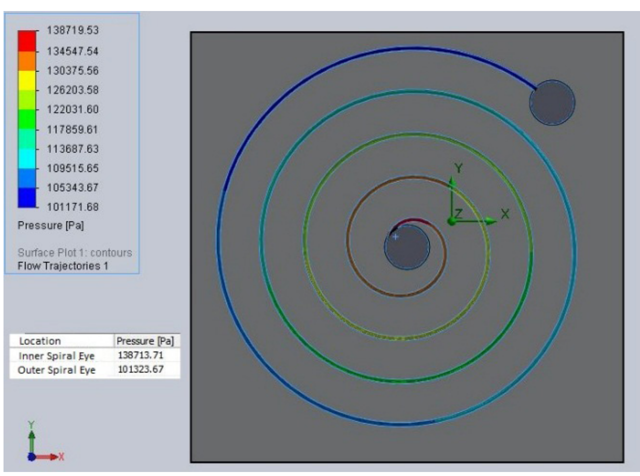

Figure 9. Pressure contours at 2.5LPH and 25 W (When Inner Spiral eye is kept as inlet).

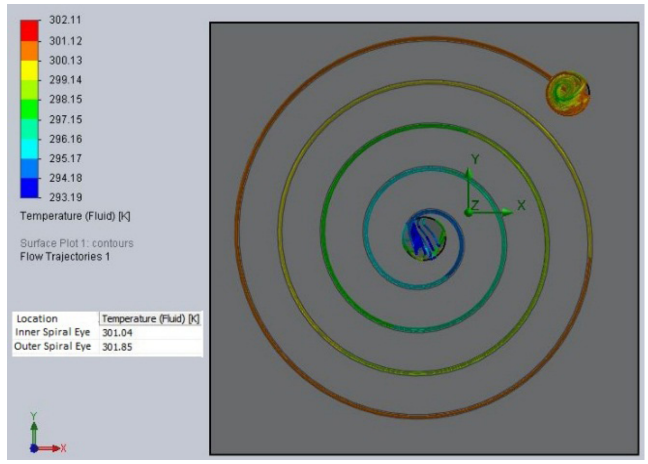

Figure 10. Temperature contours at 2.5LPH and 25W (When Inner Spiral eye is kept as inlet).

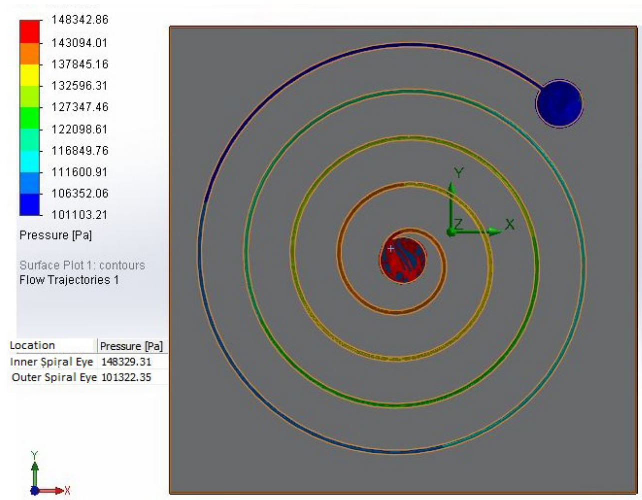

Figure 11. Pressure Contours at 3LPH and 25W (When Inner Spiral eye is kept as inlet).

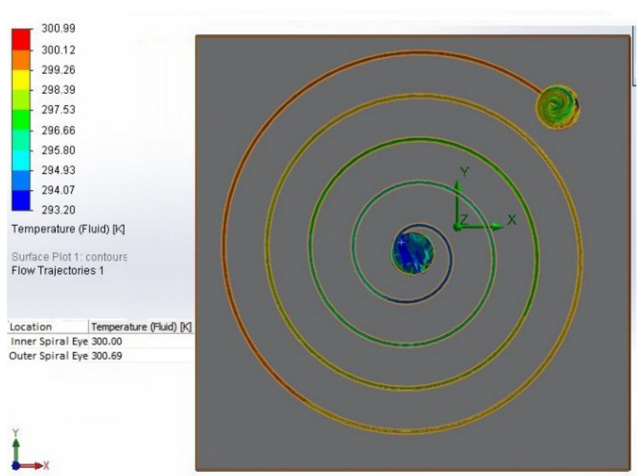

Figure 12. Temperature contours at 3LPH and 25 W (When Inner Spiral eye is kept as inlet).

Case 1.5

The boundary condition at inlet is given as mass flow rate of 3 LPH (Liter per hour) or 3 kg/h. While at the outlet the atmospheric temperature and pressure is given as a boundary condition. While the heat source of 25Watt is given at the bottom face of Spiral Microchannel Heat Sink as shown in Figure 11 and Figure 12.

Case 2: When Outer Spiral Eye is Kept as Inlet or (Entry at OS)

Case 2.1

The boundary condition at inlet is given as mass flow rate of 1 LPH (Liter per hour) or 1 kg/h. While at the outlet the atmospheric temperature and pressure is given as a boundary condition. While the heat source of 25Watt is given at the bottom face of Spiral Micro-channel Heat Sink as shown in Figure 13 and Figure 14.

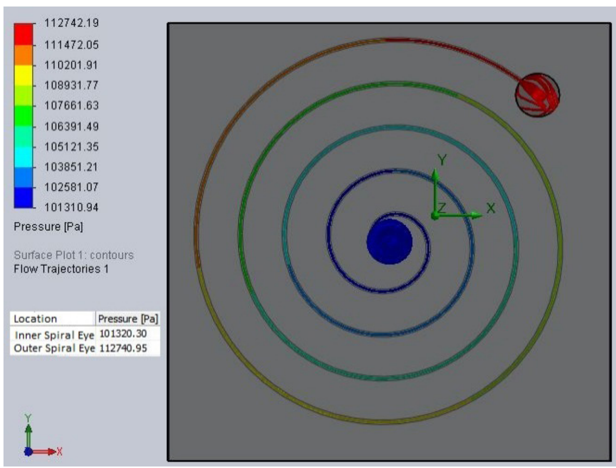

Figure 13. Pressure Contours at 1LPH and 25 W (When Outer Spiral eye is kept as inlet).

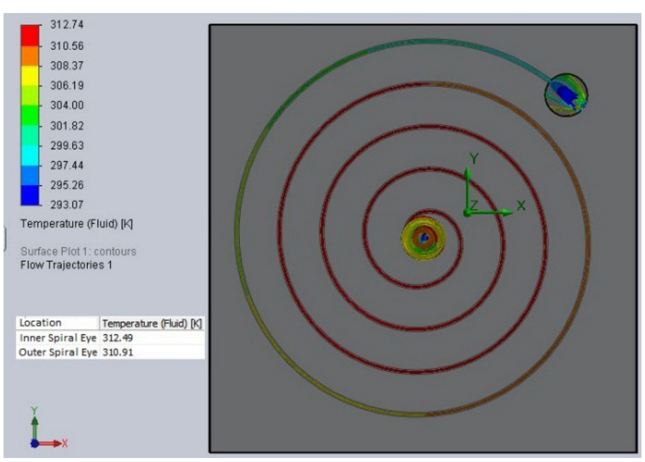

Figure 14. Temperature Contours at 1LPH and 25 W (When Outer Spiral eye is kept as inlet).

Case 2.2

The boundary condition at inlet is given as mass flow rate of 1.5 LPH (Liter per hour) or 1.5 kg/h. While at the outlet the atmospheric temperature and pressure is given as a boundary condition. While the heat source of 25Watt is given at the bottom face of Spiral Microchannel Heat Sink as shown in Figure 15 and Figure 16.

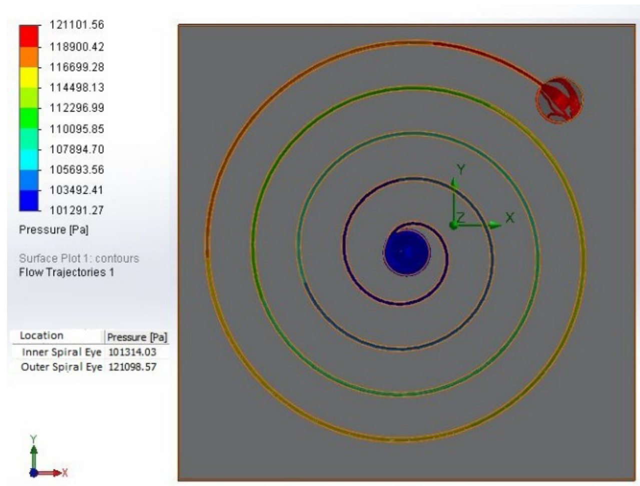

Figure 15. Pressure contours at 1.5LPH and 25 W (When Outer Spiral eye is kept as inlet).

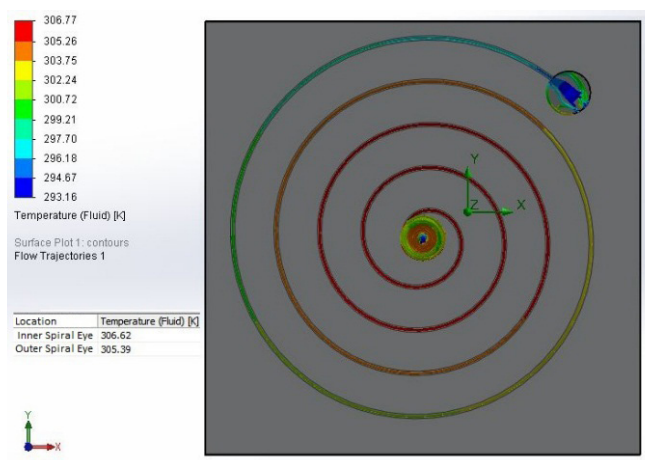

Figure 16. Temperature Contours 1.5LPH and 25W (When Outer Spiral eye is kept as inlet).

Case 2.3

The boundary condition at inlet is given as mass flow rate of 2 LPH (Liter per hour) or 2 kg/h. While at the outlet the atmospheric temperature and pressure is given as a boundary condition. While the heat source of 25Watt is given at the bottom face of Spiral Micro-channel Heat Sink as shown in Figure 17 and Figure 18.

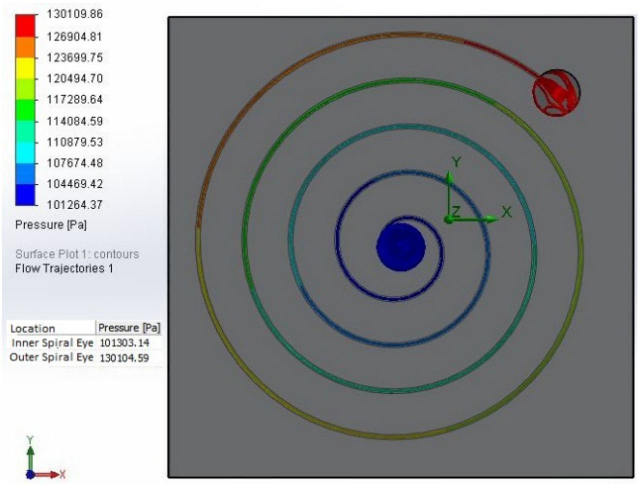

Figure 17. Pressure Contours 2LPH and 25W (When Outer Spiral eye is kept as inlet).

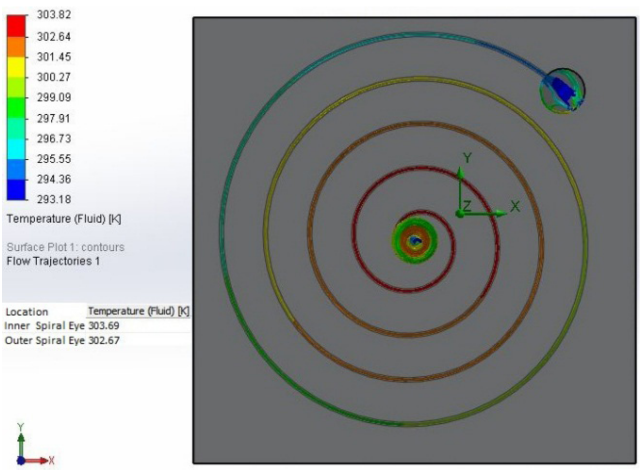

Figure 18. Temperature contours 2LPH and 25W (When Outer Spiral eye is kept as inlet).

Case 2.4

The boundary condition at inlet is given as mass flow rate of 2.5 LPH (Liter per hour) or 2.5 kg/h. While at the outlet the atmospheric temperature and pressure is given as a boundary condition. While the heat source of 25Watt is given at the bottom face of Spiral Microchannel Heat Sink as shown in Figure 19 and Figure 20.

Case 2.5

The boundary condition at inlet is given as mass flow rate of 3 LPH (Liter per hour) or 3 kg/h. While at the outlet the atmospheric temperature and pressure is given as a boundary condition. While the heat source of 25Watt is given at the bottom face of Spiral Micro-channel Heat Sink as shown in Figure 21 and Figure 22.

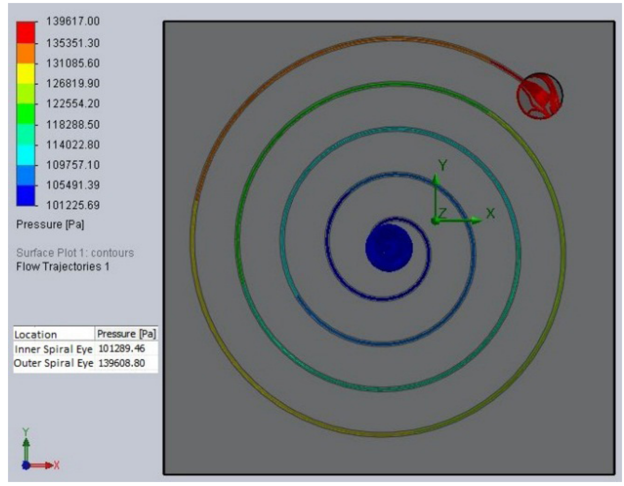

Figure 19. Pressure Contours 2.5LPH and 25W (When Outer Spiral eye is kept as inlet).

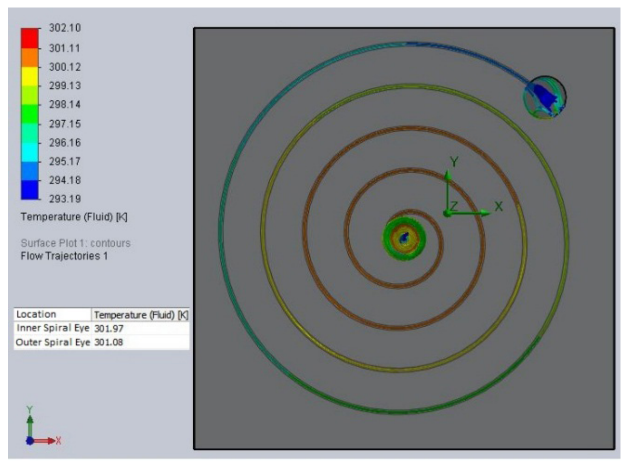

Figure 20. Temperature Contours 2.5LPH and 25W (When Outer Spiral eye is kept as inlet).

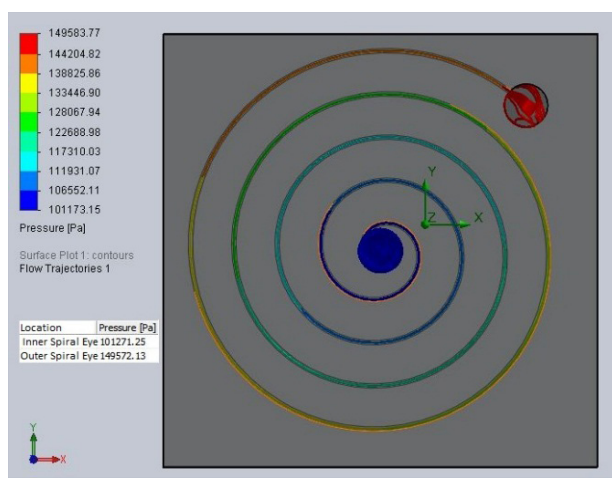

Figure 21. Pressure contours 3LPH and 25 W (When Outer Spiral eye is kept as inlet).

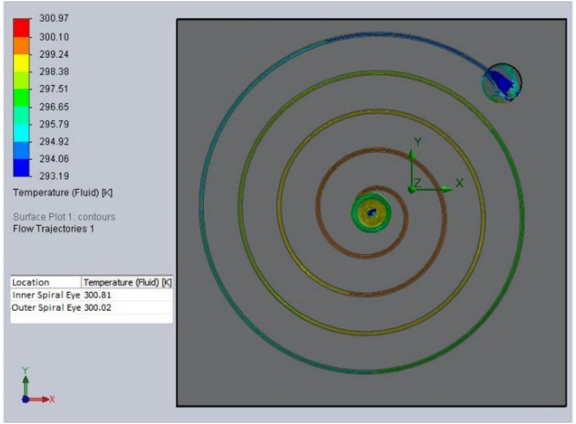

Figure 22. Temperature contours 3LPH and 25 W (When Outer Spiral eye is kept as inlet).

4. Results and Discussion

The computational analysis depicts which case of spiral profile micro channel suited best for the application of cooling the electronics components. The case which gives the best result like less pressure drop helps in depicting which more rate of heat dissipation. Even a minute difference in pressure could change the result and can make a clear vision of the researcher for choosing the best profile. It can be clearly seen from the Figure No. 3, 5, 7, 9, 11 of Case 1 and Figure No. 13, 15, 17,19, 21 of Case 2 that the Pressure Drop (ΔP) between the inner spiral eye and outer spiral eye when varied with the flow rate has ΔP less in Case 1 than Case 2. It can also be seen in the graph shown in Figure 23.Selecting the best case of spiral profile micro channel can make a big difference in enhancing the heat dissipation and growth in the field of cooling the electronic components. It can be clearly seen from the Figure No. 4, 6, 8,10,12 of Case 1 and Figure No. 14, 16, 18, 20, 22 of Case 2 that the Temperature Drop (ΔT) between the inner spiral eye and outer spiral eye when varied with the flow rate has ΔT less in Case 1 than Case 2. It can also be seen in the graph shown in Figure 24. The Figure 24.shows the temperature difference versus flow rate curve. The both Case 1 and Case 2 curves are decreasing with the increase in the flow rate. The Case 1 (when the inner spiral eye is kept as inlet) curve is below the Case 2 (when the outer spiral eye is kept as inlet) curve, which shows the Case 1 is best as compared to Case 2, because of the fact that the temperature difference is decreasing throughout as shown in Figure 24.

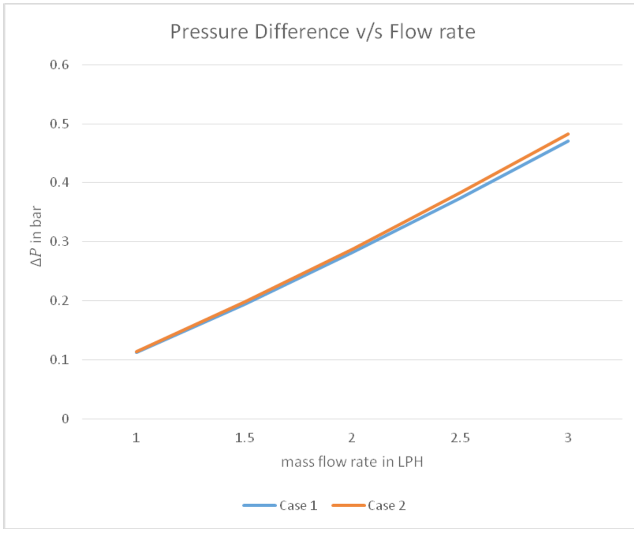

Figure 23. An increasing curve between pressure difference and mass flow rate.

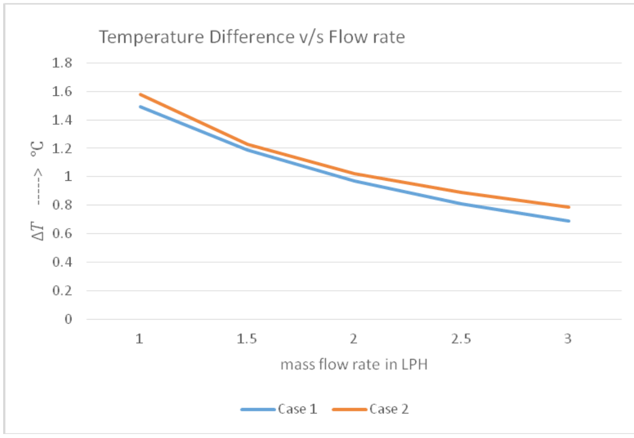

Figure 24. Temperature difference versus flow rate graph shows the decreasing curve.

5. Conclusion

The Computational Fluid Dynamics (CFD) analysis shows that the Case 1 is much more efficient than the Case 2. When inlet is kept at inner spiral eye the pressure drop and temperature drop is less as compared to inlet at outer spiral eye. Both Figure 23 and Figure 24 show that the Case 1 has fewer curves than Case 2, when varied with flow rate. The less pressure drop and less temperature drop shows the more rate of heat transfer. The computational results show that pressure drop decreases by 2.39% and temperature drop decreases by 6.99% when fluid entries at IS as compared to OS.

6. References

1. Tukerman DB, Pease RFW. High performance Heat Sinking for VLSI. IEEE Electronic Device Letters. 1981 May; 2(5):126-9.
2. Kandlikar SG, Colin S, Peles Y, Garimella S, Pease RF, Brandner JJ, Tuckerman DB. Heat transfer in micro-channel-2012 status and research needs. Journal of Heat Transfer. 2013 Jul; 135(9):1-18.
3. Kandlikar SG, Grande WJ. Evolution of micro-channel flow passages thermo hydraulic performance and fabrication technology. Heat Transfer Engineering. 2003; 24(1):3-17.
4. Wilt D, Lavine B. Fundamentals of Heat and Mass Transfer. 7th ed. Wiley India Pvt. Ltd.; 2011 Mar.
5. Cengel YA, Cimbla JM. Fluid Mechanics Fundamental and Applications. 3nd Ed. McGraw Hill; 2013.
6. Rethwisch RC, Balasubramaniam R. Material Science and Engineering. 2nd Ed. Wiley Publication; 2014.
7. Rajput RK. Thermal Engineering. 9th Ed. Laxmi Publications Ltd.; 2013.
8. Fraas AP. Heat Exchanger Design. 2nd Ed. Wiley India Pvt Ltd.; 2011.
9. Sehgal SS, Murugesan K, Mohopatra SK. Effect of channel and plenum aspect ratios on the performance of micro-channel heat sink under different flow arrangements. Journal of Mechanical Science and Technology. 2012 Sep; 26(9):2985-94.
10. Ghobadi M, Muzychka YS. Heat transfer and pressure drop in mini channel heat sinks. Heat Transfer Engineering. 2015 Jul; 36(10):902-11.