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Finite Element Analysis of Force Fed Micro Channels for High Flux Cooling Applications

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ABSTRACT:

High heat flux cooling is required in many applications such as power electronics, plasma-facing components, high heat-load optical components, laser diode arrays, X-ray medical devices, and power electronics in hybrid vehicles. In general, the exposed area that needs to be cooled for these systems is limited, and the amount of heat that needs to be removed is extremely high, thus requiring cooling of high heat fluxes. While high heat flux cooling is essential for creating an efficient cooling system, there are usually also other system requirements, such as low thermal resistance, surface temperature uniformity, low pumping power, compact design, suitability for large area cooling, and compatibility for use with dielectric fluids.In this thesis, thermal performance of the force-fed micro channel heat exchangers (FFMHX) in single-phase heat transfer mode using fluid water, R245A, R600A is analyzed using Ansys. Different models are modeled by varying micro channel heat sink height and compared by analysis. The channel length taken is 10mm. The width is kept constant at 50µm and the height is varied by 100µm and 150µm. Models are done in Creo 2.0, Thermal and CFD analysis are done in Ansys.

INTRODUCTION

HEAT SINK is a passive heat exchanger that cools a device by dissipating heat into the surrounding medium. In computers, heat sinks are used to cool central processing units or graphics processors. Heat sinks are used with high-power semiconductor devices such as power transistors and optoelectronics such as lasers and light emitting diodes (LEDs), where the heat dissipation ability of the basic device is insufficient to moderate its temperature. A heat sink is designed to maximize its surface area in contact with the cooling medium surrounding it, such as the air. Air velocity, choice of material, protrusion design and surface treatment are factors that affect the performance of a heat sink. Heat sink attachment methods and thermal interface materials also affect the die temperature of the integrated circuit. Thermal adhesive or thermal grease improve the heat sink's performance by filling air gaps between the heat sink and the heat spreader on the device.

HEAT TRANSFER PRINCIPLE:

A heat sink transfers thermal energy from a higher temperature device to a lower temperature fluid medium. The fluid medium is frequently air, but can also be water, refrigerants or oil. If the fluid medium is water, the heat sink is frequently called a cold plate. In thermodynamics a heat sink is a heat reservoir that can absorb an arbitrary amount of heat without significantly changing temperature. Practical heat sinks for electronic devices must have a temperature higher than the surroundings to transfer heat by convection, radiation, and conduction. The power supplies of electronics are not 100% efficient, so extra heat is produced that may be detrimental to the function of the device. As such, a heat sink is included in the design to disperse heat to improve efficient energy use. To understand the principle of a heat sink, consider Fourier's law of heat conduction. Fourier's law of heat conduction, simplified to a one-dimensional form in the x-direction, shows that when there is a temperature gradient in a body, heat will be transferred from the higher temperature region to the lower temperature region. The rate at which heat is transferred by conduction, , is proportional to the product of the temperature gradient and the cross-sectional area through which heat is transferred.

$$q_k = -kA\frac{dT}{dx}$$

Consider a heat sink in a duct, where air flows through the duct, as shown in Figure 2. It is assumed that the heat sink base is higher in temperature than the air. Applying the conservation of energy, for steady-state conditions, and Newton's law of cooling to the temperature nodes gives the following set of equations:

$$\dot{Q} = \dot{m} c_{p,in} (T_{air,out} - T_{air,in}) \quad (1)$$

$$\dot{Q} = \frac{T_{hs} - T_{air,av}}{R_{hs}} \quad (2)$$

Where

$$T_{air,av} = \frac{T_{air,in} + T_{air,out}}{2} \quad (3)$$

Using the mean air temperature is an assumption that is valid for relatively short heat sinks. When compact heat exchangers are calculated, the logarithmic mean air temperature is used. $\dot{m}$ Is the air mass flow rate in kg/s.

3D MODELING OF MICROCHANNEL HEAT SINK

10mm LENGTH

WIDTH 50µm & HEIGHT 100µm

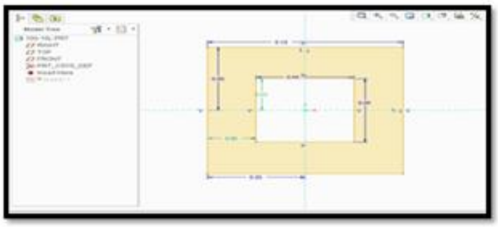


Fig - Sketch of micro channel heat sink with dimensions 100 µm * 50 µm * 10mm

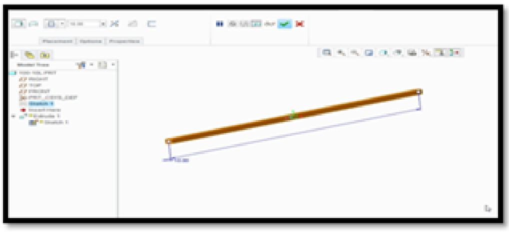


Fig – 3D model of micro channel heat sink with dimensions 100 µm * 50 µm * 10mm

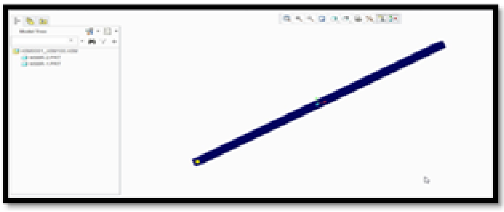


Fig – Assembly of micro channel heat sink with fluid area with dimensions 100 µm * 50 µm * 10mm

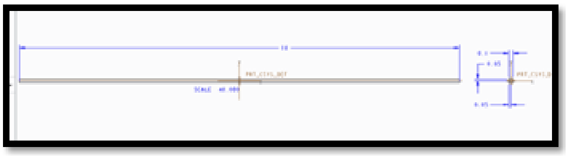


Fig – 2D Drawing of micro channel heat sink with fluid area with dimensions 100 µm * 50 µm * 10mm

WIDTH 50µm & HEIGHT 150µm

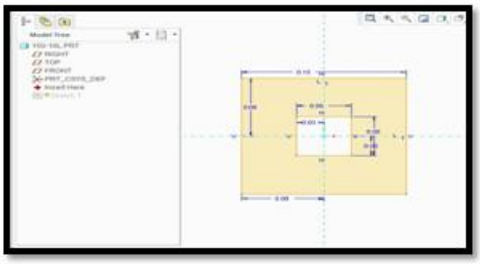


Fig - Sketch of micro channel heat sink with dimensions 150 µm * 50 µm * 10mm

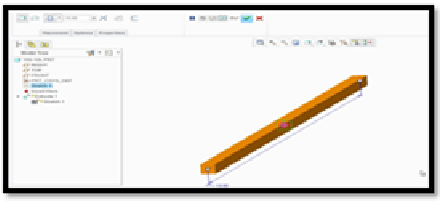


Fig – 3D model of micro channel heat sink with dimensions 150 µm * 50 µm * 10mm

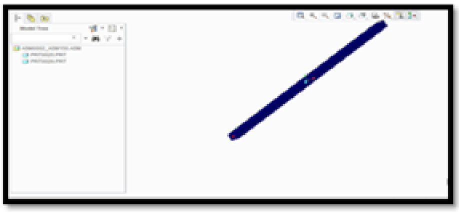


Fig – Assembly of micro channel heat sink with fluid area with dimensions 150 µm * 50 µm * 10mm

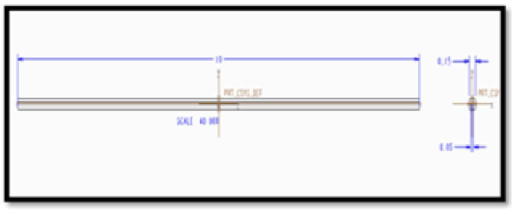


Fig – 2D Drawing of micro channel heat sink with fluid area with dimensions 150 µm * 50 µm * 10mm

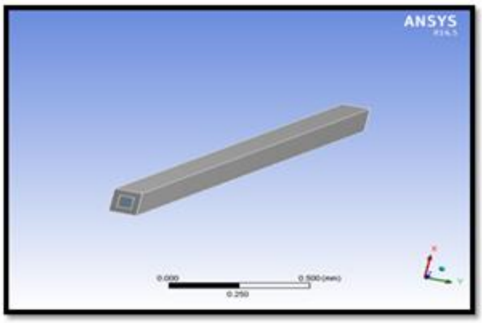
CFD ANALYSIS OF MICRO CHANNEL HEAT SINK

10mm LENGTH

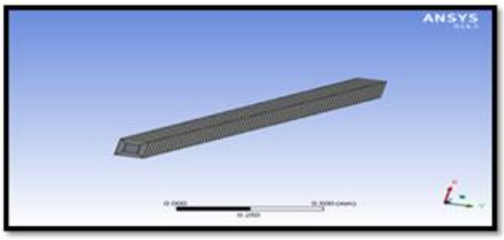
WIDTH 50µm & HEIGHT 100µm

FLUID –WATER

Import model

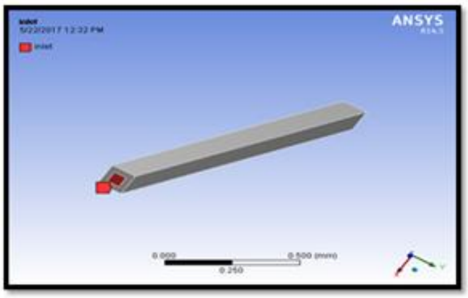


Meshed model

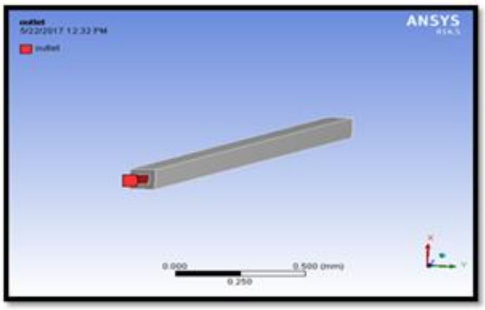


SPECIFYING BOUNDARIES FOR INLET AND OUTLET

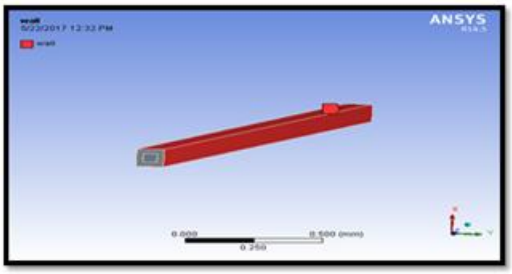
Inlet



Outlet



Wall



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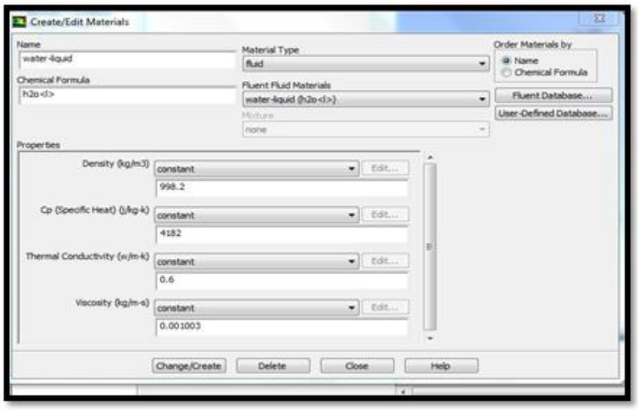
Select fluid Water



Create/Edit Materials

Name: water-liquid

Chemical Formula: h2o<l>

Material Type: fluid

Fluent Fluid Materials: water-liquid (h2o<l>)

Mixture: none

Order Materials by: ● Name ○ Chemical Formula

Properties

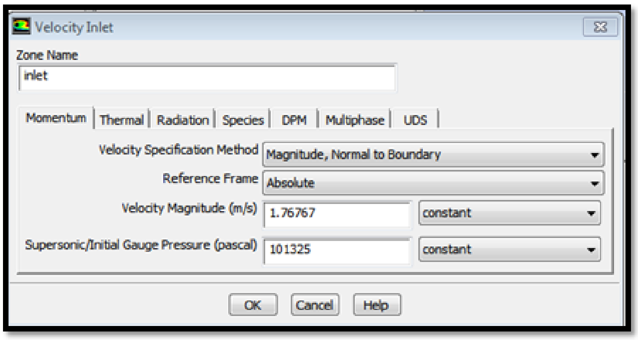
Density (kg/m3): constant — 998.2

Cp (Specific Heat) (j/kg-k): constant — 4182

Thermal Conductivity (w/m-k): constant — 0.6

Viscosity (kg/m-s): constant — 0.001003

Boundary conditions → select air inlet → Edit → Enter Inlet Velocity → 1.76767 m/s and Inlet Temperature – 298 K



Velocity Inlet

Zone Name: inlet

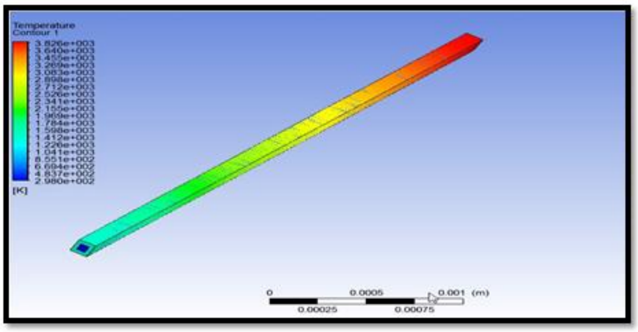
Velocity Specification Method: Magnitude, Normal to Boundary

Reference Frame: Absolute

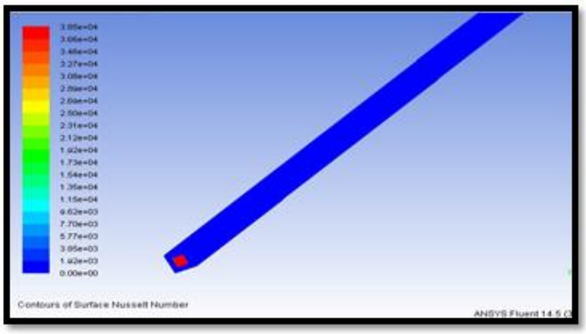
Velocity Magnitude (m/s): 1.76767 — constant

Supersonic/Initial Gauge Pressure (pascal): 101325 — constant

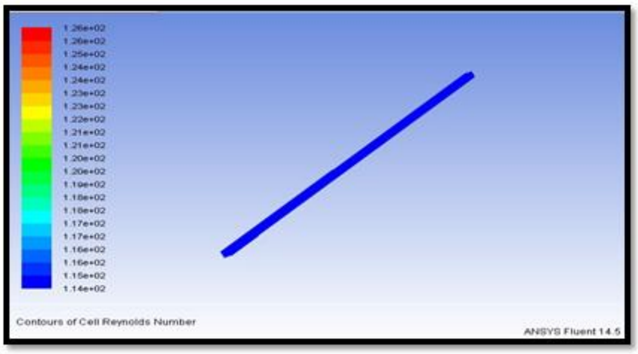
Static Temperature



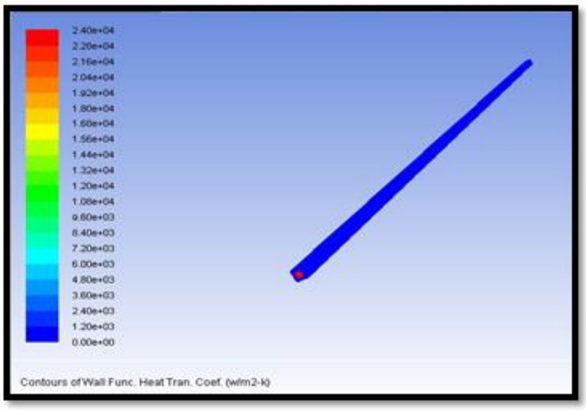
Nusselt number



Reynolds number



Heat transfer coefficient



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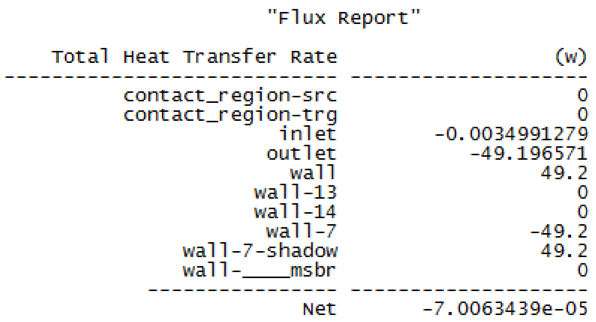

```
                     "Flux Report"

  Total Heat Transfer Rate                         (w)
-------------------------------- --------------------
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           contact_region-trg                        0
                        inlet          -0.0034991279
                       outlet            -49.196571
                         wall                  49.2
                      wall-13                     0
                      wall-14                     0
                       wall-7                 -49.2
                wall-7-shadow                  49.2
                wall-____msbr                     0
                -------------- --------------------
                          Net         -7.0063439e-05
```
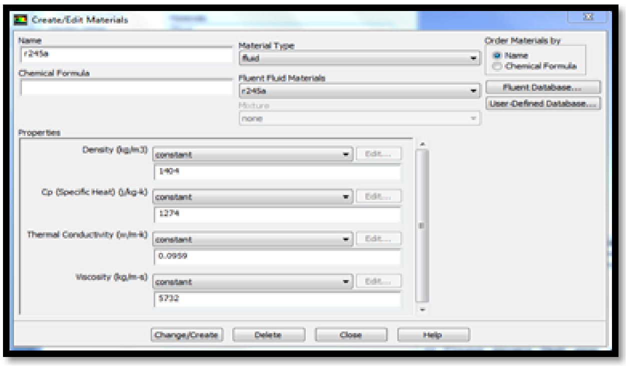

FLUID –R245A
Select fluid R245A



Create/Edit Materials

Name: r245a

Chemical Formula:

Material Type: fluid

Fluent Fluid Materials: r245a

Mixture: none

Order Materials by: ● Name ○ Chemical Formula

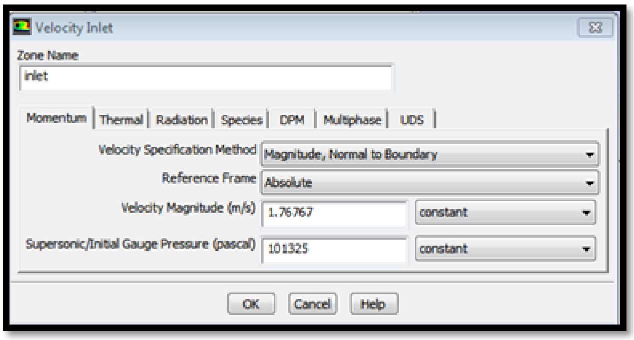
Properties

Density (kg/m3): constant — 1404

Cp (Specific Heat) (j/kg-k): constant — 1274

Thermal Conductivity (w/m-k): constant — 0.0959

Viscosity (kg/m-s): constant — 5732



Velocity Inlet

Zone Name: inlet

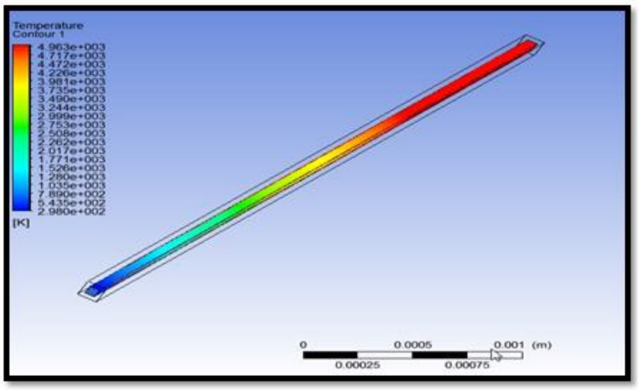
Velocity Specification Method: Magnitude, Normal to Boundary

Reference Frame: Absolute

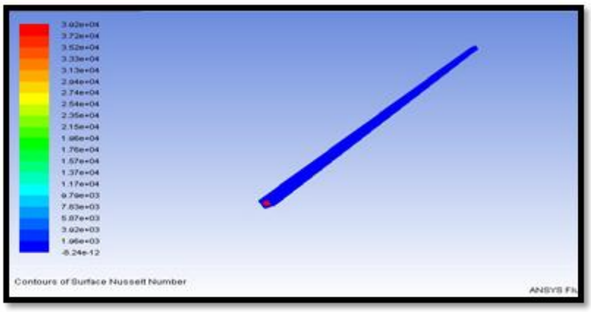
Velocity Magnitude (m/s): 1.76767 — constant

Supersonic/Initial Gauge Pressure (pascal): 101325 — constant

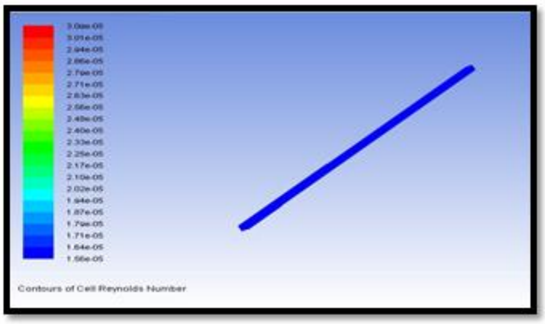
Static Temperature



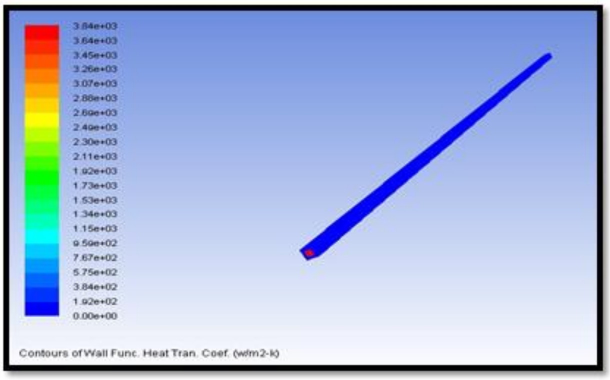
Nusselt number

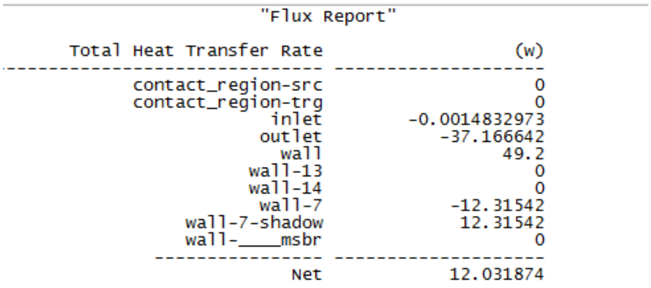


Reynolds number



Heat transfer coefficient





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                     "Flux Report"

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-------------------------------- --------------------
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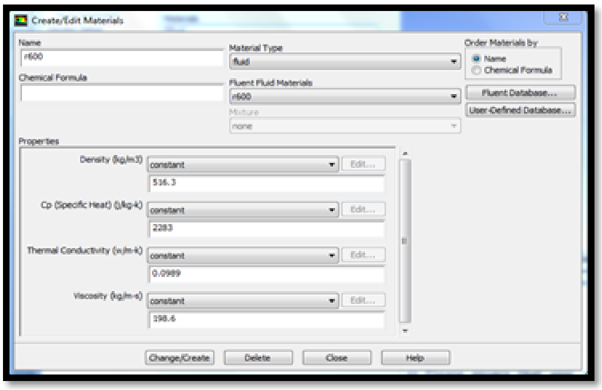
           contact_region-trg                        0
                        inlet          -0.0014832973
                       outlet            -37.166642
                         wall                  49.2
                      wall-13                     0
                      wall-14                     0
                       wall-7             -12.31542
                wall-7-shadow              12.31542
                wall-____msbr                     0
                -------------- --------------------
                          Net             12.031874
```

FLUID –R600A

Select fluid R600A



Name: r600

Chemical Formula:

Material Type: fluid

Fluent Fluid Materials: r600

Mixture: none

Order Materials by: ● Name ○ Chemical Formula

Properties

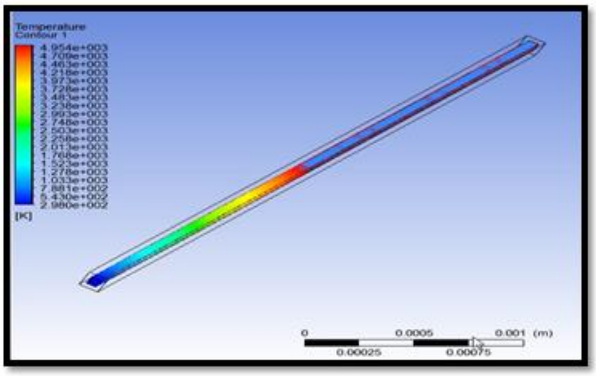
Density (kg/m3): constant, 516.3

Cp (Specific Heat) (j/kg-k): constant, 2283

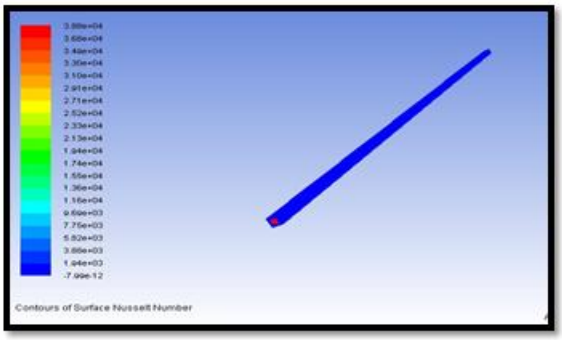
Thermal Conductivity (w/m-k): constant, 0.0989

Viscosity (kg/m-s): constant, 198.6

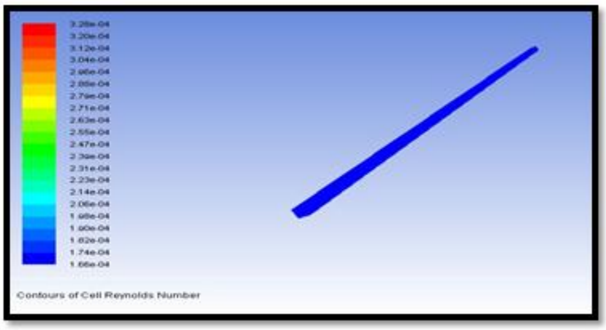
Static Temperature



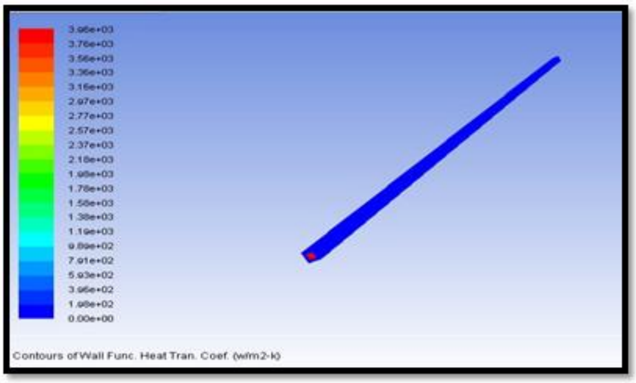
Nusselt number



Reynolds number



Heat transfer coefficient



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                       "Flux Report"

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 --------------------------------  --------------------
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          contact_region-trg                         0
                       inlet             -0.0012421905
                      outlet                -24.492032
                        wall                      49.2
                     wall-13                         0
                     wall-14                         0
                      wall-7                -8.4322679
               wall-7-shadow                 8.4322679
               wall-____msbr                         0
 --------------------------------  --------------------
                         Net                 24.706726
```

RESULT TABLES

CFD ANALYSIS

Length 10 mmFluid - Water

(µm)	Temperature (K)	Nusselt number	Reynolds number	Heat transfer co-efficient value (W/m^2-K)	Heat transfer rate (W)
Width 50µm & height 100 µm	3.826e+03	3.85e+04	1.26e+02	2.40e+04	7.00634e-05
Width 50µm & Height 150µm	4.954e+03	3.86e+04	1.26e+02	2.40e+04	0.1152642

FLUID-R245A

(µm)	Temperature (K)	Nusselt number	Reynolds number	Heat transfer co-efficient value (W/m^2-K)	Heat transfer rate (W)
Width 50µm & height 100µm	4.963e+03	3.92e+04	3.09e-05	3.84e+03	12.031874
Width 50µm & Height 150µm	4.954e+03	3.87e+04	3.09e-5	3.84e+03	36.631742

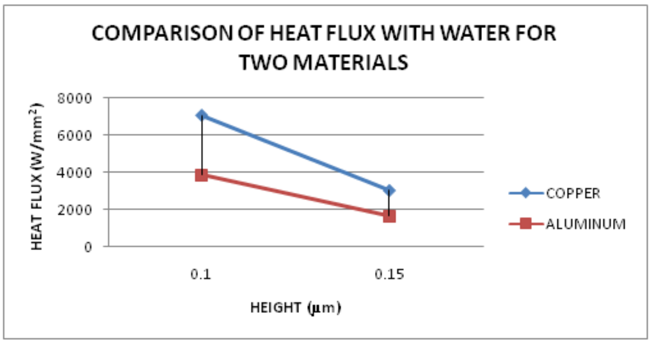
FLUID-R600A

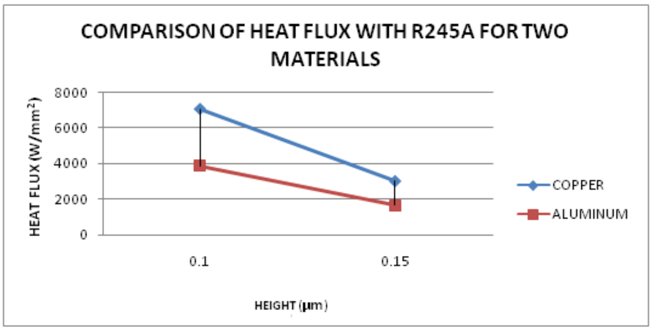
(µm)	Temperature (K)	Nusselt number	Reynolds number	Heat transfer co-efficient value (W/m^2-K)	Heat transfer rate (W)
Width 50µm & height 100µm	4.954e+03	3.88e+04	3.28e-04	3.96e+03	24.706726
Width 50µm & Height 150µm	4.954e+03	3.79e+04	3.28e-04	3.96e+03	49.306475

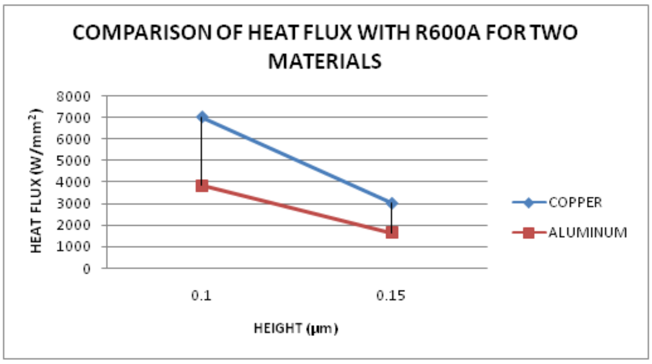
THERMAL ANALYSIS

10mm Length

			Temperature (K)	Heat flux (W/mm^2)
COPPER	Width 50µm & height 100µm	Water	365	7041.6
		R245a	365	7043.6
		R600	365	7019
	Width 50µm & Height 150µm	Water	365	3013.8
		R245a	365	3014.1
		R600	365	3009.7
ALUMINUM	Width 50µm & height 100µm	water	365	3842
		R245a	365	3842.5
		R600	365	3835.2
	Width 50µm & Height 150µm	Water	365	1644.1
		R245a	365	1644.2
		R600	365	1642.9







CONCLUSION:

Different refrigerants Water, R245A, R600A are analyzed for thermal performance in micro channel heat exchangers using Ansys. Models are done in Creo 2.0.Different models are modeled by varying micro channel heat sink height and compared by analysis. The channel length taken is 10mm. The width is kept constant at 50µm and the height is varied by 100µm and 150µm.CFD and Thermal analysis are done in Ansys. By observing the CFD analysis results, for all fluids, Nusselt number, Reynolds number are decreasing and heat transfer rate are increasing by increase of height and heat transfer coefficient is same by increase of height. Nusselt number is more when water is used, Reynolds number is more when R245A is used, Heat Transfer Coefficient is more when water is used and Heat Transfer rate is more when R600A is used. By observing the thermal analysis results, the heat flux is more for Copper than Aluminum. Heat flux is decreasing with increase of height and the value is more when R245A is used since its heat transfer coefficient is more.

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