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Heat Enhancement in Mini Channel Heat Exchanger using Software Analysis Method

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ABSTRACT
Extensive studies have been conducted over mini channel heat exchanger, the interest in mini channel heat exchanger is increasing rapidly due to use in various tools which are used in day to day life such as microprocessors in computer, ventilation, air conditioning and refrigeration. The paper investigate about the heat transfer rate in mini channel heat exchanger using Computer analysis method. Serrated type rectangular channel with 1405.54mm^2 per channel heat transfer contact surface area is opt for this type of heat exchanger. Using 31mm x 31mm base rectangle composed of 3 channels with each channel dimensions as 7.67mm x 11mm and length 31mm having 2mm x 1mm square serration across length. With the upgrade in geometry and keeping flow medium same the percentage increase in area obtained is 21.42%. The base temperature from the application ranging from 70^{0}C to 80^{0}C with air as medium having Specific heat 1006.43 J/kg-k and thermal conductivity as 0.026 w/m-k are the operating conditions for experiment. Validation of Computer analysis method is done using Analytical method.

Keywords - Heat exchanger, Heat transfer rate, cross section area, heat flux, mini channel.

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I. INTRODUCTION

The demand for miniature products in the market is growing day by day. Most of the electronic products heat while working. It is mandatory to carry that heat out of the system. Heat exchangers in the mini form of conventional type have got more importance in such applications. Mobile phones and laptops, as well as computers, have small (miniature) processors. In order to cool the processor, the mini channel heat exchanger is adopted. Aviation industries and computer processing unit are the vast fields for mini channel heat exchanger.

Geometries which are used to manufacture heat exchangers are different. The heat flow rate per unit time and cost is very precise in order to define the best heat exchanger. Heat flux (rate of heat flow) depends on the surface area in contact with the fluid flowing through the channel of a heat exchanger. It is very much appreciated to have a large contact surface area for the same internal flow volume. The geometry having such property can be adopted while designing the heat exchanger. It will directly affect the cost required to carry out the heat, and also defines the efficiency of the system.

Various ways were decided by different scientists to categories heat exchanger type i.e. whether it is a mini channel, micro channel or conventional type heat exchanger. The categories may vary especially with the hydraulic diameters of the channel of a heat exchanger. Sometimes dimensionless numbers are employed to carry out categorization of the heat exchanger.

II. RESEARCHES AND ADVANCE ABROAD

In the previously done experiments it is proved that channel evaporator has benefits on volume, weight and heat transfer. In this experiments it is proven that the louver fin is more suitable for mini channel heat exchanger that the corrugated one in reduction of air side pressure drop. The increased in surface contact area results in more hear transfer. One research states that the increased power and reduced velocity results in enhanced concentration of laser, but thermal effects would be more pronounced in case of increase in power. The increase in size of the micro channel results in the reduction of the surface tension drag.

The research study has been done on shape and contact angle of the micro channel. Numerical model of mini channel are being developed, focusing on mass transfer and heat transfer for condensation. The overall research results shows that as the hydraulic diameter decreases the condensation and heat transfer increase, and with increasing contact angle the heat transfer increases. One of the researches is that increasing refrigerant mass flow rate increases the refrigerant heat transfer coefficient. Also, the heat transfer in the evaporator is influenced by the heat transfer rate and saturation temperature.

The other one research is the performance analysis of micro-channel, round tube and coil tube by using R134a and R290 refrigerants. It is observed that for both refrigerants the coefficient of performance (COP) increases with the increase in cooling load f. The COP of the system using micro channel condenser is found 19.75% higher than with round tube condenser and 8.65% higher than with coil tube condenser using R134a. The COP of the system using micro channel condenser is found 8.21% higher than with round tube condenser and 4.04% higher than with coil tube condenser using R290.

III. ADDITIONAL INPUTS

The main purpose of the numerical simulation of the fluid flow is to analyze the distribution of the air in various shapes of heat exchanger tubes. The fluid flow analysis is oriented to obtain a result of the airflow field, useful to determine which element of the actual geometry of the channel of the heat exchanger have a greater responsibility in the enhancement of the heat transfer in the mini channel heat exchanger.

IV. METHODOLOGY

Fluid flow analysis using ANSYS software allows to predict the impact of flowing fluid on the required product. It is easy to solve complex problems related to flowing fluids, fluid and solid interaction, fluid and gaseous interaction by using fluid flow analysis in ANSYS. This computer analysis method saves time in the designing process and becomes very fast and cheaper method than conventional analysis method. For the purpose of verification, an analytical method is being used.

Various steps involved are:

3D modelling using Ansys 2019 R2 – Design Modeler.

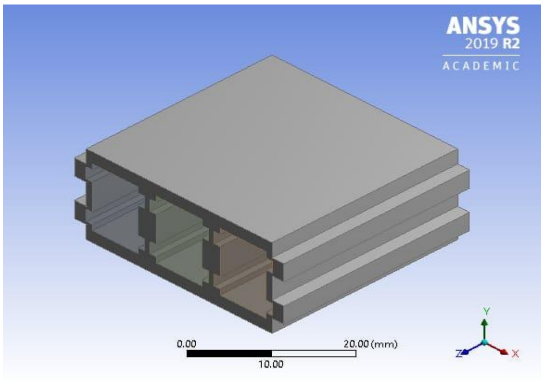

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Fig. 1.3D model of mini channel heat exchanger

4.1 Pre-processing

The required problem statement is getting transformed into an idealized and discretized computer model. Different assumptions are made concerning the type of flow to be modelled (viscous / in viscous, compressible / incompressible, steady / non-steady). Meshing is done on the 3D component. Fine meshing gives better results than auto meshing. Desired boundary conditions for the required product are given.

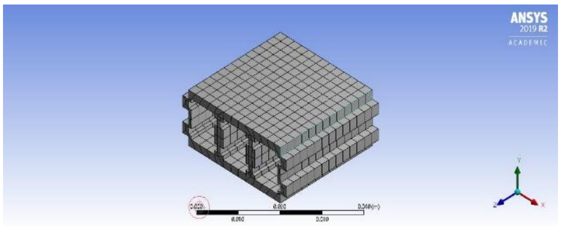

Fig. 2. Meshing of mini channel in Ansys

4.2 Solving

After proper meshing, the given problem is solved by programming matrices and solver. The background calculations were done in order to get the solutions by solving the different matrices formed by using the equations in the computer. By solving the equations the computer gives us the required results.

4.3 Post-processing

At this stage, the analyst can verify the results and conclusions can be drawn based on the obtained results. We get results in graphical, tabular form and the different colours are shown on the design so that we can determine the different conclusions. Each different colour indicates the significant amount of the quantity. The results must be in a readable form. Finally, the obtained results are visualized and analyzed in the post-processing phase. Along with the above methods, there are other ways of presenting the obtained results are for example static or moving pictures, graphs or tables.

V. CALCULATION

5.1 Serrated Fins Mini Channel Heat Exchanger:

- Heat transfer from source in upward direction due to conduction :

  K_{cu} = 385 W/m^{o}K
  K_{air} = 0.00261 W/m^{o}K
  $\Delta t = T_1 - T_2$
  = 343-309 = 34 ^{o}K

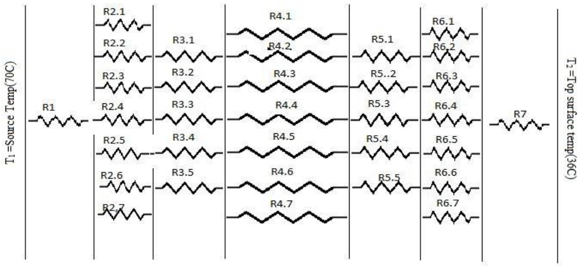

Fig. 3. Electrical Analogy

$R_1 = R_7 = 5.405\text{x}10^{-3}$ ^{o}K/W
$R_2 = R_6 = 0.01178$ ^{o}K/W
$R_3 = R_5 = 0.083666$ ^{o}K/W
$R_4 = 0.05234$ ^{o}K/W
$\sum R = R_1 + R_2 + R_3 + R_4 + R_5 + R_6 + R_7$

$$Q = \frac{\Delta t}{\sum R}$$

Q = 133.83 Watts
Where,
K_{cu} = Thermal conductivity of copper
K_{air} = Thermal conductivity of air
Δt = Temperature diffrence across mini channel
R_1 to R_7 = Resistance in mini channel
Q = Heat transfer in conduction

- Heat transfer due to convective heat transfer in single channel :

  Properties of Air at 300 ^{o}K :
  Dynamic viscosity (μ) = $1.872\text{x}10^{-5}$ kg/ms
  Kinematic viscosity (ν) = $1.608\text{x}10^{-5}$ m^2/s
  K_{air} = 0.00261 W/m^{o}K
  Specific heat at constant volume (Cp) = 1.007 KJ/kg^{o}K
  Ambient temperature (T□) = 300^{o}K
  Avg. Wall Temperature (TW) = 321.8^{o}K

$$Tmf = \frac{T\infty + T_1}{2}$$

Tmf = 310.9 ^{o}K
β = 1/Tmf
$\beta = 3.21\text{x}10^{-3}$
Δt = 21.8 ^{o}K
L = 4A/P
L = $8.14\text{x}10^{-3}$ m

Grashof number

$$Gr = \frac{L3.g.\beta.\Delta t}{\nu 2}$$

Gr = 1436.768
Pr = μ.Cp/K_{air}
Pr = 0.722
Nu = $0.27(\text{Gr.Pr})^{1/4}$
Nu = 1.532
Nu = h.L/K_{air}
h = 4.912
Q = h. Δt
Q = 107.08 W/m^2
Where,
L= Characteristics length
Gr=Grassoff number
Pr= Prandtl number
Nu= Nusselt number
h= Convective heat transfer coefficien
Q= Heat transfer in convection

5.2 Rectangular Mini Channel Heat Exchanger:

- Heat transfer from source in upward direction due to conduction :

  Kcu = 385 W/m^{o}K
  Kair = 0.00261 W/m^{o}K
  Δt = T1 – T2
  = 343-311 = 36 ^{o}K
  R1 = 5.405x10-3 ^{o}K/W
  R2 = 0.1157 ^{o}K/W
  R3 = 5.405x10-3 ^{o}K/W
  $\sum R$ = R1 + R2 + R3

$$Q = \frac{\Delta t}{\sum R}$$

Q = 253.992 Watts
Where,
K_{cu} = Thermal conductivity of copper
K_{air} = Thermal conductivity of air
Δt = Temperature diffrence across mini channel
R_1 to R_7 = Resistance in mini channel
Q = Heat transfer in conduction

- Heat transfer due to convective heat transfer in single channel :

  Properties of Air at 300 ^{o}K :
  Dynamic viscosity (μ) = $1.872\text{x}10^{-5}$ kg/ms
  Kinematic viscosity (ν) = $1.608\text{x}10^{-5}$ m^2/s
  K_{air} = 0.00261 W/m^{o}K
  Specific heat at constant volume (Cp) = 1.007 KJ/kg^{o}K
  Ambient temperature (T□) =300^{o}K
  Avg. Wall Temperature (TW) = 321.6^{o}K

$$Tmf = \frac{T\infty+T_1}{2}$$

Tmf = 310.805 ^{o}K
β = 1/Tmf
β = 3.474×10^{-3}
Δt = 21.6 ^{o}K
L = 4A/P
L = 0.00938 m

$$Gr = \frac{L3.g.\beta.\Delta t}{\nu 2}$$

Gr = 1947.48
Pr = μ.Cp/K_{air}
Pr = 0.725
Nu = $0.27(Gr.Pr)^{1/4}$
Nu = 1.6550
Nu = h.L/K_{air}
h = 4.5876
Q = h. Δt
Q = 99.1397 W/m^2
Where,
L= Characteristics length
Gr=Grassoff number
Pr= Prandtl number
Nu= Nusselt number
h= Convective heat transfer coefficien
Q= Heat transfer in convection

Table I: Heat flow across Mini Channels

	Rectangular channel type	**Serrated channel type**
Conduction	253.992 W	133.83 W
Convection(Q/A)	99.13 W/m^2	107.08 W/m^2

VI. FINITE ELEMENT ANALYSIS

6.1 Serrated Fin Mini Channel

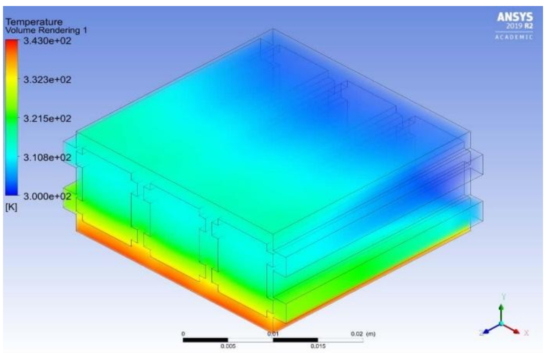

Fig. 4. Overall temperature distribution

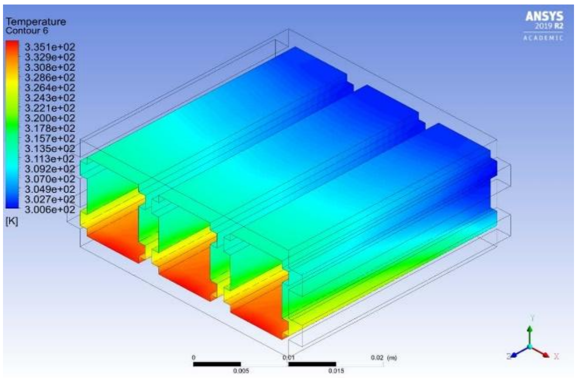

Fig. 5. Temperature distribution in channels

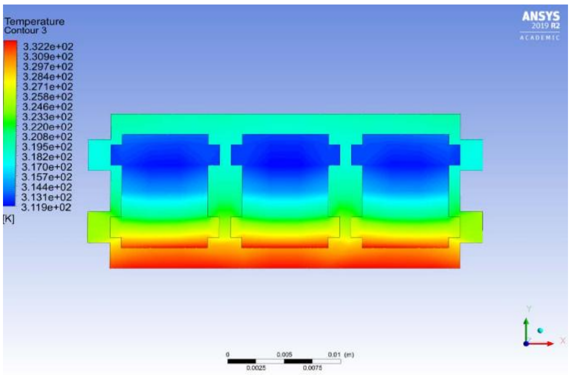

Fig. 6. Temperature distribution due to moving air

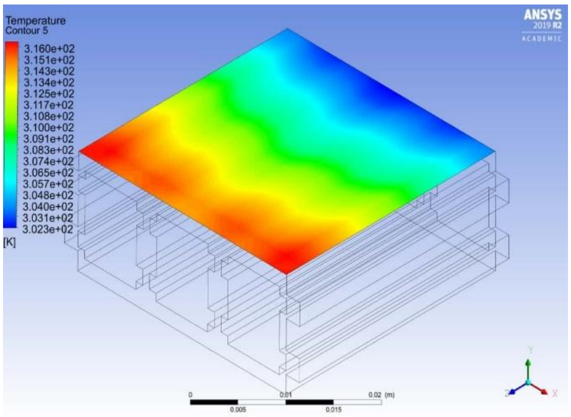

Fig. 7. Temperature on top surface of serrated mini channel heat exchanger

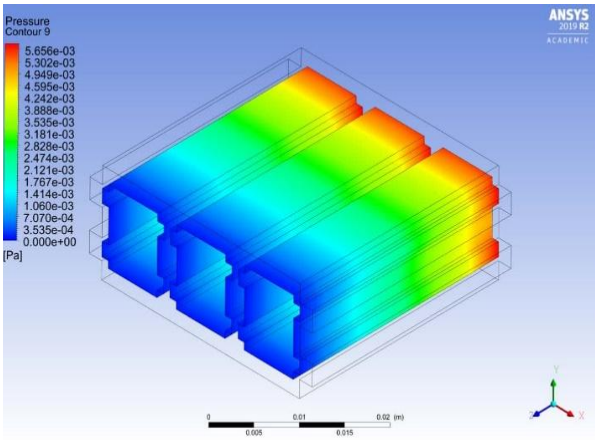

Fig. 8. Pressure visualization in channel

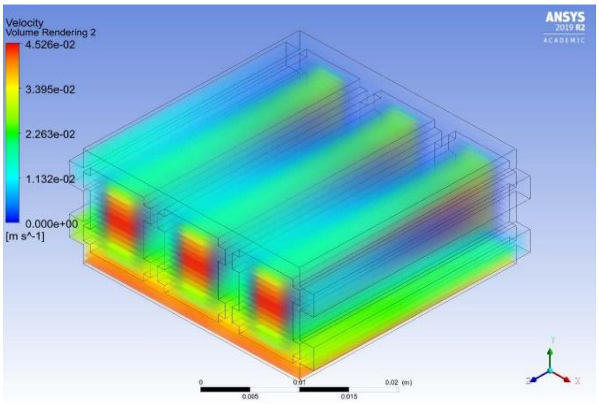

Fig. 9. Velocity of moving air in channel

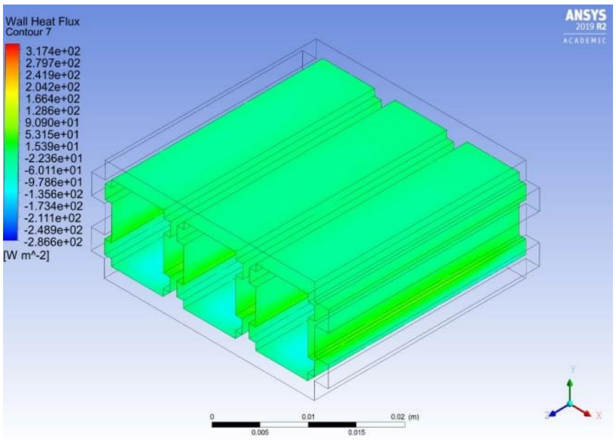

Fig. 10. Heat flux

6.2 Rectangular Mini Channel

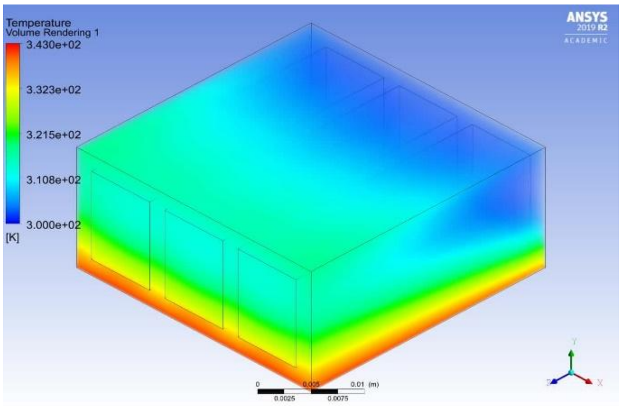

Fig. 11. Overall temperature distribution

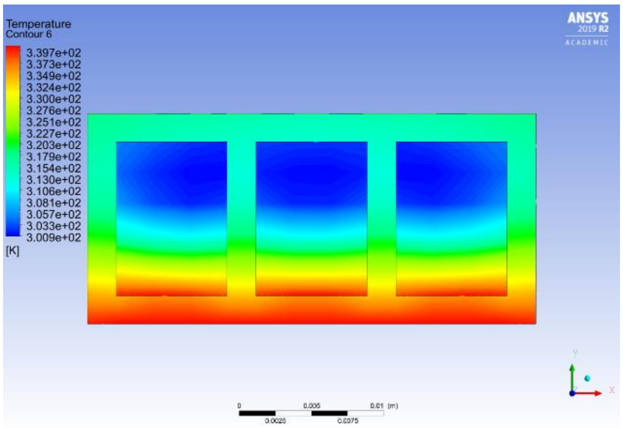

Fig. 12. Temperature distribution due to moving air

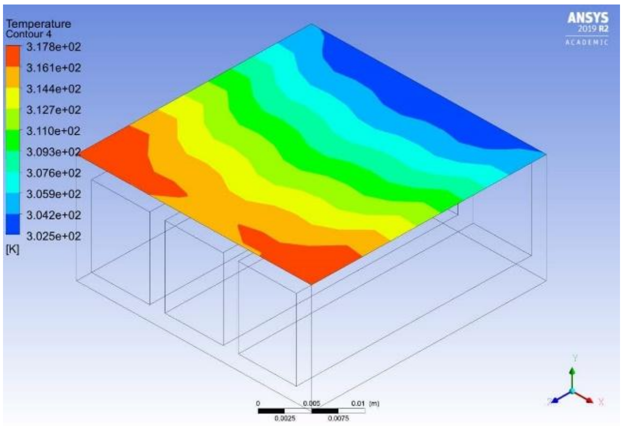

Fig. 13. Temperature on top surface of rectangular mini channel heat exchanger

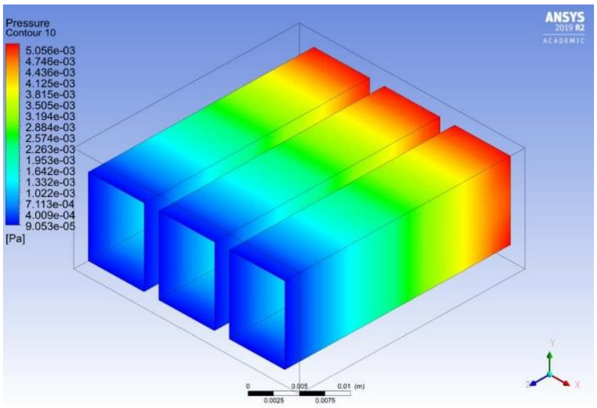

Fig. 14. Pressure visualization in channel

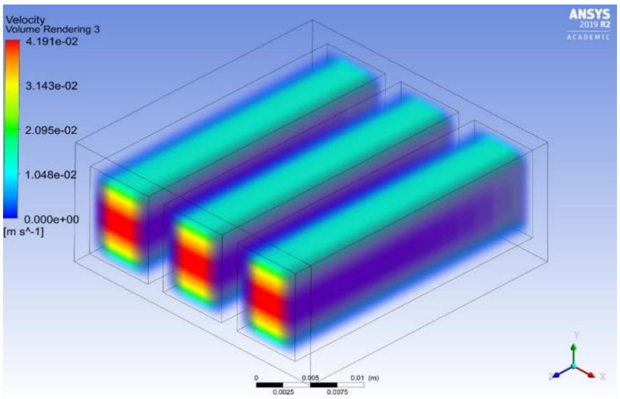

Fig. 15. Velocity of moving air in channel

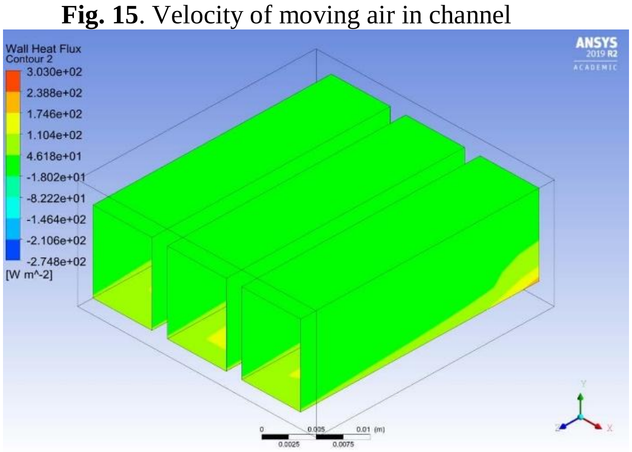

Fig. 16. Heat flux

VII. VALIDATION

Table II: Comparison of Heat Flow across Mini Channels

	Heat transfer in Rectangular channel type	**Heat transfer in Serrated channel type**
Conduction	253.992 W	133.83 W
Convection(Q/A)	99.13 W/m^2	107.08 W/m^2

As the heat transfer rate in conduction is 253.992W in Rectangular Mini Channel HE which is more as compared to heat transfer rate in Serrated Mini Channel that is 133.83W, the temperature at the top surface of HE is obtained more in Rectangular than Serrated one which clearly states that heat carried by moving air in channels of Serrated Mini channel HE (i.e.107.08W//m^2) is more than heat carried by moving air in channels of Rectangular Mini channel HE (i.e.99.113W//m^2).

This result is obtained due to increase in contact surface area in Serrated Mini channel HE. The increase in contact surface area is obtained due serrated rectangular fins provided in channel.

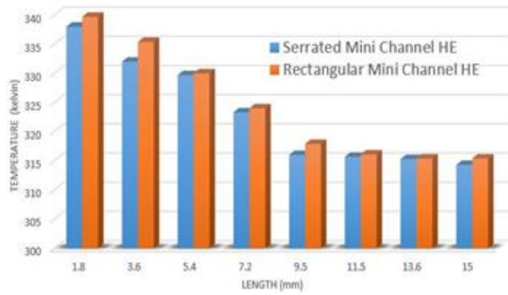

Fig. 17. Comparison of temperature distribution in vertical direction in conduction

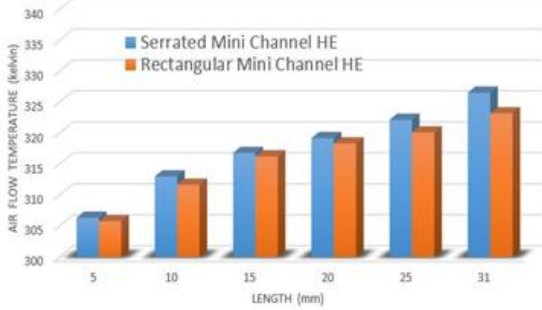

Fig. 18. Comparison of air temperature flowing through channels

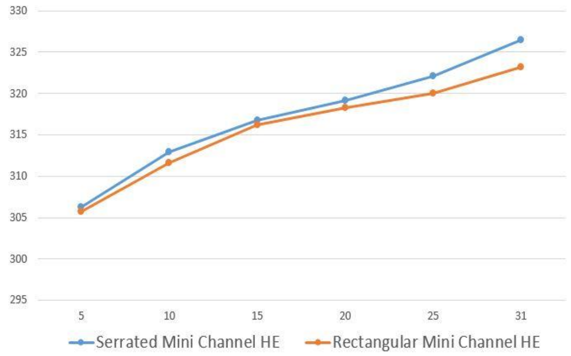

Fig. 19. Graphical comparison of rise in temperature of air flowing through channels

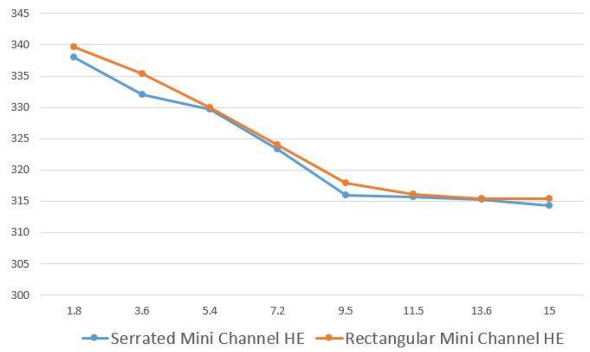

Fig. 20. Graphical comparison of fall in temperature along vertical direction of model

VIII. RESULTS

Table III: Result table

	Rectangular Mini channel HE	**Serrated Mini channel HE**
Source Temp(^{o}K)	343	343
Top surface Temp(^{o}K)	311	309
Heat transfer from source in upward direction	253.992 W	133.83 W
Convective Heat transfer	99.13 W/m^2	107.08 W/m^2
Wall Heat flux	78.29 W/m^2	109.75 W/m^2
Co-efficient of Convective Heat transfer	4.5876 W/m^{2o}K	4.912 m^{2o}K

IX. CONCLUSION

1. Copper is selected as engineering material for mini channel due to its high heat conductivity.
2. Average temperature of the top surface of serrated mini channel HE is lesser than 2^{o}C as compared to normal rectangular mini channel HE due to increase in contact area.
3. Due to use of serrated fins the percent increase in area was found to be 21.42%.
4. As more heat is taken out by moving air from source it can be concluded that the system is more efficient.

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