INTERNATIONAL JOURNAL OF RESEARCH IN AERONAUTICAL AND MECHANICAL ENGINEERING

ISSN (ONLINE): 2321-3051

Vol.4 Issue 4,

April 2016

Pgs: 98-107

Thermal Performance Analysis of Square Crossection Aluminum Fins for using in Microchannel Heat Sink via CFD

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Abstract

Now a day's compactness in every field of our life is required and essential. All the technical industries are now trying to give compactness to their product, also the customers are demanding compact product. In electronics manufacturing industries that are manufacturing Microchannel heat sink which is used in CPU, compactness as well as proper heat transfer rate through it is a big challenge of concern. The electronic industry requires increased forced-air cooling limits to cool high-end server CPUs adequately. Improving air-cooled heat sink thermal performance is one of the critical areas for increasing the overall air-cooling limit. One of the challenging aspects for improving heat sink performance is the effective utilization of relatively large air-cooled fin surface areas when heat is being transferred from a relatively small heat source (CPU) with high heat flux. While heat sinks are routinely used in most electronics applications, the rationale for selecting a particular design of heat sink or more specifically a particular fin cross sectional profile remains somewhat uncertain. Most often these types of selection procedures are based exclusively on performance evaluations consisting of formulations for extended surface heat transfer found in most fundamental heat transfer text books. Unfortunately, these formulations do not consider the role of pressure drop in determining the local fin velocity or heat transfer coefficient and, therefore, the resulting heat transfer calculations rarely pertain to actual flow conditions .So it's a big task to have compactness, as well as proper heat transfer rate through fins installed in Microchannel heat sink.

Keywords: CFD, Microchannel heat sink, fins, fins types, parallel plate fins, square fins, mathematical modeling, geometrical and thermodynamic parameters and models for thermal analysis.

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1. Introduction

The utilization of fins is an effective method to enhance the heat dissipation from a surface. Applications for finned surfaces are widely seen in air-conditioning and refrigeration, aerospace, chemical processing plants, and in the thermal control of electronic and electrical devices. There are various types of fins available in industry. Among them, square fins are especially important for compact heat exchangers due to higher surface area. From the thermal designer’s point of view, it is of significance to search for an optimum fin design. There are two categories of optimization that pertain to single fin design. The first category of optimization is to determine the best profile and dimensions that yield minimum weight or mass for a specified heat flow and a given fin shape (e.g. longitudinal, radial and pin fins). A solution was first proposed by Denpong Soodphakdee [1] authenticated by Kwang-Yong Kim [9], which was further extended by Haim H. Bau [10] and O.N. Sara [12]. However, the mathematical solutions to these kinds of optimum design resulted in fin profiles with sharp curved surfaces which are difficult or costly to fabricate. Therefore one alternative way is to fix a suitable simple profile (e.g. rectangular, triangular, parabolic, trapezoidal, etc) and then determine the dimensions of the fin so that it dissipates the maximum amount of heat for a given amount of mass. The present work falls into the second category. A fin is a surface that extends from an object to increase the rate of heat transfer to or from the environment by increasing convection. Extensions on the finned surfaces is used to increases the surface area of the fin in contact with the fluid flowing around it. So, as the surface area increase the more fluid contact to increase the rate of heat transfers from the base surface as compare to fin without the extensions provided to it. Types of extension provided on fin such as (a) Rectangular extensions, (b) Trapezium extensions, (c) Triangular extension, and (d) Circular Segmental extension. The studies of the optimum dimensions for purely convective fins have yielded numerous publications in which various fin shapes were employed. Among them only Poh-Seng Lee [5] and Gabriel Gamrat [6] considered the rectangular (square) profile. Since radiation heat transfer and free convection play equally important role in most of the practical applications except for some special cases (e.g. outer space), the neglect of radiation may cause significant errors in the calculations of optimum fin dimensions. In so far as convecting-radiating fins are concerned, few optimum studies are available in the literature. Kwasi Foli [11] employed existing software to obtain the optimal dimensions of convecting-radiating annular fins with curved surfaces. However fins with curved surfaces are difficult and expensive to fabricate.

2. Analysis

In present work cfd prediction is done for thermal performance evaluation of square crossection fins arranged in inline manner by using FLUENT 14 solver. The standard K epsilon model and pressure based solver was used for completing the analysis and getting the desired thermal effects in heat sink. Aluminum was used as a solid material of fins and air was used as a liquid fluid for doing the operation. It is observed from all the figures that the boundary conditions are satisfied asymptotically in all the cases which supporting the accuracy of the numerical results. All the figures shows that increasing values of any parameter increase the thermal boundary layer and other thermal effects like wall heat transfer coefficient and surface heat transfer function and static and total temperature. In this thermal analysis, temperature variations w.r.t. distance at which heat flow occur through the fin is analyzed. Extensions on the finned surfaces is used to increases the surface area of the fin in contact with the fluid flowing around it. So, as the surface area increase the more fluid contact to increase the rate of heat transfers from the base surface as compare to fin without the extensions provided to it. In this work parallel plate heat sink of the same volume as that of square crossection fins are compared for higher heat transfer rate. Under the same boundary condition we found that square crossection fins give better result of heat transfer.

3. Geometry:

3.1.1 Parallel plate straight fins and velocity inlet of air 10 m/s

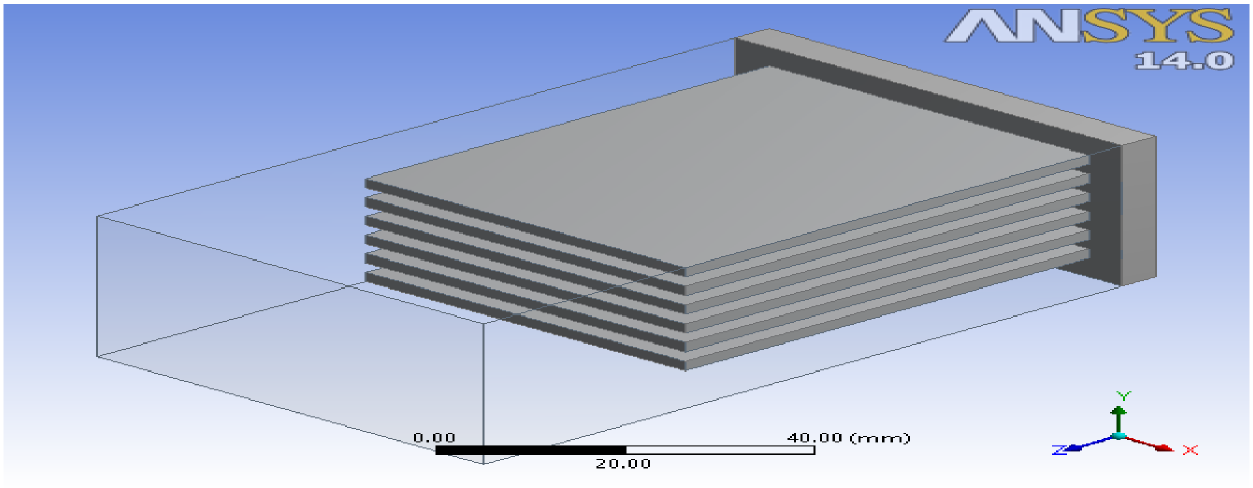

Figure 1 PARALLEL PLATE STRAIGHT FINS

3.1.2 Meshing:

Meshing is done on fluent using following meshing conditions.
Advanced size function – on: curvature
Relevance center – coarse
Initial size feed – active assembly
Smoothing – medium
Transition – slow

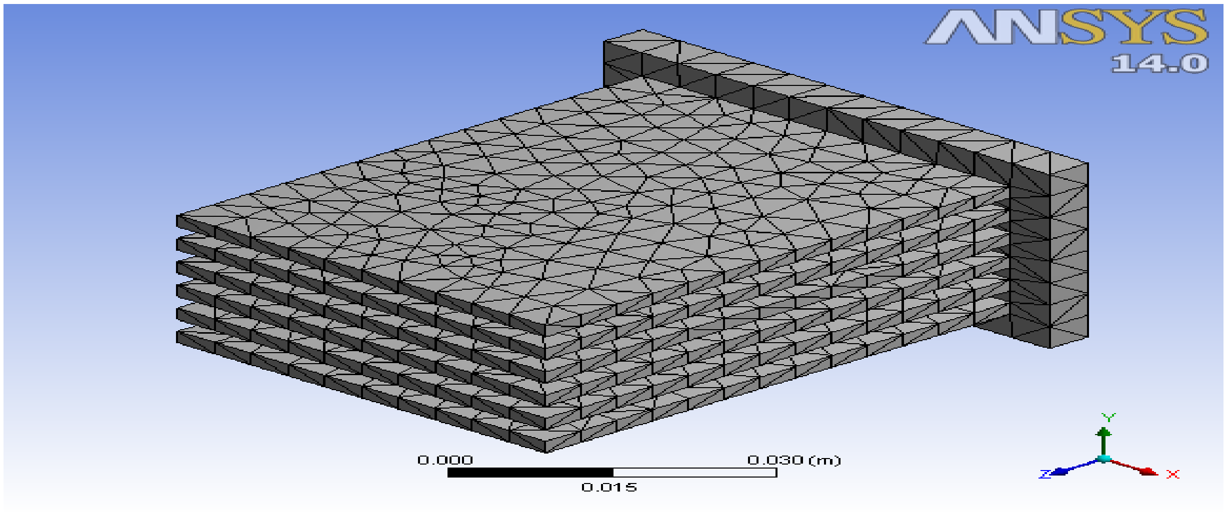

Figure 2 PARALLEL PLATE STRAIGHT FINS MESHING

3.2.1 Square fins offset 9.5, 9.25, 9.25 mm respectively between fins and velocity inlet of air 10m/s, 10m/s & 4m/s respectively for case 1st , 2nd & 3rd . For all 3 cases geometry & meshing will be similar approximately, hence only one geometry & meshing is considered. Results are shown separately for each 3 cases of square fins.

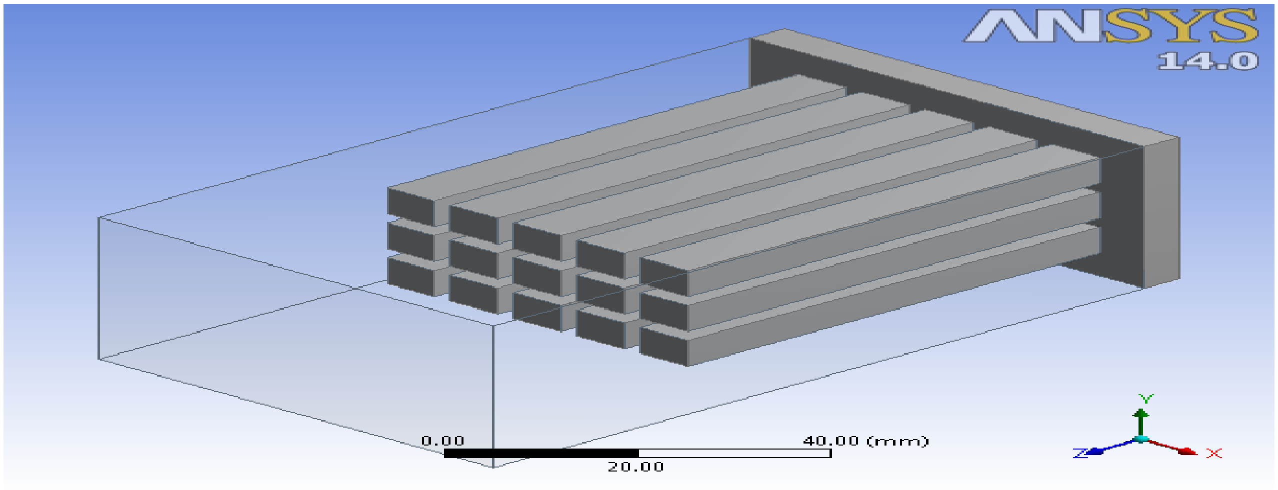

Figure 3 SQUARE FINS

3.2.2 Meshing:

Meshing is done on fluent using following meshing conditions.
Advanced size function – on: curvature
Relevance center – coarse
Initial size feed – active assembly
Smoothing – medium
Transition – slow

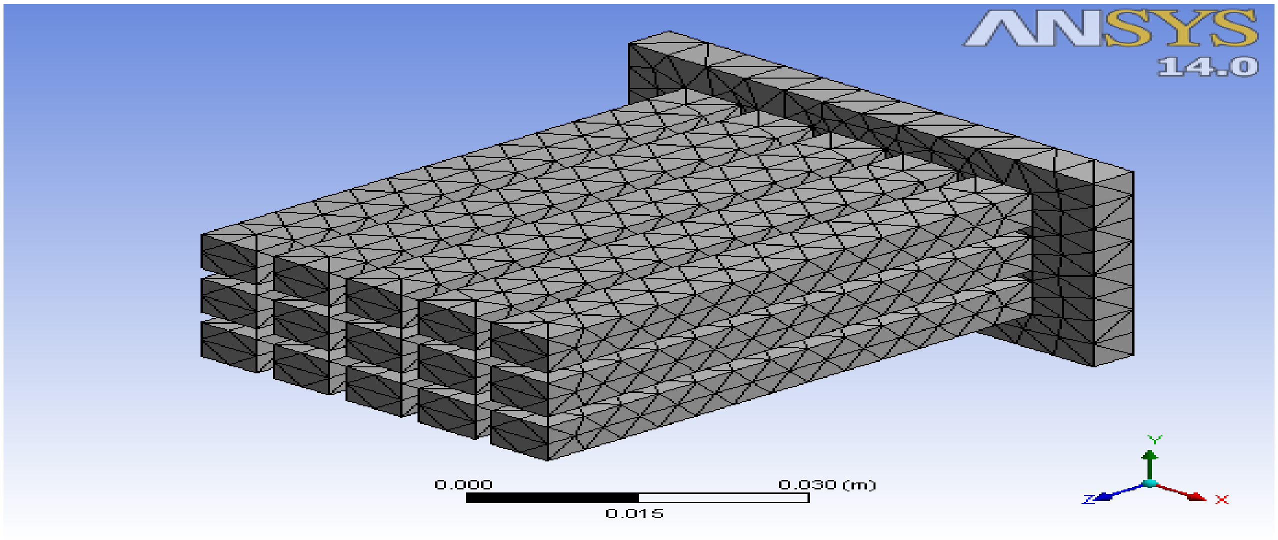

Figure 4 SQUARE FINS MECHING

1. Results:

After setting all boundary conditions and values we get desired thermal effects in terms of various plots. This is mentioned and showed in below figures.

4.1 Results of parallel plate fins:

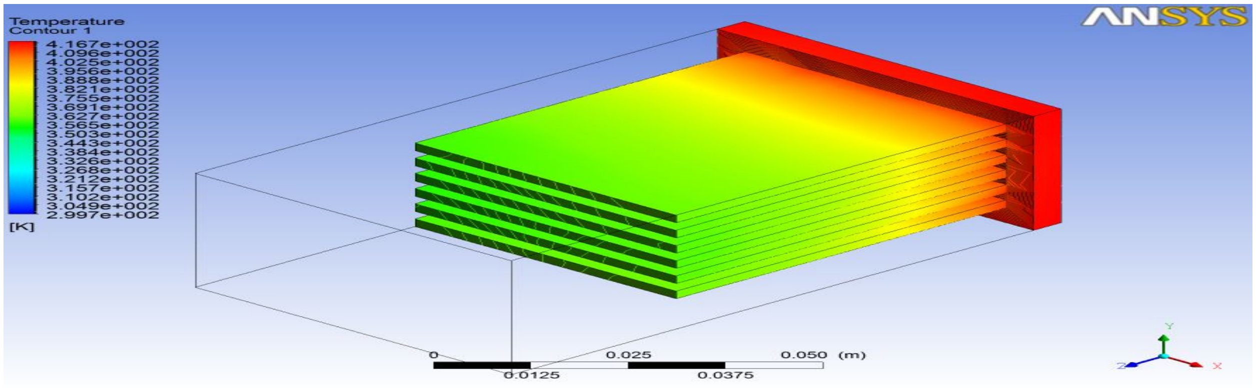

Figure 5 TEMPERATURE VARIATION IN PARALLEL PLATE FINS

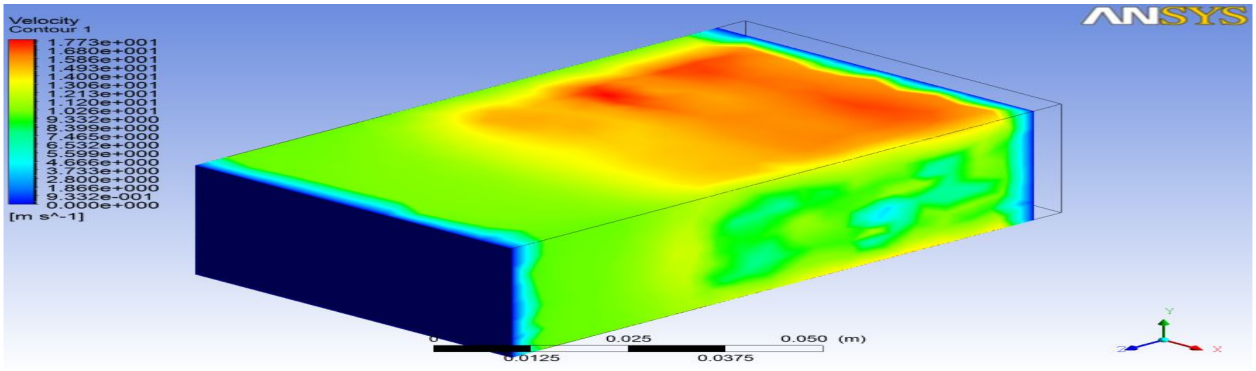

Figure 6 INLET AIR VELOCITY VARIATION IN PARALLEL PLATE FINS

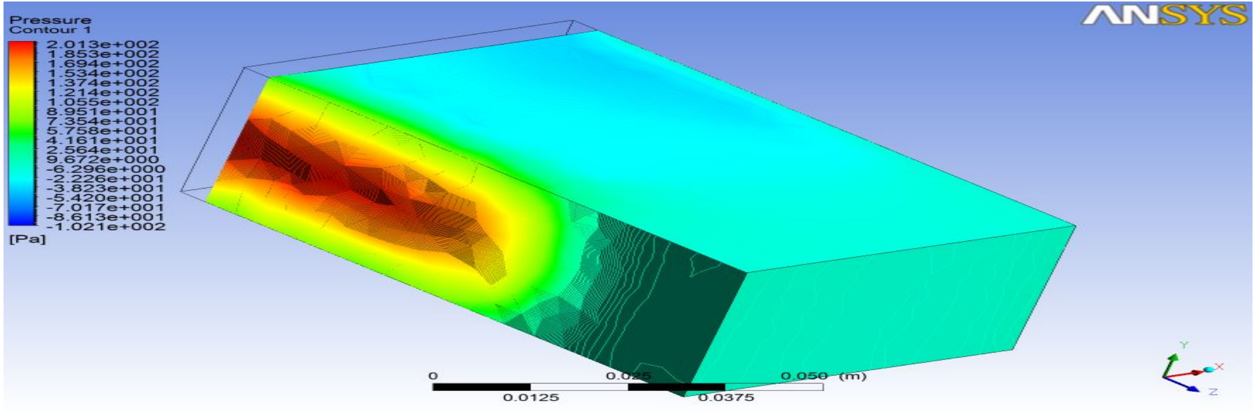

Figure 7 PRESSURE VARIATION IN PARALLEL PLATE FINS

Heat transfer rate –

```
                          Total Heat Transfer Rate              (w)
                          -------------------------------- --------------------
                                               air_inlet          81.061134
                                              air_outlet         -370.78537
                                                fin_base          289.383
                                                 fin_top              0
      Wall-part-atmosphere-part-parallel_flat_fins_&_base        -289.25708
Wall-part-atmosphere-part-parallel_flat_fins_&_base-shadow        289.25775
                          Wall-part-parallel_flat_fins_&_base          0
                                        ---------------- --------------------
                                                     Net        -0.34056854
```

4.2 Results of square fins:

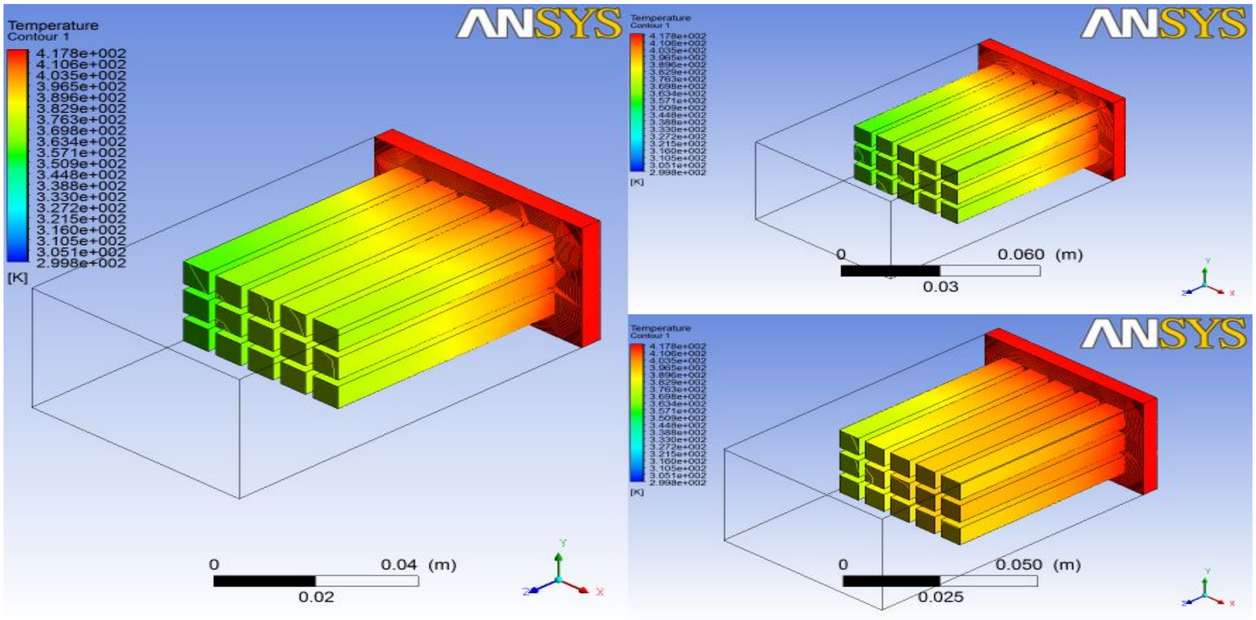

Figure 8 TEMPERATURE VARIATION IN SQUARE FINS

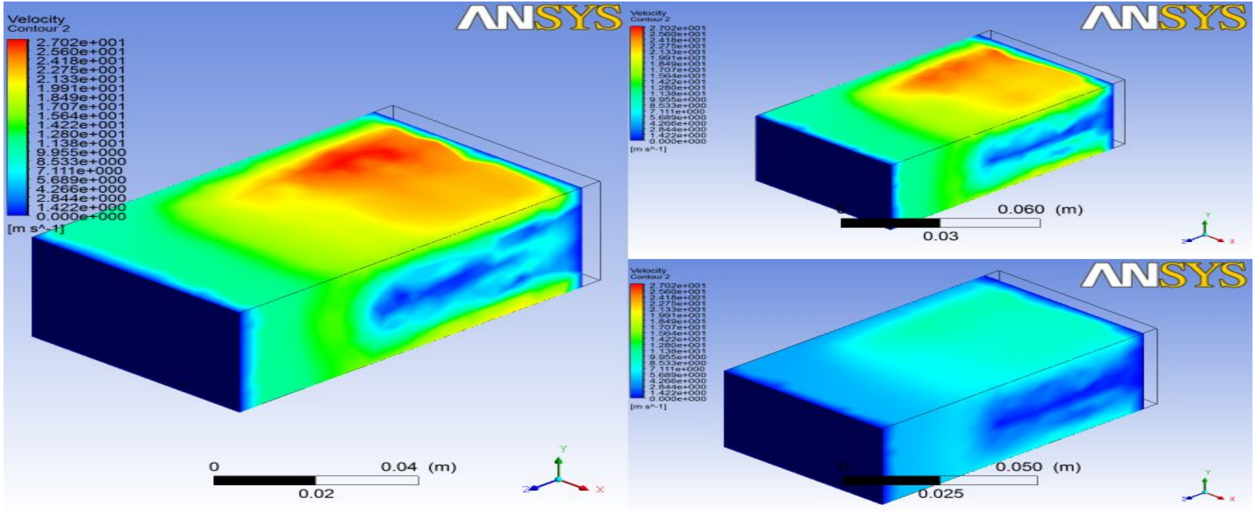

Figure 9 VELOCITY VARIATION IN SQUARE FINS

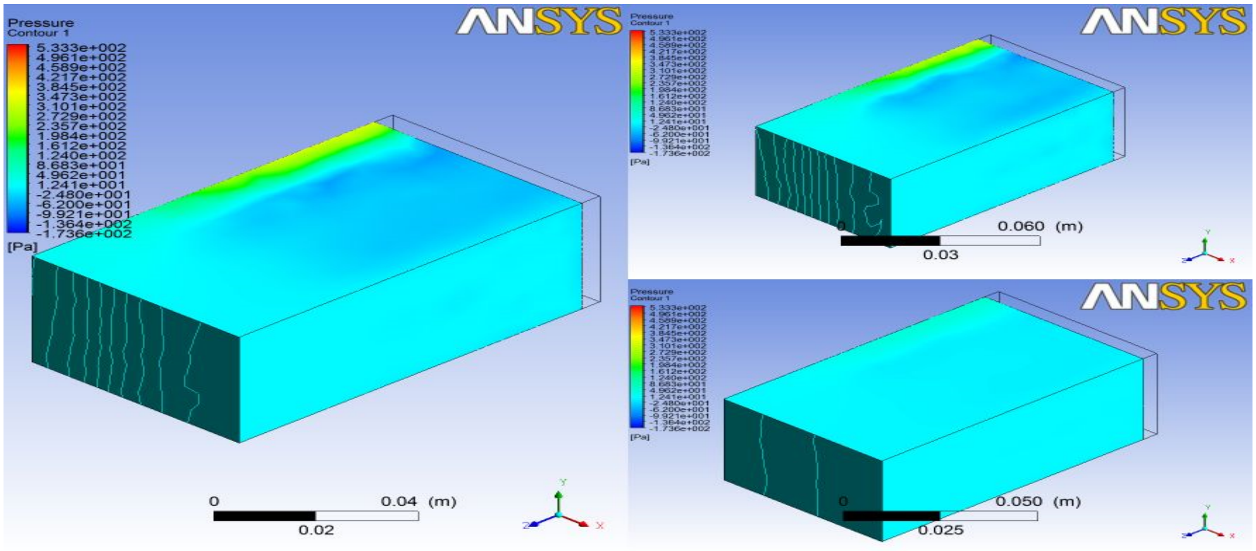

Figure 10 PRESSURE VARIATION IN SQUARE FINS

Case1) Square fins Heat transfer rate offset 9.5 mm between fins & velocity inlet 10 m/s:

```
                              Total Heat Transfer Rate              (w)
                             -------------------------------- --------------------
                                                  air_inlet        80.931335
                                                 air_outlet       -315.94705
                                                   fin_base        234.78529
                                                    fin_top                0
           Wall-part-atmosphere-part-rectangular_fins_&_base        -234.7643
    Wall-part-atmosphere-part-rectangular_fins_&_base-shadow        234.77208
                          Wall-part-rectangular_fins_&_base                0
                                              ---------------- --------------------
                                                        Net      -0.22264099
```

Case 2) Square fins Heat transfer rate offset 9.25 mm between fins & velocity inlet 10 m/s:

```
                              Total Heat Transfer Rate              (w)
                             -------------------------------- --------------------
                                                  air_inlet         81.12925
                                                 air_outlet       -321.32117
                                                   fin_base        237.88124
                                                    fin_top                0
           Wall-part-atmosphere-part-rectangular_fins_&_base       -237.87035
    Wall-part-atmosphere-part-rectangular_fins_&_base-shadow        237.87413
                          Wall-part-rectangular_fins_&_base                0
                                              ---------------- --------------------
```

```
                                   Net        -2.3068924
```

Case 3) square fins Heat transfer rate offset 9.25 mm between fins & velocity inlet 4 m/s:

```
                       Total Heat Transfer Rate              (w)
                  -------------------------------- --------------------
                                          air_inlet          32.217419
                                         air_outlet         -178.84052
                                           fin_base          145.77565
                                            fin_top                  0
           Wall-part-atmosphere-part-rectangular_fins_&_base  -145.74995
Wall-part-atmosphere-part-rectangular_fins_&_base-shadow       145.75401
                                   ---------------- --------------------
                                                Net         -0.8433876
```

5. Conclusion:

We use parallel plate fins with 10 m/s inlet air velocity & get an overall heat removal rate of -0.340 watts (“ -VE” sign shows heat removal rate) in the computer CPU heat sink. If we use a set of square fins as given in the case 3, with same material volume & lower velocity 4m/s, we can get a much higher heat removal rate of -0.843 watts (around 2.5 times more than from parallel plate fins). Hence using rectangular fins with given geometry & inlet condition (case3) is much more useful for increasing heat transfer rate from fins. Replacement of the no. of square fins arrangement gives better and efficient thermal results in various forms for increasing the heat transfer rate and results in increase in effectiveness by the pressure drop range. Improvement and increase in the life of finned tubes if it arranged according inline arrangement manner.

References:

[1] Denpong Soodphakdee, Masud Behnia, and David Watabe Copeland , “A Comparison of Fin Geometries for Heatsinks in Laminar Forced Convection: Part I - Round, Elliptical, and Plate Fins in Staggered and In-Line Configurations” *The International Journal of Microcircuits and Electronic Packaging,* Volume 24, Number 1, First Quarter, 2001 (ISSN 1063-1674).

[2] V.B. Swami, D.A. Kamble and Dr. B.S. Gawali , “Experimental and Numerical Investigation of Forced Convection Heat Transfer in an Optimized Microchannel Heat Sink” *International Journal of Micro-Nano Scale Transport ,* Volume 3 · Number 1+2 · 2012.

[3] Satish G. Kandlikar1 and Harshal R. Upadhye , “Extending the Heat Flux Limit with Enhanced Microchannels in Direct Single Phase Cooling of Computer Chips” , *IEEE Transactions on Components, Hybrids, and Manufacturing Technology*, Vol. 15, No. 5.pp. 832-842, 1992.

[4] Roy W. Knight, Donald J. Hall, John S. Goodling, and Richard C. Jaeger , “Heat Sink Optimization with Application to Microchannels” , IEEE *Transactions on Components, Hybrids, and Manufacturing Technology*, Vol. 15, no. 5, October 1992.

[5] Poh-Seng Lee, Suresh V. Garimella , Dong Liu , “Investigation of heat transfer in rectangular microchannels ” , *International Journal of Heat and Mass Transfer* 48 (2005) 1688–1704.

[6] Gabriel Gamrat, Michel Favre-Marinet, Dariusz Asendrych , "Numerical Modelling of Heat Transfer in Rectangular Microchannels", *The 2nd International Conference on Microchannels and Minichannels* ,June 17-19, 2004, Rochester, New York, USA.

[7] Mi Sandar Mon, Ulrich Gross , "Numerical study of fin-spacing effects in annular-finned tube heat exchangers" , *International Journal of Heat and Mass Transfer* , vol 47 1953–1964 (2004) .

[8] C. J. Shih and G. C. Liu , "Optimal Design Methodology of Plate-Fin Heat Sinks for Electronic Cooling Using Entropy Generation Strategy", IEEE *Transactions on Components and Packaging Technologies,* VOL. 27, NO. 3, 551, SEPTEMBER 2004 .

[9] Kwang-Yong Kim , Mi-Ae Moon , "Optimization of a stepped circular pin-fin array to enhance heat transfer performance" , *Heat Mass Transfer* ,vol 46, 63–74 (2009).

[10] Haim H. Bau , "Optimization of conduits' shape in micro heat exchangers" , *International Journal of Heat and Mass Transfer,* 41 , 2717-2723, (1998).

[11] Kwasi Foli , Tatsuya Okabe , MarkusOlhofer , Yaochu Jin , Bernhard Sendhoff , "Optimization of micro heat exchanger: CFD, analytical approach and multi-objective evolutionary algorithms" *International Journal of Heat and Mass Transfer,* xxx xxx–xxx (2005).

[12] O.N. Sara , "Performance analysis of rectangular ducts with staggered square pin fins " *Energy Conversion and Management* , 44 (2003) 1787–1803.

[13] Ala Hasan , Kai Sir_en , "Performance investigation of plain and finned tube evaporatively cooled heat exchangers" *Applied Thermal Engineering* ,23 (2003) 325–340.

[14] Alessandro Barba, Barbara Musi, Marco Spiga , "Performance of a polymeric heat sink with circular microchannels" *Applied Thermal Engineering* ,26 (2006) 787–794.

[15] Esmail M.A. Mokheimer , "Performance of annular fins with different profiles subject to variable heat transfer coefficient " *International Journal of Heat and Mass Transfer,* 45 (2002) 3631–3642.