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Finite Element Analysis of Convective Heat Transfer Augmentation from Rectangular Fin by Circular Perforation

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Abstract- It is very important to dissipate unwanted heat generated in mechanical devices such as IC engines, radiators, electronic IC's etc. to the atmosphere. Extended surfaces are widely use in many engineering application because of easy in construction, require less space, light weight. This study examines heat transfer augmentation from a rectangular fin embedded with circular perforation under natural convection compared to the equivalent solid (none perforated) fin using ANSYS 10. Fins with different diameters of hole and number of perforation keeping length constant are examined. The parameters considered were geometrical dimension and thermal properties of fin such as material properties, convective heat transfer coefficient. Study showed that as perforations increases heat transfer rate also increases up to certain dimension and then starts decreasing. Heat transfer enhancement of the perforated fin increases with increase in diameter of perforation and number of perforation.

Keywords- *Element Analysis, ANSYS, Heat Transfer Enhancement, Natural Convection, Perforated Fin*

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I. INTRODUCTION

The removal of excess heat from system components is essential to avoid damaging effects of overheating. Therefore, the enhancement of heat transfer is an important subject of thermal engineering. Heat transfer between a surface (T_o) and the fluid surrounding it (T_s) is given by $Q = h A (T_o - T_s)$. Heat transfer rate may be increased by increasing the heat transfer coefficient between a surface and its surrounding, or by increasing the heat transfer area of the surface. In most cases, the area of heat transfer is increased by extending surfaces. These extended surfaces are called as fins. Fins are used to enhance convective heat transfer in a wide range of engineering applications and offer a practical means for achieving a large total heat transfer surface area without the use of an excessive amount of primary surface area. Fins are commonly applied for heat management in electrical appliances such as computer power supplies or substation transformers. Other applications include engine cooling, condensers in refrigeration and air conditioning [1].

Fins as heat transfer enhancement devices have been quite common. The different materials like Mild steel, Stainless Steel, Aluminum, Silver and Copper *etc.* are used for making fins. As the extended surface technology continues to grow, new design ideas have been emerged including fins made of anisotropic composites, porous media, interrupted and perforated plates. Due to the high demand for lightweight, compact, and economical fins, the optimization of fin size is of great importance. Therefore, fins must be designed to achieve maximum heat removal with minimum material expenditure taking into account the ease of the fin manufacturing. The improvement in heat transfer coefficient is attributed to the restarting of the thermal boundary layer after each interruption. Thus perforated plates and fins represent an example of surface interruption [1].

II. LITERATURE SURVEY

Abdullah H. AlEssa [6] Heat transfer dissipation from a horizontal rectangular fin embedded with equilateral triangular perforations is compared numerically using one-dimensional finite element technique. The heat dissipation of the perforated fin is computed and compared with that of the solid one of the same dimensions and same thermal properties. The comparison refers to acceptable results and heat dissipation enhancement due to certain perforations.

Abdullah H. Al Essa et al. [8] has study and examine the heat transfer enhancement from a horizontal rectangular fin embedded with triangular perforations (their bases parallel and toward the fin tip) under natural convection. They considered geometrical dimensions and thermal properties as parameter of the fin and the perforations. The temperature drop is studied for perforation dimension and space between them. The experimentation results shows that gain in heat transfer enhancement for certain values of triangular dimensions is increase with its dimensions and is proportional to the fin thickness and its thermal conductivity. They state that the gain in the heat dissipation rate for the perforated fin is a strong function of both the perforation diameter and lateral spacing which attain maximum at optimum perforation dimension and spacing respectively. With perforation it reduces the fin expenditure of material.

M.R.Shaeri, M.Yaghoubi, K.Jafarpur [7] Fluid flow and conjugate conduction-convective heat transfer from a three-dimensional array of rectangular perforated fins with square windows that are arranged in lateral surface of fins are studied numerically.Results show that perforated fins have higher total heat transfer and considerable weight reduction in comparison with solid fins.

Wadhah Hussein Abdul Razzaq Al- Doori et al. [5] has study and investigate heat transfer rate from rectangular fin with circular perforation. The pattern of perforation including 24 circular perforations with increment of 8 from first fin until 56 no of perforation which is distributed in 14 Columns and 4 rows. Experiments were carried through in an experimental facility that was specifically design and constructed for this purpose. The study shows that temperature along the perforated fin length higher than that for the equivalent non perforated fin. The gain in heat dissipation rate for the perforated fin is a strong function of the perforation dimension and lateral spacing. Decreasing the perforation dimension reduces the rate of temperature drop along the perforated fin.

Kumbhar D.G, Dr. N K Sane, Chavan S T [4] has observed that heat transfer rate increases with perforations as compared to fins of similar dimensions without perforations. It is noted that in case of triangular perforations optimum heat transfer is achieved. they also concluded that heat transfer rate is different for different materials or heat transfer rate changes with change in thermal conductivity. The perforation of fins enhances the heat dissipation rates and at the same time decreases the expenditure for fin materials also. Results obtained by ANSYS and experimentation support each other.

Rupali v. dhanadhya, abhay s. nilawar and yogesh yenarkar [1] in this they study and examines the heat transfer augmentation from horizontal rectangular fins with circular perforations under natural convection compared with solid fins and Fins with different thickness keeping length constant are also examined. They use Finite element analysis using ANSYS 11 to find out heat transfer rate. Study found that as the number of perforations increases heat transfer rate increases. Heat transfer rate is found maximum in fin with 12 perforations.

III. DESIGN AND ANALYSIS OF FIN ARRAYS

3.1 Introduction

Fins are used to enhance convective heat transfer in a wide range of engineering applications. and offer a practical means for achieving a large total heat transfer surface area without the use of an excessive amount of primary surface area. Fins are commonly applied for heat management in electrical appliances such as computer power supplies or substation transformers.

Aluminium fins with dimension 100 mm X 270 mm X 2 mm diameter ranging from 12 to 20 mm and perforations number from 16 to 32 is taken for study purpose. Also comparative study is done with solid fin. Heat transfer rate from a solid fin or perforated fin depends upon fin area and heat transfer coefficient. Base temperature of fin is taken as 120^0C. The average value of heat transfer coefficient of fin is given by h = Nu. K/ L_c, where $L_c = L.\ \delta / (2.L + 2.\delta)$. The average value of heat transfer coefficient for perforated fins considered in study becomes 5.88 $W/m^{2\ 0}C$.

3.2 Modeling details

The computational domain is represented in three dimensions. The procedure for solving the problem is (A) Create the geometry (B) Set the material properties and boundary conditions. (C) Mesh the domain (D) Solve for solution.

A.Creating Geometry

We take rectangular shape shown in fig. 1(Solid) and fig. 2 (Perforated) of dimensions 100 mm X 270 mm X 2 mm, in ANSYS 10 software. Circular perforations of 12 to 20 mm diameters are created at various distances on overall length. Following table shows the details of fin with different configurations.

TABLE I. Fin Configuration

Exp. Level	Diameter	No of Perforation
P1	12	16(4x4)
P2	12	24(4x6)
P3	12	32(4x8)
P4	16	16(4x4)
P5	16	24(4x6)
P6	16	32(4x8)
P7	20	16(4x4)
P8	20	24(4x6)
P9	20	32(4x8)
P10	0	0

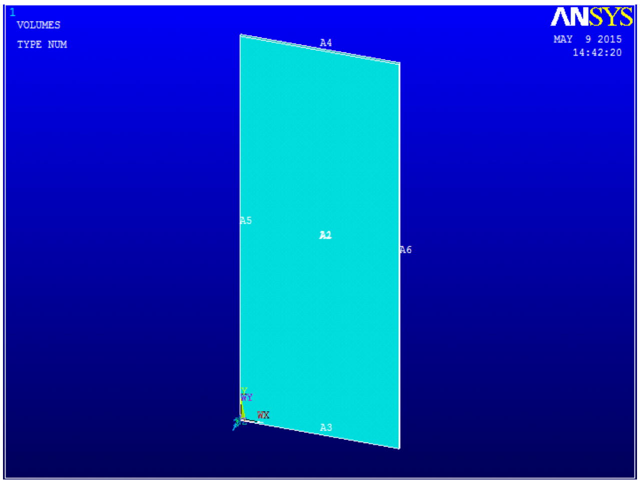

Figure 1. Rectangular solid fin.

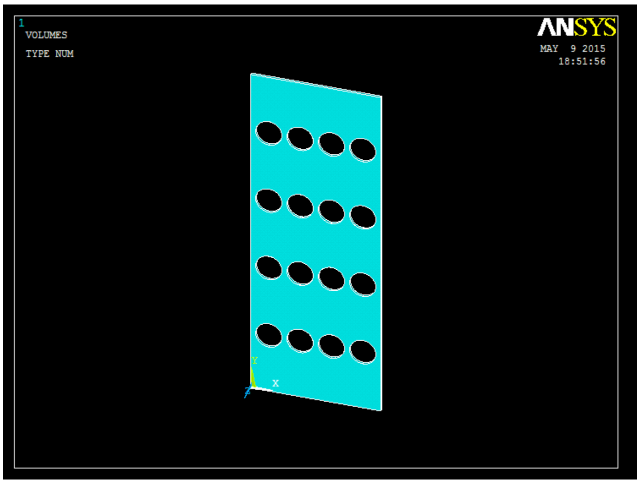

Figure 2. Rectangular Perforated fin.

B. Defining Material Properties and Meshing

Aluminum LM2 (AL - Si10Cu2Fe) has selected for the model due light weight and high heat transfer rate and heat dissipation in this material. The manufacturing process also simple in the aluminum and cost wise it is an economic.

The material having thermal conductivity, 100.4832 W/m-k,

After creating geometry and defining material properties of fin, create mesh. Figure 3 shows the mesh fin.

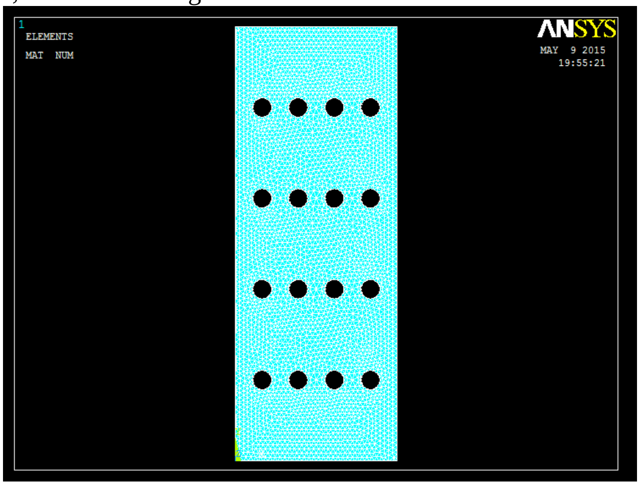

Figure 3. Mesh of Fin with 16 Perforations.

C. Applying Loads and Boundary Conditions

Base of fin is attached to the heating source which is maintained at 120 ^{0}C and this temperature is kept constant for a period of time. Therefore analysis is considered as steady state thermal analysis. Applying average value of convective heat transfer coefficient over all surfaces of fin at ambient temperature of 30 ^{0}C.

D. Solve for Solution

Applying loads and boundary conditions solve for results.

Fig. 4 shows contours of temperature distribution and Heat fluxes contours of fin P1. Like this Fig. 5, 6,7,8,9,10,11,12 and 13 for Fin P2, P3, P4, P5, P6, P7, P8, P9 and P10(non Perforated) respectively.

IV. RESULTS AND DISCUSSION CONCLUSION FROM ANSYS

All fins are compared with each other perforated fins of increasing perforation dimensions as shown in figs. 4, 5, 6, 7, 8, 9, 10, 11, 12 and 13. The analysis by Ansys shows that thermal flux is more for the fins with perforations as compared to fin without perforations. Thus we can say that the heat transfer improves with the addition of perforations. It is also observed that the thermal flux increases with increase in perforation dimension increases upto certain dimension, then again it decreases. flux is more the rate of heat transfer would be more for the fins. From this analysis we found the optimum perforation dimension for a perforated fin i.e. 16 diameter and 32 numbers of holes (P6).

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Figure 4. temperature distribution contours and Heat fluxes contours of fin P1.

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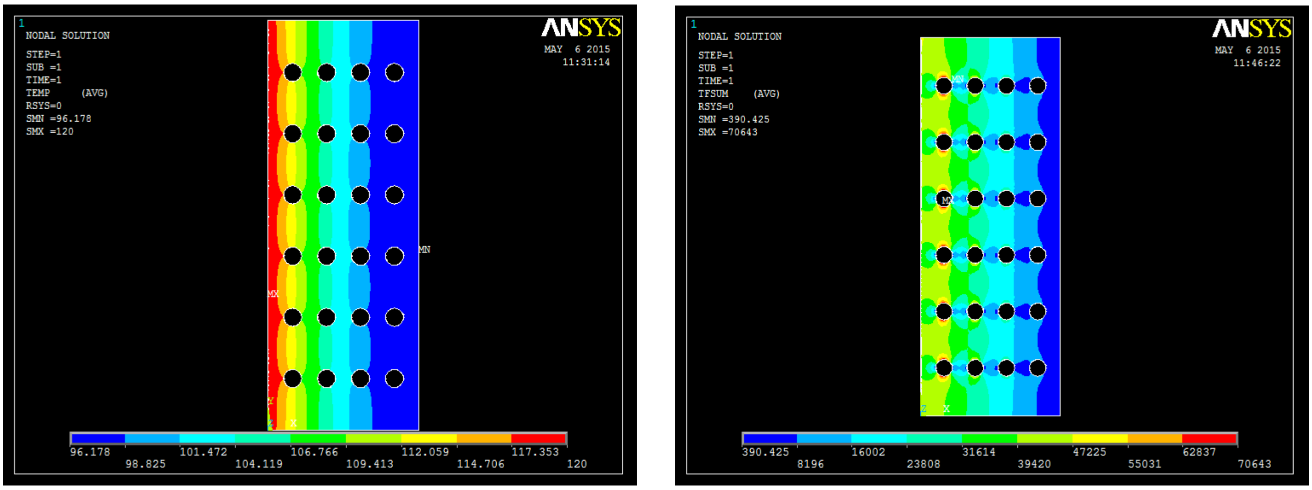

Figure 5. temperature distribution contours and Heat fluxes contours of fin P2.

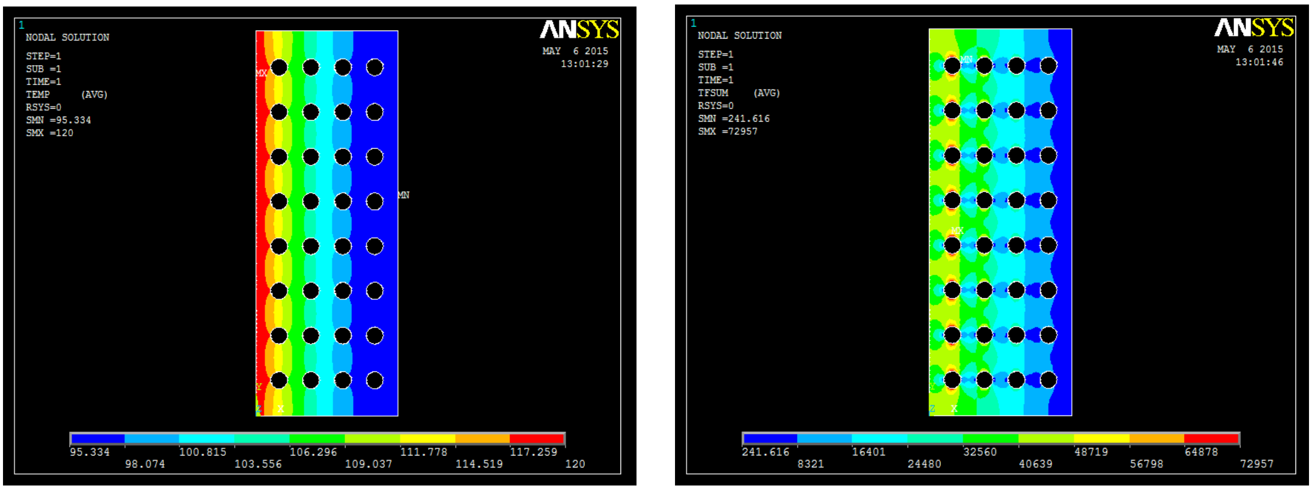

Figure 6. temperature distribution contours and Heat fluxes contours of fin P3.

Figure 7. temperature distribution contours and Heat fluxes contours of fin P4.

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Figure 8. temperature distribution contours and Heat fluxes contours of fin P5.

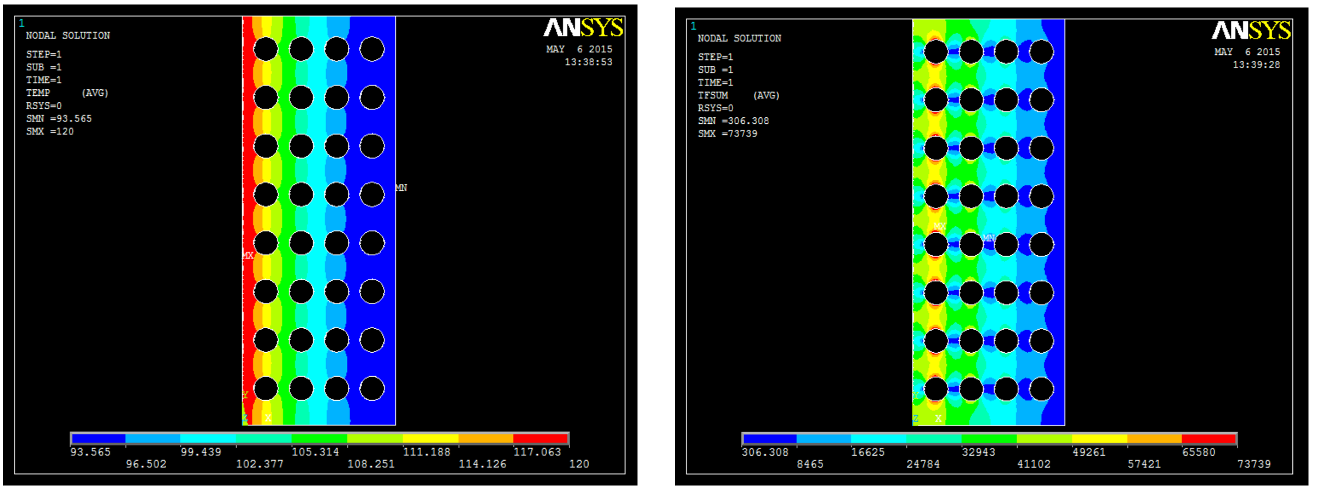

Figure 9. temperature distribution contours and Heat fluxes contours of fin P6.

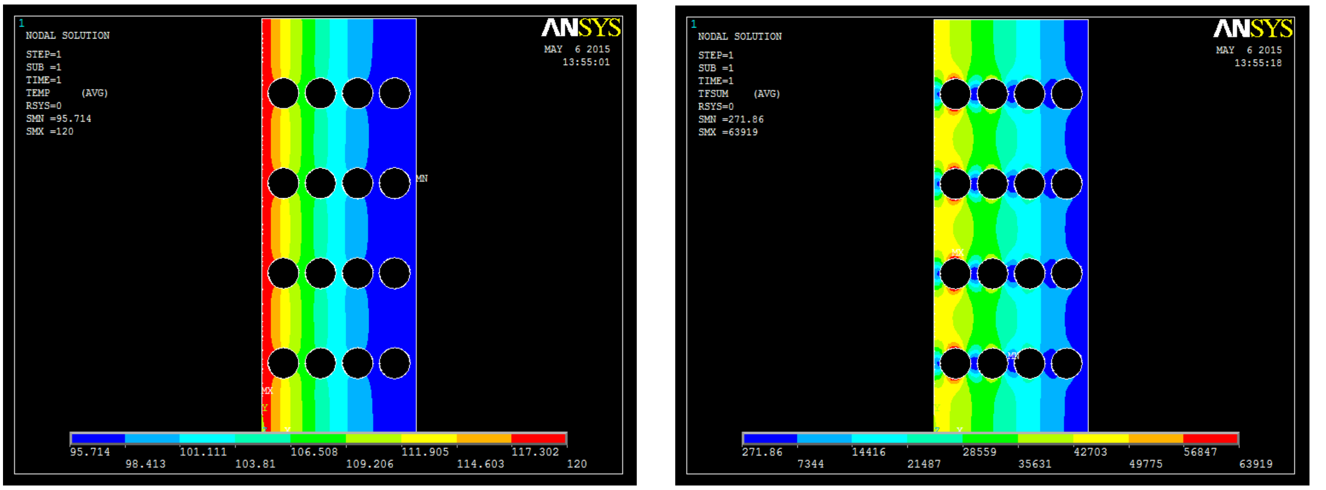

Figure 10. temperature distribution contours and Heat fluxes contours of fin P7.

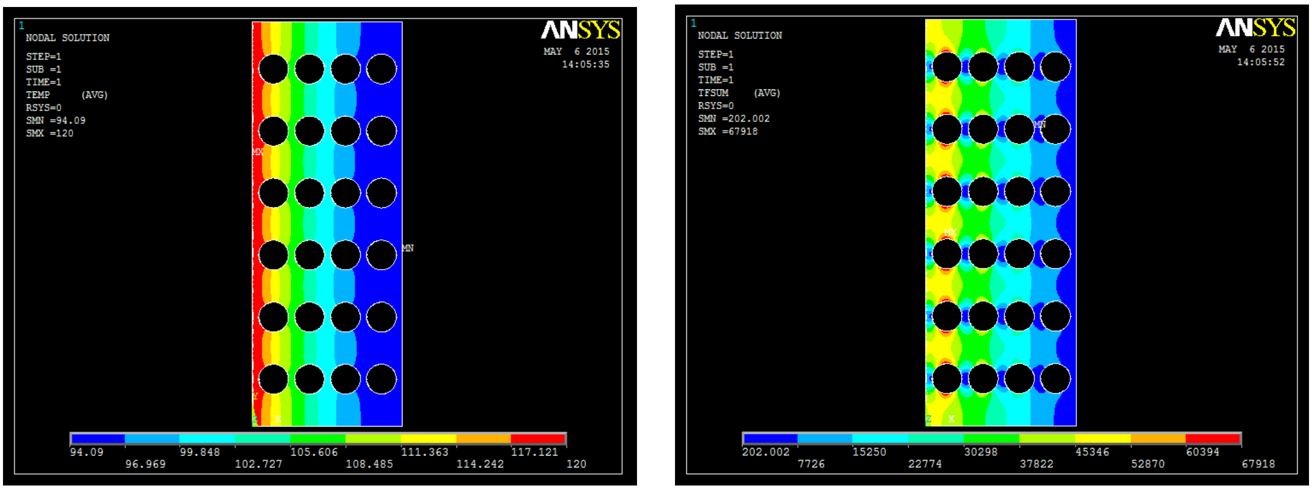

Figure 11. temperature distribution contours and Heat fluxes contours of fin P8.

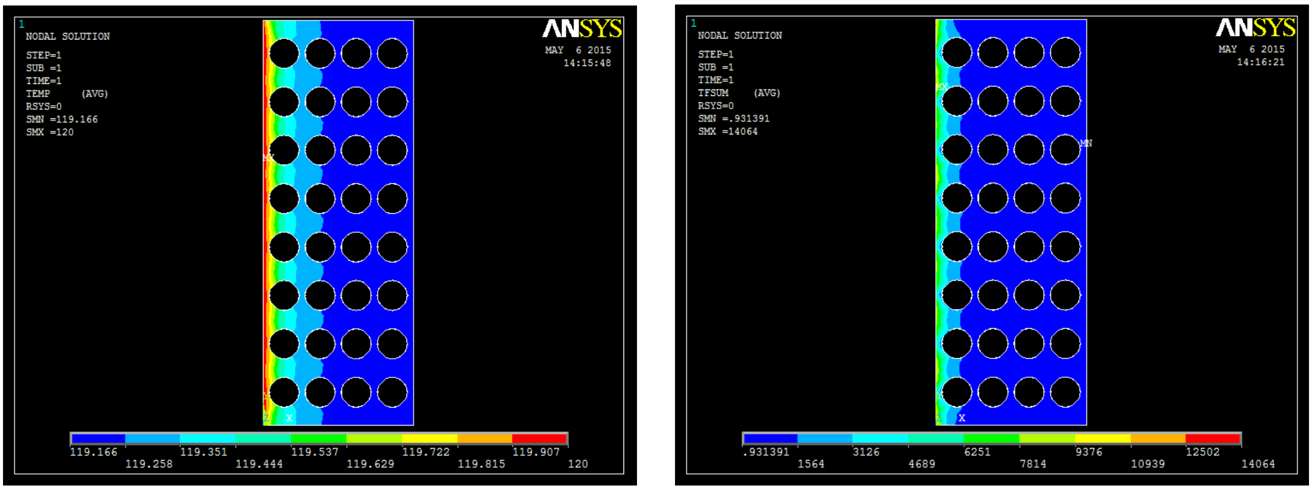

Figure 12. temperature distribution contours and Heat fluxes contours of fin P9.

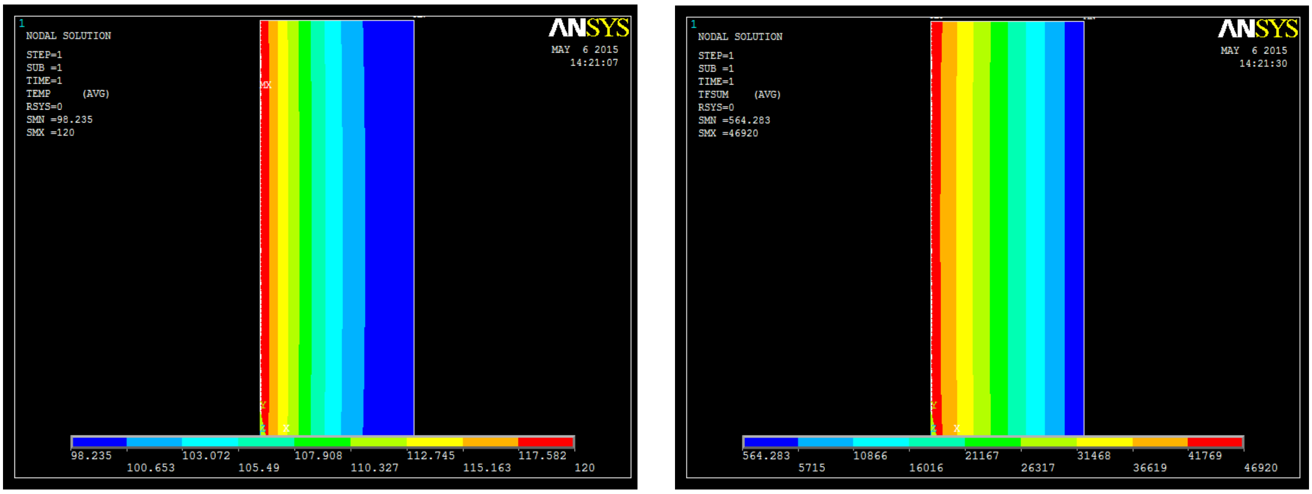

Figure 13. temperature distribution contours and Heat fluxes contours of fin P10.