Proceedings of the International Conference on Applied Mechanical Engineering Research (IC-AMER2019)
NIT Warangal, India – May 02-05, 2019
Paper No. XXX (The number assigned when the papaer is accepted)

Mixed convective heat transfer with surface radiation in a vertical channel in presence of Heat spreader

S K Mandal1*[a], Arnab Deb2[a], Dipak Sen3[a]
[a]Department of Mechanical Engineering, NIT-Arunachal Pradesh,Yupia-791112, Arunachal Pradesh, India

***Corresponding author Email: sandip@nitap.ac.in**

Abstract:
Numerical analysis of mixed convection with surface radiation on a vertical channel is conducted. Five protruding heat sources mounted on left wall of the channel and copper heat spreader attached upon each heat source. Governing equations are sloved using SIMPLER algorithm in ANSYS 16.2 software. Results were presented to depict the effects of parameters like heat spreader width (W_s=0.4H-0.8H), emissivity of heat spreader (ε_{sp}=0.1-0.9) and Reynolds number (Re 250-750) on rate of heat transfer by fixing emissivity of heat source and substrate. It was found that with increasing spreader width and emissivity heat transfer performance increases.

Keywords: Mixed convection, Surface Radiation, Heat Spreader,

1. Introduction
Enhancing the reliability and to prevent the permanent failure of electronic devices, thermal management plays an important role. Improved heat generation together with different levels of electronic packaging create a great challenge. Each electronic package having heat source with different aspect ratio, which creates some vortex in the flow field. The rate of heat transfer by convection and radiation changes with changing the area of heat transfer surface. So for efficient cooling, appropriate flow and mechanism of heat transfer must be analyzed and accordingly design must be made. As the present work is mixed convection with surface radiation, the significant literature briefly reviewed here. Smith et al. (1) numerically studied the effect of surface radiation with conjugate free convection considering diverse sizes of heat generating component mounted on a printed circuit board. An analytical study carried out on a vertical cavity by Balaji and Venkateshan (2) on surface radiation with conjugate free convection considering conducting walls and isothermal bottom. Whereas Bahlaoui et.al studied in a horizontal cavity on mixed convection with surface radiation. Premachandran and Balaji (3-4) investigated surface radiation with combine free-forced convection from vertical and also in horizontal channel considering four numbers of protruding heat sources. Fahad etal (5) analytically investigated the influence of surface radiation of a transparent gas between two asymmetrically heated vertical plate. Flow is considered to be laminar mixed convective and developing. Siddiqa et. Al (6) numerically investigated on free convection in a vertically heated wavy surface. Investigation on natural convection with surface radiation in a vertical channel with copper heat source array which simulating electronic package performed both analytically and experimentally by Sarper et.al in 2018 (7). Heat spreader also can be used to enhance the heat transfer from electronic devices. It also provides mechanical support to the devices to prevent physical damage during testing and handling .

.

2. Problem description
The schematic diagram of a rectangular vertical channel with five identical protruding heat source and rectangular heat spreader pasted upon each heat source is shown in Fig. 1. Five protruding heat sources are located at the right wall of the channel maintaining spacing'd' with successive heat source. Channel has a length 'L' and a width 'H'. Every heat source has a width 'w' and height 'h'. Each heat spreader has a width 'Ws'. Left face of the first heat source maintains a distance 'L_1'

from the entrance plane. Right face of the 5^{th} heat source is positioned at a distance 'L_2' before the outlet plane. The inlet fluid (air) temperature is assumed to be at 27°C and non-participating media. Each heat source with volumetric heat generating capacity of 100000 W/m^3 is chosen in the present case. Fluid properties are supposed to be constant.

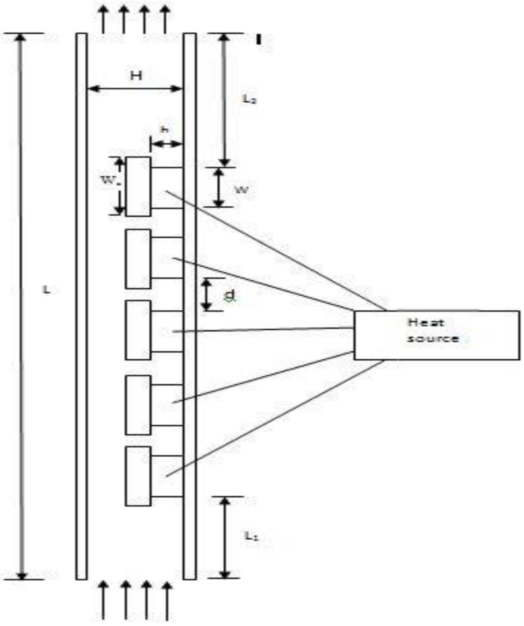

Fig 1. Schematic diagram of the problem

3. Governing equations and boundary conditions:

The governing equations for a 2D, steady, incompressible, laminar flow are given as follows:

$$\frac{\partial U}{\partial X}+\frac{\partial V}{\partial Y}=0 \quad \textbf{(1)}$$

$$U\frac{\partial U}{\partial X}+V\frac{\partial U}{\partial Y}=-\frac{\partial P}{\partial X}+\frac{1}{\mathrm{Re}}\left(\frac{\partial^2 U}{\partial X^2}+\frac{\partial^2 U}{\partial Y^2}\right). \quad (2)$$

$$U\frac{\partial V}{\partial X}+V\frac{\partial V}{\partial Y}=-\frac{\partial P}{\partial Y}+\frac{1}{\mathrm{Re}}\left(\frac{\partial^2 V}{\partial X^2}+\frac{\partial^2 V}{\partial Y^2}\right)+\frac{Gr}{\mathrm{Re}^2}\theta. \quad (3)$$

$$U\frac{\partial \theta}{\partial X}+V\frac{\partial \theta}{\partial Y}=\frac{1}{\mathrm{Re}\,\mathrm{Pr}}\left(\frac{\partial^2 \theta}{\partial X^2}+\frac{\partial^2 \theta}{\partial Y^2}\right). \quad (4)$$

Pressure outlet and velocity inlet boundary conditions are applied at the channel entrance and channel exit, respectively. No-slip boundary conditions are used at all surfaces. Surface to surface radiation model used assuming all interior surfaces are to be diffuse, opaque and gray. Coupled boundary condition was used at wall-to-wall and wall-to fluid boundaries. Emissivity of channel walls considered 0.9. Copper heat spreader emissivity varied from 0.1 to 0.9.

4. Grid independency test:

The grid independency test is performed for Re=250, Heat generation rate (q_v) equal to 1x10^5 W/m^3 considering non-uniform grid throughout the domain. It is found that when number of nodes changes from 136880 to 187671 percentage of change in non-dimensional maximum temperature less than 1. So for present study 136880 nodes are used.

5. Results and discussions:

5.1. Streamline and temperature contour:

The flow field configuration is characterized by using streamline with uniform profile of temperature and uniform velocity of the fluid thrust within the channel. Temperature contour and streamline are shown in Fig.2&3 respectively. Fig.2 shows that temperature of first heat source is much lower than other as because cold air first came in contact with the first heat source. Maximum temperature arises at penultimate heat source as large circulation beyond last heat source carries away heat to the core flow as shown in fig.3. As Reynolds number increases circulation strength also increases. As first heat source temperature is lowest compared to other, radiative heat transfer is insignificant compared to the rest. Heat source mounted on right wall substrate which carries heat by conduction, and its temperature increases which again involved in radiation. Left wall substrate temperature increases due to the radiative interaction with heat source and right wall substrate. A thermal boundary layer was developed over left wall substrate due to radiation. With increasing Reynolds number thickness of that layer decreases.

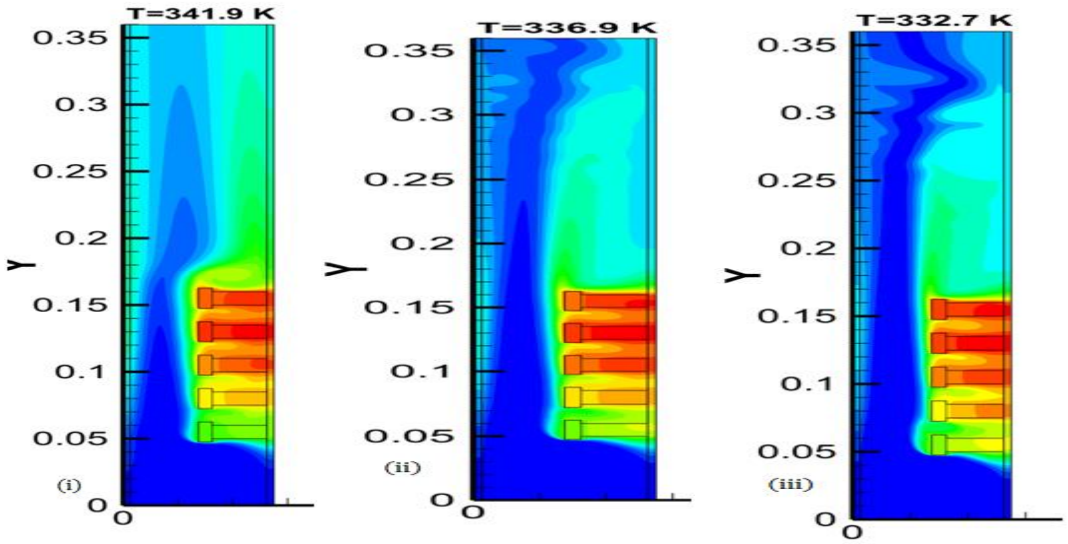

Fig 2. Temperature contour for W_s=0.6H, $\boldsymbol{\varepsilon}_c$=0.5, $\boldsymbol{\varepsilon}_{sp}$=0.5 (i) Re=250 (ii) Re=500 and (iii) Re=750

5.2. Influence of Heat spreader:

Heat spreader creates an additional heat surface area like extended surface. Whenever heat spreader attached with heat source, heat transfer takes place from heat source to heat spreader by conduction and temperature of heat source decreases. So it is important to check the influence of heat spreader on overall heat transfer within the channel. Fig. 4(i) shows that, after introducing heat spreader over the heat source non-dimensional maximum temperature ($\boldsymbol{\theta}_m$) within the channel decreases. For spreader width of 0.4H, 0.6H and 0.8H, $\boldsymbol{\theta}_m$ decreases by 6%, 9% and 12% respectively at Re 250 w.r.t without spreader. Temperature distribution for different spreader width at Re 250 are shown in Fig 5. Fig 4 (ii) depicts that when heat spreader emissivity, $\boldsymbol{\varepsilon}_{sp}$, varies from 0.1 to 0.9, non-dimensional maximum temperature decreases by 20%, 18%, and 16.5% at Re=250, 500, and 750 respectively as with increasing emissivity, radiative interaction between surfaces increases. Temperature distribution for different emissivity are shown in Fig 6.

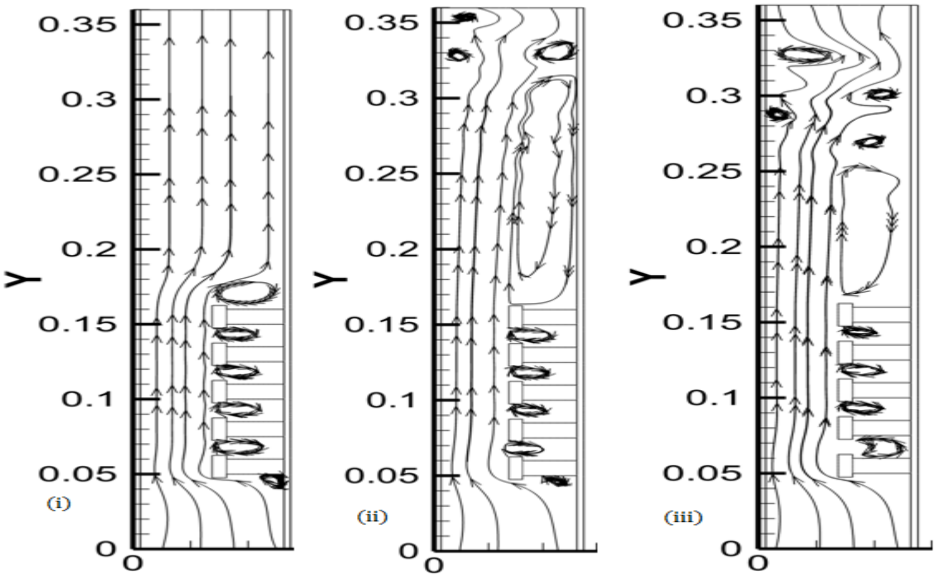

Fig 3.Streamline for W_s=0.6H, $\boldsymbol{\varepsilon}_c$=0.5, $\boldsymbol{\varepsilon}_{sp}$=0.5 (i) Re=250 (ii) Re=500 and (iii) Re=750

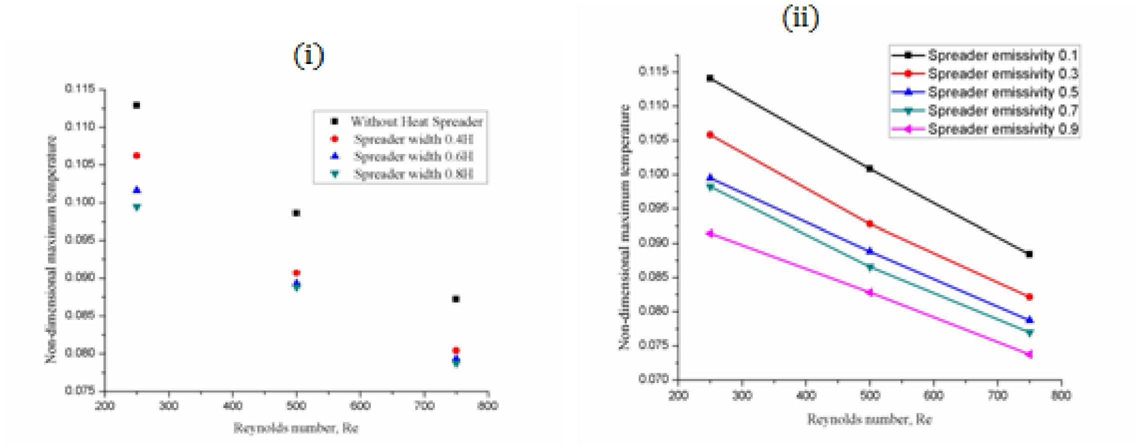

Fig 4. Graphs (i) variation of non-dimensional maximum temperature with Re for different spreader width at $\boldsymbol{\varepsilon}_c$=0.5, $\boldsymbol{\varepsilon}_{sp}$=0.5 (ii) variation of non-dimensional maximum temperature with Re for different spreader emissivity at $\boldsymbol{\varepsilon}_c$=0.5

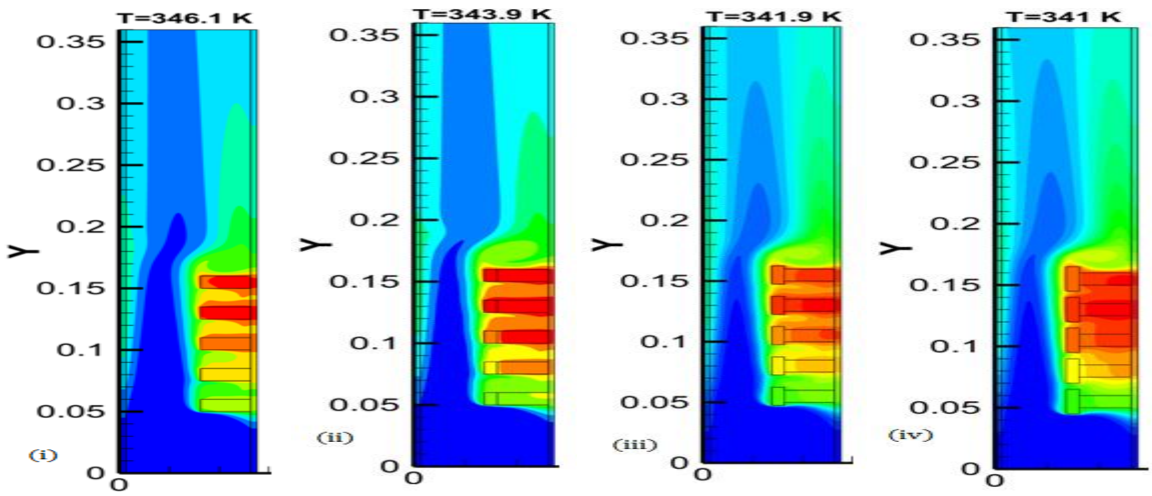

Fig 5. Temperature distribution at Re=250 for (i) without spreader (ii) W_s=0.4H (iii) W_s=0.6H (iv)W_s=0.8H

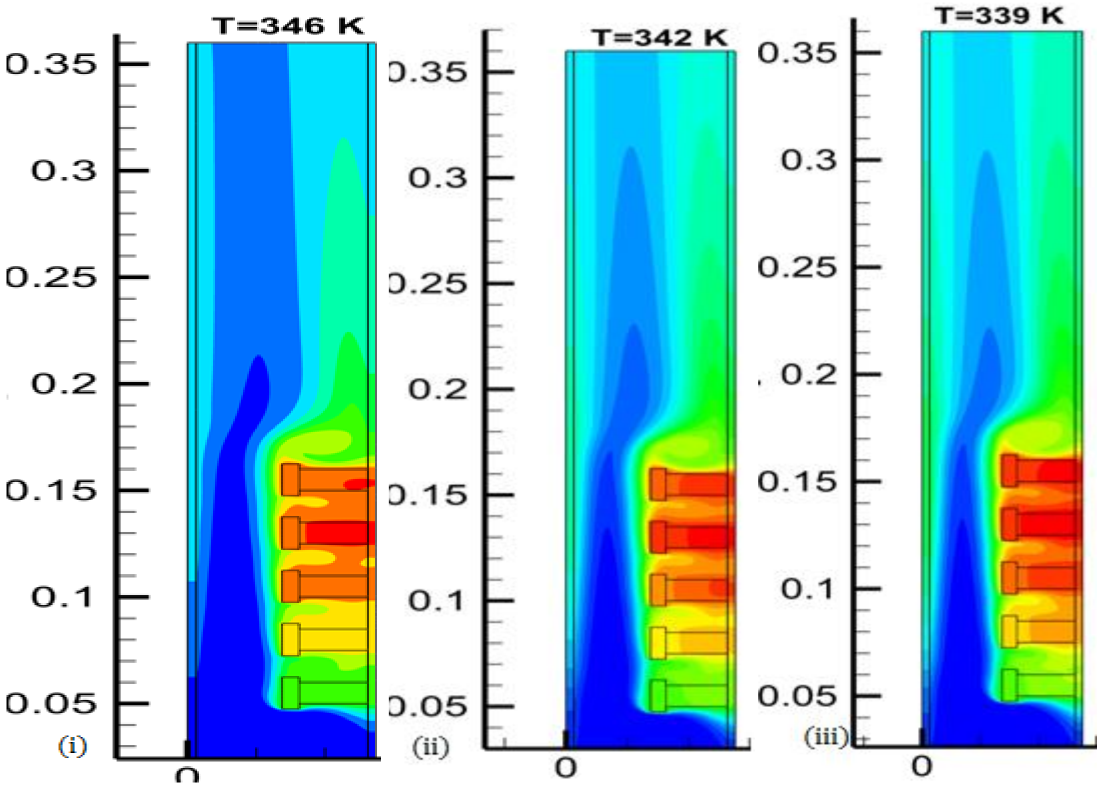

Fig 6. Temperature distribution for Re=250 (i) $\boldsymbol{\varepsilon}_{sp}$=0.1, (ii) $\boldsymbol{\varepsilon}_{sp}$=0.5 and (iii) $\boldsymbol{\varepsilon}_{sp}$=0.9

6. Conclusions;

Based on numerical study in a vertical channel it is found that with increasing spreader width and emissivity, overall heat transfer within the channel increases. Also with increasing Reynolds number radiative heat transfer decreases.

7. References:

[1] T.F. Smith, C. Beckermnn, S.W. Weber, Combined conduction, natural convection, and radiation heat transfer in an electronic chassis, ASME J. Electron. Packag. 113 (1991) 382–391.

[2] C. Balaji, S.P. Venkateshan, Combined conduction, convection and radiation in a slot, cavity, Int. J. Heat and Fluid Flow 14 (1995) 260–267.

[3] B. Premachandran & C. Balaji ‘Conjugate Mixed Convection with Surface Radiation from a Vertical Channel with Protruding Heat Sources, Numerical Heat Transfer, Part A: Applications: An International Journal of Computation and Methodology, (2011) 60:2, 171-196

[4] B. Premachandran & C. Balaji, ‘Conjugate mixed convection with surface radiation from a horizontal channel with protruding heat sources, International Journal of Heat and Mass Transfer 49 (2006) 3568–3582.

[5] Fahad G. Al-Amri, Maged A.I. El-Shaarawi ‘Mixed convection with surface radiation between two asymmetrically heated vertical parallel plates’ International Journal of Thermal Sciences 58 (2012) 70e78

[6] S. Siddiqa , M. A. Hossain , Suvash C. Saha ‘Natural Convection Flow with Surface Radiation Along a Vertical Wavy Surface’ Numerical Heat Transfer, Part A, 64: 400–415, 2013

[7] B. Sharper, M Saglam, O Aydin, Experimental and numerical investigation of natural convection in a discretely heated vertical channel: Effect of the blockage ratio of the heat Sources, Int. J. Heat and Mass Transfer 126 (2018) 894-910