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Computational study of mixed convective cooling of electronic chips with surface radiation

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Abstract:
In this present study the effect of heat spreader in a horizontal channel consisting electronic chip by mixed convection with surface radiation is examined. SIMPLER algorithm with finite volume method used to solve governing equations using ANSYS 16.2 software. Results shows that with increase in the value of governing parameters like Reynolds number and emissivity of spreader, performance of heat transfer increases.

Keywords: Heat Spreader, Mixed convection, Radiation, Electronic chip

1. Introduction
The dependability of the basic electronic components of a device has key importance for the overall reliability of the device. Electronic equipment becomes less efficient above a specified temperature limit. As temperature is increased, failure rate is enhanced exponentially. So, control of temperature of the electronic parts is a special issue in the design and operation. A virtuous literature survey suggests that many studies are focused on heat transfer augmentation with the utility of different shaped control element. Various forms of vortex generators can be used to enhance the heat transfer like protrusions, inclined blocks, wings, fin and ribs, winglets [1,2] in different geometries such as circular, non circular channel under turbulent flow[3-5] as well as laminar flows[4]. Effect of surface radiation along with mixed convection also improves the heat transfer performance [6-7]. But electronic chip covered with heat spreader can also be used to enhance the rate of heat transfer. It also avoids direct contact of air with the chips.

2. Problem description
The schematic diagram of a rectangular parallel plate channel with five identical electronic chips covered by a rectangular heat spreader is shown in Fig. 1. Electronic chips are located at the bottom wall of the channel maintaining spacing,'*d*' with successive chip. Channel has a length '*L*' and a width '*H*'. Each chip has a width '*w*' and height '*h*'. the heat spreader has a width '*Ws*' and height 'h_s'. Left face of the first chip maintains a distance 'L_1' from the inlet and Right face of the 5^{th} chip is positioned at a distance 'L_2' from the outlet. Walls of the channel has a fixed thickness '*t*'. Each chip with volumetric heat generating capacity of 100000 W/m^3 is chosen in the present case. Fluid properties are supposed to be constant.

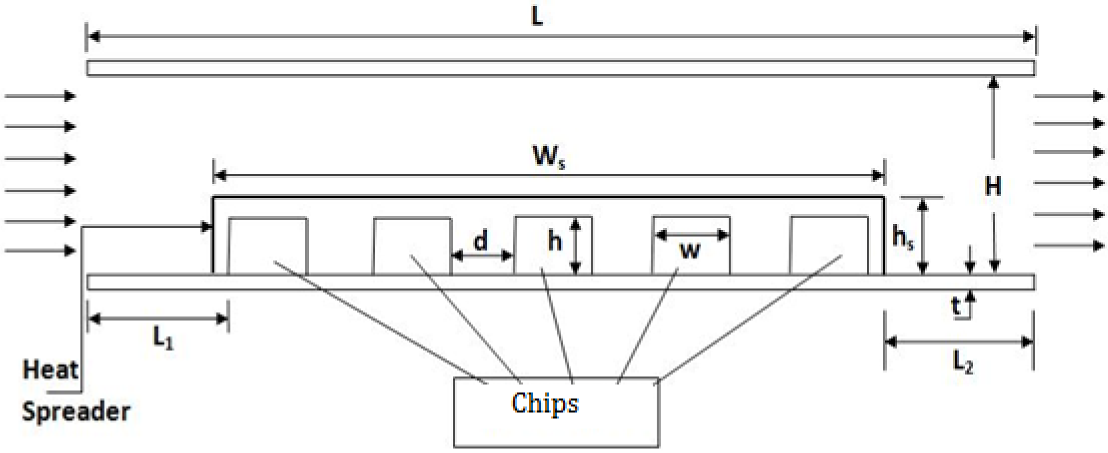

Fig 1. Schematic diagram of the problem

3. Governing equations and boundary conditions:

For a 2D, steady, incompressible, laminar flow the governing equations are given as follows:

$$\frac{\partial U}{\partial X} + \frac{\partial V}{\partial Y} = 0 \tag{1}$$

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

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

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

Surface to surface radiation model is used considering all internal surfaces are gray, opaque and diffuse. Air is a non-participating medium. No-slip boundary conditions are employed at surfaces. Couple boundary conditions are used at wall to fluid and wall to wall boundaries [7]. At inlet, velocity inlet boundary condition and at outlet, pressure outlet boundary condition is imposed.

4. Grid independency test

Grid independency study is conducted for Re=250. A non-uniform grid is used all through the domain along with very fine grids in front of the chips and spreader. Fig 2 shows that by increasing the total number of nodes from 161265 to 216279, a change only less than 1% on the maximum non-dimensional temperature. Hence node of 161265 is considered in whole study for time limits.

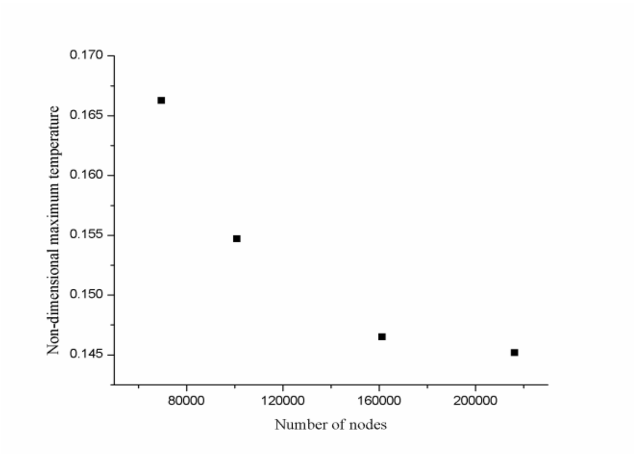

Fig 2 Variation of non-dimensional maximum temperature with number of nodes.

5. Results and discussions:

Present study is conducted for diverse Reynolds number (Re=100, 250 and 500), various emissivity of heat spreader ($\boldsymbol{\varepsilon}_s$=0.1, 0.3, 0.5, 0.7 and 0.9) fixing emissivity of substrate at 0.9 to create sufficient data for non-dimensional temperature ($\boldsymbol{\theta}$). In this investigation the dimensionless geometric parameters have been taken as L_1=2H, L_2=8H, d=w.

5.1. Influence of Reynolds number on heat transfer:

One of the considerable parameter in this present numerical study is Reynolds number. Flow field is characterized by using streamline as shown in fig. 3. Temperature distribution is shown in fig. 4.

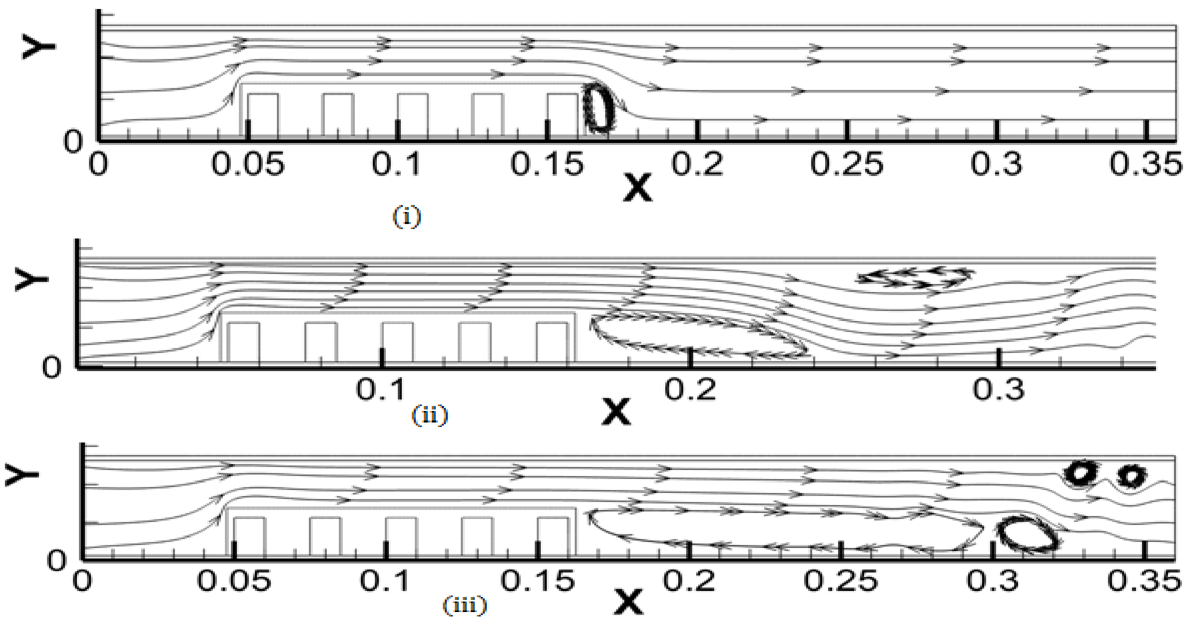

Fig 3. Streamline for $\boldsymbol{\varepsilon}_s$=0.5 at (i) Re=100, (ii) Re=250 and (iii) Re=500

From fig. 3 it is observed that with increase in Reynolds number, recirculation strength behind the spreader increases due to pressure drop. At higher Reynolds number a weak flow reversal takes place near to the top wall of the channel due to sudden expansion of cross sectional area. Fig 4 depicts that with increasing Reynolds number thermal boundary layer thickness decreases and temperature of the channel decreases. As, due to radiation, heat is transferred from spreader to top wall of the channel, thus thermal boundary layer also developed at the top wall which decreases with increasing Reynolds number

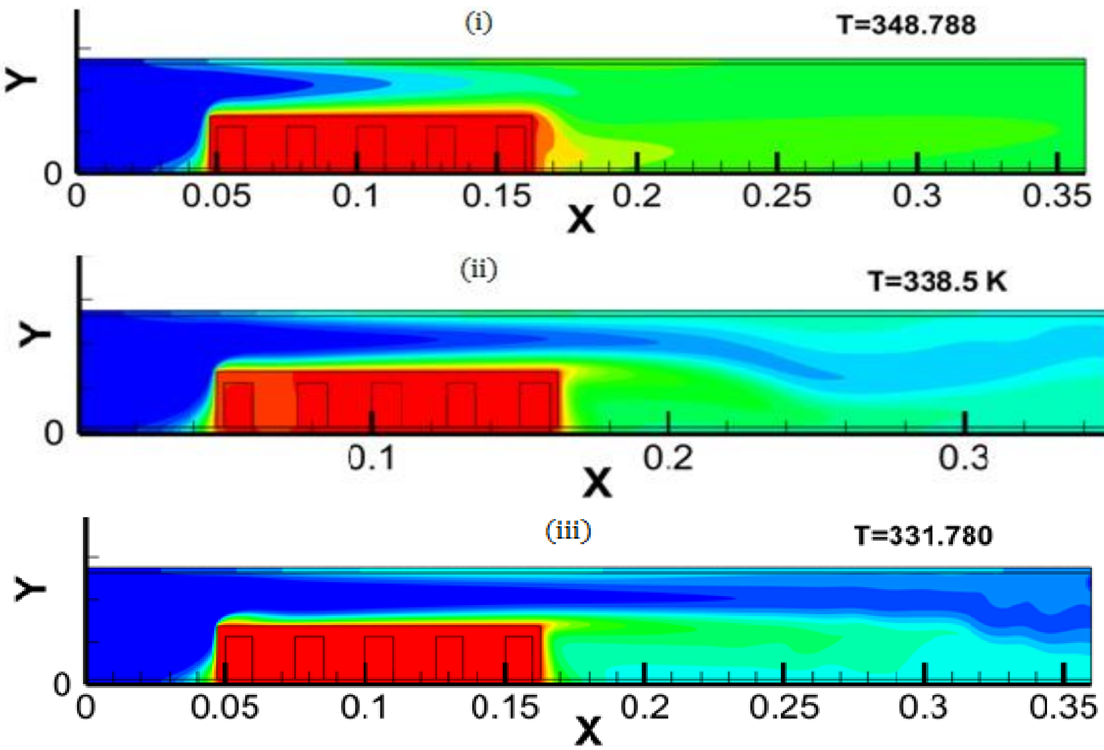

Fig 4. Temperature distribution for ε_s=0.5 at (i) Re=100, (ii) Re=250 and (iii) Re=500

5.2 Influence of Heat spreader emissivity on heat transfer

Fig 5(i) depicts that with increase in emissivity of heat spreader non-dimensional temperature decreases. When emissivity changes from 0.1 to 0.9, maximum temperature changes from 347K to 334K as radiative interaction between spreader and wall increases. Fig 5(ii) depicts the effect of surface radiation on total heat transfer. At higher Reynolds number contribution of surface radiation on total heat transfer decreases as mixed convection affect dominates. Temperature distribution for various emissivity of heat spreader is shown in fig. 6.

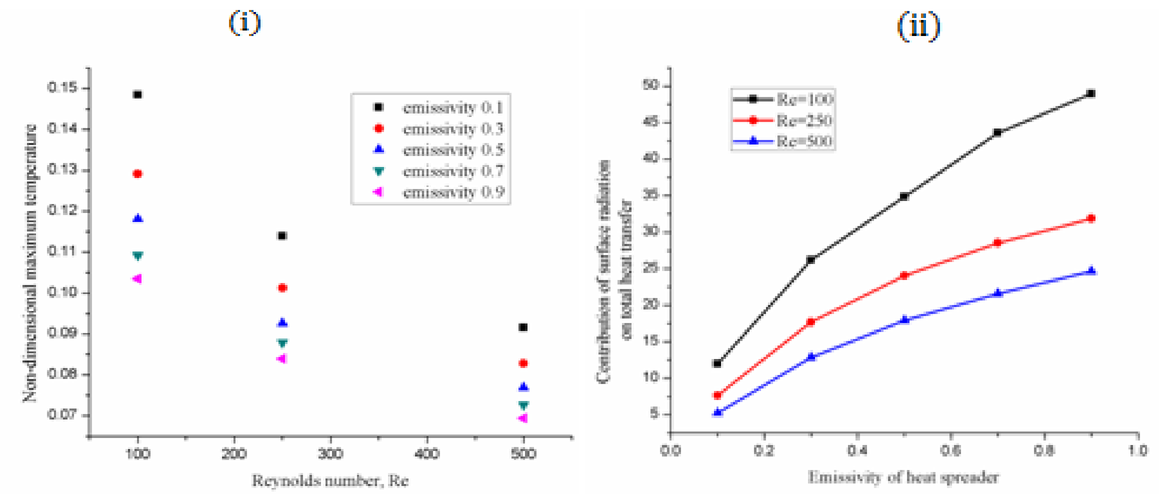

Fig 5. Graph (i) variation of non-dimensional temperature with Re for different emissivity (ii) contribution of radiation on total heat transfer for different Re

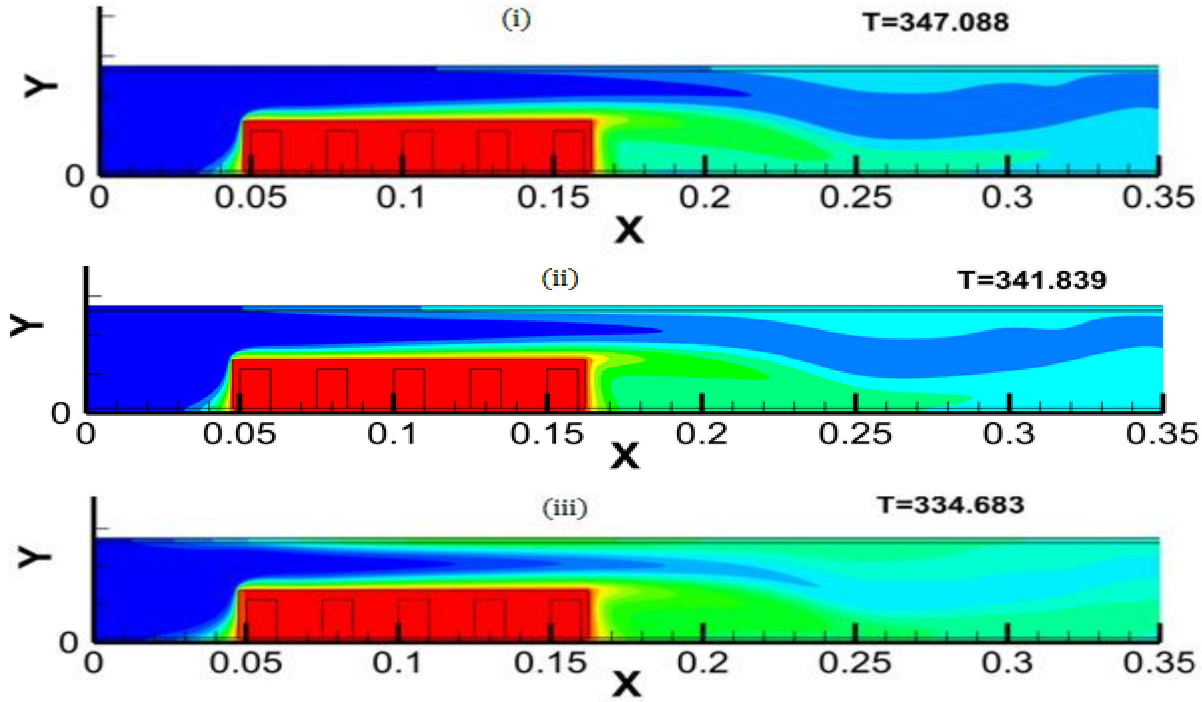

Fig 6. Temperature distribution for Re=250 (i) ε_s=0.1, (ii) ε_s=0.3 and (iii) ε_s=0.7

6. Conclusions:

From the above analysis it is observed that with the increase in Reynolds number, maximum temperature within the channel decreases, also contribution of radiation decreases. Again it is also observed that with increase in spreader emissivity temperature at the chip surface decreases.

7. References:

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