Effect Of Surface Radiation On Conjugate Convection From An Electronic Board With Multiple Embedded Discrete Heat Sources

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Abstract

The warm administration of electronics is fault-finding for guaranteeing dependability and acting, particularly in orders accompanying diversified entrenched individual heat beginnings. This study investigates the effect of surface dissemination on combine change of possession from an photoelectric board accompanying diversified heat-create elements. A linked mathematical and examining approach is used to resolve heat transfer machines, combining fallout exchange accompanying the encircling atmosphere and convective abating belongings.Results display that surface fallout considerably influences the warm disposal, specifically in depressed-speed change of possession synopsises place dissemination can give reason for a solid portion of the total heat wantonness. The ghost of diversified individual heat beginnings presents complex warm interplays, chief to local passionate spots and non-uniform hotness sketches. The study further investigate the impact of board material possessions, emissivity alternatives, and convective barrier environments on overall warm accomplishment.Understanding the interaction betwixt dissemination and change of possession in aforementioned configurations is important for optimizing chilling approaches in extreme-efficiency electronic devices. The verdicts focal point the need for joined warm administration answers that deem fallout belongings, particularly in compact and big-league-bulk photoelectric requests

1. Introduction

The present paper reports the important results of the problem of combined conduction convection radiation from a vertical rectangular electronic board equipped with three identical discrete heat sources. The heat sources are located along the vertical central axis of the board. The heat generated in the three heat sources is conducted both along and across the board, before subsequently getting dissipated by convection and radiation. Air, a radiatively transparent medium, is considered to be the cooling agent. The governing partial differential equations for temperature distribution in the entire computational domain are obtained by appropriate energy balance between the heat generated, conducted, convected and radiated. These equations are solved using finite difference formulation coupled with GaussSeidel iterative solver. A computer code is written to solve the problem and exhaustive parametric studies have been carried out. Interactive effect of radiation on conjugate convection has been elucidated.

2. PROBLEM DEFINITION AND MATHEMATICAL FORMULATION

Figure 1 shows the problem geometry considered in the presented study. It consists of arectangular slab shaped electronic board of dimensions L×W. There are three identicalembedded discrete heat sources of dimensions $L_h \times L_h$ in this slab. The heat sources areprovided along the vertical central axis of the slab, as shown. There is one heat source at thegeometric center of the plate, while the other two heat sources are symmetrically located oneither side of it. The bottom most heat source and top most heat source are at a distance L/8from the corresponding horizontal boundaries of the rectangular slab. There is a uniformvolumetric heat generation at the rate q_vW/m^3 in each heat source. The thermal conductivityand surface emissivity of the rectangular slab are, respectively, k and ε.

The heat generated in the three heat sources is initially conducted along and across theelectronic board, before getting dissipated from the boundaries of the device by combinedconvection and radiation. The cooling medium is air at temperature T∞, while the convectionheat transfer coefficient is h W/m^2 K. The governing equations for temperature distribution inthe entire computational domain are obtained by making energy balance between the heatgenerated, conducted, convected and radiated. For example, the governing equation for all theinterior nodes of each of the three discrete heat sources, upon energy balance, turns out to be:

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{q_v}{k} = 0 \qquad (1)$$

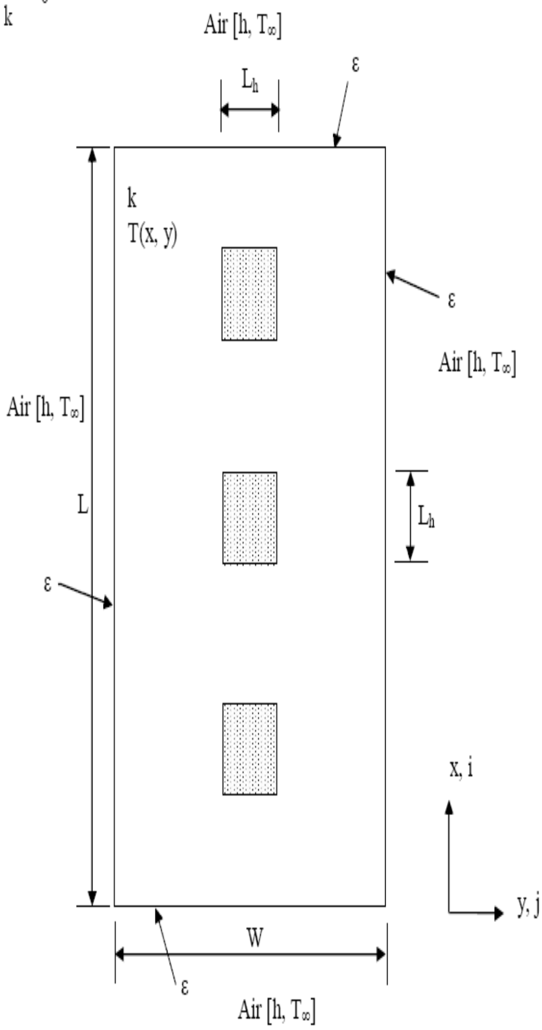

Figure 1: Schematic of the problem geometry chosen for study.

With regard to interior nodes in the non-heat source portions, the governing equation would be Eq. (1) with source term absent. For a typical interface element between the top boundary of the central heat source and the non-heat source portion, the energy balance turns out to be:

$$q_{x,cond,in} + q_{y,cond,in} + q_v \frac{\Delta x \Delta y}{4} = q_{x,cond,out} + q_{y,c}$$

Assuming that D_x = D_y, and substituting for various terms in the above equation and simplifying, one gets:

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{q_v}{2k} = 0$$

For a typical corner element of any of the heat sources, the governing equation for temperature distribution is same as Eq. (3) with the third term on the left hand side replaced by (qv/4k). With regard to the boundaries of the board, making energy balance on an arbitrarily chosen element along the left boundary:

$$q_{x,cond,in} = q_{x,cond,out} + q_{y,cond,out} + q_{conv} + q_{rad} \quad (4)$$

Substitution of appropriate expressions for various terms in the above equation and subsequent simplification leads to the following governing equation for temperature distribution along the left boundary of the board:

$$\frac{\partial^2 T}{\partial x^2} + \frac{2}{\Delta y_2}\frac{\partial T}{\partial y} + \frac{q_v}{k} - \frac{2h}{k\Delta y_2}(T - T_\infty) - \frac{2\varepsilon\sigma}{k\Delta y_2}(T^4 - T_\infty^{\ 4}) = 0 \quad (5)$$

With regard to the two corner elements of the left boundary, the governing equation for temperature distribution would get modified as:

$$\frac{\partial T}{\partial x} - \frac{\Delta x_2}{\Delta y_2}\frac{\partial T}{\partial y} + \frac{h}{k}\left(1 + \frac{\Delta x_2}{\Delta y_2}\right)(T - T_\infty) + \frac{\varepsilon\sigma}{k}\left(1 + \frac{\Delta x_2}{\Delta y_2}\right)(T^4 - T_\infty^{\ 4}) = 0 \quad (6)$$

Similar treatment is used for obtaining the temperature of the remaining boundaries as well.

3. SOLUTION METHODOLOGY AND RANGES OF

The governing equations for temperature distribution in the entire computational domain derived as above are nonlinear partial differential equations. They are converted into algebraic equations using finite difference formulation. The resulting equations are later solved using GaussSeidel iterative solver. Full relaxation has been used on temperature during iterations, while a convergent criterion of 10^{-6} has been imposed to terminate the iterations. A computer code in C ++ has been written to solve the problem.

With regard to ranges of independent parameters concerning the present problem, the surface emissivity of the electronic board (ε) is varied between 0.05 and 0.85. The lower limit of ε corresponds to a poor emitter like polished aluminum, while the upper limit of ε signifies a good emitter like black paint. The thermal conductivity (k) of the electronic board is varied between 0.25 W/m K and 1 W/m K. This is done so in view of the fact that electronic devices are typically made of materials of thermal conductivity of the order of unity. An example is glass epoxy that has k = 0.26 W/m K. For convection heat transfer coefficient (h), the appropriate range is from 5 W/m^2K to 100 W/m^2 K. The above limiting values of h, respectively, correspond to asymptotic free convection limit and asymptotic forced convection limit. Further, the height (L) and width (W) of the electronic board are fixed at 20 cm and 10 cm, respectively. The mean temperature (T∞) of the cooling agent (air) is taken to be 25ºC.

4. RESULTS AND DISCUSSION

4.1 Grid independence study

The grid sensitivity text is carried out in two phases for a standard input: q_v = 10 5 W/m^3, k = 0.25 W/m K, h = 25 W/m^2 K and ε = 0.45. In Phase – 1 of the study, the number of grids (N) in the horizontal direction is arbitrarily fixed at 113. The number of grids in the vertical direction (M) is varied. The maximum board temperature (T_{max}) is found to be changing by8.37% as M is increased from 171 to 191. A further increase in M brings down the percentage change in T_{max}. It is noticed that T_{max} changes by 5.09% as M increases from 231 to 251. A subsequent slight increase in M from 251 to 255 brings down the change in T_{max} to just 0.92%. Simultaneous to these observations on T_{max}, even the energy balance is checked and the best possible energy balance check occurs at M = 259. In view of these observations, the value of M is finalized to be 259.

In Phase – 2 of the study, the value of M is taken to be 259 as finalized above, while the number of grids in horizontal direction (N) is varied. It is seen that though the values of N >111 give a converging T_{max}, the check for energy balance is at its best for N = 113. In view of this, the value of N is finalized to be 113. In both the phases above, the number of grids in each heat source is taken as 30×30. It is noticed that any other grid size in the heat sources does not give better result than the above. Thus, all the ensuing parametric studies are carried out taking M = 259, N = 113 and number of grids per heat source = 30×30.

4.2 Variation of local temperature in the electronic board with other parameters

Figure 2 shows the local temperature distribution along the axial direction at mid-plane drawn for five different values of convection heat transfer coefficient (h). The data is obtained for a fixed input of q_v = 10 5 W/m^3, ε = 0.45 and k = 0.25 W/m K. For a given h, the temperature is increasing as one moves from the bottom of the board, reaching a local maximum a little head of top end of the first heat source. It is decreasing again, reaching a local minimum before rising again as one reaches the second heat source. The temperature now reaches a second maximum exactly at the geometric centre of the board before decreasing again. After reaching a second local minimum, the temperature is shooting up again to a third maximum a little ahead of the top end of the third heat source and is decreasing again.

There is an expected symmetry in the local temperature profile with reference to the geometric center of the board. Further, the local maximum noticed at the geometric center of the board is the largest temperature in the board, while the other two local maxima on either side of the above are identical but smaller than the central temperature. The figure further shows that the temperature at any location along the board decreases as h increases from 5 to 100 W/m 2 K. This is expected because the flow regime transits from free convection dominance to forced convection dominance with h increasing between the above two limits.In the present example, the local temperature at the geometric center of the board decreases by 24.37% as h increases from 5 to 100 W/m^2 K.

The effect of surface emissivity (ε) on local axial temperature distribution at mid-plane along the electronic board is as shown in Fig. 3. The trend followed by the temperature profile for a given ε looks similar to what has been noticed in Fig. 2. Further, at a given location, the temperature decreases with increasing ε owing to increased radiative heat dissipation from the board with other parameters held fixed. The figure further shows a comparatively larger drop in local temperature between ε = 0.05 and ε = 0.45, while the drop between ε = 0.45 and ε = 0.85 is less pronounced. In the present example, the temperature at the geometric center of the board decreases by 11.93% as ε increases from 0.05 to 0.45, while the drop in temperature is only by 6.23% as ε subsequently increases from 0.45 to 0.85.

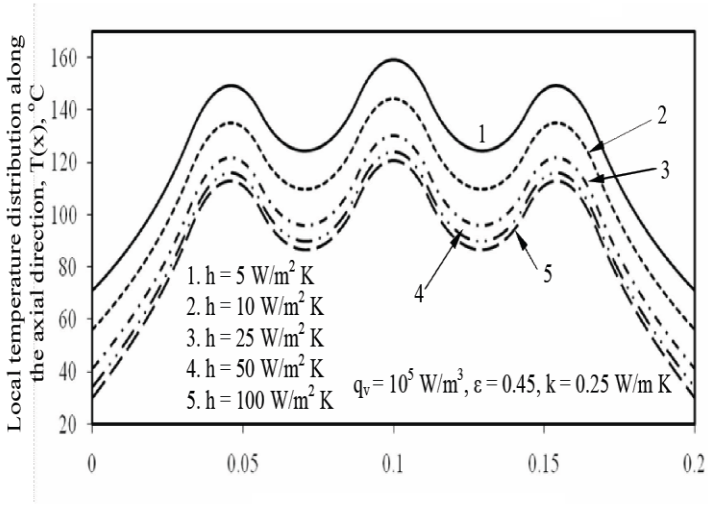

Figure 2: Local board temperature profiles in various regimes of convection.

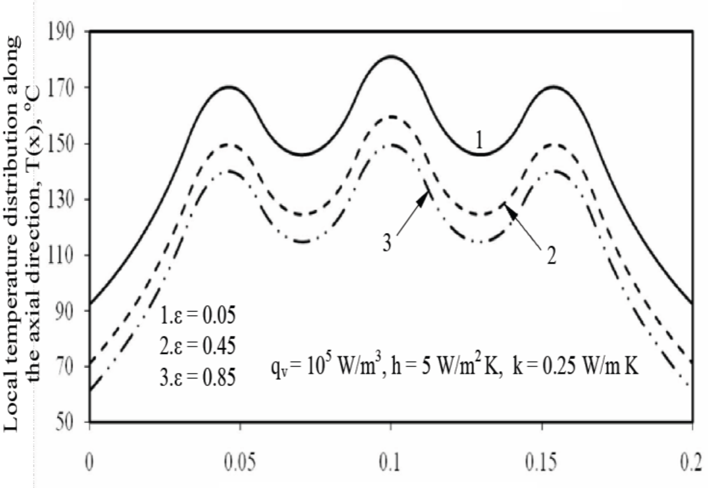

Figure 3: Local temperature profiles for various surface emissivities of the board.

5. CONCLUSION

The problem of combined conduction-convection-radiation from a vertical rectangular electronic board possessing three identical embedded discrete heat sources has been solved numerically. A computer code making use of finite difference method of solution in conjunction with GaussSeidel solver is written for the purpose. A grid sensitivity test has been carried out and the best possible grid system that gives the optimum solution vis-à-vis peak board temperature as well as energy balance has been evolved. A detailed probe into local temperature distribution in the board and maximum board temperature is made with reference to pertinent independent parameters, viz., number of heat sources, thermal conductivity, surface emissivity and convection heat transfer coefficient. Further, the relative roles played by convection and radiation in carrying the mandated heat load have been studied with regard to surface emissivity of the board in different regimes of convection.

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