Heat Transfer in Square Porous Cavity Due to Radiation and Heat Generating Strip - Part I

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Abstract. Investigation of heat transfer is presented due to a vertical heat generating strip inside the square porous cavity. The heat is assumed to be generated at isothermal rate at a strip inside the medium. The two horizontal surfaces of the cavity are cooled to lower temperature Tc. The vertical walls of the cavity are cooled adiabatically so that heat does not cross the boundary. Finite element method is applied as a solution tool to solve the governing equations. The impact of various parameters such as heating strip length, Rayleigh number and Radiation parameter are presented in terms of temperature and streamline distribution inside the porous cavity.

1. Introduction
The impact of heat transfer in porous medium is quite distinctive due to various kinds of boundary conditions being applied to the physical domain [1-10]. The shape of the domain itself plays a crucial role in deciding the heat transfer characteristics inside any given porous medium. For instance, the heat transfer in square cavity [5] is substantially different from that of annular geometry [8-9] or vertical plates [4]. It is of paramount importance to the scientist and engineers working in the field of porous media to know the amount of heat that can be transferred from the porous domain to decide its suitability to a particular application. Thus there has been lot of effort being invested to understand the heat transfer in porous medium due to various boundary conditions. The present article investigates the heat transfer due to a small heat generating strip being placed inside the porous domain.

2. Analysis
Consider a square porous domain as shown in figure 1. The heat generating strip is present at the center of cavity placed vertically. The various boundary conditions applicable are shown in figure 1.

The governing equations for the problem can be given as
\[
\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0
\]
\[
\frac{\partial u}{\partial y} - \frac{\partial v}{\partial x} = -\frac{g\beta K}{v} \frac{\partial T}{\partial x}
\]
\[
u \frac{\partial T}{\partial x} + \nu \frac{\partial T}{\partial y} = \alpha \left( \frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} \right) - \frac{1}{\rho C_p} \frac{\partial q}{\partial x}
\]

3. Results and Discussion

The investigation is carried out for three parameters such as the height of the heating strip (SH), Rayleigh number (Ra) and Radiation parameter Rd. Figure 2 shows the heat transfer behavior when the strip height is varied as 17%, 33% and 50% of the cavity height at Ra=100 and Rd=0. It is seen that the isotherms and streamlines are symmetrically divided about the left and right side of the heating strip. The smaller size of the strip shows that the isotherms are placed further to each other. This indicates that the more of the porous medium is occupied with similar temperature. The streamlines clearly show that the strength of the fluid is less when the heating strip is smaller. The increase in the strip height pushes the isotherms closer to each other that reflects that the heat transfer increases with increase in the strip height. It is also noted that large amount of heat is dissipated from upper portion of the cold surfaces as compared to its lower portion which is very much obvious from the isotherm corresponding to 0.1. The fluid cell tilts towards the top corners when the height of the strip is increased. This shows that the fluid flows from the strip towards the upper corners and returns back by dissipating its thermal energy in that area.

Figure 3 shows the effect of changing Rayleigh number at SH=25% and Rd=0. The Rayleigh number is changed as Ra=10, Ra=100 and Ra=150. The low Rayleigh number is known to support conduction heat transfer due to lack of fluid movements. This is very much clear from figure 3a which shows smoothly distributed isotherms with the fluid movement restricted to lesser area in the porous domain. The increase in Rayleigh number completely changes the isothermal and streamlines distribution owing to increased fluid velocity which is reflected in terms of higher value of stream function.

The effect of changing the Radiation parameter is shown in figure 4. It is found that the isotherms are evenly distributed when radiation parameter is increased. It must be noted that the mathematical model used incorporates radiation effect as equivalent conduction thus the isotherms and streamlines shows that the conduction effect increased due to increase in Rd.
Figure 2: Effect of Heater Height (SH) a) SH = 17% b) SH = 33% c) SH = 50%
Ra = 100, Rd = 0.05
Figure 3: Effect of Rayleigh Number (Ra) a) Ra = 10 b) Ra = 100 c) Ra = 150
SH=25%, Rd=0.05
Figure 4: Effect of Radiation Parameter (Rd) a) Rd = 0.1 b) Rd = 0.5 c) Rd = 1
Ra = 100, SH = 25%
4. Conclusions
Heat Transfer in porous cavity due to a small heat generating strip inside the porous medium is analyzed with the help of FEM. It is noted that the
- Isothermal lines and streamlines are distributed symmetrically about the strip.
- Heat transfer increases with increase in strip length.
- Higher Rayleigh number increases heat transfer.

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