Numerical analysis of natural convection in differentially heated triangular cavities.

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A recent study [1] has shown that the addition of flat mirrors, placed between the successive rows of a tilted photovoltaic module installation increases the irradiance and consequently the electric production by about 20%. However, an increase in panel temperature degrades this electricity production by about -0.5% /°C for polycrystalline silicon and about half that for amorphous silicon. Controlling the temperature and its homogeneity at the surface of the panel is therefore essential for optimize performance and to predict, as well as possible, the electric production. This will also allow us to improve the summer cooling of the modules by optimizing the geometry and, if possible, to exploit hybrid photovoltaic-thermal generation.

In this work, we have numerically studied 2-D natural convection flows generated inside prismatic cavities with isosceles and scalene triangular profiles. The 2-D simulation of flows is a first approximation of the average real flows allowing for the reduction of computation times. In addition, numerical simulations using the finite element method are a suitable tool to quantitatively determine the heat transfer coefficient and the hot spot temperature for different geometries and boundary conditions [2]. The fluid considered in the cavities is air (Pr = 0.7).

Firstly, we validated the numerical tool by considering natural convection flows in isosceles cavities as studied by Hoffman et al. [2]. Three aspect ratios (defined as the height of the cavity divided by the haft-base) A_1=0.5; A_2=1; A_3=2.25; and the Rayleigh number in the range 10^0 to 10^{10} were considered. Secondly, we studied a non-symmetric (scalene) cavity composed of two aspect ratios. The academic boundary condition of Dirichlet type is first investigated. Then the Neumann boundary condition is considered because the heat flow is a more realistic representation of what happened to real panels. The mean Nusselt number on the different walls, the kinetic energy, and the temperature in the cavity area were evaluated for the different values of the Rayleigh numbers. The streamlines patterns and isotherms obtained for these values of the Rayleigh number allow us to analyse the natural convection flows for the different geometries.

An asymmetric cavity with a constant heat flux density along the left inclined wall, a cold right inclined walls and a cold base is presented in Fig. 1.

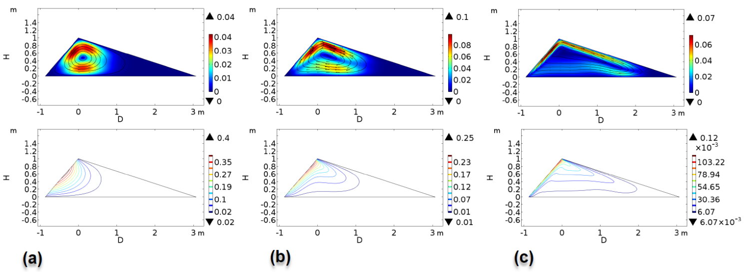

Fig. 1 Streamline (upper) and isotherms (lower) for (a) Ra = 10^3 (b) Ra = 10^5, (c) Ra = 10^7

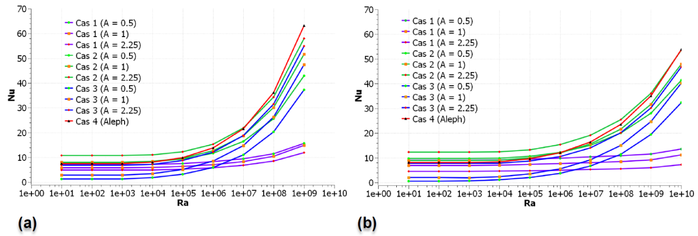

Fig. 2 Mean Nusselt number vs Rayleigh numbers for different aspect ratios (a) Constant hot temperature along left inclined wall, (b) Constant heat flux along left inclined wall.

In this article, the results of Figures 1 and 2 and others results, will be compared, and analyzed. The impact of the geometries and boundary conditions will also be evaluated. Finally, suggestions for the best thermal conditions will be considered.

References

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