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Optimal location of a pair heat source-sink in an enclosed square cavity with natural convection through PSO algorithm☆

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ABSTRACT

In this paper, the optimum positions of a pair heat source-sink in an enclosure have been studied. The objective of this investigation is to minimize the maximum temperature (T_{max}) on the heat source with constant heat flux. For this, a Particle Swarm Optimization algorithm (PSOA) has been used. Continuity, momentum and energy equations with the Boussinesq approximation for a laminar and incompressible flow of a Newtonian fluid have been solved by finite volume method. The present study has been carried out for governing parameters like Rayleigh numbers (Ra) from 10^3 to 10^6, the cavity aspect ratio, $A = H/L = 1$ and the source and sink sizes D_0 from 0.2 to 0.5. Numerical results revealed that the optimum configurations are a function of Rayleigh numbers and the source and sink sizes.

1. Introduction

In recent years, the thermal performance of electronic packages have become an integral part of almost every phase of modern living. Better reliability of this equipment requires that, they be maintained at a relatively constant temperature that should be below the maximum service temperature specified by the manufacturer. Consequent to the dimension shrinkage of electronic equipment, the heat fluxes increase which in turn demands more efficient cooling strategies. While liquid cooling may provide the answer to this, air cooling is still one of the preferred methods up to certain heat flux levels due to its desirable characteristics in thermal equipment design such as absence of mechanical or electromagnetic noise, low energy consumption which are very important in portable computers and reliability [1–5].

Besides cooling of the electronic components, there are numerous other practical applications of natural convective cooling in rectangular enclosures with various combinations of the temperature gradients, cavity aspect ratios, placement of the heat source and cold surfaces, etc. [6–32].

Study of thermal management of electronic devices has been done in partially open cavities by Hsu and Wang [10] and Jilani et al. [33], and in enclosed cavities by Du and Bilgen [34], Deng et al. [35] and da Silva et al. [36].

The problem of convective heat transfer and optimal locations of heat sources in an enclosure has been studied in many literatures because of wide ranges of engineering applications of such processes. The parameters frequently considered are Rayleigh number, distance between heat sources and the ratio between heat source dissipation rates [37–39]. The optimum position of single and multiple chips has been studied in Ref. [36] and [40–42]. Recently, Dias and Milanez [43] have used Genetic algorithms in optimization studies of heat sources in a cavity. They have validated the results obtained by Silva et al. [36] which showed that this approach is computationally more feasible and faster than an extensive search technique.

Literature review above reveals that researches mostly have focused on optimal positions of heat sources in cavities while the effect of heat sinks has not been considered. The main objective of the present study is to optimize the position of a heat source and sink in order to minimize the maximum temperature on the heat source (T_{max}) for different values of Rayleigh numbers and lengths of those source and sink. It is worthwhile mentioning that with regard to the definition of global conductance [36], minimum value of temperature on the heat source leads to a maximum value for conductance.

2. Problem definition and mathematical model

The physical model is shown in Fig. 1. Heat transfer by natural convection from the heat source at the optimum positions of left heat source and right sink installed on the vertical wall has been studied in a square cavity with aspect ratio ($A = H/L = 1$).

2.1. Governing equations and boundary conditions

The governing equations were written with the following assumptions; the flow is laminar with a Newtonian fluid, there is no viscous heat dissipation and no variation in the fluid properties except density variation in vertical direction (the Boussinesq

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