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Entropy generation due to natural convection cooling of a nanofluid ☆

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ABSTRACT

In the present work, entropy generation due to natural convection of a nanofluid that consists of water and Cu in a cavity with a protruded heat source has been studied. To investigate both the First and the Second Law of Thermodynamics for this considered problem the numerical scheme carried out based on finite volume method with the SIMPLE algorithm for pressure–velocity coupling. In this study, the effect of Rayleigh number, solid concentration and heat source location on entropy generation have been revealed. Consequently the optimum case has been selected since the thermal system could have the least entropy generation and the best heat transfer rate. The results have shown the maximum value of Nusselt number and minimum entropy generation are obtained when heat source mountains in the bottom horizontal wall.

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1. Introduction

Laminar natural convection on cavities has attracted many researchers, due to its practical engineering applications, such as heat removal from electrical and electronic equipments, solar collectors and nuclear reactor design. Among the papers on natural convection in cavities, some of them focused on natural convection enhancement utilizing nanofluids [1–5].

However many studies have been performed on natural convection in cavities with various impediment placed inside, in the form of partitions and bodies acting as a heater [6–8]. The effect of a single and multiple partitions on heat transfer phenomena in an inclined cavity was investigated by Mezrhab et al. [9]. Buoyancy forces in a square enclosure divided by an impermeable partition between air and water filled chests were carried out by Oztop et al. [10]. Bilgen [11] studied natural convection in a cavity with a thin fin on the hot wall. In this work the effect of fin position on the hot wall and the length of fin were investigated. He found that Nusselt number, is a decreasing function of the fin length, and also the optimum fin position is near the center of the cavity. P. Kandaswamy et al. [12] numerically studied buoyancy driven convection in a square cavity induced by two mutually orthogonal and arbitrarily located baffles. They found that heat transfer is enhanced by increasing the vertical baffle length. Also increase of the horizontal baffle length augments heat transfer only when it is below of the center of the cavity. The effect of location and dimension of protruded heat source on the natural convection flow and temperature fields in a square cavity filled by nanofluid have already investigated by Mahmoudi et al. [13].

However to find the optimal design of thermal systems with minimum loss of available energy, one route is minimization of entropy generation as introduced by Bejan [14]. This method has already been extensively applied to the forced and free convection problems and has been well established in the literature [15–24]; entropy generation was mostly analyzed in enclosures filled by conventional fluids (such as water, ethylene glycol, etc.) and the effect of nanoparticles on entropy generation in enclosures has not been adequately investigated. The study of thermal nanofluid flow between parallel disks with special attention to entropy generation has been recently simulated by Yu Feng et al. [25]. Another study has been carried out by Jie Li et al. [26] to analyze entropy generation in trapezoidal microchannels for steady laminar flow of pure water and CuO-water nanofluids. They minimized entropy generation in the considered microchannel in terms of most suitable channel aspect ratio and Reynolds number range. Pawan K. Singh et al. [27] analyzed the entropy generation due to flow and heat transfer in three different channels: microchannel, minichannel and conventional channel with alumina-water nanofluids as the model fluid. Their result showed that whether using the alumina-water with high viscosity as a coolant in microchannels, minichannels and conventional channels is advisable or not depends on flow regime. They also offered an optimum diameter to minimize the entropy generation rate.

The main aim of this study is to examine the entropy generation due to natural convection heat transfer of a nanofluid in a square cavity heated with a protruded heat source. Since nanofluid consists of very small sized solid particles, therefore in low solid concentration it is reasonable to consider nanofluid as single phase flow [28], so in

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