Natural convection heat transfer between inner sphere and outer vertically eccentric cylinder

Wen Ruey Chen

Department of Energy Application Engineering, Far East University, No. 49, Chung Hua Rd., Hsin-Shih, Tainan County 744, Taiwan, ROC

1. Introduction

The human foods are decreasing gradually when the development of the biomass energy. The food lack will face crisis and threat in the future. The application of the renewable energy will be attracted more attention, such as solar energy, wind-force and terrestrial heat etc. The solar energy was the most extensively applied among them because of its importance in the thermal storage systems of the solar energy collectors. In particular, the natural convective fluid about buoyancy-driven flow in enclosed spaces are being investigated most extensively; hence the natural convection heat transfer in the annulus between two concentric and eccentric cylinders, and that in the annulus between two concentric and vertically eccentric spheres have received considerable attention from researchers in many diverse fields of applications. Such problems commonly occur within the geophysical fields, cooling of electronic equipment, aircraft cabin insulation, solar energy collectors, thermal storage systems as well as nuclear reactor design, and many other practical situations. As a result, extensive experimental and theoretical works deal with flow and associated heat transfer characteristics for laminar and turbulent thermal convection in annuli between two isothermal horizontal concentric and eccentric cylinders [1–8]. Experimental research on natural convection in annuli between two isothermal concentric spheres has been described in Refs. [9–11]. The flow patterns in the annuli between the concentric spheres were observed for various radius ratios, Prandtl numbers, and Rayleigh numbers. These were crescent eddies, kidney-shaped flows, and falling-vortices. Using the numerical analysis to investigate steady-state laminar free convection in annuli between two isothermal concentric spheres in Refs. [12–15] have been reported in the literature. The transient natural convective problems in the same geometric configuration dealing with uniform wall temperatures have been made in Refs. [16–20]. Further understanding of the different geometric configuration in a steady-state and transient convective heat transfer phenomena is essential to design and operation of various engineering application of thermal fluid systems, such as solar energy collectors and energy systems including nuclear reactors. This would be the reason for the fact that studies on natural convection between concentric and vertically eccentric spheres have increased recently [21–23]. Simultaneously, the author has also studied the effects of a height and radius ratio as well as buoyancy in the laminar free convection flow between sphere and vertically cylinder with concentric geometric structure and constant temperature boundary conditions. A numerical solution for geometric shape between concentric and vertically eccentric spheres of various radius ratio with a large range of Rayleigh number $Ra = 10^5 - 5 \times 10^6$ has been computed. However, most of the studies are concerned with the concentric or vertically eccentric spheres of the problems, thus knowledge about thermal convection with other combination of the different geometric shape [25–28] is limited in thermal science field.