Numerical Simulation of Convective Heat Flow in a Solar Water Heater

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Abstract

The research and development regarding the solar water heater systems in Sri Lanka is limited due to the technological reasons. Most of solar water heaters are assembled within the country by importing the parts from other countries such as China and India. The experimental data regarding the effectiveness of the solar water heater systems in Sri Lanka are also not available. Therefore, in this study, we focus on simulation of heat and fluid flow in a solar water heater and estimate sensitive parameters. Here we consider passive direct solar water heater system with an evacuated-tube (water-in-glass) solar collector.

The thermal-fluid analysis of the system consists in solving the combined equations of incompressible Navier-Stokes equations with Boussinesq approximation. Here heat and fluid flow is assumed to be unsteady, two-dimensional and laminar. For discretization of the governing equations, the finite volume method is used. As a numerical tool, OpenFOAM CFD software and the merged PISO-SIMPLE(PIMPLE) algorithm is used.

As a starting point we investigate the heat transfer process of water in a circular tube with a hemispherical cup at the bottom of the tube since it is the one of the key component of the solar water heater. Numerical results shows that natural heat convection is quite efficient in heat absorption in solar water heaters installed with appropriate system parameter values.

The sensitivity of the system parameters on heat transfer process is studied by considering one evacuated-tube. The numerical results suggests a moderated level inclination angle ($\theta = \pi/4$) to improve the performance of a solar water heater. Also it is found that the use of longer tubes with higher length to diameter ratio improve the performance of a solar water heater. However it is required to concern about the practical situations before implementing these settings. This research also studies the sensitivity of boundary and initial data on heat transfer process of an evacuated-tube. Thus, it is found that when

the solar radiation is high the performance of the solar water heater is improved. The numerical results suggests that the cold water inlet temperature is not directly effect to the buoyancy of the induced flow; however it causes high temperature gain.

The heat flow of a solar water heater with an evacuated-tube solar collector is investigated by numerical simulation. The total velocity profile and the temperature profile are studied. The results confirm a superior thermal performance within the system where a large amount of water particles are around 55°C. Since there exist a significant stagnant area within the storage tank, the expected time to equilibrium may be high.