Abstract

Solar air heaters (SAHs) are widely used for heating of building and drying of agricultural products. SAHs are mainly based on force convection or natural convection. For a force convection based SAH, a blower is required to blow the air through the air heater channel. In the natural convection based SAHs, flow of air inside the air heater channel occurs due to buoyancy force and no blower is required. In many applications, free convection based solar air heaters are preferred as there is no requirement of blower and easy maintenance. Furthermore, it is easy to fabricate, noise-free, durable and require low maintenance cost. Despite extensive studies on natural convection based solar air heaters, several issues have not been properly addressed such as flow transition in inclined channel, effect of atmospheric wind, detailed flow and heat transfer analysis with different fin configurations and porous medium at the outlet.

The following four problems have been investigated in the present study: (i) the effect of atmospheric wind on the performance of natural convection based solar air heaters, (ii) the effect of fins on the bottom side of the absorber plate and the identification of an optimum arrangement of fins for higher heat transfer with less material (iii) the effect of flow resistance at the exit of the channel on the natural convection heat transfer inside the solar air heaters, (iv) laminar, transition and turbulent regimes in a natural convection based solar air heater. In the present work, numerical and experimental investigations have been performed for the natural convection based solar air heaters. Numerical simulations have been carried out by using the Reynolds-Averaged Navier-Stokes (RANS) and Large Eddy Simulations (LES) models. To perform the experiments, an experimental set-up has been fabricated.

A detailed numerical investigation has been carried out in this work to understand the effect of atmospheric wind on heat transfer in natural convection based solar air heaters. A 3D inclined rectangular channel has been considered for the numerical simulations. The top wall of the channel is maintained at constant heat flux condition, and the other walls of the channel are assumed to be adiabatic in all the simulations. For heat transfer calculations, combined convection and surface radiation is considered in the present study. All the inner surface of the walls of the channel are assumed to be black and the emissivity, ε of the plates are taken to be 0.95. The numerical simulations are carried out by varying the values of heat flux, q'' = 250 W/m^2, 500 W/m^2 and 750 W/m^2**,** velocity of the atmospheric wind, V_{wind} = 0.0, 0.2, 0.6, and 1.0 m/s, and the inclination angle of the channel, θ =15°, 30°, 45°, and 60°. In the parametric study, various directions of free stream flow are also considered such as cross flow over the channel, along the main flow direction of the channel and the diagonal to the channel. It is shown that the mass flow rate starts to drop beyond an angle of inclination of 45 degrees in the presence of atmospheric wind, which is not the case for still conditions with no wind.

To obtain an optimum fin arrangement in a natural convection based solar air heater with a rectangular fin array attached to the bottom side of the absorber for better heat transfer and higher mass flow rate of heated air, a numerical study have been performed and the results have been presented for various fin sizes and spacing between the fins. An inclined rectangular channel similar to the dimensions of a typical solar air heater has been considered for this study. Three different fin configurations viz. continuous long fins for the whole length of the channel, inline interrupted and staggered interrupted arrangements of fins have been studied. The present analysis aims to identify the optimum configuration of the fin array for enhanced heat transfer. The spacing between the fins and the height of the fins are varied to obtain an optimum configuration. The numerical simulations are performed for the heat flux, q'' of 250 W/m^2, 500 W/m^2 and 750 W/m^2 on the absorber plate. The inclination angles of the channel, θ

considered in the parametric study are 15°, 30°, and 45° with respect to the horizontal plane. The results show that with the spacing between fins, S = 5.4 cm performs better in the case of longitudinal continuous fin arrangement. On the other hand, a fin spacing of 4.75 cm shows higher heat transfer in the case of staggered fin configuration. Compared to nine long uninterrupted fins, using the staggered arrangement with 15×10 fins saves up to 33% of fin material for same heat transfer.

The effect of flow resistance due to the presence of porous medium representing agricultural products at the exit of free convection based solar air heater has been studied experimentally and numerically. An air heater has been developed as an inclined channel and integrated with a drying chamber to conduct the experiments. Constant heat flux condition is provided by electrical heating on the top absorber plate of the channel. Experiments have been conducted for heat flux ranging from 250 to 750 W/m^2 for the channel inclination angle of 30^o. The height of porous material bed has also been varied in the drying chamber while the porosity is set at 0.36. In the numerical study, the surface-to-surface radiation model has also been considered for the modelling of heat transfer within the channel. For all the heat flux values considered in the experiments, numerical simulations have been performed for the inclination angles of 15°, 30° and 45°. In this analysis, the temperature distribution in the channel wall, the flow pattern, the difference in the mass flow rate and temperature of the outlet air have been investigated with different heights of the porous medium. For the porous medium thicknesses of 63 mm and 126 mm in the chamber, the mass flow rate is reduced by approximately 20% and 30%, respectively for all the heat flux values considered in this study.

The natural convection flow transition from laminar to turbulent inside a parallel plate channel has been studied numerically at the angles of inclinations of 15°, 30° and 60° with respect to horizontal plane. A numerical study has been carried out using the large eddy simulations (LES) to understand the flow transition from laminar to turbulent. To carry out the

numerical investigations, a three dimensional rectangular channel is considered. The top plate of the channel is exposed to the constant heat flux condition of 250 W/m^2 and the bottom wall is assumed to be adiabatic. Periodic boundary conditions are applied to the sides of the channel. In this study, the main focus is on the effect of the angle of inclination on the flow transition from laminar to turbulent and the development of thermal boundary layer in the channel at different angles of inclination. The results indicate that due to the rapid growth of both the velocity and thermal boundary layers, the early transition occurs at the lower angle of inclination of the channel with respect to horizontal plane. The temperature distributions obtained at various cross sections show that strong mixing occurs at the lower angle of inclination relatively at the early stage of the flow.