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Numerical Modeling of Hot Air Multi-pass Solar Dryer

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Abstract

This article presents the investigation of modeling solar drying system using partial differential equation module of MATLAB to predict the thermal conditions of a drying system with pebble beds as heat storage medium. A 2-dimensional geometry of the air heater was examined using both Dirichlet and Neumann boundary conditions to define the heat transfer and temperature gradient at the walls of the system. Appropriate thermal equations were used to define the multi-layer drying system with specific properties of materials which have significant effect on the performance efficiency of the solar collector. Finite element method of meshing the system component was employed to solve the heat transfer equation. The dynamic simulation of the air heater was tested for 5000 s at the average maximum daily temperature of 318 K with solar irradiation of 800 Wm^{-2}. Despite five cabinet channels design, the temperature gradient of hot air distribution at various points was less than 1 K. The heat transfer simulation of the system has been achieved in good agreement with the reported studies. However, the mass transfer aspect of the model still needs to be improved upon for better and accurate collector characterization.

Key-words: Heat transfer; Hot air distribution; Multi-pass; Numerical; Solar collector

1. Introduction

Energy is a critical function of human survival on earth. The concomitant effects of using organic fuel pose serious challenges to sustainability. Hence, renewable energy remains the viable source of energy for all. No doubt that the United Nations and various governments are increasing their annual energy plan contribution, especially on the research and development of renewable energy sector. Hence, the researchers in the solar energy are now on their toes to achieve the vision 2030 of UN on renewable energy for all.

Heat transfer is defined by Kaviany (2011) as the transport of thermal energy due to spatial variation in temperature within the medium or with other surrounding media while Bejan (1993) said that mass transfer takes place in an environment with non-equilibrium in concentration of chemical species. It was stressed further that drying process remains the classical example of mass transfer. The thermal and mass transfers are two principal activities that form the solar drying process whereas solar thermal air heater was viewed as combination of heating, cooling and humidification processes that are evaluated by conservation laws (Akpinar et al. 2005, Midilli and Kaushik 2003, Panwar et al. 2012 and Prommas et al. 2010).

Crop drying is a means of reducing the moisture content of edible agricultural product such as grain and vegetable with the sole motive of extending its shelf span without compromising the quality. It is an economical technique used to preserve farm products in which moving hot air of temperature between 40°C and 60°C remove moisture from crops and medicinal herbs (Janjai et al. 2008, Midilli and Kaushik 2003 and Panwar et al. 2012). However, a range of temperature between 60°C and 80°C with air velocity of 1.0 ms^{-1}-1.5 ms^{-1} and relative humidity of 0.1-0.2 was reported as favourable condition for drying (Akpinar et al. 2005).

Solar air dryer is a simple and easily made system that harvests the energy from solar irradiance by a flat or

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