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Drying of agricultural crops by solar energy

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Abstract

The main application for solar energy in southern Mediterranean countries in agriculture is the drying of agricultural crops. The optimisation of dryers necessitates complete knowledge of the whole drying process, thus leading to energy savings and avoiding environmental pollution by using renewable sources of energy. We present a study concerning thermal behaviour of a solar air heater as a source of energy for drying agricultural products. In order to simulate the functioning of our solar collector, we chose a simple model based on the evaluation of different heat transfer coefficients in the collector and within the external environment, which allows determining the overall collector heat loss coefficient. Our purpose was to calculate the fluid outlet temperature, the output energy used and thermal efficiency as a function of ambient temperature, incident solar radiation, wind speed and air mass flow rate. The present suggested model's results demonstrated that the air heater has paid off since we can attain the temperature on the order of 80°C at the fluid outlet and 60% in thermal performance.

Keywords: Solar energy; Climatic factors; Flat-plate collector; Heat loss coefficient; Thermal efficiency; Drying agricultural crops

1. Introduction

In this study we present an analysis of a drying convective pilot using solar energy. This solar dryer is essentially composed of three parts: a solar plan collector, a drying box and a chimney. We are interested in analysing the different components of this dryer and its energy balance. The solar dryer is designed to meet certain demands: essentially agricultural use such as for harvesting, a modest dried production and simple maintenance.

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In this paper we present a detailed, but simple, study concerning the thermal behaviour of a solar air heater as a source of energy for drying agricultural products. This analysis is based on experimental measurements carried out at the Solar Applications Laboratory in the National Institute of Scientific and Technology Research (Tunisia).

2. Choice and conception of the dryer

In our conception of the solar collector, its length is chosen so that we get a maximal output temperature of air. If we study the distribution of the temperature on its length, we get an evolution that converges toward a constant maximal value. The particular shape of the absorber is not arbitrary: we tried to maximise the surface of exchange in order to increase the thermal exchanges by convection. In the case of a flat absorber, we would have a surface of 2.5 m^2; for our case the surface reached 8.6 m^2. We can also benefit from the shape of the collector which seems to be an important mass flow since the other shapes (too groove and wavy) benefit the half of the maximal mass flow seen only that the section of air passage will be reduced. The insulator is a layer of glass wool characterised by its weak conductivity (λ= 0.045 $Wm^{-1}.K^{-1}$). The inner part is covered with a silvered surface that has an important role in thermal loss reduction towards the rear while reflecting the part of the radiance transmitted by the absorber. The cavity of stagnant air between cover and absorber serves as a trap of the radiance transmitted through the cover. It is the role of a greenhouse that stores the heat and stocks it until saturation of the thermal inertia of the stagnant air to nourish the absorber and that also nourishes the fluid in heat [1–3].

3. Heat balance equations

3.1. Hypotheses

- The regime is permanent.
- The lateral losses to the level of the collector are negligible.
- The soil temperature is equal to the ambient temperature: $T_{soil} = T_a$.
- We disregard the conduction through the cover and through the absorber.
- The temperature on a horizontal slice of the absorber is constant.

3.2. The overall collector heat loss transfer coefficient

We attempted to evaluate the energy balance of the collector. At first, we defined the overall collector heat loss coefficient (*Ut*) that leads us first to calculate the thermal losses and then to evaluate the well stocked useful energy [2,3].

We define the following fluxes with regard to an element of surface of the collector:

- exchanged flux between the transparent cover and the ambient middle:

$$\varphi_1 \, dS\left(hc_{v-a} + hr_{v-a}\right)\left(T_v - T_a\right) \quad (1)$$

- exchanged flux between the transparent cover and the absorber:

$$\varphi_2 = dS\left(hc_{p-v} + hr_{p-v}\right)\left(T_p - T_v\right) \quad (2)$$

- exchanged flux between the absorber and the intern face of the insulator:

$$\varphi_3 = dS\left(hc_{p-is1} + hr_{p-is1}\right)\left(T_p - T_{is1}\right) \quad (3)$$

- exchanged flux through the insulator by conduction:

$$\varphi_4 = dSh_{cd}\left(T_{is1} - T_{is2}\right) \quad (4)$$

- exchanged flux between the insulator and the ambient middle:

$$\varphi_5 = dS\left(hc_{is2} + hr_{is2-a}\right)\left(T_{is2} - T_a\right) \quad (5)$$