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Performance evaluation of a novel multi-pass solar air heating collector

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Abstract

In this present investigation, the performance of a new solar air heating collector of multi-pass mode is presented. The solar air heating system is theoretically modelled by applying energy balance expressions to reflect the network of convection and radiation heat flows. The theoretical analysis of the active air heater is supported by SIMSCAPE^{TM} numerical tool while the proposed multi-pass solar collector system was tested under the meteorological condition of Seri Iskandar, Malaysia (4.385693° N and 100.979203° E). These techniques were used to audit the solar energy balance of the solar dryer system. The performance indices of the drying system were evaluated and the system thermodynamic correlations were obtained. Daily maximum temperature gradient between ambient and the system collector was 30.42°C. The thermal collector efficiency and optical efficiency were 59.96% and 72.26%, respectively. Improvement on system thermal delivery by the sensible porous matrix of 9.37% was achieved. The predicted performance level was compared with the test result and a relatively fair agreement was obtained. However, the instantaneous thermodynamic properties of air at the system boundary need to be defined to accomplish better accuracy on the relevant correlations.

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Keywords: SIMSCAPE; Dryer; Collector; Efficiency; Multi-pass

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1. Introduction

Strategic transformation in securing the environment from further degradation by fossil fuel has been spelt out in the sustainable development goals (SDG) adopted by the United Nations in 2015. Therefore, the performance and reliability of renewable energy, especially solar energy are on test to meet the global energy demand. Open sun drying is still a common practice among farmers in developing countries. This has reflected in reduced quality and quantity of dried product, which is unable to meet international market standard. In addition, this traditional drying approach is characterised by low drying rate, high labour involvement, rain and rodent attack.

Nomenclature

M	Moisture (g)
n, k	Drying parameters
T	Temperature (°C)
t	Time (s)
RH	Relative humidity (%)
C	Specific thermal capacity $(J(kg.^{o}C)^{-1})$
$\dot{m}$	Air mass flow rate (kgs^{-1})
x	Length (m)
I	Solar energy flux (Wm^{-2})
U	Thermal energy $(W(m^{2}.^{o}C)^{-1})$
F'	Collector performance factor
A	Area (m^{2})
h	Heat transfer coefficient $(W(m^{2}.^{o}C)^{-1})$

Greek Symbols

α	Absorptivity
τ	Transmissivity

Subscripts

R	Ratio
eq	Equivalent
f	Fluid
p	Collector plate
r	Radiation
c	Convection
amb	Ambient
dk	Drying deck
g	Glass
ch	Drying chamber

Drying technology involves a means of generating hot air to dehydrate a substance that contains a certain percentage of moisture in its composition. Therefore, a mass transfer of water molecule occurred in the process of drying operation. Different successful approaches have been used to produce hot air such as electrical filament, burning of fossil fuel, chemical adsorption and desorption. Although, many of these are not sustainable in nature, while some are adversely affecting the environment. Therefore, a relatively free and eco-friendly option of modernised (indirect) solar drying is a way out of these deficiencies.

Significant achievement has been made on the performance of single pass and double pass collectors. Recently, Fudholi et al. [1] designed a forced convective double pass solar air heater with six pieces of solar collector plates made of aluminium and a transparent cover. They optimised their solar air heater to achieve collector, pickup and