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Faculty of Engineering
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CONTENTS

INVITED SPEAKERS

ISSN : 2355-5157

DESIGN OPTIMIZATION OF FLAT-PLATE SOLAR COLLECTOR USING SOLAR ENERGY FOR AGRICULTURE PRODUCTS IN LIBYA

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ABSTRACT

Due to environmental issues and the limited resources of fossil fuels, it has been taken more and more attention to renewable energy sources. Drying fruits and vegetables is one of those indispensable processes that require natural resources in the form of fuels. Solar dryer is fast becoming a preferred method of drying products considering the potential of saving significant amounts of conventional fuel. By raising the temperature while allowing air to pass through and get rid of the moisture. The study will involves a theoretical study to investigate the effect of air flow rate, air temperature and thermal resistance at surface by study the characteristics inside the flat plate solar collector of dryer system. The results of this thesis later on can be used to determine the best performance of the system then will find the optimization solar drying system, hence research has a great economic potential for Libya as well as for the other developing countries in neighborly

Keywords *: Single and double flow solar air heater; thermal performance; pressure drop; flow channel depth.*

1. INTRODUCTION

Due to environmental issues and the limited resources of fossil fuels, it has been taken more and more attention to renewable energy sources. Solar energy is the most considerable energy source in the world. Sun, which is 1.495×10^{11} (m) far from the earth and has a diameter of 1.39×10^{9} (m), would emit approximately 1353 (W/m2) on to a surface perpendicular to rays, if there was no atmospheric layer. The world receives 170 trillion (KW) solar energy and 30% of this energy is reflected back to the space, 47% is transformed to low temperature heat energy, 23% is used for evaporation/rainfall cycle in the Biosphere and less than 0.5% is used in the kinetic energy of the wind, waves and photosynthesis of plants[1].

The technologies include solar water heat, solar thermal electricity and solar air heat. Solar air heating is a solar thermal technology in which the energy from the sun, can be useful for drying wood such as wood chips for combustion. Practical use of solar air heat can be found also on food products such as fruits, vegetables, cereals and fish. Crop drying by solar energy is considered as environmentally friendly. Solar air heat is useful in the process of drying products by raising the temperature while allowing air to pass through and get rid of the moisture. Can make significant contributions to solving some of the most pressing problems facing the world's energy now. At the same time, there are many kinds of energy systems. One of them is a flat plate solar air collectors. Flat plate solar air collector is one of the solar thermal energy systems[2].

The principle function of a solar thermal system is to convert incident solar radiation into thermal energy that can be used for a specific application . These flat-plate collectors may be thought of as a special type of heat exchanger that converts solar radiation into thermal energy[2].

ISSN : 2355-5157

1.1 Flat plate solar air collectors.

The typical flat plate solar air collector as seen in Fig.1 Is consist of dark flat-plate absorber, transparent cover that reduces heat losses, heat-transport fluid to remove heat from the absorber, and heat insulating backing. When solar radiation passes through the transparent cover and collide with the surface of the blackened absorption of high absorbance, and are absorbed a large portion of this energy through the panel, and then transferred to air ducts or tubes of liquids to be carried away for different applications. The underside of the plate to absorb the side of the casing and well insulated to reduce losses conductivity[3].

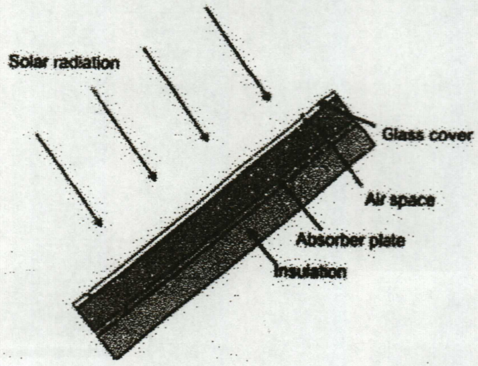

Figure 1. Components of flat plate solar air collector

2. THEORETICAL MODELING

In the usual the optimization of a product process can be done by collecting data of process parameters from exist cases and operate. Subsequently analyze these data in order to find the optimum design value of the parameters. But in this study, the solar flat plate collector is only the prototype. Thus, we cannot vary the parameters of the system. Therefore, we do not have the performance data for various values of the system parameters for the optimization procedure.
To simplify this problem, we need to use the simulation method to obtain the data with various values of system parameter. How come this?, we should start with formulation mathematical model of the system. To ensure the accuracy of the model, we will compare the performance of the system obtained from the simulation with that similar studies with literature. Once the model has been validated, we will use the model to generate the data on the performance of the system with different values of system parameters. Finally, we will use these generated data for our optimization process. The schematic diagram of these steps is shown in Figure 2.

ISSN : 2355-5157

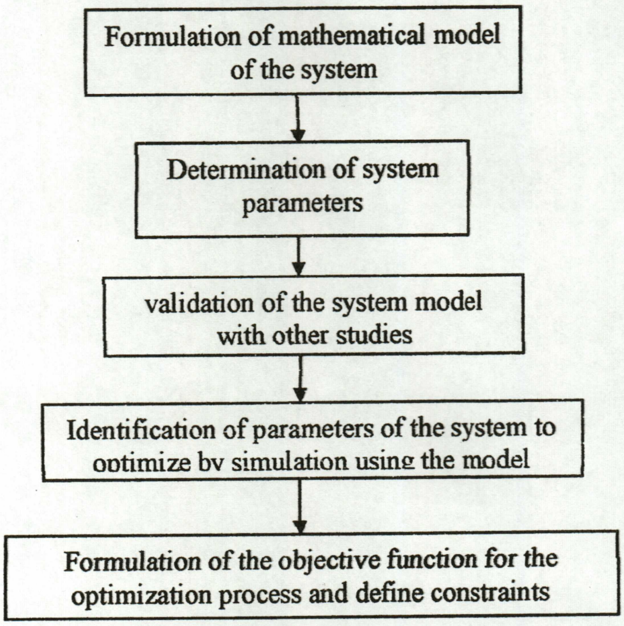

Figure 2. Schematic diagram showing the method used in this work

2.1 **Theory Of Air Based Solar Flat Plate Collector**

The computer simulation model of the solar air collector, which predicts the temperatures at different positions of the collector.

2.1.1 **Formulation of the model for collector**

Flat plate collector will be design for applications requiring moderate temperature not exceeding 100°C. It is relatively cheap and can be easily constructed. It uses both beam and diffuses solar radiation and is well suited for the drying of agricultural crops. In the solar dryer system, the airflow is driven by a fan operated by electricity and air flows in a parallel plate passage below the absorber plate. The heated air is sucked at the end of the collector.

Considering the duct of elemental length, *dx* at a distance *x* from the inlet, (Figure 3), Let the air mass flow rate through the duct be $\dot{m}$, The bulk mean temperature of the air changes from T_f to $(T_f + dT_f)$ as it flows through the distance *dx*, The mean temperatures of the absorber plate and the plate below are T_{pm} and T_{bm}

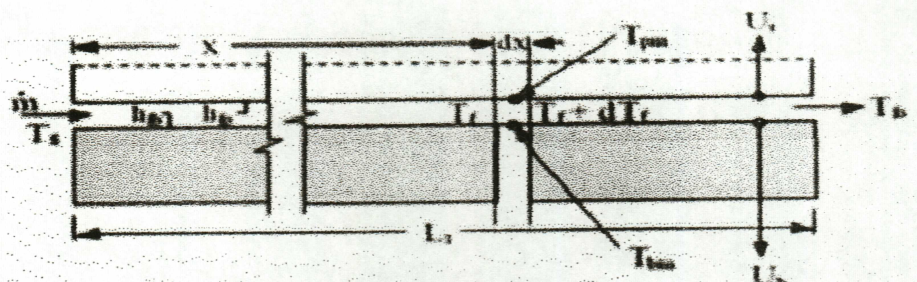

Figure 3. A typical solar air collector

ISSN : 2355-5157

Energy balances for the absorber plate, the plate below it and the air flowing in between [4].

$$SA = U_t A(T_{pm} - T_a) + h_1 A(T_{pm} - T_f) + \frac{\sigma A}{\frac{1}{\varepsilon_p} + \frac{1}{\varepsilon_b} - 1}(T_{pm}^4 - T_{bm}^4) \quad (1)$$

S = Flux absorbed in the absorber plate I (τα)
A = W.dx
U_t = *Top loss coefficient based on the temperature difference* $(T_{pm} - T_a)$

$U_b = Bottom\ loss\ coefficint\ based\ on\ the\ temperature\ difference(T_{bm} - T_a)$

$h_1 = Convective\ heat\ transfer\ coefficint\ between\ the\ absorber\ plate\ and\ the\ air\ stream$

$h_2 = Convective\ heat\ transfer\ coefficint\ between\ the\ bottom\ plate\ and\ the\ air\ stream$

$\varepsilon_p = Emissivity\ of\ the\ absorber\ plate\ surface$

$\varepsilon_b = Emissivity\ of\ the\ bottom\ plate\ surface$

$dt = T_{pm} - T_{bm}$ *is small*

$$T_{pm}^4 - T_{bm}^4 = 4T_{av}^3(T_{pm} - T_{bm})$$

Where

$$T_{av} = \frac{T_{pm} + T_{bm}}{2}$$

Thus

$$h_r \cong \frac{4\sigma T_{av}^3}{\frac{1}{\varepsilon_p} - \frac{1}{\varepsilon_b} - 1}$$

Simplification: it is assumed that the bottom loss coefficient U_b is much smaller in magnitude than the top loss coefficient U_t

$$S = U_L(T_{pm} - T_a) + h_1(T_{pm} - T_f) + h_r(T_{pm} - T_{bm}) \quad (2)$$

$$h_r(T_{pm} - T_{bm}) = h_2(T_{bm} - T_f) \quad (3)$$

$$\frac{mC_p}{W}\frac{dT_f}{dx} = h_1(T_{pm} - T_f) + h_2(T_{bm} - T_f) \quad (4)$$

From Eq. (3),

$$T_{bm} = \frac{h_r T_{pm} + h_2 T_f}{h_r + h_2}$$

Substituting the expression for T_{bm} into Eq. (2)

ISSN : 2355-5157

$$T_{pm} = \frac{S + U_L T_a + h_e T_f}{U_L + h_e}$$

Where

$$h_e = [h_1 + \frac{h_r h_2}{h_r + h_2}]$$

h_e is effective heat transfer coefficient between the absorber plate and air stream.

It follows,

$$(T_{pm} - T_a) = \frac{S + h_e(T_f - T_a)}{U_L + h_e}$$

From Eqs. (2) to (4), it follows,

$$\frac{mC_p}{W}\frac{dT_f}{dx} = S - U_L(T_{pm} - T_a)$$

Using $(T_{pm} - T_a) = \frac{S + h_e(T_f - T_a)}{U_L + h_e}$ *in the above Equation,*

$$\frac{mC_p}{W}\frac{dT_f}{dx} = \frac{1}{\left(1 + \frac{U_L}{h_e}\right)}\{S - U_L(T_f - T_a)\}$$

In an analogous manner to the fluid flat-plate collector, a collector efficiency factor F` given by,

$$F` = \left(1 + \frac{U_L}{h_e}\right)^{-1}$$

$$Q_u = A_c[S - U_L(T_{pm} - T_a)]$$

$$Q_u = A_c F`[S - U_L(T_{pm} - T_a)]$$

Equation for the fluid becomes,

$$\frac{mC_p}{W}\frac{dT_f}{dx} = F`\{S - U_L(T_f - T_a)\}$$

The fluid temperature distribution is obtained as,

$$\frac{\left(\frac{S}{U_L} + T_a\right) - T_f}{\left(\frac{S}{U_L} + T_a\right) - T_{fi}} = exp\left[-\frac{WF`U_L x}{mC_p}\right]$$

ISSN : 2355-5157

Use, at $x = 0$, $\quad T_{fi} = T_f$

$$Q_u = F_R A_c\left[S - U_L\left(T_{fi} - T_a\right)\right]$$

$$F_R = Heat\ removal\ factor$$

$$F_R = \frac{mC_p}{A_c U_L F^{`}}\left[1 - exp\left\{-\frac{F^{`}U_L A_c}{mC_p}\right\}\right]$$

$$A_c = Area = W.L$$

$$F" = \frac{F_R}{F^{`}} = \frac{mC_p}{A_c U_L F^{`}}\left[1 - exp\left\{-\frac{F^{`}U_L A_c}{mC_p}\right\}\right]$$

$$\frac{mC_p}{A_c U_L F^{`}} = non - dimensional\ flow\ rate$$

3. DISCUSSION

The collector model expressed in equations above is a system of differential equation which we cannot solve using analytical method. To solve these equations, we proposed to use the implicit finite difference method. Numerical values of different parameters such as outlet temperature, efficiency and the pressure drop will be compute corresponding to temperature of climate Libyan, and different values of mass flow rate.

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