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

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ABSTRACT

The study of the heat transfer of solar collector with a new design is using double pass and absorber plate with fins. The mathematical formulation and analytical analysis for such a double-pass solar collector were developed theoretically. The performance of the device was studied experimentally as well. The theoretical predicted and experimental results were compared with another design, i.e., a down ward-type single-pass solar collector and double-pass operations reported in our previous work.

Significant improvement in heat-transfer efficiency is achieved with the fins design and the extended heat transfer area. The effects of mass flow rate and the heat-transfer efficiency enhancement as well as on the power consumption increment are also discussed. The efficiency of the collector is strongly dependent on the flow rate and number of fins, its increases with flow rate.

This experiment study shows that, the solar collector with finned absorber has efficiency 51.515% at a wind velocity is 0.5 m/s with number of fins is 6 pieces. The solar collector with finned absorber has outlet temperature until 145.170 °C at a mass flow rate of over 0.05 kg/s and wind velocity is 0.5 m/s. This experiment study shows that the finned absorbers more than efficiency of conventional style solar air collector and flat plate absorber without fins. This study shown that finned absorber is 10 % more efficient than conventional style solar air collector.

Based on CFD calculations with temperature fluid flow out of the bottom line seems to be higher (yellow to red) compared to the inflow parallel on it (green color). In the outlet channel is higher temperature (93°C) than the inlet channel temperature (26°C), so the addition of proven solar collector with fins can increase the temperature of the heat required for drying fruits, especially tomatoes in Libya.

Keywords: heat-transfer efficiency; double-pass; solar collector; fins, CFD.

INTRODUCTION

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 (Adam D. W, 2013).

Libya has the potential to become a renewable energy giant according to

Responding to Climate Change. It boasts a very high daily solar radiation rate - on a flat coastal plain it is about 7,100 watt hours per square metre per day (Wh/m²/day) and in the south region it is about 8,100 Wh/m²/day. Compare the UK to Libya, Great Britain has less than half that amount at about 2,950 Wh/m²/day.

The use of renewable energies has been introduced in wide applications due to its Convenience and being economically effective in many applications. The renewable energy sources used in Libya consists of photovoltaic conversion of solar energy, solar thermal applications, wind energy, and biomass. In addition, the abundance of solar energy in Libya it suitable for converting solar energy into thermal energy for drying agricultural products.

1.1 Problem Statement

The solar collector is one of the vital components of the solar drying system. Conventional solar air collectors mainly consist of an absorber plate with a parallel plate forming a passage of air flow. The heat transfer for this type of solar collector is low which results in lower thermal efficiency. Hence, different modifications are suggested and applied to improve the heat transfer coefficient between the absorber plate and the air. These modifications include the used an extended heat transfer area, such as finned absorber.

1.2 Main Problem to be solved

A solar dryer system suitable for agricultural products have been designed, constructed and evaluated under the Libya climate conditions. The main components of the system are double-pass solar collector with finned absorber, the blower, auxiliary heater and the drying chamber. One of the most important components of a solar energy system is the solar collector. The performances of pass solar collector with fins absorbers will be analyze.

Drying fruits and vegetables such as grapes, etc 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 fruits, food grains considering the potential of saving significant amounts of conventional fuel. However, solar energy collectors are special kind of heat exchangers that transform solar radiation energy to internal energy of the transport medium. The major component of any solar system is the solar collector. Of all the solar thermal collectors, the flat platee collectors though produce lower temperatures.

The efficiency of solar air collector has been found to be low because of low convective heat transfer coefficient between absorber plate and the flowing air which increases the absorber plat temperature, leading to higher heat losses to the environment. In addition, one of the major requirements in using solar energy for drying application is the development of a suitable drying system, which should be fast and energy efficient, hence the simulation is an important tool for design and operation control. For the designer of a drying system, simulation makes it possible to find the optimum design and operating parameters. For the designer of the control system, simulation provides a means to device control strategies and to analyze the effects of disturbances (Soteris A.K, 2004). Since the problem of dried products is aggravated by the lack of viable drying technology, a systematic research on solar drying of products will contribute to the knowledge on the production of quality dried products for local consumption. This study will also generate much scientific information for researchers, processors and users.

1.3 Objectives of Study

Research on solar collectors was conducted to determine:

1. To find the optimum parameter for the solar flat-plate collector,suitable absorber and it characteristic for solar flat-plate collector for real solar irradiation of Libya. 2. The overall aim of this work is to understand the flow and temperature distribution of air through solar flat plate collector. 3. Design a model of fins absorbers of collector and calculate its efficiency. 4. Study the effect of mass flow rate, number and height of fins on efficiency by using CFD.

RESEARCH METHOD

3.1 The Formulas in the Double Pass Solar Collector

Fig. 4.10 shows the various heat transfer coefficients of a finned double-pass solar collector with lower fin. Fig. 4.11 shows energy balance for each element of the fin with a height (dz).

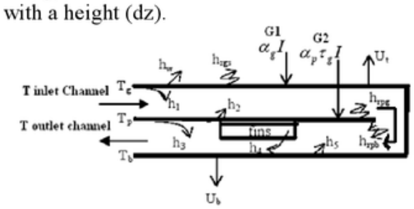


Fig.3.1 Schematic of heat transfer coefficients in double pass solar collector with lower fin

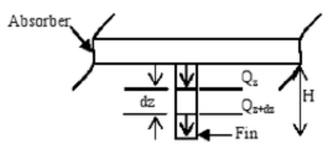
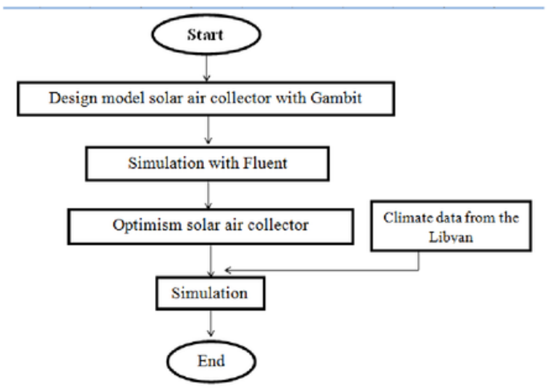


Fig. 3.2 schematic of energy balance for each element of the fin

3.1. MetodePenelitian



3.3 The Simulation Model of a Flat – Plate Solar Collector System

3.2.1 Numerical model

To conduct numerical simulation, the computational domain is meshed with control volumes built around each grid using Gambit software (version 2.4.6), which is the preprocessor for Fluent software (version 6.3.26). Numerical simulation was carried out using steady state implicit pressure based solver which is an in-built in the commercially available software FLUENT (version 6.3.26). The governing partial differential equations, for mass and momentum are solved for the steady incompressible flow. The velocity-pressure coupling has been effected through SIMPLE algorithm (Semi Implicit Method for Pressure- Linked Equations). First order upwind schemes were chosen for the solution schemes.

To be able to perform the simulation, first made of geometric shapes solar collector using Gambit software. After the creation process is complete geometric shape, the shape of the created mesh to be readable by Fluent's software. To prove the results of manual calculations, then performed simulations using CFD software. By entering all the data of solar collector system, then the iteration to obtain convergent value. After the iteration, it will get the final results of simulation in the form of energy movement in the solar collector.

3.2.2 Numerical scheme

Conservation equations were solved for the control volume to yield the velocity and temperature fields for the water flow in the absorber tube and the temperature fields for the absorber plate. Convergence was effected when all the residuals fell below 1.0e-6 in the computational domain. Computational domain was modeled using the preprocessor routine called Gambit and meshing was also done using appropriate grid cells of suitable size available in the routine.

The grid independence test was performed to check validity of the quality of mesh on the solution. The influence of further refinement did not change the result by more than 0.75% which is taken here as the appropriate mesh quality for computation.

DESIGN AND CALCULATION

Libya is an oil exporting country located in the middle of North Africa with Site Latitude is 30^0 - 32^0, with 6 million inhabitants distributed over an area of 1,750,000 Km^2. The daily global solar radiation data obtained from three Libyan locations: Sabha- desert region, Ghdames- middle region and Tripoli- Mediterranean region were used to establish a relationship between daily diffuse fraction and daily clearness index KT. In general, the abundance of solar energy in Libya is evident from the annual daily average of global solar irradiance, which ranges between 5 and 7 kWh/m^2.day on horizontal surfaces

Table 4.3 Iteration Result

First Assumptions (°C)	Iteration Assumptions (°C)	Variabel °C	Final Iteration (°C)	Differ Iteration
55	97.589020	Tg	97.589024	0.000004
40	43.449249	T_{f1}	43.449250	0.000001
100	130.130956	Tp	130.130955	0.000001
60	71.802267	T_{f2}	71.802265	0.000001
65	74.272485	Tb	74.272514	0.000029

4.1 Result and Discussion

The variation of the measure of solar collector and efficiency is shows in figure below:

Table 4.2 Good Efficiency of Solar Collector

No	Part	Value of part	Efficiency Theory
1	Length Glass	1.2 m	51.515%
2	Width Glass	0.8 m	51.515%
3	Legth Absorber	1 m	
4	Width Absorber	0.8 m	51.515%
5	Leght of fin	1 m	51.515%
6	Fins Number	6	51.515%
7	Height of fin (lower channel)	0.2 m	51.515%
8	Height upper channel	0.18 m	51.515%
9	Mass flow rate	0.05 kg/s	51.515%
10	Velocity	0.5 m/s	51.515%
11	Radiation	7,100 W/m^2	51.515%

4.2 Computational Fluid Dynamics (CFD)

Resukt and Discussion CFD

To assess the thermal performance of the glazed solar collector with mprovements in design, a base model with plat flat absorber with fins at under channel is analyzed and the results are as shown in bewlow.

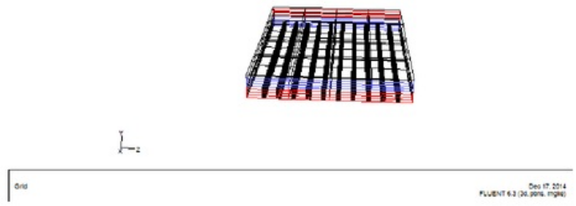


Fig. 4.18 3-D Model Transparent of Double pass flat plate Solar Collector with lower Fins

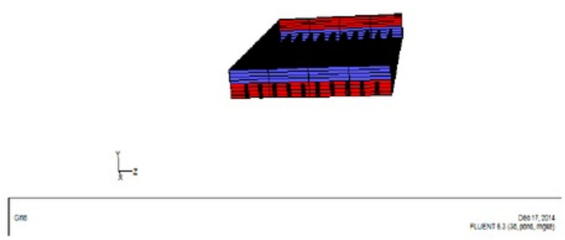


Fig. 4.19 3-D Model Transparent of Double pass flat plate Solar Collector with lower Fins

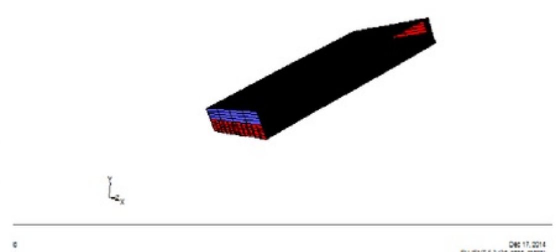


Fig. 4.20 3-D Model of Double pass flat plate Solar Collector with lower Fins

The numerical methods used to solve the equation set are iterative whereby the equations are repeatedly re-constructed and solved until there is no change in the dependent variables. The algebraic equations are constructed in such a way that if the coefficients were constant, a converged solution would be guaranteed using the Gauss-Siedel method (simplest numerical method for solving simultaneous equations).

7 Results in convergent iteration achieved to iteration 26. Achieved on the convergent value of continuity 2.0930e^{-04}, x-velocity 9.5029e^{-04}, y-velocity 5.6812e^{-04}, z-velocity 3.8347e^{-05}, energy 2.7595e^{-07}, k 6.9376e^{-04} and epsilon 7.4946e^{-04}. The iteration movement chart as shown below.

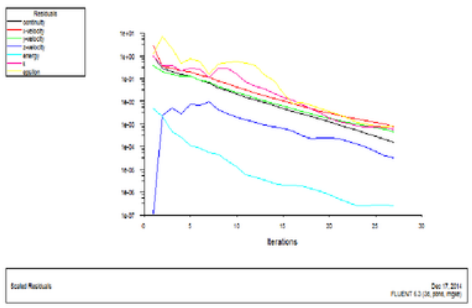


Fig. 4.21 Iteration movement chart

The temperature distributions of the absorber plate as obtained from the simulation for flow with lower fins are shown in Figure below.

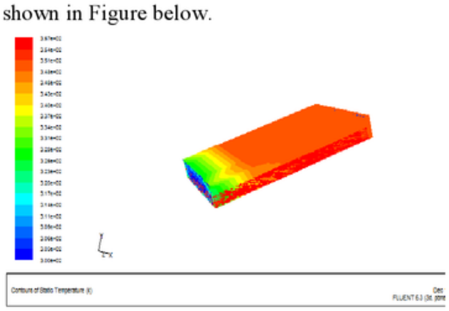


Fig. 4.22 Variation of Temperature Drop across Solar Collector

The results of the calculation of the temperature distribution of the solar collector side view as shown in the figure above. The magnitude of the temperature on the picture painted of the lowest prices in blue, then green, yellow and red the highest. On this side of the entrance channel looks fluid on the set at 26°C and the temperature of the fluid out on the parallel channel reaches below 83°C. Seen in the figure above, the temperature of the fluid flow out of the bottom line seems to be higher (yellow to red colour) compared to the inflow parallel on it (green colour). This indicates outlet channel is higher temperature (83°C) of the inlet channel temperature (26°C) proved to be Computational Fluid Dynamics.

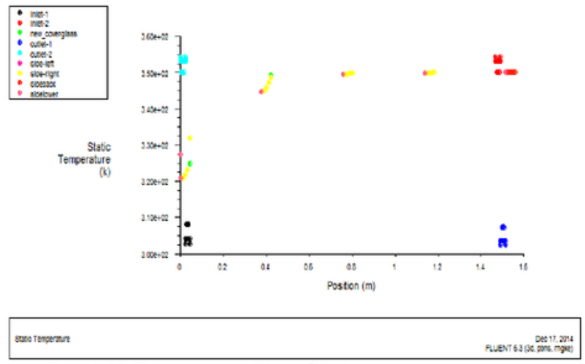


Fig. 4.23 Temperature Plot of Solar Collector

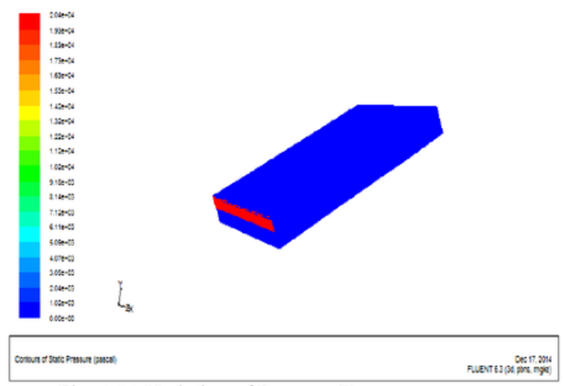


Fig. 4.24 Variation of Pressure Drop across Solar Collector

Great pressure on the pictures above were drawn from the lowest price in blue, then green, yellow and red the highest. Visible in the above image, fluid pressure in the inlet channel is the higher (red colour) compared with the outlet channel underneath (blue colour).

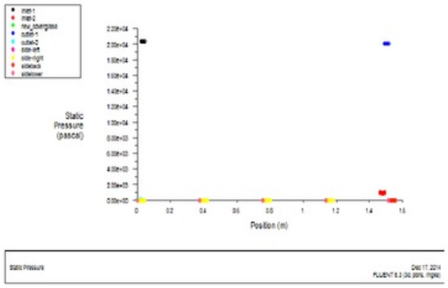


Fig. 4.25 Pressure Plot of Solar Collector

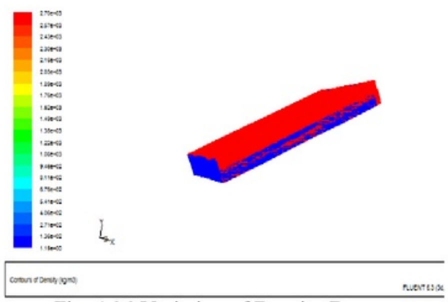


Fig. 4.26 Variation of Density Drop across Solar Collector

Great mass of the pictures above were drawn from the lowest price in blue, then green, yellow and red the highest. Visible in the above image, the inlet channel for fluid mass is the higher (red colour) compared with the outlet channel underneath (blue colour).

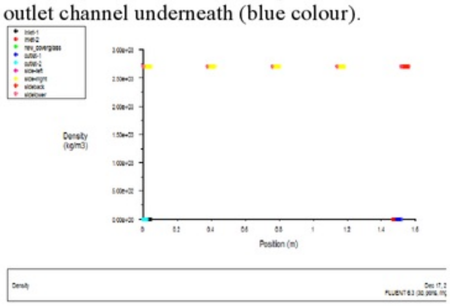


Fig. 4.27 Density Polt of Solar Collector

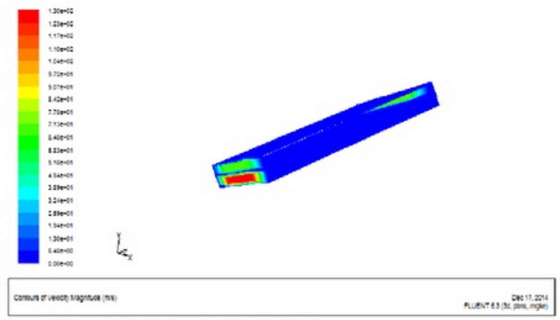


Fig. 4.28 Velocity Plot of Solar Collector

Great speed in the picture above is drawn from the lowest price in blue, then green, yellow and red the highest. Visible in the above image, the channels for that speed fluid in the lower (green colour) compared to the channel underneath (red colour) for the fluid out.

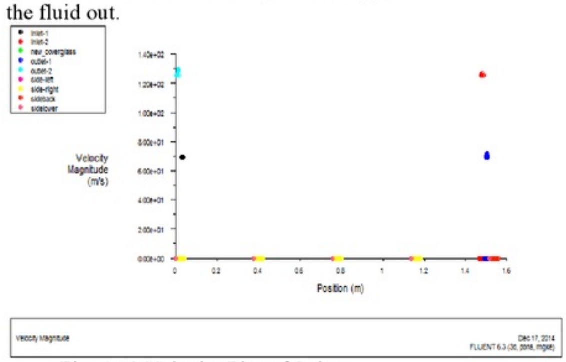


Fig. 4.29 Velocity Plot of Solar Collector

CONCLUSION

Prediction outlet temperature of a finned double-pass solar air collector was studied. It involves a theoretical and experimental study to investigate the effect of mass flow rate and solar radiation on outlet temperature. A steady state form solution to determine the outlet temperature was obtained for energy balance equations. It solves the simultaneous equations for temperature at each element of a finned double-pass solar air collector. A matrix inversion method was employed. For given sets of operating conditions the theoretical and experimental outlet temperatures of a finned double-pass solar air collector can be obtained.

Performance curves of double-pass solar air collector with finned absorber in lower channel have been obtained. These include the effects of mass flow rate and solar radiation on efficiency of the solar collector. The efficiency of the collector is strongly dependent on the flow rate and number of fins, its increases with flow rate. The solar collector with finned absorber has efficiency until 51.515% at a mass flow rate of over 0.05 kg/s and wind velocity is 0.5 m/s. The solar collector with finned absorber has outlet temperature until 145.17 oC at a mass flow rate of over 0.05 kg/s and wind velocity is 0.5 m/s.

Ekechukwu and Norton reviews have shown typical conventional style solar air collector to have efficiencies between 40% - 50%. Fudholi et al concluded that multi-pass solar air collectors with heat transfer surface enhancement to have efficiencies between 60 % - 70 %. Sopian et al. studied the effects of changes in upper and lower channel depth on the thermal efficiency with and without porous media of the double-pass solar air collector for various operation conditions. They concluded that typical thermal efficiency of the double-pass solar air collector with porous media is about 60 % -70 %.

This experiment study shows that the finned absorbers efficiency are 51.515 %, its more than efficiency of conventional style solar air collector and flat plate absorber without fins. This study shown that finned absorber is 10 % more efficient than conventional style solar air collector.

Based on CFD calculations with temperature fluid flow out of the bottom line seems to be higher (yellow to red) compared to the inflow parallel on it (green color). In the outlet channel is higher temperature (83oC) than the inlet channel temperature (26oC), so the addition of proven solar collector with fins can increase the temperature of the heat required for drying fruits, especially tomatoes.

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