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The effect of Discrete V-down rib roughness over Double pass roughened solar air heater

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Abstract: A recent decade, the various number of investigations shows that the implementation of various geometrical roughness results the enhancement of the thermal efficiency. In such double pass flow solar air heater, the initial air flows in upper channel and reverse its direction to reaches in lower channel of the collector. A mathematical model is developed for double pass solar roughened air collector with different influencing parameters such as solar radiation, inlet air temperature, length of solar collector, and flow rate. The results shows that these parameters have significant influence on the thermal efficiency.

Index Terms **- Solar air heater; double pass; Artificial roughness; Thermal Efficiency**

I. INTRODUCTION

The growing global population reveals energy as a prime aspect for wealth creation and economic development for individual as well as countries [1]. The depletion of the fossil fuel and price hike is deep matter of concern for global market. The present environment degradation drawn the researcher attention toward the possibilities of non-conventional energy sources such as solar energy [2].

Solar energy is inexhaustible and eco-friendly. The 1.7×10^{14} kW of solar energy availability fulfil the present consumption rate of all available commercial energy resources on the earth. The most favorable utilization of solar energy is done with the help of the solar air collector [3].

The flat plate air collectors are widely used in solar drying and space heating. The low efficiency of such flat plate collector leads to the importance of design of an air collector with high efficiency.

The various design components such as single pass, double pass, plate coating, phase change materials, porous matrixes, roughness etc, would lead to a better thermal performance of the solar collectors[1-8].

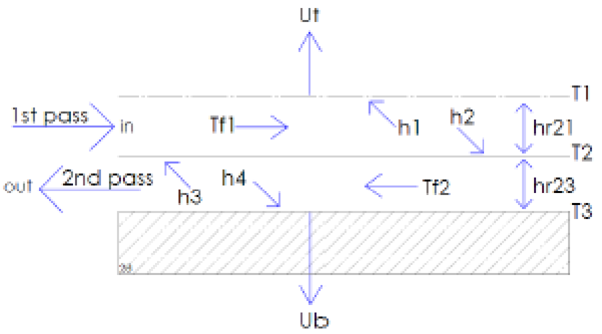
The literature review involved the numerous of studies based on the experimental and analytical models of the solar air heater. Struckmann [4] evaluated the performance of a Flat-Plate Collector the efficiency as linear function dependent on the operating condition such as Solar irradiance (I), Fluid inlet temperature (Ti) and Ambient air temperature (Ta).

Chabane et al [5] investigated the dynamic behavior of the collector which is influence by air flow, various air inlet temperature and gap between the transparent cover and absorber plate. Fudholi et al [6] examined efficiency of the double pass solar collectors containing with rectangular fin with the help of changing the intensity of solar radiation and the mass flow rate.

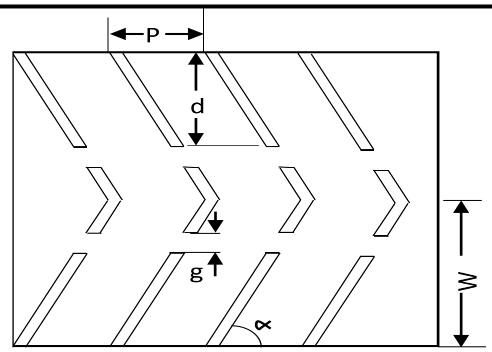
Han et al. [7] investigated the effect of V-shaped rib in single pass square channel duct to evaluated the thermal performances. Although, no research article is present for discrete V shape roughness for double-pass counter flow solar air heater.

II. METHODOLOGY

The current research involves the numerical model for double-pass counter flow with discrete V shape roughness placed over the absorber plate (Fig.1). The developed energy balance equations for double-pass counter flow solar air heater (Fig.1. (a)) represented as [5-8];



(a) Cross sectional view



(b) discrete V- shape roughness

Fig.1. Double pass solar air heater [1]

For top plate; $S_1 + h_{r21}(T_2 - T_1) + h_1(T_{f1} - T_1) = U_T(T_1 - T_a)$

For absorber plate; $S_2 = h_3(T_2 - T_{f2}) + h_2(T_2 - T_{f1}) + h_{r23}(T_2 - T_3) + h_{r21}(T_2 - T_1)$

The radiation heat transfer coefficient is determined as;

between the glass cover and sky; $h_{rs} = \sigma\varepsilon_1(T_2 + T_1)(T_2^2 + T_1^2)\frac{(T_1 - T_s)}{(T_1 - T_a)}$

between the glass cover and absorbing plate; $h_{r21} = \frac{\sigma(T_2+T_1)(T_2^2+T_1^2)}{\frac{1}{\varepsilon_2}+\frac{1}{\varepsilon_1}-1}$

between the absorbing plate and the bottom plate; $h_{r23} = \frac{\sigma(T_2+T_3)(T_2^2+T_3^2)}{\frac{1}{\varepsilon_2}+\frac{1}{\varepsilon_3}-1}$

The amount of heat transferred in the first pass fluid is given by; $Q_1 = mC_p(T_{f1} - T_{fi})$

The amount of heat transferred in the second pass fluid is given by; $Q_2 = mC_p(T_{f2} - T_{f1})$

And finally, the output temperature and collector efficiency are given by;

$T_o = T_{fi} + \frac{(Q_1 - Q_2)}{mC_p}$ and $\eta_c = \frac{mC_p(T_o - T_{fi})}{I}$

However, it is predicated that a double-pass configuration would lead to a higher-pressure loss leading to large fan power as compared to single pass resulting an increase of rate of electricity consumption.

Table:1 Parametric values

I	600-1000W/m^2	**ε$_1$**	0.94
α	60°	**ε$_2$**	0.9
W	0.75m	**ε$_3$**	0.94
L	1.5m	**α$_1$**	0.06
h$_g$	0.05m	**α$_2$**	0.95
h$_c$	0.025m	**τ$_1$**	0.84
m	0.002 kg/sec	**V**	1 m/s
T$_a$	298K	**σ**	5.64×10^{-8} W/m^{2}K^4
T$_{fi}$	0.025 W/mk		

III. RESULTS AND DISCUSSION

The numerical relations equations presented in the earlier section are solved using MATLAB. The code is written to calculate the temperatures, heat transfer coefficients and efficiency of the double pass solar air collector with discrete V-shape rib roughness. The results shows that the absorptivity, emissivity and transmissivity for the surfaces in the air collector have a minimal influence on the simulation result.

It is observed from the Fig. 2 that both absorber plate temperature and output fluid temperature linearly increase as the radiation increase and reached optimal values of 900W/m^2. This happened due to high transmissivity-absorptivity product values for high value of solar radiation.

The result shown in Fig.2, predicts that the effect of solar radiation (600-1000W/m^2) to the output fluid temperature from 308-320K and efficiency varies from 70% -73%. The result demonstrates that model developed for counter flow discrete v-groove collector is able to correctly predict the performance of the air collector.

The solar radiation data, ambient and inlet air temperature and the air collector's characteristics used to perform the experiment in all aspects the simulation model to reproduce the experimental result as close as possible and verify if the simulation model generate reliable outputs.

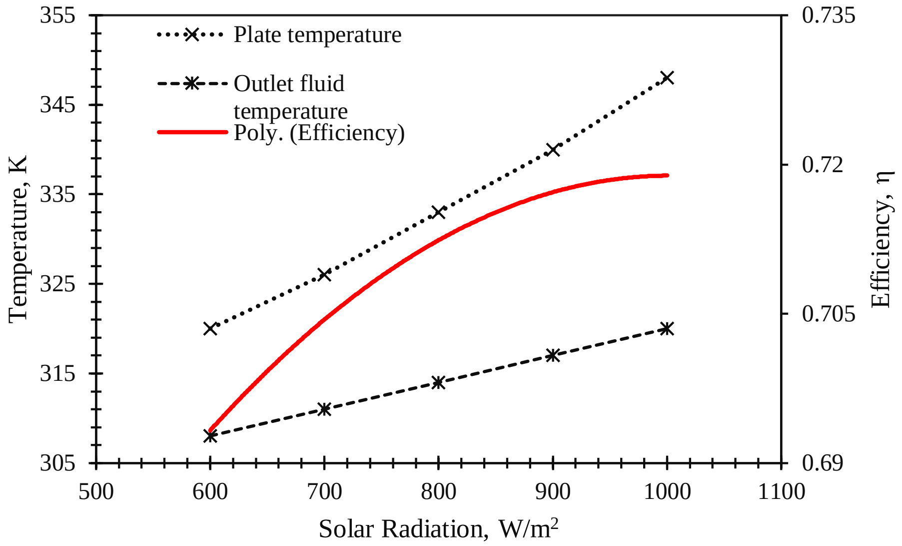


Fig.2. Variation of Plate Temperature, Output Temperature and Efficiency

IV. CONCLUSION

The mathematical model developed for discrete V-shape rib roughness and the simulation with the help of MATLAB is correctly predicted with the output air temperature, plate temperature and thermal efficiency. A parametric study determined significant effect of solar radiation on the efficiency of the air collector. On the other hand, the deviation is attributed to the change in flow condition in the channel.

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