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Entropy Generation of double pass Solar Collector System with embedded porous matrix

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Abstract: The Owing to the thermodynamics irreversibility related for double pass flat plate solar air heater. The air flow through solar duct channel characterized fluid friction and heat transfer losses. The present analysis is carried with the embedded porous matrix in the lower channel of double pass solar air heater. The present investigation involves second law of thermodynamic concepts to evaluate working conditions. The fluid temperature distribution is reported for entropy generation location for its at minimum level and maximum heat transfer coefficient.

***Index Terms* - Solar Collector System, porous matrix, Entropy Generation**

I. INTRODUCTION

The present energy demands the demands of solar energy substitution to fulfil the present energy demands. These energies are found with very low cost and without any limitation [1]. The conventional flat plate solar air heater resulting the low thermal efficiency due to the formation of laminar sub-layer over the absorber plate [2]. Consentingly, the researcher drawn their attention to improve the performance of solar air heater.

The researchers implemented various roughness geometries over absorber placed, packed matrix, Phase change material (PCM), multi-pass collectors etc. to enhance the thermal efficiency [3].

The benefits of porous materials as an alternative technique resulting to the increase of heat transfer area contributing to the enhancement of heat transfer coefficient between absorber plate and flowing fluid [4]. Hence, the embedded porous matrixes are good passive technique for heat transfer augmentation generating a high pressure drop. In order to maximum available energy, the thermodynamics losses in the terms of entropy generation should to minimized [5]. Hence, decreasing energy losses is getting more important.

Mohamad [6] carried the investigation with the double-pass solar air collector with porous media and showed that the thermal efficiency is enhanced by 18% compared to the conventional solar collector. Sopian et al. [7] studied the effects of channel depth of the double-pass solar air collector embedded with and without porous media in lower channel resulting the thermal efficiency of such solar air collector with porous media is about 60-70%.

Furthermore, Naphon [8] predicted the heat transfer augmentation and entropy generation of the double-pass solar air heater with longitudinal fins. Baytas [9] reported that the local entropy generation maps are feasible for laminar natural convection heat transfer with porous cavity for calculation of thermal efficiency. Demirel and Kahraman [10] analyzed entropy generation rate of forced convection heat transfer inside rectangular packed duct uniform heating showing the entropy generation equipartition over the cross section of the bed.

The present paper represents the second law-based methodology for calculation of entropy generation rate. The numerical calculation used for double pass solar air heater with porous matrix as depicted in Fig.1, for laminar forced convection flow.

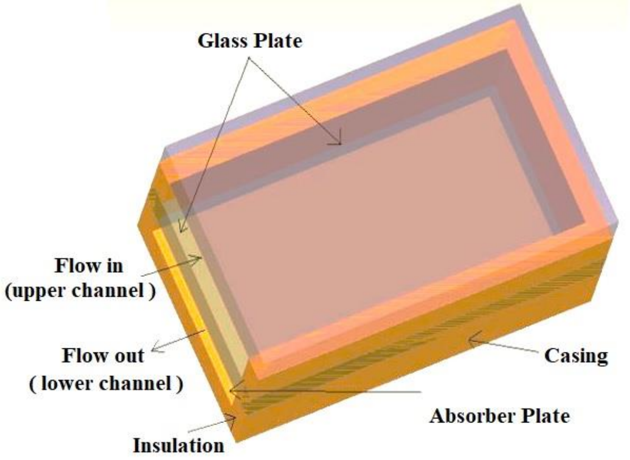

Fig.1. Double pass solar air heater with porous matrix

II. MATHEMATICAL MODELING

The present mathematical model is developed considering the parameters as shown in Table 1, for the double pass solar air heater. A porous matrix is embedded in the lower channel and the duct is perfectly insulated. The effects of the porous layer region along with thermal conductivity are investigated with the help of the temperature difference between inlet and outlet fluid.

Table.1: values of working parameters

S.No.	Input Parameters	Values
1	Thermal conductivity of solid matrix, k (W/mK)	386.0
2	Intensity of solar radiation, (W/m^2)	750, 800
3	Inlet air temperature, T$_i$(K)	288,303
4	Air mass flow rate per unit width, (kg/s)	0.01
5	Porous medium (Glass wool)	0.8 porosity
6	Plate Type	Flat Plate
7	Length of solar air heater, L(mm)	2000
8	Width of solar air heater, w(mm)	1000
9	Depth of solar air heater, D(mm)	100
10	Ambient Air Pressure, P$_a$(bar)	1

In order to establish the hydrodynamics and thermal, a second law analysis is widely employed to evaluate the entropy generation due to both fluid friction and heat transfer for optimization criteria.

The entropy generation rate for control volume is given by $d\dot{s}_{gen} = \dot{m}ds + \frac{q`dx}{(T_f+\Delta T_m)} \geq 0.$

It is known for reversible process, $d\dot{s}_{gen} = 0$ and irreversible process, $d\dot{s}_{gen} = 0$ From, the first law statement, we get, $\dot{m}dh = q`dx$ and from second law statement, we achieved, $dh = T_f \times ds + \frac{dp}{\rho}$.

Now on comparing these equations, the entropy generation rate per unit duct length is given by;

$\dot{S}_{gen} = \frac{d\dot{s}_{gen}}{dx} = \frac{q`\Delta T_m}{T_f^2} + \frac{\dot{m}}{\rho T_f}\left(-\frac{dp}{dx}\right) \rightarrow \dot{S}_{gen} = \dot{S}_{\Delta T} + \dot{S}_{\Delta P}$; Where, $\dot{S}_{\Delta T}\ and\ \dot{S}_{\Delta P}$, represents the irreversibility due to heat transfer across the wall-fluid and fluid friction respectively [11].

III. RESULT AND DISCUSSION

A Computations procedure based on the control volume method is used to solve the entropy generation with the associated boundary conditions. The differential equations are discretized by the means of Finite volume method.

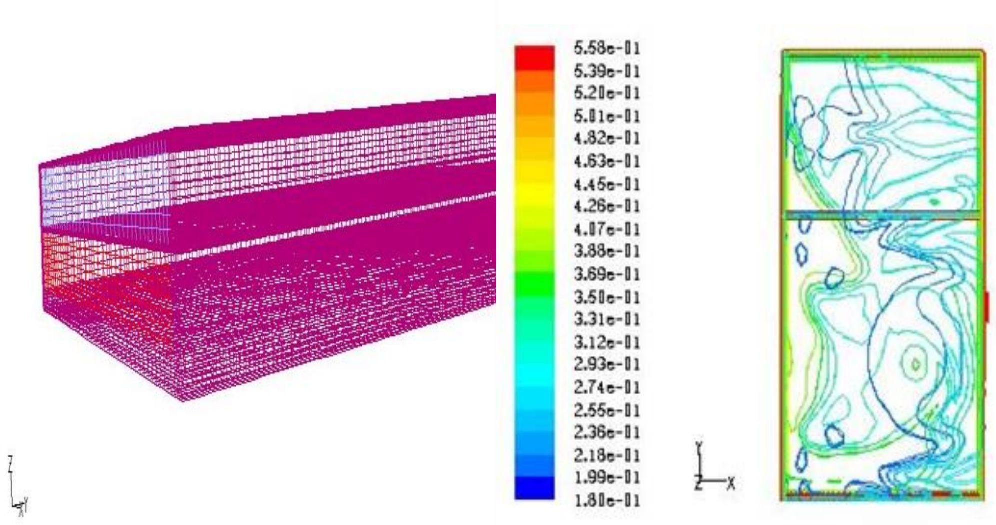

Fig.2. (a) Meshing of double pass solar air heater with porous matrix

Fig.2. (b) Entropy generation distribution of double pass solar air heater with porous matrix with respect to rise in temperature $(\Delta T/I)\ of\ 0.025$

A 3D model was developed using the CFD numerical package as depicted in Fig.2 (a) showing the meshing of double pass solar air heater. An experimental model was used to evaluate the entropy generation distribution. Fig. 2(b) depicts Entropy generation distribution of double pass solar air heater with porous matrix with respect to rise in temperature $(\Delta T/I)\ of\ 0.025$.

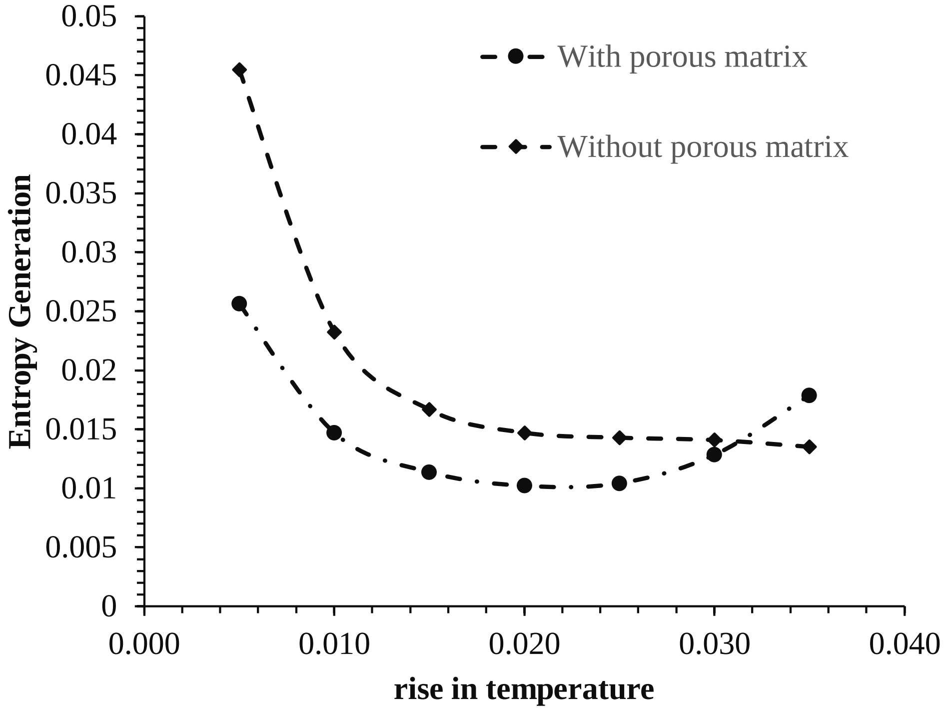

Fig.3 Entropy generation rate w.r.t rise in temperature

The results reveals that the permeability characteristic of the porous material is due to fluid friction corresponding to different porous layer thickness contributing to different values of the Darcy number. It was obverse that due to the significant macroscopic resistance and increasing of porous layer thickness or decreasing its permeability resulting to an increase of entropy generation rate. Fig. 3 depicts the entropy generation rate with respect to rise in temperature for embedded porous matrix inside lower channel of double pass solar energy. It increases until a maximum value corresponding to a critical thickness of the porous layer that depends on the permeability. Above this critical thickness, the rate of entropy generation decreases and becomes even lower than the value obtained for the fluid case when the annular gap is filled above 95%.

IV. CONCLUSION

The present analysis considered the effect of porous matrix embedded in lower channel of double pass solar heater for irreversibility distribution ratio and entropy generation. It has been observed that entropy generation is minimum satisfying the second law of thermodynamics. The double pass solar air heater with embedded porous matrix results better having effective efficiency with minimum entropy and entropy generation number as compared to double pass solar air heater without embedded porous matrix.

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