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Enhancement Experimentally the Performance of Wires Mesh-Solar Air Collector

Isbeyeh W. Maid
Power Mechanics Dept.
Engineering Technical College
Middle Technical University
Baghdad-Iraq
iwm_53@yahoo.com

Kifah H. Hilal
Power Mechanics Dept.
Engineering Technical College
Middle Technical University
Baghdad-Iraq
kifhilal@gmail.com

Ali Najm Moussawi*
Power Mechanics Dept.
Engineering Technical College
Middle Technical University
Baghdad-Iraq
alinajm.an90@gmail.com

***Abstract*— Three models were used to analyze a double pass-counter flow solar air collector (SAC-DPCF); which included conventional model and two forms of wire mesh: diamond and spiral. The results shown that the Model III has maximum values of air temperature raise of (23.7°C), useful energy of (331.2 W), thermal efficiency of (64.1%) and thermo-hydraulic efficiency of (63.7%) respectively at air mass flow rate of 0.0139 kg/s. The thermal efficiency was improved by (16.6%) with spiral form wire mesh and by (19.1%) with diamond form wire mesh at 0.02 kg/s. The thermal efficiency was improved by (10.2%), (9.5%) and (8.1%) for models (I), (II) and (III) respectively when the air mass flow rate increased from 0.0139 kg/s to 0.02 kg/s.**

Keywords—solar air collector; wire mesh; experimental; efficieny Introduction

I. Introduction

Solar energy collector is a special kind of a heat exchanger. It converts the solar radiation which penetrates the glass cover to internal energy that carries by an air (transport fluid). Basically, there are three mains types of solar air heaters; single pass-single flow (SPSF), double pass-parallel flow (DPPF) and double pass-counter flow (DPCF). The third type has efficiency principally due to high heat transfer coefficient of air and low heat losses. A double pass counter flow solar air collector consists of two channels, the air passing in upper channel and then return and passes through the lower channel in the opposite direction. The air is a transfer fluid which carries the heat that converted from the radiation from the sun then its pass through the lower channel. Application of the solar air collector: Drying, Pre-heating, Space heating and cooling.

Summary of previous researches; Chen [1], studied the effect of attack angle of screen mesh on the pressure drop and overall conductance at fixed flow rate for developing a high performance heat sink. The heat transfer surface area and friction factor are increased with decreasing inclination angle. Gupta [2], studied experimentally and theoretically SAC-DPCF without and with wire mesh. It was found that the efficiency with wire mesh was more than the efficiency without wire mesh by about 20-25%. Dhatkar et al. [3], reviewed the SAHs with wire mesh absorber. Different types of SAC include the design of SAH, heat transfer enhancement, pressure drop, type of flow with different locations of wire mesh were studied. Based on literature review, it is concluded that most of the studies carried out on SAH with porous media and extended surfaces. Saleh [4], studied experimentally and theoretically the thermal performance of SAC with wire mesh. The experimental results showed that the efficiency enhanced is not less than 25% with wire mesh, while the theoretical results show the efficiency enhanced not less than 28% with wire mesh. Kabeel, et al. [5], reviewed the literatures that dealing with improvement methods, design configurations and applications of different types of solar air heaters (SAHs) such as DPCF. An absorber plate had different modifications, such as fins; longitudinal, corrugated, with baffles and artificially roughened absorbers that led to increase the heat transfer area, Also an absorber with selective coated gives good improvement of the efficiency of SAHs. Roy and Hoque [6], studied experimentally the performance of double pass SAH with rectangular wire mesh. The results shown that the maximum collector efficiency and the outlet air temperature are about 82.2% and 42.75°C respectively at air mass flowrate of 0.0251 kg/s and solar intensity of 1000 W/m^2. Adnan [7], studied the performance enhancement of double pass SAH by using steel wire mesh experimentally. The results shown that the average thermal efficiency for the case without wire mesh varies is 23% to 30%, while the average thermal efficiency for the case with wire mesh varies is 28% to 72%. Atilla et al. [8], investigated experimentally the thermal performance of a new solar air collector with copper mesh. The thermal efficiency is ranged from 25% to 57%, while the thermal-hydraulic efficiency of the collector is ranged from 14% to 44% at air mass flow rate ranged from 0.031-0.038 kg/s.

II. Theory

A. *Experimental Setup*

Three models were used in the present analysis as shown in table 1. The experimental analysis was conducted at Iraq, Baghdad city climate (longitude

44.4°, latitude 33.3°) in spring conditions. The solar collector was tilted at an angle 32.05° with horizontal (spring conditions) [9]. This test rig is a double pass counter flow type (SAC-DPCF). An analysis includes three models as shown in table 1.. Fig.1 shows photography view of the SAC with instruments and measurement devices. The present rig is a double pass-counter flow (SAH-DPCF). This test rig made of galvanized steel (gauge 18) with dimensions; Length of (120 cm), Width of (60 cm) and Depth of (15 cm), it has two passages (every passage has depth of 7.5 cm) with fillet end (Radius=5.5 cm) for making the flow of fluid (air) more smoothly and for reducing the losses caused by air impact at end of the upper passage. An Armaflex (HT type) has thermal conductivity (k) value of (0.038 W/m K) with (3 cm) thickness used to insulate the sides and back of the SAH for reducing the heat losses which takes by convection and conduction. In the middle (between two passages) of test section placed an absorber plate (copper metal) with dimensions; Length of (120 cm), Width of (60 cm) and thickness of (0.03 cm). This plate coated with black-matte for increasing the absorptivity value (α) of the plate. One glass cover place on the upper surface of SAH with dimensions; Length of (122 cm), Width of (62 cm) and thickness of (0.6 cm). The supply fan of air (0.5 Horsepower and 2800 RPM) connected with the upper passage by flexible cylinder with diameter of (7.5 cm). Two cones, first cone in the entrance of the upper passage and the other in exit of the lower passage.The entrance and exit (Round) connected with the entrance and exit cones with dimensions; Length of (10 cm) and Diameter of (7.5 cm). Three dampers (vanes) in the entrance and exit cones for distributing the air uniformly. Instruments and measurement devices which used with their specifications are; Fan (0.5 hp, 2800 RPM), Solar power meter (TES-1333R Model, Accuracy ±10 W/m^2), Thermocouples (Temperature range –270 to 1260 °C, K-type, Accuracy +/- 1.1 °C or 0.4%), Data logger (BTM-4208SD Model, 12 Channels), Pressure Manometer (PM-9102 Model, ±200 mbar, Accuracy ±2%), Hot Wire Anemometer (YK- 2005AH, Accuracy ±2%) and Vane Probe Anemometer (DVA-6000T Model, 0.25 to 30 m/sec, Accuracy±0.1 m/sec).

TABLE 1. MODELS OF THE SAC IN THE PRESENT ANALYSIS

Models	Content
Model I	Conventional SAC
Model II	SAC with wires mesh (spiral form)
Model III	SAC with wires mesh (diamond form)

1	Solar Power Meter	2	Vane Probe Anemometer
3	Air blower	4	Pressure Manometer
5	Hot Wire Anemometer	6	Data Logger
7	Ambient Temp. Logger	8	Thermocouple
9	Glass cover & Abs. plat	10	Flexible Pipe
11	Inlet & Outlet Cones	12	Stand with tilt 32°
13	Test section	14	Fillet End

Fig. 1 Photography view of the solar air collector with instruments and measurements devices

Two forms of wire mesh were used in this analysis as a porous media: as shown in fig. 2.

1. Cylinderic spiral form wire mesh: (10 pieces) with dimensions is: Width=0.6 m, Outer diameter=0.06 m and total weight=1.76 kg.
2. Diamond form wire mesh, with dimensions is: (14 pieces) Width=0.6 m, Angle of attack=32 ° , Height=0.06 m and total weight=1.74 kg.

(a) Spiral form

(b) Diamond form

Fig. 2 Photography view of two forms of wire mesh

A. *Experimental Analysis*

The experimental analysis of the solar air collector has been done by the following equations.

Air mass flow rate ($\dot{m}$), (kg/s)

$$\dot{m} = \rho_a \times V_a \times A_c \quad (1)$$

ρ_a: Air density at average temperature, in (kg/m^3) [10].

$$A_c = W \times h \quad (2)$$

Useful energy (Q_u), (W)

$$Q_u = \dot{m} \times C_p \times (T_o - T_i) \quad (3)$$

C_p: Specific heat of air at constant pressure, in (J/kg K) [10].

Thermal efficiency, (η_{th}) [11]

$$\eta_{th} = \frac{Q_u}{A_t \times I_s} \quad (4)$$

$$A_t = L \times W \quad (5)$$

Thermo-hydraulic efficiency, (η_{th-hyd}) [11]

$$\eta_{th-hyd} = \frac{Q_u - PP}{A_t \times I_s} \quad (6)$$

$$PP = \frac{FP}{\eta_B} \quad (7)$$

$$FP = \frac{\dot{m} \times \Delta P}{\rho_a} \quad (8)$$

η_B: The blower efficiency is 0.18 [12].

III. Results and Discussions

EES software used to solve the experimental equations. In this analysis, the readings recorded every 30 min during the day. The results showed that model (III) had maximum outlet temperature of air (T_o) which equal (54°C) at 0.0139 kg/s, and it is more than in models (I) and (II) by (9.4%) and (5.6%) respectively as shown in fig.3.

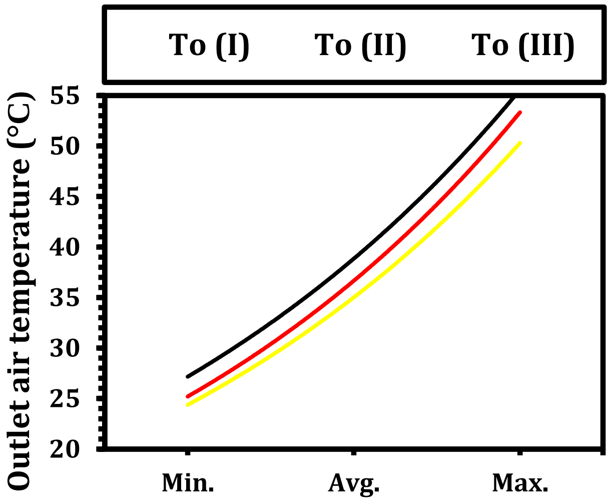


Fig. 3 Comparison in outlet air temperature for all models at 0.0139 kg/s

The air temperature raise (ΔT) increases when the solar radiation (I) increases. Maximum air temperature raise was found in model (III). Fig.4 shows the values of air temperature raise of models (I), (II) and (III) are (15.1°C), (17.9°C) and (19.7°C) respectively at 0.02 kg/s. The improvement in air temperature raise for models (II) and (III) over model (I) are (15.6%) and (23.4%) respectively.

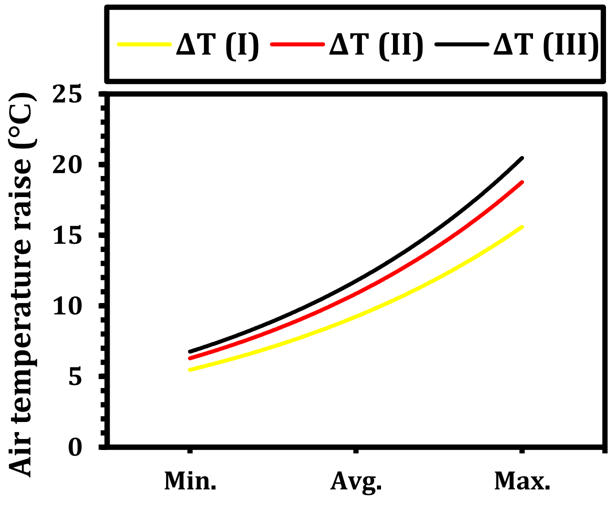


Fig. 4 Comparison in air temperature raise for all models at 0.02 kg/s

Fig.5 shows the comparisons in useful energy (Q_u) of air between all wires mesh models at 0.0139 kg/s. The enhancement in average useful energy in models (II), (III) are (14.5%), (24.2%) at (0.0139 kg/s) respectively, and (17.5%), (22.5%) at (0.02 kg/s) compared to model (I) (Conventional).

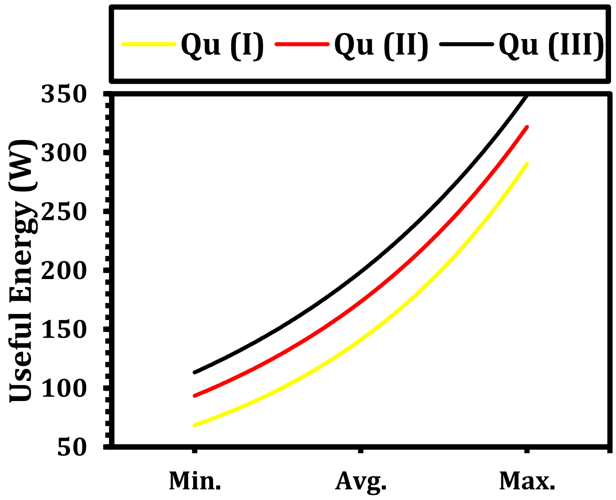


Fig. 5 Comparison in useful energy of air for all models at 0.0139 kg/s

The thermal efficiency (ηth) increases when the useful energy of air increases. The improvement in average thermal efficiency of the conventional solar air collector (model I) was by (17.2%) and (16.6%) with spiral wire mesh (model II) at (0.0139 kg/s) and (0.02kg/s) respectively and by (20.9%) and (19.1%) with diamond wire mesh (model III) at (0.0139 kg/s) and (0.02kg/s) respectively. Fig.6 shows the comparision in thermal efficiency between models of SAC at 0.0139 kg/s.

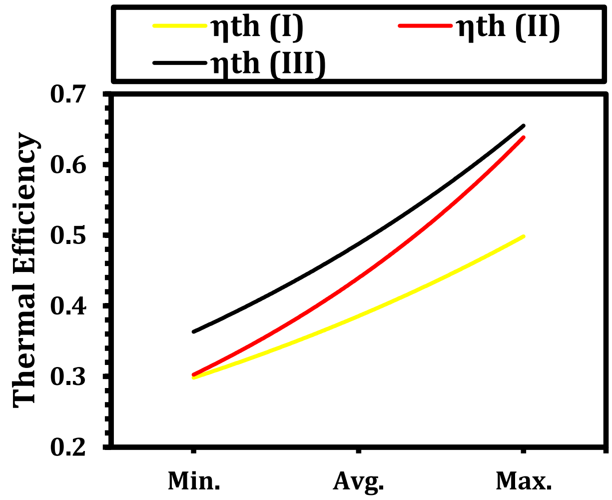


Fig. 6 Comparison in thermal efficiency of all models of SAC at 0.0139 kg/s

The behavior of thermo-hydraulic efficiency (η_{th-hyd}) is similar to behavior to thermal efficiency because of the pumping power is very low. The highest average of thermos-hydraulic efficiency in model (III) of (50.5%), and it's about (20.6%) and (4.6%) more than in models (I) and (II) respectively at 0.0139 kg/s. Fig.7 shows the comparision in thermo-hydraulic efficiency between models of SAC at 0.0139 kg/s.

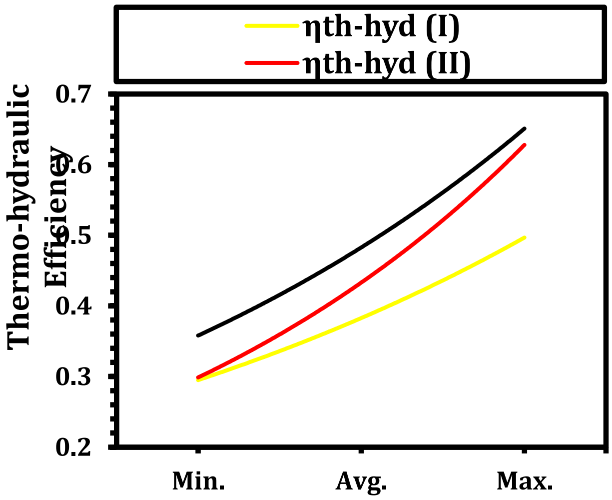


Fig. 7 Comparison in thermo-hydraulic efficiency of all models of SAC at 0.0139 kg/s

The air temperature raise decreases when the air mass flowrate increases. Fig.8 shows the effect of air mass flowrate on the average air temperature raise for all models.

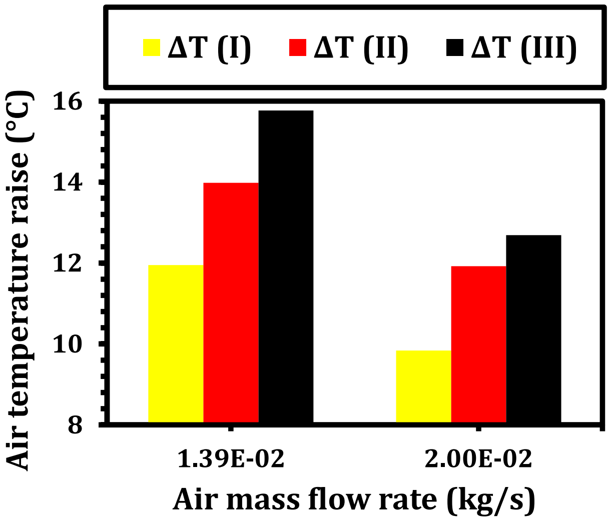


Fig. 8 Effect of air mass flowrate on average air temperature raise for all models

The useful energy increases when the air mass flow rate increases. The enhancement in average useful energy of air in models (I, (II) and (III) due to increases in air mass flowrate from (0.0139 kg/s) to (0.02 kg/s) by (15.6%), (18.5%) and (13.7%) respectively. Fig.9 shows the effect of air mass flowrate on the average useful energy of air for all models.

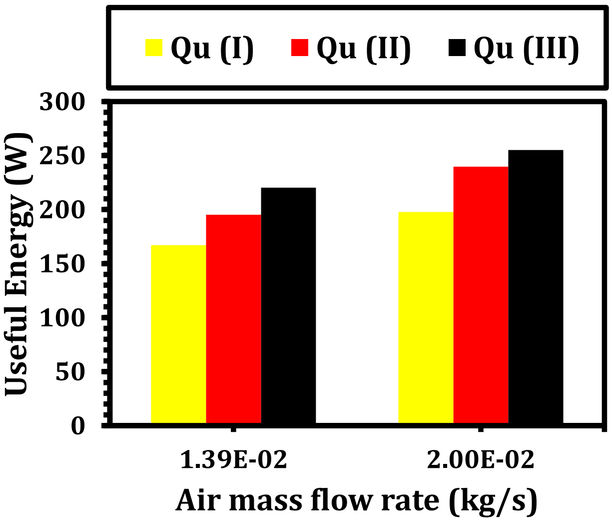


Fig. 9 Effect of air mass flowrate on average useful energy of air for all models

The thermal efficiency of the solar air collector increases when the air mass flow rate increases. The enhancement in average thermal efficiency of SAC in models (I, (II) and (III) due to increases in air mass flowrate from (0.0139 kg/s) to (0.02 kg/s) by (10.2%), (9.5%) and (8.1%) respectively. Fig.10 shows the effect of air mass flowrate on the average thermal efficiency of SAC for all models.

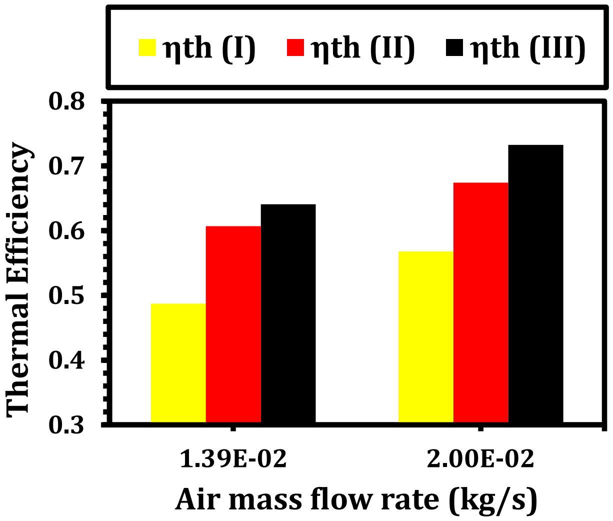
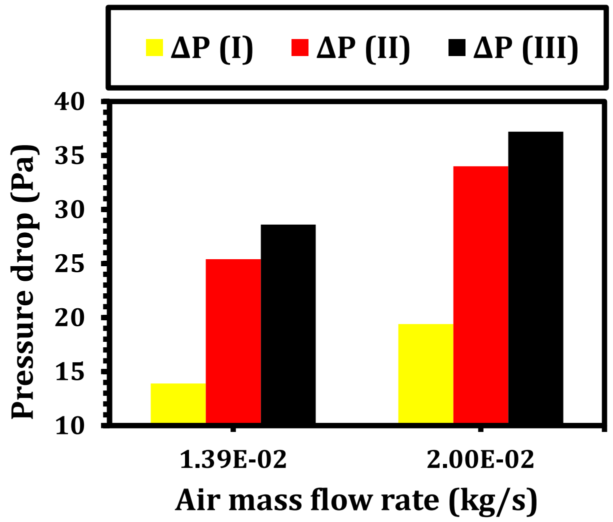


Fig. 10 Effect of air mass flowrate on average thermal efficiency of SAC for all models

The pressure drop through the solar collector increases when the mass flowrate of air increases. The values of pressure drop of models (I), (II) and (III) are (13.9 Pa), (25.4 Pa) and (28.6 Pa) respectively at 0.0139 kg/s. Fig.11 shows the effect of mass flow rate of air on the pressure drop for all models.



IV. Conclusions

Replacing conventional SAC by spiral mesh SAC and diamond mesh SAC have the following effects: Improving the useful energy of working fluid, thermal efficiency of SAC and thermo-hydraulic efficiency of SAC by (14.5%, 24.2%), (17.2%, 20.9%) and (16.8%, 20.6%) respectively at (0.0139 kg/s). The thermal efficiency of models (II) and (III) has improved by (9.5%) and (8.1%) when the mass flowrate of air increases from (0.01239 kg/s) to (0.02 kg/s).

SYMBOLS

$\dot{m}$: air mass flow rate, (kg/s)
ρ_a: Air density at average temperature, (kg/m^3)
V_a: Air velocity at test section outlet, (m/s)
A_c: Cross section area of the test section, (m^2)
W: Width of the test section, (m)
H: Height of the channel, (m)
Q_u: Useful energy of air, (W)
C_p: Specific heat of air at constant pressure, (J/kg K)
T_i: Air temperature at inlet of test section, (°C)
T_o: Air temperature at outlet of test section, (°C)
η_{th}: Thermal efficiency of the solar air collector, (-)
I_s: Solar radiation, (W/m^2)
A_t: Area of the test section, (m^2)
L: Length of the test section, (m)
η_{th-hyd}: Thermo-hydraulic efficiency of the solar air collector, (-)
PP: Pumping power, (W)
FP: flow power, (W)
η_B: Blower efficiency, (-)
ΔP: Pressure drop through the heater, (N/m^2)
Pf: Performance factor of the solar air collector, (-)

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