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Experimental Study of Jet Impinging Double-Pass Solar Air Heater Using Wire-Mesh.

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Experimental Study of Jet Impinging Double-Pass Solar Air Heater Using Wire-Mesh

دراسة عملية لسخان هواء شمسي ذو مسارين بنافث نافوري باستخدام شبكة سلكية

M.M. Atiya, *G.I. Sultan* and A.A. Hegazi

KEYWORDS:
Double pass solar air, Jet impingement, Wire mesh, Efficiency

الملخص العربي:- **هذا البحث يقدم دراسة عملية لتحسين أداء سخان الهواء الشمسي ذو النافث النافوري باستخدام شبكة سلكية معدنية. تم إنشاء عدد 2 جهاز إختبار متماثلين بمساحة 0.5 متر مربع، الأول مع إستخدام شبكة سلكية والأخر بدون إستخدام الشبكة السلكية. تم إجراء جميع الاختبارات في جامعة المنصورة - مصر خلال شهر سبتمبر 2019. في هذه الدراسة ، تم تغيير معدل سريان الهواء (0.0201, 0.0186, 0.0163, 0.0143 كجم/ ثانية) و قطر النافث النافوري (3, 5, 7, 9 mm). أوضحت النتائج أن الكفاءة الحرارية لسخان الهواء الشمسي تزداد بزيادة معدل سريان الهواء وبتقليل قطر النافث النافوري. أقصى كفاءة حرارية يومية لسخان الهواء الشمسي ذو النافث النافوري كانت 72.33% باستخدام الشبكة السلكية و 61.89% بدون إستخدام الشبكة السلكية عند معدل سريان هواء 0.0201 كجم/ ثانية وقطر نافث نافوري 3 مم. وأدنى كفاءة عند قطر 9 مم. بالإضافة إلى أن أقصى نسبة تحسين في الكفاءة الحرارية نتيجة إستخدام الشبكة السلكية حوالي 29.48% عند قطر نافث نافوري 5 مم.**

***Abstract*— This paper manages the test examination of the Solar Air Heater (SAH) exit temperature and efficiency. The trial test segment is planned and manufactured to study the jet impingement effect on the absorber plate with wire mesh, among circular jets in a channel of SAH, and compared with traditional SAH with the jet plate. The proposed solar air heater is tested by varying the nozzle diameter to have the values 3 mm, 5 mm, 7 mm and 9 mm while the mass flow rate of air range is 0.0147–0.0201 kg/s. The research declared that the maximum thermal efficiency is gained at 3 mm hole ID. The maximum thermal efficiency is 72.33% with wire mesh and 61.89% without wire mesh at the mass flow rate is 0.0201 kg/s. The lowest performance is recorded at the 9 mm diameter hole. The best percentage increase in efficiency of the IJDPSAH with metal wire mesh occurs at 5 mm is 29.48%.**

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I. INTRODUCTION

SOLAR air heater is one of the most important systems that collect sunlight and convert it to thermal energy. It has many usages including area heating and drainage of crops this as leaves, false, and greens and also used in some industrial applications. On the other hand, it is environmentally friendly and has less maintenance cost and long-life products. However, unfortunately instantaneous thermal performance of solar air heaters is low due to lower values of heat transfer coefficient between the air flow and absorption surface due its high temperature and thus greater loss of heat to the surrounding. Thus, it becomes necessary to enhance several techniques to develop the air heater performance. Luampon and Krittakom [1] studied the solar air heater thermal efficiency together with the wire mesh neat structure. In their test, solar irradiance into workout utilized the sun-oriented test system in the research center. Their exploration comprises of two primary parts. Initial segment: sunlight-based test system testing. Sun based irradiance utilized 4 incandescent lights with 1,500 W. A manual for the norm (The EN-12975-2), a correlation between sun-powered air warmer with and without wire work impeccable was directed. its discovered that the warm proficiency of the bask-strong air cooling with introducing wire work impeccable was expanded and more prominent than without wire work spotless about 34.81%. Ho et al. [2] evaluated the improvement in thermal efficiency of a reused solar air heater using metallic wire-mesh theoretically and experimentally. They compared different configurations in which a single-pass flat-plate, double-pass and recycling double-pass which has a wire mesh packing. Their solar air heater double-pass with wire mesh efficiency was relatively higher than that of the other geometry for various recycle ratios and mass flow rates. They noticed that the pressure drop increases due to implementing wire-mesh in solar air heaters while economic feasibility is taken into consideration. Roy et al. [3] fabricated and tested experimentally the thermal duty of solar air heater. It consists of a horizontal section which is painted with a black colored and the vertical section is filled with paraffin wax. Also, the effect of mass flow rate of air on thermal efficiency and exit temperature are examined. They found that increasing air mass flow rate led to increase thermal efficiency and the maximum difference in temperature between the inlet and exit of the solar air heater is 36 °C at a rated value of air mass flow rate of 0.0116 kg/s when using wire mesh. In this case, the thermal efficiency is 39% higher in comparison with conventional solar air heater. The maximum efficiencies recorded for solar air heater with and without wire mesh were 54.6% and 29.24%, respectively, at flow rate of air 0.0251 $kg.s^{-1}$ and solar radiation intensity of 1005 W/m^2. El-Khawajah et al. [4] experimentally studied single-pass SAH with 2 fins as well as 6 shelves packed with wire layers between the fins and the heater and compared with the case of six fins. It was declared that for a similar mass stream rate, the SAH of six balances has higher productivity contrasted with the framework that has two blades. The values of maximum efficiencies for the SAHs were observed at the air mass stream of 0.042 kg/s. The best efficiencies in cases of six-finned and two-finned SAHs were 79.81% and 71.8%, respectively. Rajarajeswari and Sreekumar [5] conveyed a sun-based drier incorporated with a framework sun-oriented air radiator having a zone of 6 m^2 and attempted a point-by-point execution examination to investigate the techno-business practicality of the framework. The maximum temperature recorded at exit of the air heater was 70 °C when the framework was exposed to no stacked condition. The solar dryer was stacked with 30 kg new tomato, which has 4 mm in thickness. The underlying dampness substance of 90.62% diminished to 18.28% in a period of 3 hours. The financial analysis of the drier was investigated too. Velmurugan and Ramesh [6] introduced an efficient investigation to the present vitality request. An endeavor has been made to build the warm proficiency of sunlight-based air warmer by utilizing a wirework to improve the warmth move, in this manner expanding the effectiveness. The grid sun-based air warmer with a wirework produces higher warm effectiveness over the traditional level plate sun-oriented air radiator by utilizing a low carbon steel wirework. They discovered a 5% expansion in effectiveness as the contrasted and regular framework. Aldabbagh et al. [7] experimentally tested solar air heater of single and double-pass in case of using steel wire-mesh layers which are fitted on the flat plate absorber. The effect of air mass flow rate on thermal efficiency is studied. They observed that the maximum solar air heater efficiencies are obtained for the single and the double-pass solar air heaters have the values of 45.93% and 83.65%, respectively, as air mass flow rate is 0.038 kg/s. Omojaro and Aldabbagh [8] assessed the warm exhibition of a solitary and twofold pass sun oriented air warmer with balances connected and utilizing a steel wirework as safeguard plate. They found that the most extreme productivity got for the single and twofold pass air warmer was 59.62% and 63.74%, respectively, for air mass stream of 0.038 kg/s. Matheswaran et al. [9] studied the exergy efficiency of a single-pass double-duct jet plate of a solar air heater (SPDDJPSAH). Their experiment is completed at various mass stream rate 0.002–0.023 kg/s, stream pitch proportion X/D_h of 0.435–1.739, length pitch proportion Y/D_h of 0.435–0.869 and fly measurement proportion D_j/D_h of 0.043–0.109. Their outcomes indicated that SPDDJPSAH has been upgrading the powerful productivity by 21.2% and exergy proficiency by 22.4%. The impacts of mass stream rate and fly plate plan parameters on the exergy effectiveness have been introduced. The improved estimations of stream insightful pitch proportion $X/D_h = 1.739$ & $Y/D_h = 0.869$ and breadth proportion $D_j/D_h = 0.065$ are distinguished at the mass stream pace of 0.0035 kg/s and yields the most extreme exergy proficiency of 4.36%. Aboghrara et al. [10] investigated experimentally the effect of operating parameters on both thermal efficiency and exit air temperature of solar heater (SAH). The effect of air mass flow rate and solar radiation intensity on exit air temperature and efficiency are included. Their obtained results declared that the air impingement jet has a great effect on corrugated absorber plate and led to improve heat transfer characteristics. They concluded that the air mass flow rate affected the heat transfer associated the solar air heaters. The thermal efficiency of their proposed design solar air heater is 14% more as compared to the smooth one at solar radiation intensity range 500–1000 W/m^2, 308 K ambient temperature and 0.01–0.03 kg/s mass flow rate of air. Soni and Singh [11] carried out an examination for cross stream conditions. The impact of stream and geometry parameters, particularly fly measurement and water driven width has been considered. The mass stream rate for their examination is changed comparing to Reynolds number in the range 4600–12,000. The fly measurement D_j/D_h, X/D_h, and Y/D_h are in the range: 0.053–0.084, 0.53–0.63, and 0.53–0.63, respectively. They found that the gatherer proficiency increments, and temperature rise diminishes with the expansion in air mass stream. All the above-recorded execution parameters are seen as most extreme at fly width to water powered measurement proportion of 0.07. Rajaseenivasan et al. [12] tested and studied the diameters of jet plate openings 3, 5 and 7 mm with angles 0°, 10°, 20°, 30°, 60° and 90° and obtained the characteristics of heat transfer and compare it with conventional air heater type which detect that the high rendering is found with 30° of attack, and the worse performance is carried out with 0°. Othman et al. [13] studied the holes of different shapes: square and triple geometric. The studied diameters were as follows 6 mm holes with square and triangular geometric shapes and 10 mm hole diameter with triangle shape. They noted that the temperature decreases as the rate of air flow inlet increases and at 6 mm hole diameter gives higher temperature compared to the 1 mm hole diameter. Belusko et al. [14] studied theoretically and experimentally enhancing the coefficient of heat transfer between air flow and the heated surface of a glazed collector using air jet impingement. They found that the flow impingement jet distribution was the most significant parameter in detecting the efficiency. They also found that by increasing absorber hole spacing, the solar air heater efficiency is increased. They recorded 21% improvement in thermal efficiency of the solar collector when using jet impingement.

A comparison between the different previous works is listed in Table (I).

TABLE (I)
PREVIOUS SCIENTIFIC RESEARCH RESULTS

Author	Modification	Results
Ansari and Bazargan [17]	Ribbed surface.	With the use of ribs, the efficiency increased by 61%.
Pramanik et al. [15]	Double-pass with the bottom finned surface.	The SAH efficiency and air exit temperature are increased up to 69% and 94 °C, respectively.
Chabane et al. [18]	Longitudinal semi cylindrical fins.	Maximum efficiency obtained without and with fins are 40.02 and 51.5%, respectively.
Aboghara et al. [10]	Jet impingement on corrugated absorber plate.	Corrugated surfaces have 14% increase in air heater thermal efficiency as compared to the smooth one.
Omojaro and Aldabbagh [8]	Single and double-pass solar air heater with extended surface and steel wire mesh.	The maximum efficiency obtained for the single and double-pass air collectors are 45.93 and 83.65%, respectively.
El-Khawajah et al. [4]	Fins with wire mesh and steel wire mesh.	The maximum efficiency of the proposed SAHs reached is 79.81%.

Pramanik et al. [15] presented a model of SAH with particular safeguard covering with longitudinal blades at the base of safeguard to create blistering gases by devouring sun-oriented vitality in the daytime. It is kept in position so that air will stream because of constrained convection and the whole arrangement set at an edge of 15° to 17° tendency according to the thought about the worldwide position (20.2961° N, 85.8245° E). The exceptional specific covering applied over the whole aluminum safeguard plate to build the warmth engrossing limit. It is discovered that the immediate productivity and air exit temperature expanded up to 69% and 94 °C. The contrast between the hypothetical and test esteems exists in 1.23-9.75%. Krishnananth and Murugavel [16] presented the performance of a double-pass solar air heater fabricated and integrated with thermal storage system. Paraffin wax was used as a thermal storage medium.

The aim of present work is studying the thermal performance of impinging jet double-pass solar air heater IJDPSAH with/without steel wire-mesh as the studied mass flow rate of air (0.0147, 0.0163, 0.0186 and 0.0201 $kg.s^{-1}$) and a jet diameter (3 mm, 5 mm, 7 mm and 9 mm).

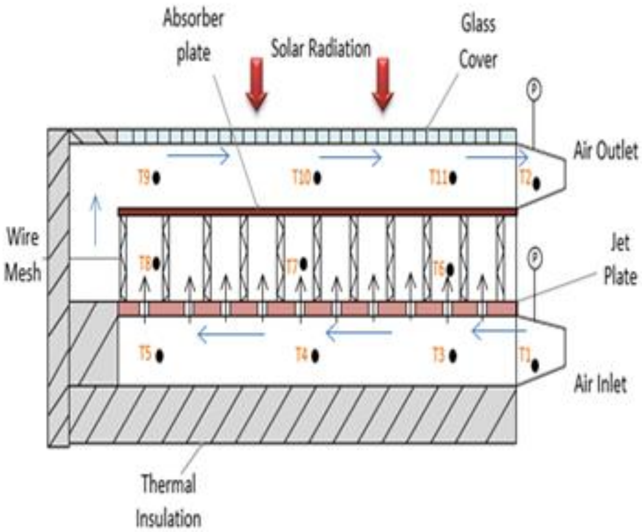
II. EXPERIMENTAL SETUP

A schematic perspective on the dual through air collector with jet impingement and wire mesh is shown in Fig. 1. SAH frame as an enclosure with the area of 1.10 m in length (L), by 0.5 m width (W) and thickness 0.18 m (t). The cover of the air heater is a normal window glass of 3 mm thicknesses. The thickness of the absorber plate which fabricated from iron is 1 mm. The inside surfaces of the solar air heater are coated by a black color. The distance from the glass cover to absorber plate was 5 mm, jet plate has a thickness of 3 mm and the distance between the holes are X = 10 cm and Y = 10 cm. The different diameters the of holes were 3 mm, 5 mm, 7 mm, 9 mm, while the wire mesh is installed vertically between the holes of the jet along the board, then the dimensions of wire mesh are: thickness 2 mm, length 50 cm, and height 7 cm. The number of wire mesh in the collector was 11 and distance was 10 cm among the wires mesh layers. The temperature is measured in different locations using a calibrated J-Type thermocouple. In the airflow area conventional and modified devices in the same conditions, timing and temperature are measured at 22 points along the complex and these are placed in equal distance. Calibrated J-type thermocouples are laid in this way linked to a global temperature indicator (Yokohama temperature recorder, accuracy of ±1 °C) is to determine the temperature. The solar radiation intensity is measured along the day hours by the solar power meter (TES-1333R). Air blower of 710 W is utilized to give the ideal mass flow rate of air is utilized to compel the air into the sun-oriented air warmer channel. All tests are done from 9 am to 5 pm neighborhood time. Experiments were conducted in Mansoura city, Egypt.

An error analysis based on the accuracy and the percentage error in every scale device is shown in Table (II).

TABLE (II)
ERROR AND ACCURACY OF VARIOUS USED GAUGE DEVICES.

Instrument	Accuracy	% Error
Thermometer	± 1 °C	± 1.97%
Thermocouples	± 0.1 °C	± 0.2%
Solar power meter	± 1 W/m^2	± 0.5%
U-tube manometer	± 0.2 cm	± 6%
Mass flow rate, useful thermal energy and thermal efficiency		2.21%, 3.6%, and 3.64%, respectively



● Thermocouple P pressure gauge

Fig. 1. Schematic diagram of proposed design of SAH.

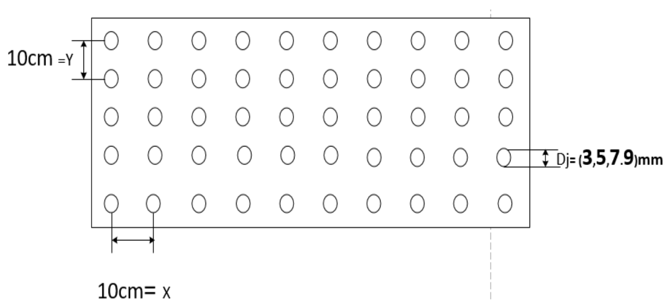


Fig. 2. Schematic cross-sectional view of jet plate.

Fig. 3. Image of the experimental system.

Fig. 4. Photo of wire-mesh position in the collector.

III. CALCULATION PROCEDURE

The useful thermal gain is calculated from the following equation:

$$Q_u = mC_p\left(T_{f,out} - T_{f,in}\right) \quad (1)$$

The SAH thermal efficiency is calculated as:

$$\eta_{th} = \frac{Q_u}{I \times A} x100 \quad (2)$$

The percentage improvement in SAH efficiency is calculated by:

$$\%imp.\ in\,\eta_{th} = \frac{\eta_{th,MS} - \eta_{th,OS}}{\eta_{th,OS}} \quad (3)$$

IV. RESULTS AND DISCUSSION

The SAH thermal performance with air impingement jet double-pass with/without metal wire-mesh is tested experimentally under the climate conditions of Mansoura, Egypt (Latitude 31° 04′ N, Longitude 31° 21′ E). The mass flow rate of air in this study was changed from 0.0147 $kg.s^{-1}$ to 0.0201 $kg.s^{-1}$. The jet diameter was varied from 3 mm to 9 mm.

Figure 5 shows the hourly variation of the exit air temperature for IJDPSAH without/with wire mesh with solar radiation at certain air mass flow rate of 0.0147 $kg.s^{-1}$ and d_j = 3 mm air jet diameter. It is found that the maximum exit air temperature of IJDPSAH without/with steel wire mesh were 53.6 °C and 57.2 °C, respectively, and the maximum values of exit air temperature and the instantaneous solar radiation are recorded at 1 pm.

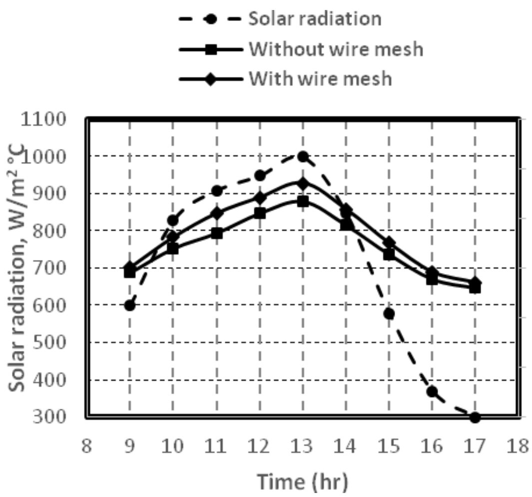


Fig. 5. Variation of solar radiation and outlet air temperature of IJDPSAH with/without metal wire mesh with time.

Figure 6 illustrates the thermal efficiency hourly variation for IJDPSAH without/with wire mesh with solar radiation at air mass flow rate of 0.0201 kg.s^{-1} and d_j = 3 mm air jet diameter. It is found that the maximum hourly thermal efficiency of IJDPSAH without/with steel wire-mesh and were 73.33%, 86.07%, respectively. Also, the solar radiation and maximum values of exit air temperature are recorded at 1 pm.

Fig. 6. Variation of solar radiation and thermal efficiency of IJDPSAH with/without metal wire-mesh with time.

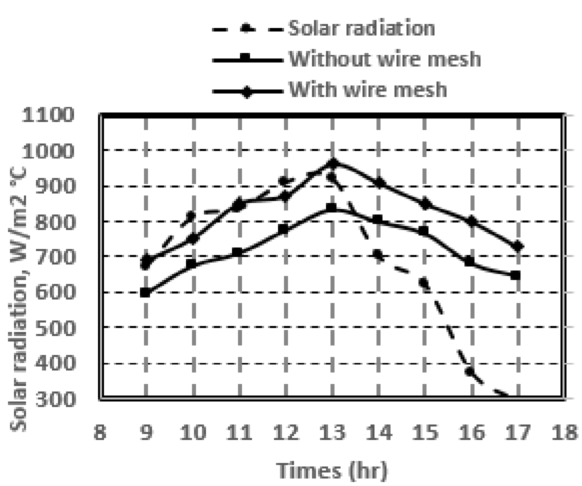


Fig. 6. Variation of solar radiation and thermal efficiency of IJDPSAH with/without metal wire-mesh with time.

Figure 7.a illustrates air mass flow rate influence on the temperature of exit air at 3 mm jet diameter for IJDPSAH with and without metal wire mesh. From this figure, the daily mean exit air temperature reduces with raising the air mass flow rate in IJDPSAH without/with wire mesh. The exit air temperature decreases from 46.95 °C to 44.01 °C with using wire mesh and from 44.55 to 42.22 °C without wire mesh when the mass flow rate rises from 0.0147 to 0.0201 kg.s^{-1}. It is concluded that the exit air temperature of the IJDPSAH with metal wire mesh is higher in comparison to that of IJDPSAH in case of without metal wire mesh.

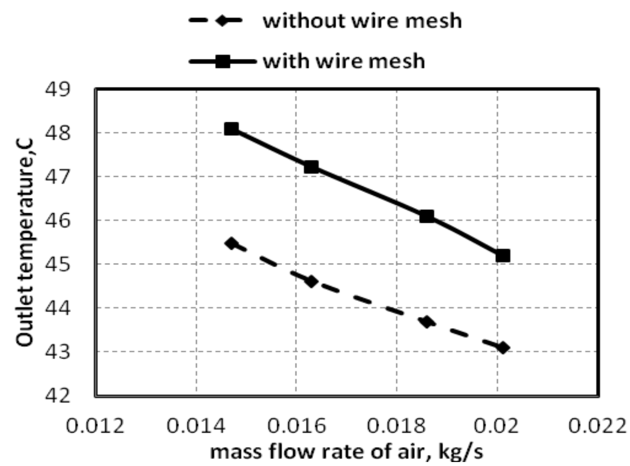


Fig. 7.a. Impact of mass flow rate on the outlet air temperature for IJDPSAH with/without wire mesh at 3 mm jet diameter.

Figure 7.b explains the impact of mass flow rate of air on solar air heater thermal efficiency at 3 mm jet diameter for IJDPSAH with and without metal wire mesh. The daily average thermal efficiency increases with increasing air mass flow rate through IJDPSAH with/without wire mesh. The efficiency increases from 60.85% to 72.33% with wire mesh and from 50.88% to 61.98% in case of without wire mesh when the rate of flow of air rises from 0.0147 to 0.0201 kg.s^{-1}. It is clear that IJDPSAH efficiency is higher with metal wire mesh as compared to the IJDPSAH without metal wire mesh.

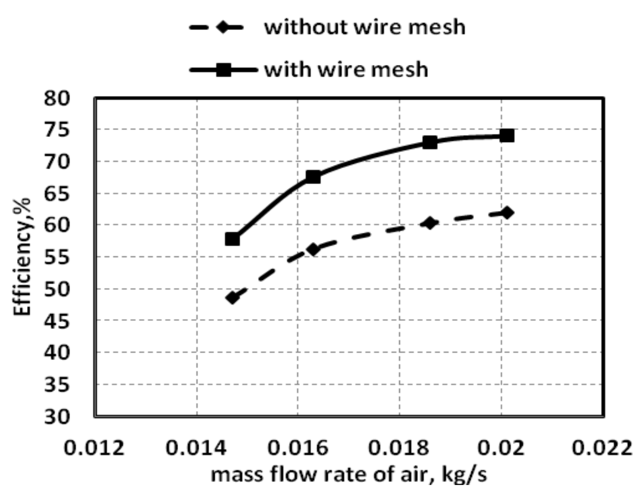


Fig. 7.b. Mass flow rate influence on efficiency of IJDPSAH with/without wire mesh at 3 mm jet diameter.

Figure 8.a illustrates the impact of mass flow rate of air on the temperature at the exit of SAH at 5 mm air jet diameter for IJDPSAH with and without metal wire mesh. From this figure, the daily mean exit air temperature reduces with raising mass flow rate of air through IJDPSAH with/without wire mesh. The exit air temperature decreases from 45.5 °C to 43.05 °C when using wire mesh and from 42.03 °C to 40.82 °C without wire mesh as the mass flow rate of air is varied from 0.0147 to 0.0201 kg.s^{-1}. It is clear that the exit air temperature of the IJDPSAH with using metal wire mesh is higher as compared to that of without metal wire mesh.

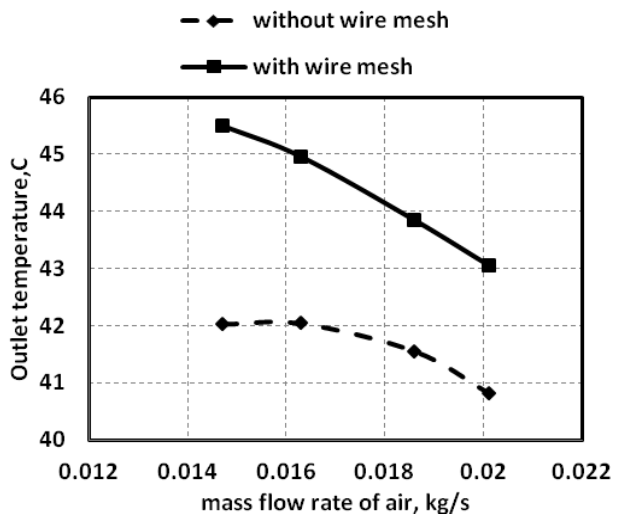


Fig. 8.a. Air mass flow rate influence on exit air temperature for IJDPSAH with/without wire mesh at 5 mm jet diameter.

Figure 8.b indicates the effect of mass flow rate of air on the solar air heater thermal efficiency at 5 mm air jet diameter for IJDPSAH with and without metal wire mesh. From this figure, the daily average efficiency increases with increasing air mass flow rate IJDPSAH with/without wire mesh. The thermal efficiency increases from 55.93 to 64.35% with wire mesh and from 41.36% to 51.31% without using wire mesh as the mass flow rate rises from 0.0147 to 0.0201 $kg.s^{-1}$. It is clear that the thermal efficiency of IJDPSAH with metal wire mesh is higher compared to that of without metal wire mesh.

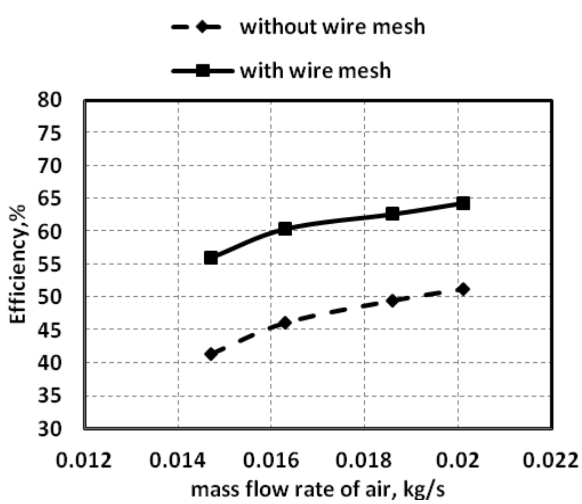


Fig. 8.b. Air mass flow rate influence on efficiency for IJDPSAH with/without wire mesh at 5 mm jet diameter.

Figure 9.a illustrates air mass flow rate influence on the exit air temperature at 7 mm jet diameter for IJDPSAH with and without metal wire mesh. From this figure, the daily mean outlet air temperature reduces with raising air mass flow rate IJDPSAH with/without wire mesh. The outlet air temperature decreases from 45.72 to 42.35 °C with wire mesh and from 42.65 to 40.16 °C without wire mesh when the mass flow rate increases from 0.0147 to 0.0201 $kg.s^{-1}$. It is concluded that the exit air temperature of the IJDPSAH with metal wire mesh is bigger when compared with that without metallic wire mesh.

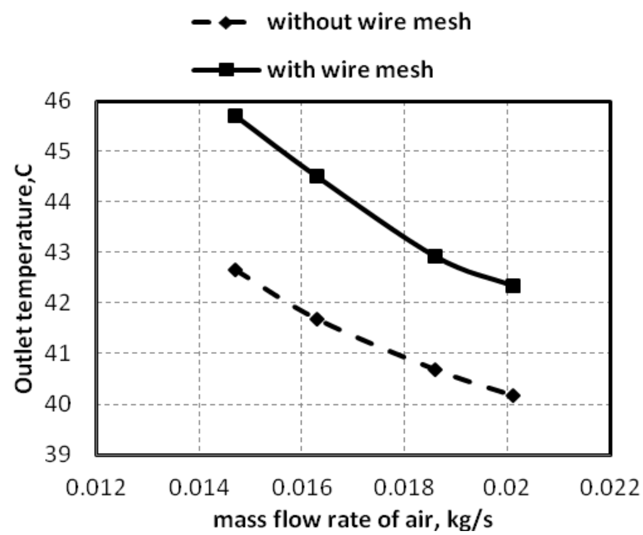


Fig. 9.a. Effect of mass flow rate on the outlet air temperature for IJDPSAH with/without wire mesh at 7 mm jet diameter.

Figure 9.b illustrates air mass flow rate influence on the thermal efficiency at 7 mm jet diameter for IJDPSAH with and without metal wire mesh. From this figure, the daily average thermal efficiency raises with raising air mass flow rate IJDPSAH with/without wire mesh. The thermal efficiency rises from 51.86 to 60.71% with wire mesh and from 39.42 to 48.21% without wire mesh when the mass flow rate rises from 0.0147 to 0.0201 $kg.s^{-1}$. It is concluded that the thermal efficiency of the IJDPSAH with metal wire mesh is higher when compared with that without metal wire mesh.

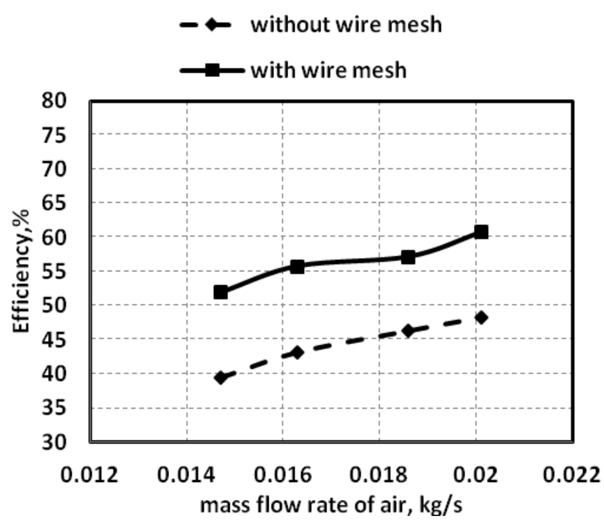


Fig. 9.b. Air mass flow rate influence on the efficiency for IJDPSAH with/without wire mesh at 7 mm jet diameter.

Figure 10.a illustrates air mass flow rate influence on exit air temperature at 9 mm jet diameter for IJDPSAH with and without metal wire mesh. From this figure, the daily mean exit air temperature reduces with increasing air mass flow rate IJDPSAH with/without wire mesh. The outlet air temperature

decreases from 43.82 to 42.46 °C with wire mesh and from 41.57 °C to 40.58 °C without wire mesh when the mass flow rate decreases from 0.0147 to 0.0201 $kg.s^{-1}$. It is concluded that the exit air temperature of the IJDPSAH with metal wire mesh is higher when compared to that without metal wire mesh.

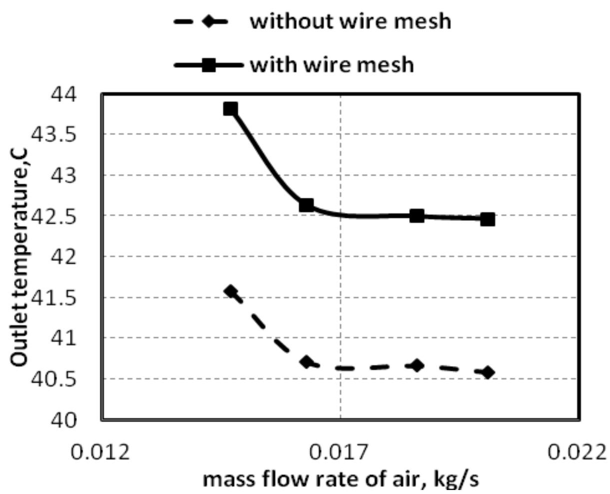


Fig. 10.a. Air mass flow rate influence on the outlet air temperature for IJDPSAH with/without wire mesh at 9 mm jet diameter.

Figure 10.b represents the effect of air mass flow rate on IJDPSAH thermal efficiency at 9 mm jet diameter with and without metal wire mesh. From this figure, the IJDPSAH daily average thermal efficiency increases with increasing mass flow rate of flowing air with/without metallic wire mesh. The exit air temperature decreases from 45.09 °C to 58.52 °C with wire mesh and from 36.48 to 46.11 °C without wire mesh when the mass flow rate increases from 0.0147 to 0.0201 $kg.s^{-1}$. It is concluded that the thermal efficiency of the IJDPSAH with metal wire mesh is higher when compared with that without metal wire mesh.

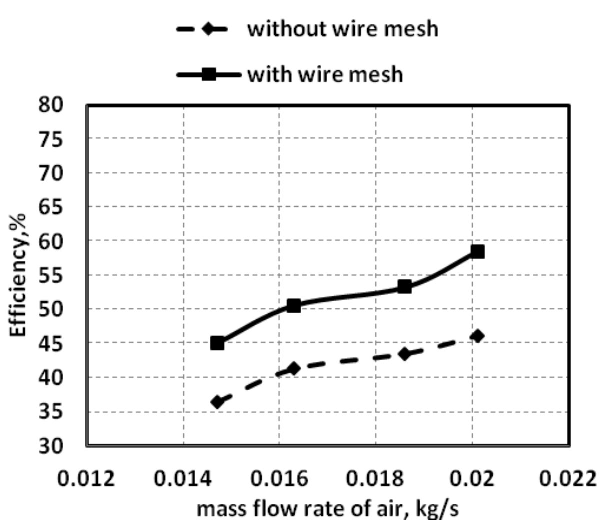


Fig. 10.b. Air mass flow rate influence on efficiency for IJDPSAH with/without wire mesh at 9 mm jet diameter.

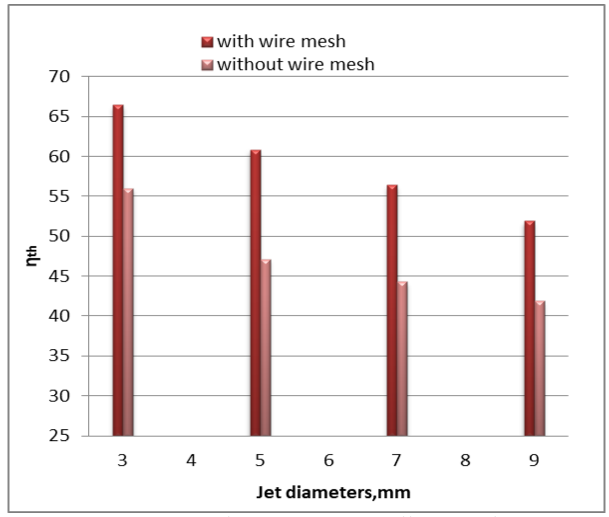


Fig. 11. Jet diameter influence on thermal efficiency of IJDPSAH with/without wire mesh.

Figure 11 illustrates the effect of jet diameter on thermal efficiency of IJDPSAH with/without wire mesh. This figure declared that IJDPSAH average daily thermal efficiency with metal wire mesh at 3 mm, 5 mm, 7 mm and 9 mm jet diameter is about 66.38%, 60.83%, 56.36%, 51.88%, respectively, compared to IJDPSAH without metal wire mesh which is about 55.96%, 47.09%, 44.26%, 41.85%, respectively.

V. CONCLUSION

The present experimental work investigated the effects of impinging jet holes diameters (3, 5, 7, 9 mm), and air mass flow rate (0.143-0.201 $kg.s^{-1}$) on air heater performance in cases of with and without wire meshes on the perforated absorber plate.

The conclusions of the present work are:

1. The metal wire mesh with impinging jet in the double pass solar air heater has a significant effect on SAH performance.
2. Increasing air mass flow rate led to increase the thermal efficiency and decrease the exit air temperature of the IJDPSAH.
3. Decreasing jet diameter led to increase the thermal efficiency and decrease exit air temperature of the IJDPSAH.
4. The maximum average daily thermal efficiency of the IJDPSAH with metal wire mesh is 72.33%, whereas the efficiency of the IJDPSAH without metal wire mesh is 62.96%, at 3 mm jet diameter and mass flow rate of air 0.0201 $kg.s^{-1}$.
5. The percentage increase in efficiency of the IJDPSAH with metal wire mesh at 3, 5, 7 and 9mm jet diameter is enhanced by about 18.70%, 29.48%, 27.53% and 23.89%, respectively, compared to IJDPSAH without metal wire mesh.

LIST OF SYMBOLS

A	Area of collector, (m^2)
C_p	Specific heat, (kJ/kg.K)
d_j	Jet hole diameter, (m)
I	Solar radiation, (W/m^2)
L	Length of heater, (m)
$\dot{m}$	Mass flow rate, (kg/s)
Q_u	Useful thermal energy, (W/m^2)
$T_{f,in}$	Inlet air temperature, (°C)
$T_{f,out}$	Outlet air temperature, (°C)
t	Thickness of heater, (m)
W	Width of heater, (m)
η_{th}	Thermal efficiency, (%)

ABBREVIATIONS

IJDPSAH	Impingement Jet, Double-Pass Solar Air Heater
SAH	Solar Air Heater
SPDDJPSAH	Single-Pass, Double Duct Jet Plate Solar Air Heater

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