JCARME
ISSN: 2228-7922
Journal of Computational and Applied Research in Mechanical Engineering
Vol. 8, No. 1, pp. 85-96
jcarme.sru.ac.ir

Evaluation of solar-chimney power plants with multiple-angle collectors

H. Hoseini and R. Mehdipour*

Department of Mechanical Engineering, Tafresh University, Tafresh, Iran

Article info:
Received: 02/02/2017
Accepted: 02/12/2017
Online: 10/04/2018

Keywords:
Solar-chimney power plant,
Renewable energy,
Collector,
Chimney.

Abstract
Solar chimney power plants are solar thermal power based plants, including three parts of collector, chimney, and turbine, which are able to produce electrical energy. One of the effective parameters in increasing the power production is the collector angles versus horizon. In the present study, a numerical analysis of a solar chimney power plant for different angles of the collector (divergent, convergent and horizontal type collector) is proposed. The introduced numerical model uses mathematical models of heat transfer. In this regard,the effect of various angles of the three considered collectors on temperature distribution and power production of the solar chimney is evaluated. Divergent type collectors produce more power than convergent and horizontal collectors, as they produce more velocity and mass flow rates. It is shown that increasing the angle of a divergent-type collector (keeping the inlet height constant) increases the power production and decreases the output temperature. The angle variation of 0.8 to 1 increases the divergent type collector output power by 11 % and decreases the output temperature by 0.78%. In the other case, when the output height is kept constant and the collector angle changes, the performance of the divergent type collector is better than the other two collectors. Power production in a constant mean height is shown to be 3 times and 1.5 times more than the convergent and horizontal collectors, respectively.

Nomenclature

A	Area (m^2)	**Greek symbols**	
c_p	Heat capacity (J/(kg.K))	α	Absorptivity thermal diffusivity (m^2/s)
d	Diameter (m)	ε	Emissivity
f	Friction coefficient	σ	Stefan – Boltzmann constant
g	Gravitational acceleration(m/s^2)	ρ	Density (kg/m^3)
h	Convection heat transfer coefficient (J/(m^2.K))	τ	Transmissivity
H	Height (m)	**Subscripts**	
I	Solar radiation (w/m^2)	a , air	Air
m	Mass flow rate (kg/s)	amb	Ambient
P	Pressure (Pa)	c	Collector

**Corresponding author*
email address: raminme56@gmail.com

P_e	Power output (w)
q	Heat transfer (J)
T	Temperature (K)
V	Velocity (m/s)
ch	Chimney
g	Ground
r	Radiation
sky	Sky

1. Introduction

Regarding the growing need for cheap and unlimited energy sources, renewable energies have been paid more attention during the last years. One of the main sources of renewable energies is the solar energy. The solar chimney was introduced firstly by J. Schlaich in late of 1970 [1]. Less than four years later, he outlined his ideas and theories in a conference [1]. hen in early 1980, a plant with a 194.6 m height and 10.08 m diameter chimney, and a 240 m diameter collector was built in Manzanares, Spain, which produced maximum power of 50 kW. Solar chimney includes three parts of a solar collector (including the energy storage layer in bottom), a chimney and a turbine. In this process, ambient cold air enters to the collector and warms during moving through the channel and its density decreases. Appeared pressure difference caused by the density difference of the warm air, inside the collector, and the local cold air leads the air to move towards the chimney. The employed turbine, at the entrance of the chimney, gets the kinetic energy of the airflow and converts it to the electrical energy. Then the airflow exits from the top of chimney by the created density difference and the chimney suction. Solar chimney has been worldly studied in many works. The main part of accomplished surveys related to the solar chimney is about the numerical analysis of flow field, system temperature distribution, and power production of the plant. In numerical analyses, the results were compared by results of the small created model or by present results in Manzanares, Spain [1]. Bernardes [1-4] presented a numerical and analytical model for explaining the performance of solar chimney and studied the effect of various ambient conditions and structural dimensions on the power output. Based on the results of their previous study, the factor of pressure drop at the turbine and collector diameter are important parameters for designing solar chimney. They employed results of their own made small model as well as the results of the Spain plant to verify their model. Tingzhen [5] developed a numerical analysis for the collector, turbine, and chimney and compared the results with those of Spain model and studied the effects of the turbine and its blades on the chimney efficiency. Petela [6] and Maia [7] in a mathematics model, attempted thermodynamic analyzing of the solar chimney system and its component performances based on energy and energy balance. Gannon [8] also performed thermodynamic analyses on the solar chimney collector. Sangi [9] solved the relations governing the solar chimney geometry in Manzanares by two numerical methods using a repetitive technique and fluent software, as well as applying $k - \varepsilon$ model to obtain velocity and temperature distributions. They studied the performance of a solar chimney power plant and estimated the quantity of the produced electrical energy in Iran in another paper [10]. Dai [11] and Larbi [12] studied the effects of parameters such as chimney diameter, chimney height and ambient temperature on the performance of the solar chimney power plant. Kasaeian [13, 14] studied simulation and optimization of the shape of solar chimney plant. They showed in an experiment model that the height and diameter of the chimney are the most important physical variables for solar chimney design. Also, they studied the effect of various ambient conditions on solar chimney efficiency. Moreover, Patel [15] studied the effect of geometric parameters on the performance of a solar chimney power plant. Koonsrisuk [16, 17] proposed a mathematical model for the solar chimney power plant in Thailand, and they investigated the factor of pressure drop at the turbine and dynamic similarity in solar chimney modeling. Gou [18, 19] numerically evaluated the optimal turbine pressure drop ratio. Zhou [20, 21] concentrated on the performance of solar chimney power plant in Tabbat plateau using a mathematical model. Their results showed that power production was more than twice of other places with the same latitude. They also presented the optimal chimney height based on preventing the making negative buoyancy and producing more power. Pretorius [22] studied the effect of various parameters on the performance of solar chimney such as quality of glasses used as the collector roof, turbine inlet loss coefficient, and various types of soils. Choi et. al [23], investigated performance of solar chimney analytically. They established a water storage system to conserve heat energy during the night. Coccic et al. [24] developed a one-dimensional compressible flow in a solar chimney power plant to obtain buoyancy force, velocity distribution, temperature, pressure and density variation at the collector as well as the chimney.

Some of the researchers [25-27] introduced a combined system for producing water and electricity. Zuo [25] concluded that the combined system can significantly increase the efficiency of solar energy.

Solar chimney has many advantages like the simple design, stable and trusted energy production, few moving parts, and consequently low maintenance and repair costs. The best advantage is producing electrical energy without polluting the environment. The most important objective in this field is increasing the produced power.

The previous arts in this field were mostly devoted to study the effects of geometrical parameters like collector diameter, height, and diameter of the chimney as well as some environmental parameters like ambient air temperature, soil type, and turbine pressure loss. In the present study, the effects of changes in collector geometry and angle variation of the collector are assessed.

To approach this objective, a good knowledge about the detailed performance of the solar chimney is required. In this regard, a numerical simulation based on a mathematical model of heat transfer is proposed in this study. The model is in the same dimensions to the Manzanares power plant. The angle of the collector respect to the horizon, as one of the efficient parameter in increasing the power production, is comprehensively assessed in this study. A multiple-angel collector is simulated in various states, and the effects of the angle on temperature distribution in the collector and power production of the solar chimney are discussed. Variety of angles which forms three different shapes of divergent, horizontal and convergent form collectors are evaluated from the aspects of power production and temperature. It is shown that the divergent type collector brings about more power compared to the convergent and horizontal ones (Fig. 1). In the present study, the effects of collector height on the amount of power production are investigated as well. Height increment at the inlet and outlet of the collector is shown to influence the power production and temperature distribution. It will be found that divergent-form collectors perform better than convergent and horizontal types.

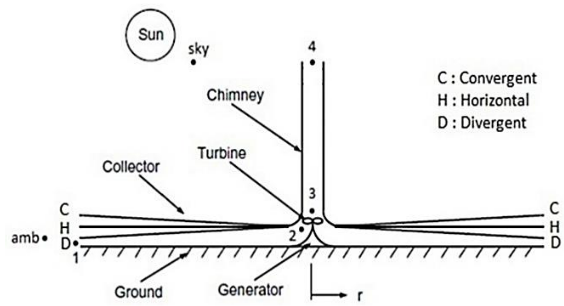

Fig. 1. Schematic of the solar chimney power plant with divergent, convergent and horizontal type collectors.

2. Mathematical modelling

In this section, a thermodynamic analysis on the system components, like the solar chimney, collector and turbine are introduced individually.

2.1. Governing equations on the collector

Heat transfer in a collector is an important and effective issue on the performance of a solar chimney. Collector determines the amount of heat transfer from roof to the ambient, from roof to the air flow in the collector and from the ground to the air flow in the collector, and the air is warmed during going through the collector. The flow in the collector can be laminar, transient, or turbulent. The following assumptions are considered in the solar collector:

1. The flow is steady.
2. The air follows the ideal gas law.
3. Vertical gradient of temperature in the collector is neglected.
4. Energy lost to the ground is neglected.
5. The Boussinesq approximation is valid.

Temperature, velocity, and pressure distribution are obtained by solving conservation of energy, momentum and mass equations. These equations are indicated for the air flow in the collector of the solar chimney and for a control volume of radius r to r+dr shown in Fig. 2. Also, energy equations are defined for the considered control volume based on the thermal network shown in Fig. 3.

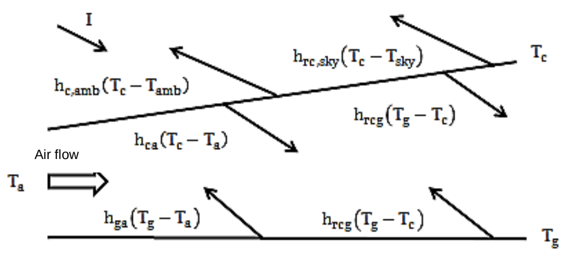

Fig. 2. Energy balance diagram in the control volume considered in the collector.

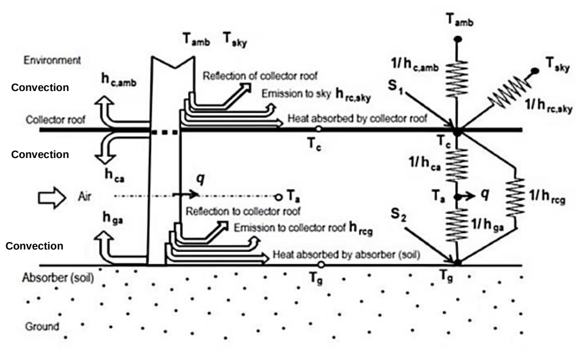

Fig. 3. Thermal network for solar chimney collector.

Energy balance equation (Eq. (1)) for the airflow indicates heat transfer between air flow in the collector, the roof of the collector and the ground [25].

$$A_g q_{ga} + A_c q_{ca} = c_p \dot{m}_{air}(T_2 - T_1) \qquad (1)$$

The following relation calculates mass flow rate [25]:

$$\dot{m}_{air} = \rho_a A V_a \qquad (2)$$

Density variations of the air flow inside the collector is calculated based on the Boussinesq approximation [6]:

$$\rho_a = \rho_{amb}\left(1 - \beta_{amb}(T_a - T_{amb})\right) \qquad (3)$$

$$\beta_{amb} = \frac{1}{T_{amb}} \qquad (4)$$

Energy exchange for the collector roof that shows energy absorption from the sun, its transfer to the inside of the collector, and its loss to the outside of the collector can be calculated from following relations [25]:

$$S_1 = q_{rc,sky} + q_{c,amb} + q_{ca} + q_{r,cg} \qquad (5)$$

The amount of the absorbed energy from the sun by the roof of the collector is:

$$S_1 = \alpha_c . I \qquad (6)$$

Mechanism of heat transfer between collector roof and airflow inside the collector is forced convection heat transfer that is calculated by:

$$q_{ca} = h_{ca}(T_c - T_a) \qquad (7)$$

Heat transfers between the ground and the air flow inside the collector is:

$$q_{ga} = h_{ga}\left(T_g - T_a\right) \qquad (8)$$

Heat transfer between the collector roof and the ambient air is:

$$q_{c,amb} = h_{c,amb}(T_c - T_{amb}) \qquad (9)$$

The forced convection heat transfer coefficient of ambient air is calculated according to the relation used in Ref. [25]. For calculating the heat transfer coefficients of the collector, the governing equations for the flat plate with constant heat flux can be used. Equations are introduced in two categories of laminar and turbulent flows by relations used in Refs. [3, 28] The radiation heat transfer between the collector roof and ambient air can be calculated as follows:

$$q_{rc,sky} = \varepsilon\sigma\left({T_c}^4 - {T_{amb}}^4\right) \quad (10)$$

The contribution of radiation heat transfer, between the collector roof and the ground, can be obtained as the following relation:

$$q_{r,cg} = \varepsilon\sigma\left({T_c}^4 - {T_g}^4\right) \quad (11)$$

The energy exchange of the ground is calculated by Eq. (12), which includes the amounts of received transmission energy from the collector surface and the amount of transfer to the air content of the collector and its exchange with collector surface [25].

$$S_2 = q_{ga} + q_{r,cg} \quad (12)$$

The amount of received radiation by the ground is:

$$S_2 = \alpha_g \tau_c I \quad (13)$$

Bernoulli equation governing on the collector is as follows:

$$P_1 + \frac{\rho_1 V_1^2}{2} = P_2 + \frac{\rho_2 V_2^2}{2} \quad (14)$$

2.2 Governing equations in the turbine

The mounted turbine at the entrance of the chimney turns the kinetic energy of the crossing air through the chimney to the electrical power. The process in the turbine is assumed to be isentropic [9]. The power production in the turbine is calculated from the following relation [6]:

$$P_e = c_p \dot{m}_{air}(T_2 - T_3) \quad (15)$$

Due to the isentropic assumption and ideal gas assumption for the air the following relation can be employed (See Fig. 1):

$$\frac{P_3}{P_2} = \left(\frac{T_3}{T_2}\right)^{\gamma/\gamma-1} \quad (16)$$

2.3 Governing equations in the chimney

Chimney turns the thermal energy in the collector to the Kinetic energy. The created density difference in the system caused by increased temperature leads to the pressure difference and driving force for driving the turbine and natural suction. Chimney walls assumed adiabatic. Governing pressure equation in the chimney can be written as:

$$P_3 = P_4 + \rho_3 g H_{ch} + \Delta P_f \quad (17)$$

ΔP_f is the frictional loss within the chimney that is indicated as below:

$$\Delta P_f = f \frac{\rho H_{ch}}{d_{ch}} \frac{V^2}{2} \quad (18)$$

f denotes the friction coefficient of the chimney wall, which is calculated by the relations used in Ref. [1]
The pressure at the outlet of the chimney is obtained by the following relation:

$$P_4 = P_{amb} - \rho_{amb} g H_{ch} \quad (19)$$

3. Solution algorithm

The given equations in the previous section are non-linear. Values related to temperature in different points and power production can be obtained by using the repetitive algorithm and initial estimations for temperature and mass flow rate in different parts of the system. P_3 and P_4 are achieved using the chimney equations. The velocities at points 1-4 (shown in Fig. 1) is obtained by continuity equation. Its solution flowchart is given in Fig. 4. Dimensional and physical characteristics used in this model are given in Table 1 and 2, respectively.

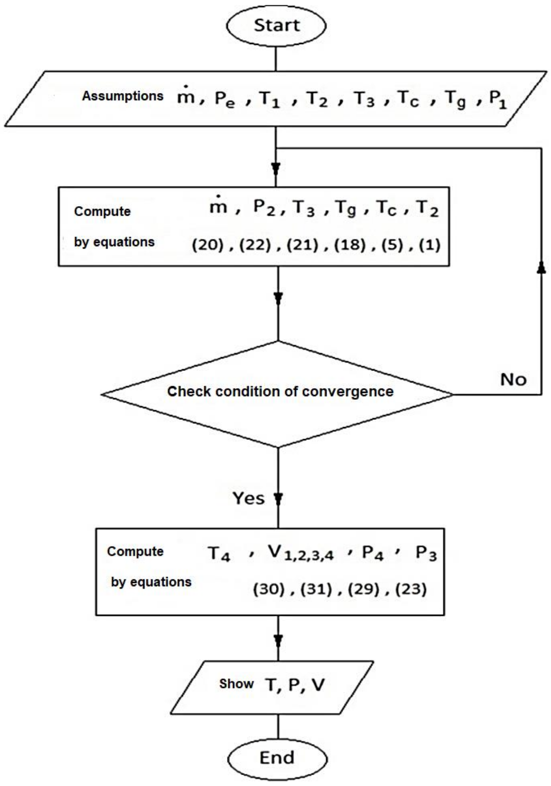

Fig. 4. Solution algorithm flowchart.

Table 1. Used physical properties in modelling.

Solar radiation (W/m^2)	1000
Ambient pressure (Pa)	101325
Ambient temperature (K)	293
Prandtl number	0.712
Gravitational acceleration(m/s^2)	9.81
Ambient air density (kg/m^3)	1.151
Ideal gas constant	287
Air conductivity (W/(m.K))	0.0263
Collector roof absorptivity (α_c (m^2/s))	0.15
Ambient air velocity (m/s)	3
Air viscosity	18.65×10^{-6}
Collector roof emissivity	0.87
Stefan – Boltzman constant (σ)	5.667×10^{-8}
Ground absorptivity (α_g (m^2/s))	0.9
Collector transmissivity (τ_c)	0.85
Heat capacity (J/(kg.K))	1005

Table 2. Employed dimensional features in modelling the divergence, convergence and horizontal collectors.

Parameter	Divergent	Horizontal	Convergent
Collector radius (m)	120	120	120
Mean Collector height (m)	1.802	1.802	1.802
Chimney radius (m)	5.08	5.08	5.08
Chimney height (m)	194.6	194.6	194.6
Teta (degree)	1.1	0	1.1
Collector outlet Height (m)	2.955	1.802	0.65

4. Model verification

The model verification is accomplished using results of Sangi [9], Dhahri [29] and Huang [30]. In this regard, the air temperature at the collector outlet, the velocity at the chimney inlet and the temperature distribution through the collector are compared to the corresponding results of the Manzanares solar chimney power plant, Sangi [9], Dhahri [29] and Huang [30].
Comparisons between results of the present study for the divergent type collector with similar works in the literature are shown in Figs. 5 and 6.

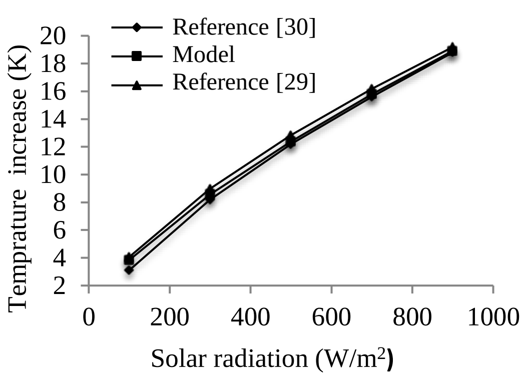

Fig. 5. Effects of solar radiation on the temperature increment in the divergent-type collector (Comparison between the present results and those of Dhahri [29] and Huang [30]).

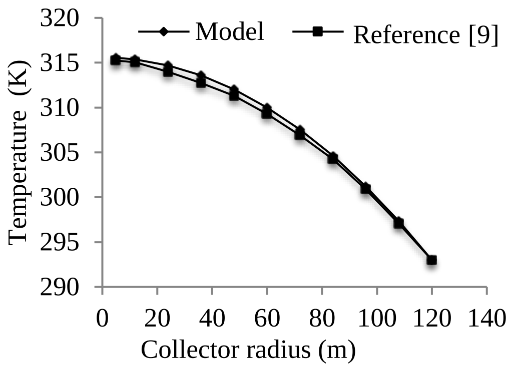

Fig. 6. Temperature distribution in the divergent type collector (comparison with results of Sangi [9]).

4.1. Mesh independency

Effects of the number of elements used in the collector model on the obtained results should be considered. The outlet temperature of the collector is employed as the criterion. By increasing number of elements, the outlet temperature varies, the variation continues up to element number of 400. Furthermore, elements don't influence the obtained temperature. Fig. 7 shows the effects of numbers of elements in the collector on the collector outlet temperature.

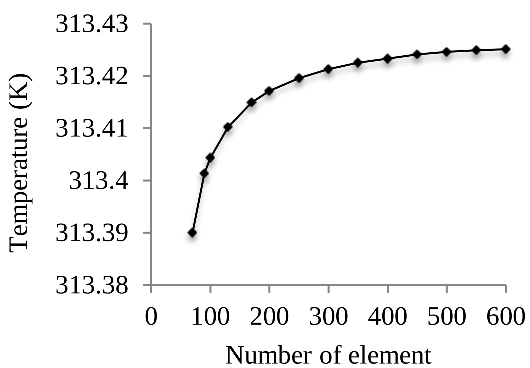

Fig. 7. Influence of number of independent elements in divergent type collector on the collector outlet temperature.

5. Results and discussion

Fig. 8 shows influences of roof angle of a divergent type collector with constant inlet height on collector outlet temperature and power production in the turbine, for radiation 1000 W/m^2. As can be seen in the figure, when the roof angle of the collector increases the collector outlet temperature decreases, and since the collector outlet height is going to be higher by increasing the angle, the area increases leading to decreased temperature. Increasing the roof angle of the collector, also leads to more power production in the turbine, since the mass flow rate and the velocity increase at chimney entrance.

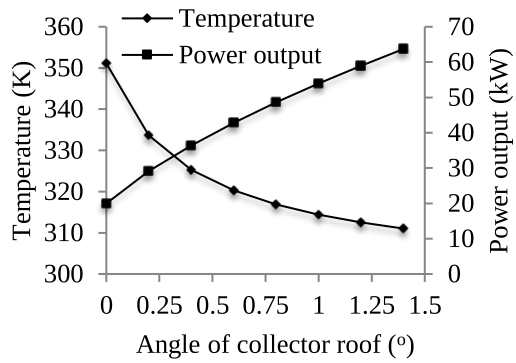

Fig. 8. Effect of roof angle of a divergent- type collector with constant inlet height on collector outlet temperature and power output in the turbine.

Variations of the outlet temperature for the various solar radiations are plotted for the three types of collectors (convergent, divergent and horizontal type), with constant mean height, in Fig. 9.

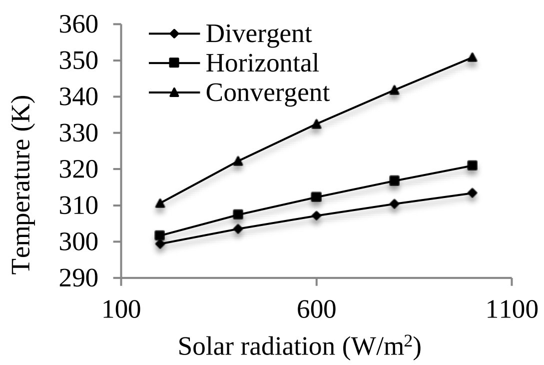

Fig. 9. Temperature at the collector outlet versus solar radiation, for mean collector height of 1.802 m.

As can be found from the figure, increasing the solar radiation may enhance the outlet collector temperature by absorbing more thermal energies. But in convergent type collector, the temperature increase is more because of less area. Power productions in the turbine for the variety of solar radiations are demonstrated for the three types of collectors, with constant mean height, in Fig. 10. As the figure shows, the power production increases with solar radiation, since thermal absorbing and collector outlet temperature increase, the temperature difference between the chimney base and the chimney outlet is more. Then the buoyancy force is more and air flow velocity in the system increases leading to moving of the turbine blades. It can be found from the figure that the power production in the divergent type collector is more since the mass flow rate and velocity at the chimney entrance are higher.

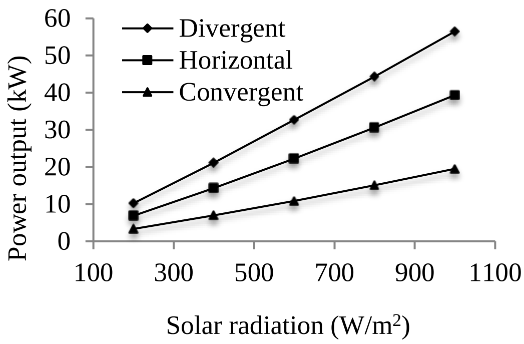

Fig. 10. Effects of solar radiation on the power output in the turbine, for mean collector height 1.802 m.

Fig. 11 shows the temperature distribution of the airflow passing through the collector for roof angle of 1.1° and radiation of 1000 W/m^2. As can be observed in the figure, the temperature of the air, passing through the collector, increases with more absorbed radiation.

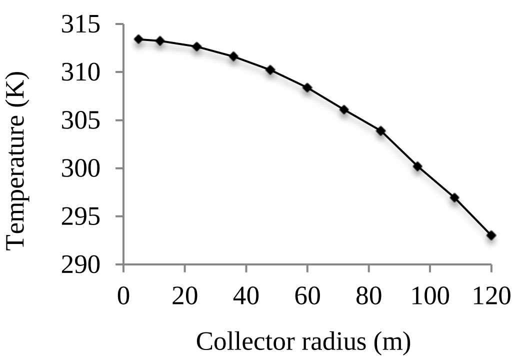

Fig. 11. Temperature distribution of the airflow passing through the collector.

Fig. 12 shows the effects of roof angle (divergent, convergent, and horizontal) on the turbine power production for radiation of 1000 w/m^2 and collector outlet constant height of 2 m. As explained before, temperature increasing level in the divergent type collector is more than the two other types. Therefore, the suction level and the turbine power production is more.

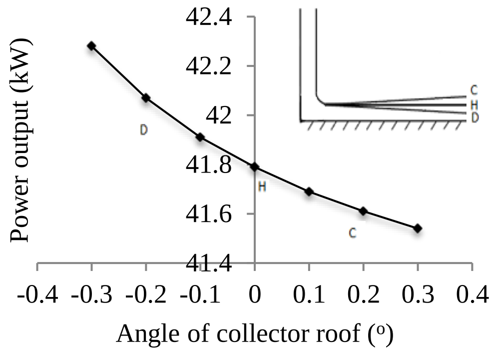

Fig. 12. Effects of the roof angle (divergent, convergent, horizontal) on the turbine power production for constant height of collector outlet.

Effects of collector roof angle (divergent, convergent and horizontal) on the air temperature at the collector outlet are shown in Fig. 13. The figure is plotted for the constant outlet height and radiation of 1000 W/m^2.

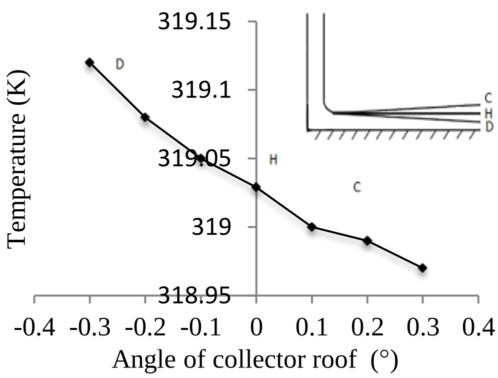

Fig. 13. Effects of collector roof angle (divergent, convergent and horizontal) on the air temperature at the collector outlet, for the constant outlet height .

As can be seen in the figure, the temperature variation is low because of constant outlet height. Although the temperature in the divergent type collector is more than two other forms which is due to the lesser outlet area and consequently the more air velocity.

Fig. 14 shows the effects of collector roof angle (divergent, convergent and horizontal) on the turbine power production for constant inlet height of 2m and radiation of 1000 W/m^2. Mass flow rate, as well as the velocity at the chimney entrance in the divergent type collector, is more than two other states, so the power production and the suction level increases.

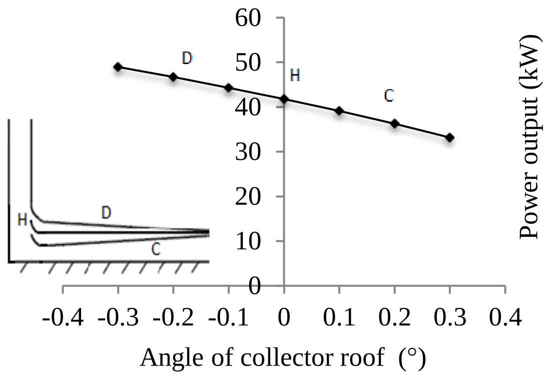

Fig. 14. The effects of collector roof angle (divergent, convergent and horizontal) on the turbine power production for the constant inlet height.

Effects of collector angle (divergent, convergent and horizontal) on the outlet air temperature of collector for constant inlet height and radiation power of 1000 W/m^2 is shown in the Fig. 15. As can be seen, the temperature variation is significant due to the alteration of outlet height. The temperature of divergent type is more than the horizontal (zero degrees) and the convergent type collector, as it has less outlet surface and, in consequence, more air flow velocity.

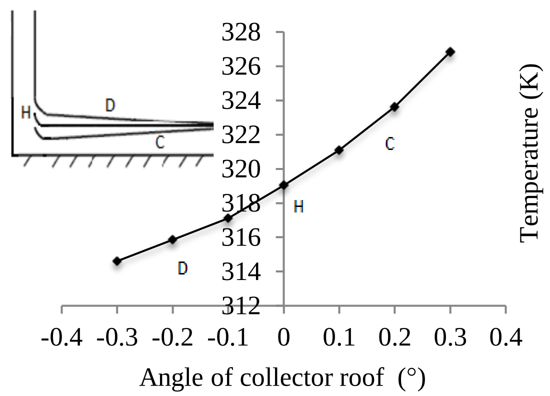

Fig. 15. The effects of collector angle (divergent, convergent and horizontal) on the outlet air temperature of collector for the constant inlet height.

Some conclusions can be remarked based on the above discussions as follows:

1. The performance of the divergent type collector is better than the two other forms, due to higher amounts of mass flow rate and power production. Power production in the divergent type collector is 3 and 1.5 times more than the convergent and the horizontal collectors, respectively.
2. Since the divergent type collector has better performance than the convergent and the horizontal collectors, the effects of angle increment in the divergent type collector for constant inlet height is investigated. In this case, the more the angle, the more the power production may be achieved; in a way that within the angle variation from 0.8° to 1°, the power production increases by 11%.
3. The results are obtained based on three states for the collector: constant inlet height, constant mean height and constant outlet height :

- In the divergent type collector with constant inlet height, when the angle increases, the temperature decreases and the power production increases as mass flow rate increases in a way that within an angle variation from 0.8° to 1° the outlet temperature decreases by 0.78% and the power outlet increases by 11%.
- For the constant mean height of the collector, if the receiving radiation increases, outlet temperature in the convergent type collector is more than the two others, and the power production in the divergent type collector is more than the two other forms. So increasing the radiation from 800 W/m^2 to 1000 W/m^2 enhances the temperature in the convergent type collector by 2.63% and the power production in the divergent type collector by 21.59%.
- For the constant inlet height of the collector, because of more outlet height than the two other types, if the collector angle of divergent type increases, the produced power is more and the collector outlet temperature is lesser than the two other cases. While by increasing the angle of the convergent type collector, because of lesser outlet height compared to the other two cases, the produced power decreases and the collector outlet temperature increases. For

the produced power decreases and the collector outlet temperature increases. For angle variation of 0.1° to 0.2° in the divergent type collector, the outlet temperature decreases by 0.46% and the power output increases by 5.37%. In the convergent type collector, the former increases by 0.79% while the latter decreases by 7.34%.

6. Conclusions

The performance of the solar chimney power plant for three types of divergent, convergent and horizontal collectors is comprehensively assessed in this study. In this regard, an inclusive mathematic model is proposed for thermal simulation of the turbine, the collector and the chimney. The governing equations are solved numerically.

1. The results reveal that the performance of the divergent collector is higher than the two other types since it has more mass flow rate.
2. The outlet air temperature of the divergent collector and turbine production power are obtained 313.4K and 56.5kw, respectively, for the radiation power of 1000 W/m^2.
3. Due to the better performance of the divergent type collector, effects of angle increasing in the divergent collector for constant inlet height are studied. In this case, the production power is found to be intensified when the angle increases.
4. The results are obtained based on three cases namely constant inlet height, constant mean height and constant outlet height of the collector. In the divergence collector with constant inlet height, when the angle increases, the temperature decreases and the produced power increases due to higher mass flow rates. For the case of constant mean height of the collector, when the receiving solar radiation increases, the outlet temperature in the convergent collector is higher than the other forms, in contrast, the produced power of the divergent collector is higher than two other forms. For the case of constant outlet collector height, the temperature and produced power in the divergent collector is higher than the other forms, but the difference is not significant in comparison with previous cases.

Reference

[1] M. A. Bernardes, A. Vob, G. Weinrebe, “Thermal and technical analyses of solar chimneys”, *Solar Energy* Vol. 75, pp. 511-524, (2003).

[2] M. A. Bernardes, “Convective heat transfer coefficients for solar chimney power plant collectors”, *Heat transfer-Mathematical modelling, Numerical Methods and Information Technology*, Prof. Belmiloudi A, (2011).

[3] M. A. Bernardes, T. W. von Backstrom, D. G. Kroger, “Analysis of some available heat transfer coefficients applicable to solar chimney power plant collectors”, *Solar Energy* Vol. 83, No. 2, pp. 264-275, (2009).

[4] M. A. Bernardes, T. W. von Backstrom, “Evaluation of operational control strategies applicable to solar chimney power plants”, *Solar Energy* Vol. 84, No. 2, pp. 277-288, (2010).

[5] M. Tigzhen, L. Wei, X. Guoling, X. Yanbin, G. Xuhu, P. Yuan, “Numerical simulation of the solar chimney power plant systems coupled with turbine”, *Renewable Energy* Vol. 33, No. 5, pp. 897-905, (2008).

[6] R. Petela, “Thermodynamic study of a simplified model of the solar chimney power plant”, *Solar Energy* Vol. 83, No. 1, pp. 94-107, (2009).

[7] C. B. Maia, J. O. Castro Silva, L. Cabezas-Gomez, S.M. Hanriot, A. G. Ferreira, “Energy and exergy analysis of the airflow inside a solar chimney”, *Renewable and Sustainable energy reviews* Vol. 27 pp. 350-361, (2013).

[8] A. J. Gannon, T. W. von Backstrom, “Solar chimney cycle analysis with system loss and solar collector performance”, *Solar energy engineering*, pp. 122-133, (2000).

[9] R. Sangi, M. Amidpour, B. Hosseinizadeh, “Modelling and numerical simulation of solar chimney power

plants", *Solar Energy*, Vol. 85, No. 5, pp. 829-838, (2011).

[10] R. Sangi, "Performance evaluation of solar chimney power plant in Iran", *Renewable and Sustainable energy reviews* Vol. 16, No. 1, pp. 704-710, (2012).

[11] Y. J. Dai, H. B. Huang, R. Z. Wang, "Case study of solar chimney power plants in Northwestern regions of China", *Renew Energy* Vol. 28, no. 8, pp. 1295-1304, (2003).

[12] S. Larbi, A. Bouhadjar, T. Chergui, "Performance analysis of a solar chimney power plant in the southwestern region of Algeria", *Renewable and Sustainable energy reviews* Vol. 14, No. 1, pp. 470-477, (2010).

[13] A. Kasaeian, M. Ghalamchi, M. Ghalamchi, "Simulation and optimization of geometric parameters of a solar chimney in Tehran", *Energy Conversion and Management* Vol. 83, pp. 28-34, (2014).

[14] A. Kasaeian, E. Heidari, Sh. Nasiri Vatan, "Experimental investigation of climatic effects on the efficiency of a solar chimney pilot power plant", *Renewable and Sustainable energy reviews*, (2011).

[15] S. K. Patel, D. Prasad, M. R. Ahmed, "Computational studies on the effect of geometric parameters on the performance of a solar chimney power plant", *Energy conversion and Management*, Vol. 77, pp. 424-431, (2014).

[16] A. Koonsrisuk, T. Chitsomboon, "Mathematical modeling of solar chimney power plants", *Energy* Vol. 51, pp. 314-322, (2013).

[17] A. Koonsrisuk, T. Chitsomboon, "Dynamic similarity in solar chimney modelling", *Solar Energy* Vol. 81, No. 12, pp. 1439-1446, (2007).

[18] P. Gou, J. Li, Y. Wang, Y. Liu, "Numerical analysis of the optimal turbine pressure drop ratio in a solar chimney power plant", *Solar Energy* Vol. 98, pp. 42-48, (2013).

[19] P. Guo, J. Li, Y. Wang, Y. Wang, "Evaluation of the optimal turbine pressure drop ratio for a solar chimney power plant", *Energy Conversion and Management*, Vol. 108, pp. 14-22, (2016).

[20] X. Zhou, F. Wang, J. Fan, RM. Ochieng, "Performance of solar chimney power plant in Qinghai-Tibet Plateau", *Renewable and Sustainable energy reviews* Vol. 14, No. 8, pp. 2249-2255, (2010).

[21] X. Zhou, J. Yang, B. Xiao, G. Hou, F. Xing, "Analysis of chimney height for solar chimney power plant", *Thermal Engineering*, (2008).

[22] J. P. Pretorius, D. G. Kroger, "Critical evaluation of solar chimney power plant performance", *Solar Energy* Vol. 80, No. 5, pp. 535-544, (2006).

[23] Y. J. Choi, D. H. Kam, Y. W. Park, Y. H. Jeong, "Development of analytical model for solar chimney power plant with and without water storage system", *Energy*, Vol. 112, pp. 200-207, (2016).

[24] A. S. Cocic, V. D. Djordjevic, "One dimensional analysis of compressible flow in solar chimney power plants", *Solar Energy*, Vol. 135, pp. 810-820, (2016).

[25] L. Zuo, Y. Zheng, Z. Li, Y. Sha, "Solar chimneys integrated with sea water desalination", *Desalination* Vol. 276, No. 1, pp. 207-213, (2011).

[26] X. Zhou, B. Xiao, W. Liu, X. Guo, J. Yang, J. Fan, "Comparison of classical solar chimney power system and combined solar chimney system for generation and seawater desalination", *Desalination*, Vol. 250, No. 1, pp. 249-256, (2010).

[27] N. Niroomand, M. Amidpour, "New combination of solar chimney for power generation and seawater desalination", *Desalination and Water Treatment*, Vol. 51, pp. 7401-7411, (2013).

[28] J. P. Holman, *Heat transfer*, 10th ed, McGraw-Hill, New York, pp. 247-248, 236.

[29] A. Dhahri, A. Omri, J. Orfi, "CFD modelling of a solar chimney power plant", *International Congress on Renewable Energies and the*

Environment, (2012).
[30] H. Huang, H. Zhang, Y. Huang, F. Lu, "Simulation calculation on solar chimney power plant system", *International conference on power engineering*, pp. 1158-1161, (2007).

How to cite this paper:

H. Hoseini and R. Mehdipour, "Evaluation of solar-chimney power plants with multiple-angle collectors" *Journal of Computational and Applied Research in Mechanical Engineering*, Vol. 8, No. 1, pp. 85-96, (2018).

DOI: 10.22061/jcarme.2017.2282.1213

URL: http://jcarme.sru.ac.ir/?_action=showPDF&article=772