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Research paper

The Effect of Solar Chimney Dimensions on its Performance in Nasiriya City Weather Conditions

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Abstract

In this study, a numerical study was carried out on the effect of the solar chimney dimensions on its performance. Five different models of solar chimney were studied in terms of the diameter of the solar collector, the height of the air intake entrance of the collector and the height of the solar chimney. The five models were compared with others according to the conditions surrounding the solar chimney. The study showed that the increase in the dimensions of the solar chimney increases the utilized energy and the external air velocity is inversely proportional to the performance of the solar chimney due to increasing the thermal losses from the collector. The results showed also that increasing the temperature of the ambient air and the solar radiation increases the performance and productivity of the solar chimney. The analytical results of this paper were compared with previous literature studies and showed a great convergence between them.

Keywords: *Solar energy, Chimney, performance, efficiency.*

1. Introduction

Due to world development in the last 20 years, the demand of energy increasing day by day. Different energy sources might have a significant role to play in the production of electricity has been adopted. Generally, solar energy can be consider inexhaustible energy resource and economic. A solar chimney is one important technique which represent the passive solar heating and cooling system. Kiwan et al.(2018) [1] presented study of produces distilled water and generates electricity by using new solar chimney power distillation plant (SCPWDP). Effects of the collector material type,the depth and the area of water in the water section, and the height of the collector at the entrance have been numerically investigated. The results indicated that each surface area of the water section there is an optimum value of water depth, and reducing in the rate of water production beyond this value. Also the authors concluded the capability of the SCPWDP togenerate electricity of 9.95 kWh/m2 and distilled water of2.43 tons/m2 at a location in Jordan. The influence of the chimney shape on the solar chimney power plant improvement was studied by Bouabidi et al.(2018) [2]. Chimney power plants with: divergent, standard, opposing chimney and convergent have been used based on velocity fields, the static pressure, the temperature distribution and the magnitude velocity. They found that highest velocity occurs with divergent configuration in compared with other type due to the chimney configuration change resulted by the static pressure distribution. Najm andShaaban (2018)[3] conducted optimization and numerical investigation of the solar chimney power intensity under different operating conditions. The CFD code of finite volume ANSYS Fluent was used with discrete or donates (DO) radiation model. The research findings denoted that increasing in collector radius leads to increases in the energy transfer to the air where the optimum radius ofcollector was 17 times the chimney radius for an irradiance of 500 W/m2 and 160 Pa turbine pressure drop. Two types of experiments on solar chimney (SC) performancewith and without phase change material were investigated by Fadaei et al.(2018) [4]. According to the achieved results found enhance the thermal efficiency of the solar chimney SC by using paraffin wax. In their study, a good agreement was observed between experimental data with numerical results.

Neves and Silva (2018) [5] have experimental and numerical study on the effects of wind movement for a solar chimney performance with changed state of wind direction and speed, over a base of case model. Both influence of wind-driven natural ventilation and buoyancy on the a solar chimney performance were carried out where major drop in the chimney volumetric flow rate was detected due to wind direction opposite to the inlet vent, at low velocities too, such as 0.6 m/s. Currently, the researchers have been conducted some projects about combine a solar desalination and solar chimney system such as Asayeshet al.(2017) [6]. The results appearance that at the collector inlet between radii 125and 85m represented the best performance desalination system. Also they found considering local rates by most efficient economic output with adopted configuration. Four kinds of influencing factors on the solar chimney performance represented by configuration, material usages, installation conditions, and environment are studied by Shi et al. (2018) [7]. They proposed with solar radiation and high cavity, a gap of cavity of 0.2–0.3 m, equal outlet and inlet, a height/gap ratio of around 10, an inclination angle of 45–60°. Improve the performance of solar chimney found with both the emissivity and absorptivity of solar absorber materials while the absorptivity appears to be wide significant. With replacing chimney outlet/inlet area ratios (COAR, representing the degree of divergence) over a large range of values for solar power plants of divergent-chimney (DSPPs) are simulated by Xu and Zhou (2018)[8]. The temperature significantly reductions above the boundary layer

separation point with decrease of buoyancy of the divergent chimney due to the reverse flow from the ambient cool air as COAR is large. Solar double chimney power plant (SDCPP) are numerically studied by Caoet al.(2017) [9] where employed Mathematical models of the SDCPP. They found that the producedpower of the SDCPP is 1.59 times higher than that of the CSCPP and 2.77 times greater than that of the SSCPP. Hosseini et al. (2017) [10] have numerically study on the natural convection solar air heater with longitudinal rectangular fins of the performance of solar chimney where three-dimensional domain based on the finite volume method and steady state condition used to discretize the equations. It is observed that improve thermal efficiency and heat transfer occurred with increasing in number of fins at a constant width of the collector.For production of fresh water and electricity,integration of sea water desalination with new solar chimney power system studied by Lu Zuo et al. (2011)[11]. The results revealed to the economic benefit where crude salt may be another productin addition to the fresh water production and power generation.
The present study introduces an insight numerical simulation based on influence diameter and height of solar chimney on thermal performance.

2. Mathematical Model

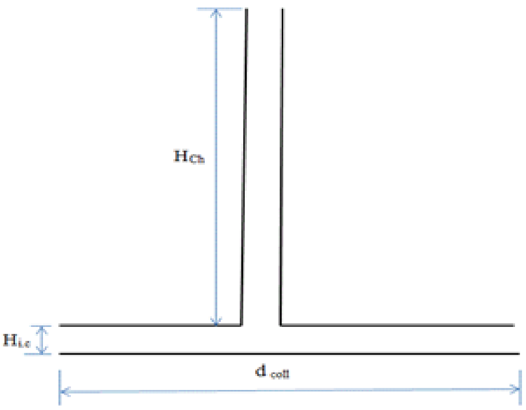

Fig. 1: the mathematical model

The collector efficiency can be estimated [12]:

$$\eta_{coll} = \alpha - L\frac{\Delta T}{G} \quad (1)$$

α= effective absorption coefficient.
$\Delta T = T_c - T_a$
G=solar irradiance (W/m^2)
Convective heat transfer coefficient(L)[13]:

$$L = 2.8 + 3\ V_a \quad (2)$$

Neglected radiation energy between ambient and collector.
Neglected any loss in solar collector.

Properties of air[14]:
Density:

$$\rho_{air} = 1.1614 - 0.00353(T_a - 300) \quad (3)$$

Specific Heat

$C_P = [1.0($ … $)$

Thermal conductivity:

$K_{air} = 0.0$ … 5)

Dynamic viscosity

$\mu = [1.846$

$$Ra = Gr \times Pr = \frac{g \times \beta (T_s - T_m) \times d_h^3}{v^2} \times Pr \quad (6)$$

The coefficient of volumetric thermal expansion(β) can be found from:

$$\beta = \frac{1}{T_m} \quad (7)$$

d_h = The hydraulic diameter.
It can be found by [16]:

$$d_h \cong H_{i.c} \quad (8)$$

$H_{i.c}$= Height of inlet solar collector
The Nusselt number can be represented by [16] :

$$Nu_m = 0.54 \times Ra^{0.25} \quad \text{for} \quad 2\times10^4 < Ra < 8\times10^7 \quad (9)$$

$$Nu_m = 0.15 \times Ra^{0.33} \quad \text{for} \quad 8\times10^7 < Ra < 8\times10^{11} \quad (10)$$

Where :
$\Delta P_{ch.}$ =The pressure developed in chimney is calculated from equation [17]:

$$\Delta P_{ch.} = g \times H_{Ch.} \times (\rho_{i.c} - \rho_{e.c}) \quad (11)$$

The maximum air inlet velocityto chimney (without any turbines) is computed by [18]:

$$U_{max.} = \sqrt{\frac{2\ X \Delta P_{ch.}}{\rho_{e.c}}} \quad (12)$$

The power output of solar chimney power plant can be found as [19] :

$$Power = \Delta P_{ch.} \times U \times A_c \quad (13)$$

3. Boundary Conditions

Model 1 ($d_{coll.}$=15,$H_{ch.}$=35,$d_{Huderolic}$=0.3).
Model 2 ($d_{coll.}$=25,$H_{ch.}$=50,$d_{Huderolic}$=0.4).
Model 3 ($d_{coll.}$=50,$H_{ch.}$=75,$d_{Huderolic}$=0.5).
Model 4 ($d_{coll.}$=60,$H_{ch.}$=85,$d_{Huderolic}$=0.6).
Model 5 ($d_{coll.}$=75,$H_{ch.}$=100,$d_{Huderolic}$=0.7).
Efficiency of collector= 80%.

4. Results and Discussion

The power producedby solar chimney power plant with ambient air velocity are presented in Figure 2 for five models. It can be seen that decreases in power output of solar chimney power plant with increases in ambient air velocity for different models where the Maximum power of solar chimney power plant observed at model 5 due to increases in length and diameter of chimney in compared with other models.

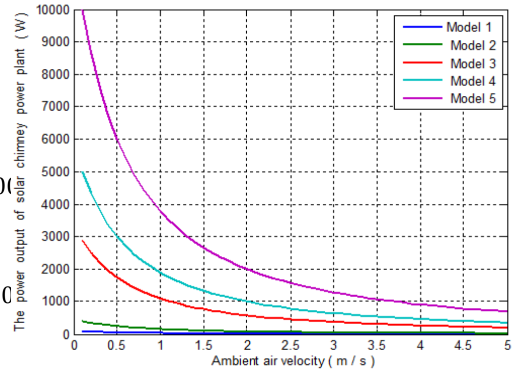

Fig. 2: The output power of solar chimney with ambient air velocity

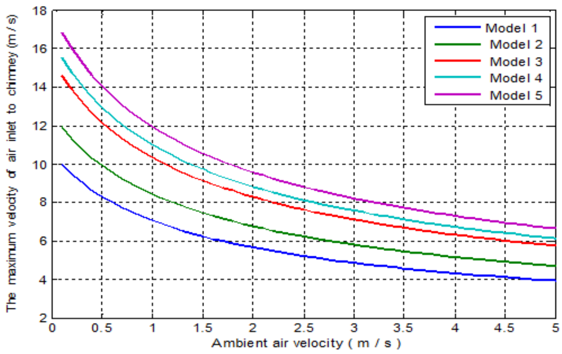

Fig. 3: The maximum velocity of air inside the chimney with ambient air velocity

Figure 3 shows the data maximum velocity of air inlet to chimney with air outlet velocity of chimney for different models. The results illustrated the decreases in air inlet velocity to chimney with increases in air outlet velocity for five models due to the different between the density of air outlet and inlet of chimney where the temperature effect on the air density then the outlet air velocity more than inlet air velocity of chimney.

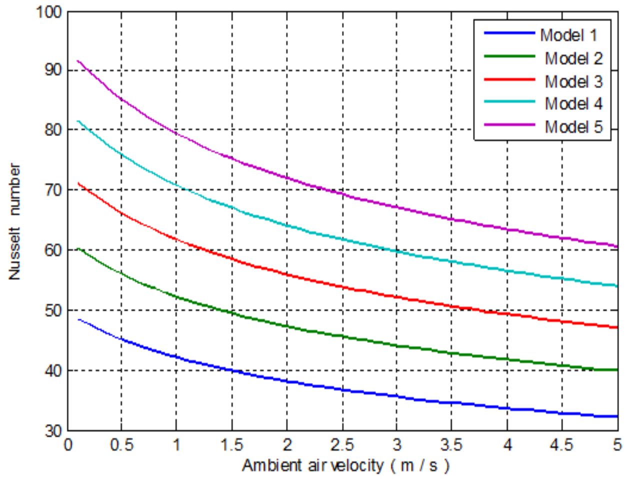

Fig. 4: Nusselt number and ambient air velocity

The Effect of air outlet velocity of chimney on Nusselt number with different models are presented in Figure 4. It is noticed that the Nusselt number increases with decreases in air outlet velocity of chimney for all models. Also the results indicated the maximum Nusselt number observed at Model 5 due to increase the diameter and height of chimney where based on equation 9 the Rayleigh number effect on Nusselt number and the difference temperature in equation 6 decreases caused to increases in outlet air velocity.
Five models for the power output of solar chimney power plant with incident solar radiation are presented in figure 5. The obtained results denoted to influence the incident solar radiation on power output of solar chimney power plant where the highest power output of solar chimney observed with model five in compared to other models due to increases in dimensions of chimney.
Figure 6 and 7show the effect of outlet air temperature of chimney on the power output of solar chimney power plant and air inlet velocity of chimney respectively. The results indicted to increases in power output of solar chimney power plant with increases outlet air temperature of chimney. Also, It can be seen that increases in inlet air velocity of chimney with increases in temperature due to decreases in density of air. However the efficiency of the power plant in the world decreases with increases in temperature of air outlet flow then can be considered this type of power plant more applicable and economic.

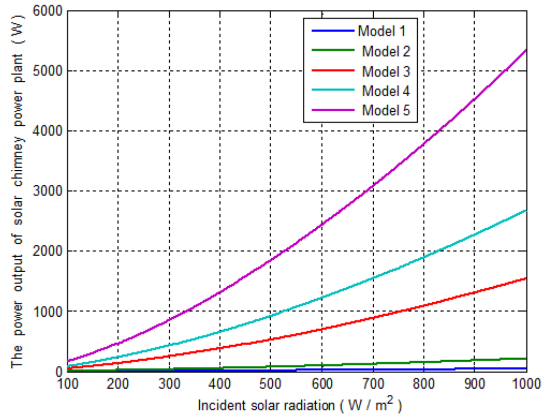

Fig. 5: The power output of solar chimney power plant with incident solar radiation

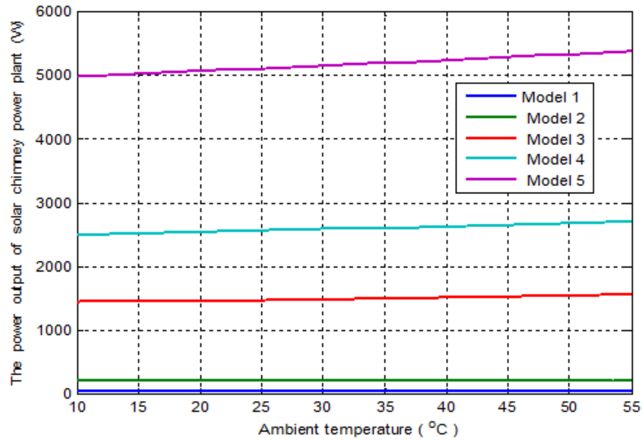

Fig. 6: The power output of solar chimney power plant with ambient temperature

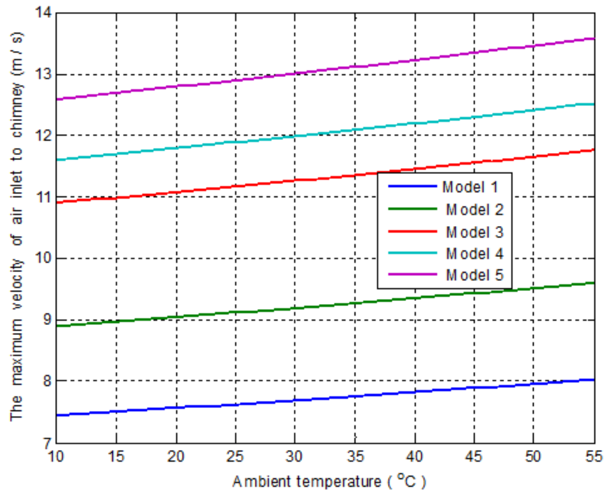

Fig. 7: The maximum velocity of air inside the chimney with ambient temperature

To validation, compared with the work of Hosseini et al. (2017) [10] for numerical study at same boundary conditions where the results showed good agreement as shown in Figure 8.Hosseini et al. (2017) [10] used a free convection for longitudinal rectangular fins of solar air heater inside the chimney to investigate theturbulent flow and heat transfer in the finite volume method of a three-dimensional domain under and a steady state condition to discretize the equations. They examined the different interruption gaps with discontinuous fins in the solar chimney to find the discontinuous fins with suitable interruption gaps wasimprove the performance of continuous fins in comparison with solar chimney**.** It is the ame manner of present study which enhance the performance of heat transfer more than the previous study since the maximum velocity of entering air would increased because the intensity of air. The maximum difference between these velocity lines is not more than 0.5 m/s. Therefore, this study has acceptable results.

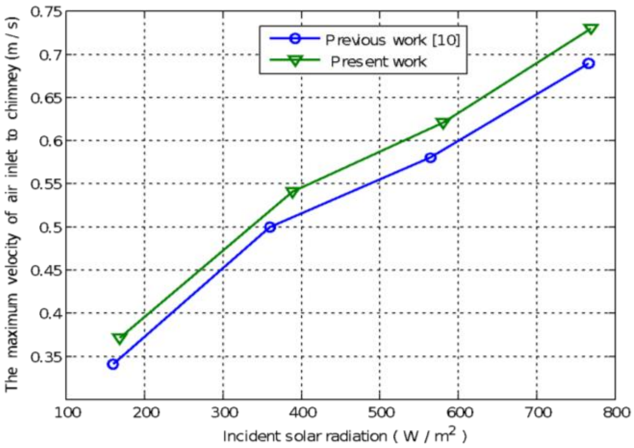

Fig. 8: The validity of present study with previous work [11]

5. Conclusions

Numerical simulation of performance solar chimney with five modelsat different boundary conditions investigated in this paper. The obtained results showed the following point:-
The Maximum power of solar chimney power plant detectedat model 5 due to increases in length and diameter of chimney in compared with other models
The results illustrated the reductions in air inlet velocity to chimney leads to increases in air outlet velocity for five models
Effect the incident solar radiation on produced power by solar chimney power plant where the highest power output of solar chimney observed with model five.
Rises in produced power of solar chimney power plant with increases outlet air temperature of chimney
Increases in inlet air velocity of chimney with increases in temperature due to decreases in density of air
With the boundary condition such as (rise temperature, rise solar radiation, decreases wind velocity) in Iraq then can be used this type and obtained good results.

Nomenclature

1-Ac=the area of chimney
2-T_a= ambient air temperature
3-T_c= the temperature of surface collector
4-T_m= the mean temperature of air inside solar collector.
5-V_a= the velocity of air ambient temperature
6-Pr=the prandtl number
7-Gr=Grashof number
8-$\rho_{i.c}$=the density of inlet air to collector
9-$\rho_{e.c}$=the density of exit air to collector

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