COMPARISON BETWEEN SIMULATED AND CALCULATED POWER OF THE SOLAR CHIMNEY WITH BLACK CONCRETE BASE USING ANSYS PROGRAM

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Abstract

A solar chimney has been analyzed by solving its governing equations and compare with the simulated results. The solar absorbent of the chimney is selected as a black painted concrete, which is useful as an energy saver at night. The numerical simulation using ANSYS, based on solving the governing equations with suitable assumptions and boundary conditions for many variables such as the collector area, the chimney height, the ambient temperature, and the exit area of the chimney. The results shows that the chimney height and base area are very important parameters for improving the gained power, and it is also important to choose the region with suitable mean ambient temperature. And economically there are limitations to collector and chimney sizes to get suitable profit output power and any increment in system size becomes a small percentage increment in profit output power. The results compared with some experimental data from other results researchers and there is a good agreement between simulated and calculated results.

Keywords: Solar Chimney, Concrete Base, Solar Collector, ANSYS, Simulation

مقارنة بين القدرة النظرية والمحسوبة لمدخنة شمسية ذات قاعدة كونكريتية سوداء بأستخدام برنامج ANSYS

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الخلاصة

تم تحليل المدخنة الشمسية عن طريق حل المعادلات الحاكمة ومقارنة النتائج مع نتائج المحاكاة. إن اللوح الماص للمدخنة الشمسية تم اختياره من الكونكريت المطلي باللون الاسود والذي يعتبر مفيدا لخزن الحرارة ليلا. إن المحاكاة العددية باستخدام برنامج ANSYS 11.0 تم بناءه على حل المعادلات الحاكمة مع الفرضيات والشروط الحدية المناسبة لعدة متغيرات مثل مساحة المجمع ارتفاع المدخنة ودرجة حرارة المحيط و مساحة مخرج المدخنة. أظهرت النتائج أن ارتفاع المدخنة ومساحة المجمع هي عوامل مهمة جدا لتحسين القدرة الناتجة، وكذلك من المهم اختيار المنطقة بمعدل درجة حرارة محيط مناسبة.وان هناك محددات اقتصادية لحجم المدخنة والمجمع الشمسي للحصول على قدرة خارجة مناسبة وان أي زيادة في الحجم يقلل من نسبة الزيادة في القدرة الخارجة المفيدة. ناظرت النتائج في هذا البحث مع بعض النتائج التجريبية لباحثين آخرين وان هناك تقاربا جيدا بين نتائج الحسابات والمحاكاة .

Nomenclature

LATIN SYMBOLS

SYMBOL	DESCRIPTION	UNITS
$\dot{m}$	Working air mass flow rate	kg/sec
A_o	Exit chimney area	m^2
Cp	Specific heat at constant pressure	J/kg.K
H	Chimney height	M
h	Enthalpy	J/kg
h_a	Convective heat transfer coefficient between the absorber and the air flow inside the collector.	$W/m^2.K$
h_c	Convective heat transfer coefficient between the cover and the air flow inside the collector.	$W/m^2.K$
h_{rc-a}	Radiation heat transfer coefficient between the cover and the absorber .	$W/m^2.K$
I_t	Total energy projected by the solar radiation on a surface	W/m^2
k	Thermal conductivity of working fluid	W/m. ^oC
p	Air pressure	N/m^2
q	Rate of heat transfer	Watt
Q	Energy transfer by the working fluid	Watt
R	Specific gas constant	J/kg.K
S	Absorbed solar radiation	W/m^2
S_a	Solar radiation absorbed by the absorber.	W/m^2
S_c	Solar radiation absorbed by the transparency cove.	W/m^2
T_∞	Temperature of the air out of the collector	^oC
T_f	Air flow temperature	^oC
T_i	Mean air temperature at inlet to the chimney tower.	^oC
Ue	Overall heat transfer coefficient the absorber to the earth through the isolator.	$W/m^2.K$
U_t	Overall heat loss coefficient from cover and the air out the collector plus the radiation heat transfer.	$W/m^2.K$
V	Air velocity	m/sec
V_o	Exit velocity	m/sec
X_r	Body forces in r-direction	N
ΔT	Collector air temperature rise $=(T_i - T_a)$	^oC

GREEK SYMBOLS

SYMBOL	DESCRIPTION	UNITS
μ	Air dynamic viscosity	N.s/ m^2
η	Efficiency	
ρ	Air density	kg/ m^3
$\tau\alpha$	Visual efficiency	
τ	Transmission coefficient	
α	Absorption coefficient	
Φ	Loss energy	Watt
σ	Stefan- Boltzman constant=5.669×10^{-8}.	w/m^2k^4
ε_g	ground emittance	------
ε_c	Canopy film emittance	------

INTRODUCTION

The concept of solar chimney power technology was first conceived in 1931 by a German author, Hanns Gunther, and has been proven with the successful operation of a pilot plant constructed in Manzanares, Spain in the early 1980s by Professor Schlaich with the support of both the German government and a Spanish electric company (Schlaich,1995).

(Haff,1984) the first one to describe the principles and construction of the pilot plant in Manzanares, it had been concluded that economical power generation will be possible with large scale plants design for up to 400MW. Also, find a number of fundamental differences between the solar chimneys and the other power generation installations. As opposed systems, they don't require direct radiation, but still generate current when the sky is overcast and the radiation is 100% diffused. On the other hand, atmospheric infrared radiation plays an important role in the overall energy balance of solar chimneys, while in concentrating systems or in the case of photovoltaic generators the infrared thermal radiation has only a very slight influence or none at all. The authors finally concluded that a solar chimney with an installed capacity of over approximately 50MW could generate electricity economically.

(Haff,1983) presented the preliminary test results from the Manzanares pilot plant. By depending on the test results and the operation experience gained throughout the period of the test, he has found that the agreement extent between the physical model and the measurements was good. The most important result so far is that with ground like that in Manzanares, with modified plant dimensions, the daily peak could theoretically be increased by approximately 8% without increasing the cost of the plant. And he found that at the very first attempt the simple principle, the reliability and above all the favorable cost-power relation for large-scale plants were confirmed on scale, which may be called unique among known solar chimney power plants.

(Jackobs,1984) studied the theoretical analysis of the solar-driven natural convection energy conversion system. They presented a theoretical study of solar-powered natural convection tower (chimney) performance. Both heated and cooled towers were analyzed. The later used evaporating water as the cooling mechanism. The results, which were applicable to any open cycle configuration, showed that the ideal conversion efficiencies of both heated cooled natural convection towers were linear functions of height. The performance of heated tower in an adiabatic atmosphere had been found to approach the ideally Carnot efficiency limit of approximately 3.4%/km. The ideal limit to cooled water performance when including water pumping requirements was approximately 2.75%/km.

(Al-Heaty,2002) developed a general computer model to predict the performance of solar chimney plants. The analysis was based on the nonlinear numerical solution, using Finite Element Method, for the system of governing partial differential equations (continuity, momentum, and the energy equations) of the conventional heat transfer fields through the plant collector and chimney tower passages. It was resulted the Finite Element Method gives accurate results, nearly to the exact solution in the analysis of solar chimney power plant.

(Gan,1998) study the performance of a glazed solar chimney for heat recovery in naturally-ventilated buildings was investigated using the CFD technique, Its validated against experimental data from the literature and good agreement between the prediction and measurement was achieved. The predicted ventilation rate increased with the chimney wall temperature. The effects of solar heat gain and glazing type were investigated. It was shown that in order to maximize the ventilation rate in a cold winter, double or even triple glazing should be used.

(Toufik Chergui,2010) presented the related to heat transfer and airflow modeling analysis in solar chimneys, according to some dominant parameters. A typical case of application is given in this study. It consists in analyzing a natural laminar convective heat transfer problem taking place in a chimney. Heat transfer and fluid dynamic aspects of the airflow, through an axis symmetric system in a dimensionless form, with well defined boundary conditions is thus examined. Results are related to the temperature distribution and the velocity field in the chimney and in the collector, determined by solving the energy equation, and the Navier–Stokes equations, using finite volume method.

(Mullett,1987) carried out an analysis for solar chimney aimed particularly at deriving overall efficiency and significant performance data. Numerical values were consistent with the available information on the 200m solar chimneys at Manzanares, Spain, and project designs. It was found that the overall efficiency was directly related to the height of the chimney and was shown to be 1% for a height of 1000m and it was concluded that the solar chimney was essentially a large-scale power generator.

(Reheault,1988) studied the problem of steady laminar flow developing free convection in a vertical channel formed by two parallel plates of dissimilar non-uniform temperatures by using a finite difference method to solve the governing equations. The results were reduced in a non-dimensional form and correlations were derived for the case of air, which can be used in solar chimney design.

(Koonsrisuk,2009) shows that the achievement of complete dynamic similarity between a prototype and its models imposed the use of different solar heat fluxes between them. It is difficult to conduct an experiment by using dissimilar heat fluxes with different physical models. Therefore, this study aimed to maintain dynamic similarity for a prototype and its models while using the same solar heat flux. The study showed that, to achieve the same-heat-flux condition, the roof radius between the prototype and its scaled models must be dissimilar, while all other remaining dimensions of the models are still similar to those of the prototype.

(Koonsrisuk,2010) they analyzed to increase the power production over the area occupied by the plant. The ratio height/radius, maximum mass flow rate and maximum power under the constraints of a fixed area and volume are determined. They found that the power generated per unit of land area is proportional to the length scale of the power plant. The analysis is validated by a detailed mathematical model. Pressure losses are reported in terms of the dimensionless length scale of the system. They indicate that the pressure drop at the collector inlet and at the transition section between the collector and chimney are negligible.

(Maad,1992) analyzed numerically the natural convection flow between two heated vertical plates to design and realize solar chimney of the greatest efficiency, by considering the variation of the fluid properties with temperature and the pressure drop due to the flow acceleration at the channel entrance. They solved the equations of the momentum, continuity and energy by a finite difference method with an experimental study to validate the theoretical analysis. Grid generated turbulence was used to improve the heat transfer in the channel. It was seen that the temperature in the middle of the channel was high and could reach 50% of the wall temperature. The hydrodynamic and thermal field becomes very unstable and the average Nusselt number increased according to the quality of grid arrangements.

(Zhou,2006) in China a simulation study was carried out to investigate the performance of the power generating system based on a developed mathematical model. The simulated power outputs in steady state were obtained for different global solar radiation intensity, collector area and chimney height. By inter comparison, it is found that the simulated power outputs are basically in agreement with the results calculated with the measurements, which validates the mathematical model of the solar chimney thermal power generating system. Then in experimental solar chimney power setup consisted of a 5m-radius air collector and 8 m-height chimney has been built.

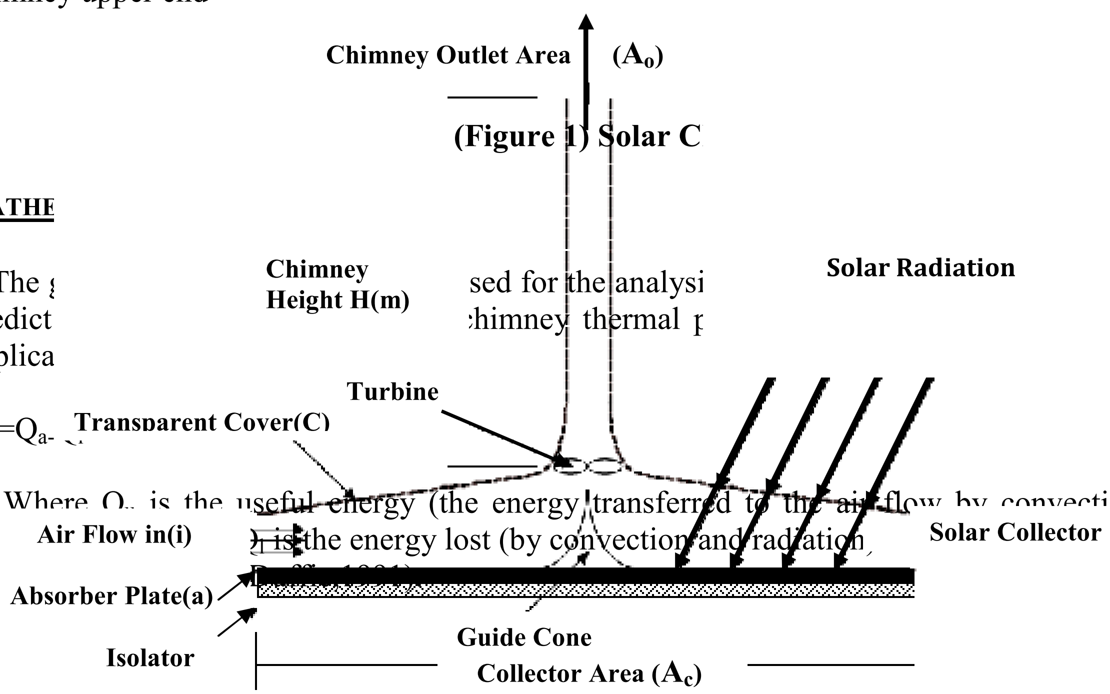
The temperature distribution in the solar chimney power setup was measured. Temperature difference between the collector outlet and the ambient usually can reach 24.1°C, which generates the driving force of airflow in the setup. This is the greenhouse effect produced in the solar collector. It is found that air temperature inversion appears in the latter chimney after sunrise both on a cool day and a warm day (Zhou,2007). Its mainly focused on structure models, efficiency of energy conversion and other related problems for solar chimney power technology.

(Dai ,2003) study solar power plant chimney, and the influence of chimney height, diameter of the solar collector, ambient temperature, solar irradiance and the efficiency of wind turbine, in which the height and diameter of the chimney are 200 m and 10 m, respectively, and the diameter of the solar collector cover is 500 m, and found its able to produce 110~190 kW electric power on a monthly average all year.

The present study focused on studying many variable effects the performance of a domestic solar chimney such as the chimney height and the chimney rectangular base area and the ambient temperature. And the simulation compared with the case study of (Dai ,2003). A detailed analysis of the measured temperature fields for solar chimney power systems had been reported.

GEOMETRY DESCRIPTION

The solar chimney studied in the present work is shown in (Figure1), which consists of vertical chimney with height (H) and width (w), with a turbine supported on top of guide cone which placed on the center of the absorbed plate (p), the absorbed plate with the covering transparent material and the down isolator considered as a solar collector with area (Ac).
Air flow enters from collector sides and rises as it heated by the absorber to the exits opining of the chimney upper end



(Figure 1) Solar C

MATHE

The g ... sed for the analysi ... y balance to predict ... chimney thermal p ... suitable and applica

Q_u=Q_{a-} ... (1)

Where Q_u is the useful energy (the energy transferred to the air flow by convection), Q_a is the ab ... is the energy lost (by convection and radiation ...
Fc ...

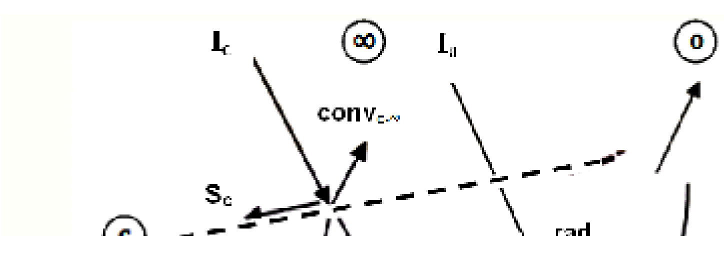
Q ... (2)

$S=I_t\,.(\tau\alpha)$ (3)

$Q_l=U_e\,A_c\,(T_a-T_\infty)$ (4)

Then $Q_u=(\tau\alpha)\,I_t\,A_c - U_e\,A_c\,(T_a-T_\infty)$ (5)

And for solar chimney collector (where the air flow in and out) shows in (Figure 2):



(Figure 2) Collector Energy Balance.

1- The transparence cover (c) energy balance equation (Duffie,1991):

$$S_c + h_{rc-a}\,(T_a-T_c) + h_c\,(T_c-T_f) = U_t(T_c-T_\infty) \qquad (6)$$

2- The absorber (a) energy balance equation:

$$S_a=h_a(T_a-T_f)+h_{rc-a}(T_a-T_c)+U_e(T_a-T_\infty) \qquad (7)$$

$h_{r,c-a}$ is the radiation coefficient from the ground to the canopy (Holman,1989):

$$h_{r,c-a} = \frac{\frac{1}{2}\sigma\left(T^2{}_g + T_c^{\,2}\right)\left(T_g + T_c\right)}{\left(1/\varepsilon_g\right)+\left(1/\varepsilon_c\right)-1} \qquad (8)$$

3- The airflow (f) energy balance equation:

$$Q_u=h_a\,A_c\,(T_a-T_f)-\,h_c\,A_c\,(T_c-T_f) \qquad (9)$$

$$T_f=(T_\infty/4)+(3T_o/4) \qquad (10)$$

$$Q_u = \dot{m}\,C_p\,(T_o - T_\infty) = \frac{3}{4}\dot{m}\,C_p\,(T_f - T_\infty) \qquad (11)$$

$$m=\rho A_o V_o \qquad (12)$$

Due to (Schlaich1995):

$$V_o = \sqrt{2gh\;(T_o - T_\infty)/T_\infty} \qquad (13)$$

By applying continuity equation between the inlet (i) and the outlet (o):

$$V_i= V_o\,A_o\,\rho_o/A_i\,\rho_i \qquad (14)$$

The collector efficiency, :(Kays,1966) which represents an indicator to its performance, given by

$$\eta_c = \frac{c_p \dot{m} \Delta T}{\pi R_c^2 I_T} \tag{15}$$

And the output power (Zhou,2006) and (Zhou,2007) is:

$$P_o = 0.33\ \eta\ \rho A_o V_o^3 \tag{16}$$

NUMERICAL SIMULATION:

The heat transfer and flow rate of ambient air when flowing freely from solar collector perimeter, under the collector canopy and over the absorber, towards the chimney tower inlet, is mainly governed by partial non linear differential equations, representing the conservation principals of mass, momentum, and energy; and can be written as; (Yaun ,1967):

Continuity equation:

$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho v_r)}{\partial r} + \frac{1}{r}\frac{\partial(\rho v_\theta)}{\partial \theta} + \frac{\partial(\rho v_z)}{\partial z} + \frac{\rho v_r}{r} = 0 \tag{17}$$

Where v_r, v_θ, v_z are the air velocity components in r, θ and z-directions respectively.

Momentum equation:

$$\rho\left(\frac{Dv_r}{Dt} - \frac{v^2{}_\theta}{r}\right) = \rho Xr - \frac{\partial p}{\partial r} + \frac{\partial}{\partial r}\left[\mu\left(2\frac{\partial v_r}{\partial r} - \frac{2}{3}\nabla .q\right)\right] + \frac{1}{r}\frac{\partial}{\partial \theta}\left[\mu\left(\frac{1}{r}\frac{\partial v_r}{\partial \theta} + \frac{\partial v_\theta}{\partial r} - \frac{v_\theta}{r}\right)\right] + \frac{\partial}{\partial z}\left[\mu\left(\frac{\partial v_r}{\partial z} + \frac{\partial v_z}{\partial r}\right)\right] + \frac{2\mu}{r}\left(\frac{\partial v_r}{\partial r} - \frac{1}{r}\frac{\partial v_\theta}{\partial \theta} - \frac{v_r}{r}\right) \tag{18}$$

where $\nabla .q = \frac{\partial v_r}{\partial r} + \frac{1}{r}\frac{\partial v_r}{\partial r} + \frac{\partial v_z}{\partial \theta} + \frac{\partial v_z}{\partial z} + \frac{v_r}{r}$. (19)

Energy equation:

$$\frac{1}{r}\frac{\partial}{\partial r}\left(kr\frac{\partial T}{\partial r}\right) + \frac{1}{r^2}\frac{\partial}{\partial \theta}\left(k\frac{\partial T}{\partial \theta}\right) + \frac{\partial}{\partial z}\left(k\frac{\partial T}{\partial z}\right) + \Phi = \rho\frac{Dh}{Dt} - \frac{Dp}{Dt} \tag{20}$$

where

$h = c_p.T$ & $p = \rho RT$

$$\Phi = 2\mu\left[\begin{array}{l}\left(\frac{\partial v_r}{\partial r}\right)^2 + \left(\frac{1}{r}\frac{\partial v_\theta}{\partial \theta} + \frac{v_r}{r}\right)^2 + \left(\frac{\partial v_z}{\partial z}\right)^2 + \frac{1}{2}\left(\frac{\partial v_\theta}{\partial r} - \frac{v_\theta}{r} + \frac{1}{r}\frac{\partial v_r}{\partial \theta}\right)^2 + \frac{1}{2}\left(\frac{1}{r}\frac{\partial v_z}{\partial \theta} + \frac{\partial v_\theta}{\partial_z}\right)^2 + \\ \frac{1}{2}\left(\frac{\partial v_r}{\partial z} + \frac{\partial v_z}{\partial r}\right)^2 - \frac{1}{3}(\nabla .q)^2\end{array}\right] \tag{21}$$

and $\frac{D}{Dt} = \frac{\partial}{\partial t} + v_r\frac{\partial}{\partial r} + \frac{v_\theta}{r}\frac{\partial}{\partial \theta} + v_z\frac{\partial}{\partial z}$ (22)

ASSUMPTIONS:

The following assumptions are considered:

1. The system performance is steady.
2. The problem of convectional heat transfer in the collector is that of constant wall temperature.
3. The working air thermal conductivity, k, and the coefficient of viscosity, μ, are constants.
4. The working air behaves as an ideal gas.
5. For the flow through the collector passage and at each (r), the pressure is constant in the vertical direction, that is to say $\frac{\partial p}{\partial z} = 0$.
6. The flow through the collector has complete symmetry with the θ direction, that is to say, $\frac{\partial}{\partial \theta}=0$.
7. The main direction of flow in the collector is the (r) direction, no flow in the z and θ directions (v_z, v_θ =0).
8. The airflow varies inside the chimney tower with z and r-directions, and it has no variation in the θ direction, i.e. $\frac{\partial \upsilon}{\partial \theta} = 0$.
9. The air inlet to the chimney collector from the down sides and flows out from the chimney top opening end without friction or leakage.
10. The thermal effect causing the buoyancy force is considered, and wind-induced natural ventilation in the ambient is neglected.
11. The temperature of the roof under the heat insulator bed is equal to that of the ambient $T\infty$.

BOUNDARY CONDITIONS:

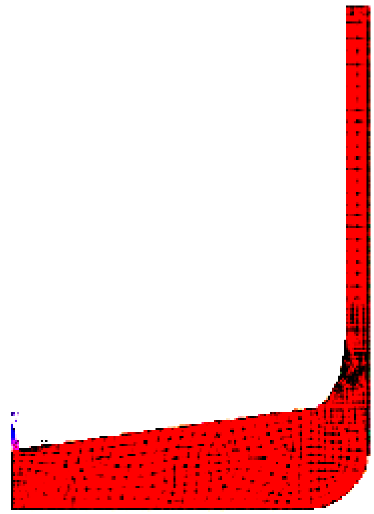
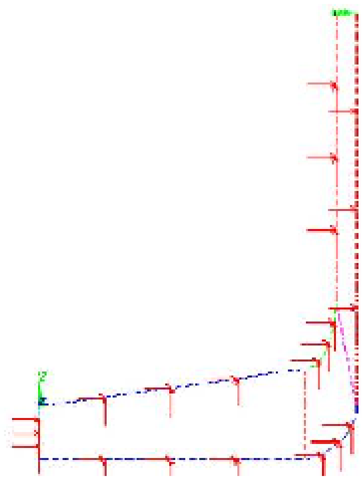
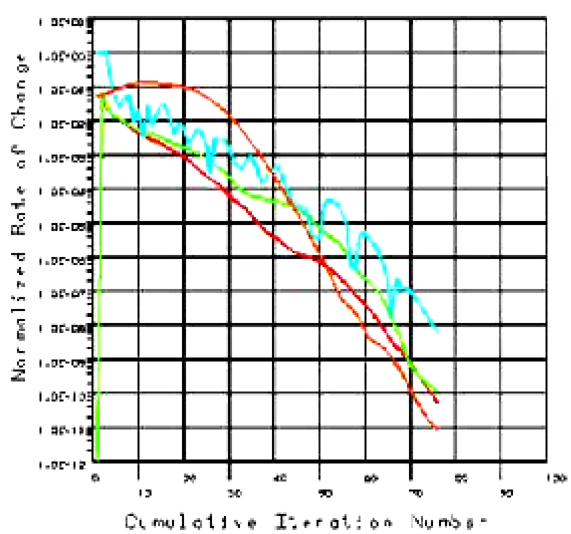
The following Boundary conditions are considered:

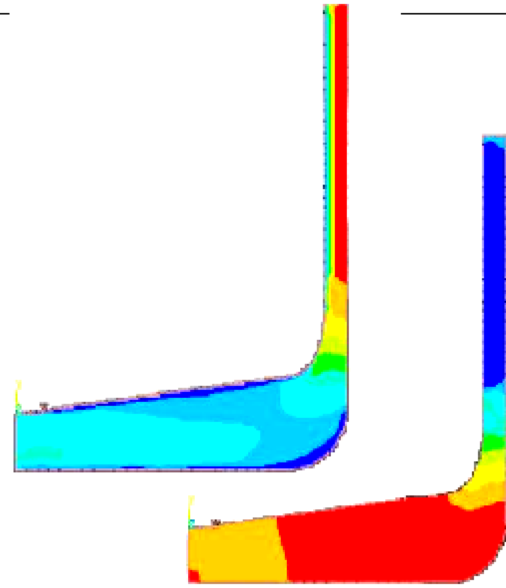
1. The velocities components in X and Y directions are set to zero at the chimney walls and the absorbed plate.
2. The pressure at the outlet end of the chimney is atmospheric pressure.
3. The temperature of the airflow enter to the collector sides is at the same ambient temperature $T\infty$.
4. The temperature difference between the ambient temp $T\infty$ and the absorber temp Ta is about 24.1^{o}C (Zhou,2007) which generate the driving force of airflow in the setup.
5. The inlet flow velocity components in x-axis are (Vi) and in y-axis is (0).
6. Properties (pressure, temperature and density) at the inlet assumed at standard atmospheric.

SIMULATION PROCEDURE:

By using ANSYS for numerical simulating the chimney, assuming axial summitry 2-D, and due to symmetry only half of the chimney was solved, and below the procedure of the simulation:

ANSYS commands	Process	Screen Plot

Preprocesser Modeling, Create, (Keypoints, lines and area) Meshing, Size Cntrls, Mesh	drawing the model, keypoints, lines and areas generation for the section of the axiymmetrical chimney Meshing the domain	
ANSYS commands	**Process**	**Screen Plot**
Flotran set up Fluid properties Loads, Apply, fluid/ CFD.	Setup the flow properties Applying loads (Boundary conditions) Velocity, walls no slip condition, pressure.	
Solution Run Flotran Close	Starting the iteration till the convergence occurs	

Postprocessor Plot results, Counter plot, Nodal solution VSUM Pressure	Plotting the resulting velocities and pressure distribution within the chimney	

RESULTS AND DISCUSSION:

A comparison between results got from simulation and that got from solving the governing equations shown in (Figure 3), results shows that the output power gained by the power generating systems increases with the increment of chimney height (H) and also, with the increment of collector area (A_c), the chimney height taken from 1 to 4 m, which is suitable height for domestic houses roofs, while the collector area taken from 1 to 16 m^2, as rectangular area.
The comparison between simulation and calculation results shows a good agreement about 5% in average, the small difference between simulated and calculated results is due to the assumption for the simulation like assuming the inlet velocity only in x-dir and the outlet is only in y-dir and the flow is one-dimensional at inlet and outlet and no heat loss due to friction, and the different which is not exceed 7% at chimney height of 4 m, and that at chimney height 1 m is about 2%, because with the increment of chimney height a larger force introduced that driving the turbine which is produced by more convection of heated air. The ambient temperature used for measuring the results in (Figure 3) was chosen as 25^{o}C, which is convenient as average temperature for the selected regions.
(Figure 4), shows the variation of the output power with the variation of chimney height and different ambient temperature of 10^{o}C, 20^{o}C, 30^{o}C and 40^{o}C, it is clear that the gained power increases with the increment of the ambient temperature, that because a high ambient temperature produce a high absorber temperature (T_a), which cause more heated air that forced the turbine blades to rotate faster.
The different between calculated and simulated output power for all ambient temperatures for different collector height is clear in (Figure 5), and that different decreases as the ambient temperature increase, that because with small value of $T\infty$ cannot heated the absorber well in order to provide a force enough for driving the turbine, or the low ambient temperature cannot usually produce enough driving force because part of the heat energy is absorbed and stored by the concrete absorber, that is appear in calculation measurement while in simulation it always consider that the convection force available and can produce even few power.
The influence of outlet area of the chimney on the output power of the solar chimney at different chimney heights was shown in (Figure 6), where with the increasing of the exit chimney area A_o the

outlet power will decrease, that's due to decrement of outlet velocity caused by increasing the exit chimney area A_o (from continuity equation), and with the increment of chimney height the effect of the exit chimney area A_o decreasing due to the larger power generated due to larger force introduced. Both calculation and simulation done for collector area of 16 m^2, to show the effect of the outlet area clearly due to maximum power gained with this area as in (Figure 3).

(Figure 7), shows the power gained from the chimney by calculation and simulation for variations of collector area for different values (1,3,9,16) m^2 and the chimney height for different values (1,2,3,4) m, it indicates that the larger the collector size and the higher the chimney height, the greater will be the power production of the solar chimney power plant.

In (Figure 8), the comparison between the simulation results with the experimental results got from (Dai ,2003) was shown. The effect of solar chimney height and diameter of collector on the power generation appears for each case, and there is a good agreement between them.

(Figure 9) shows the effect of the ambient temperatures and solar chimney heights difference on the power gained by the chimney when the collector area is (A_o =0.5 m^2). when $T\infty$=30°C. it can shown as the chimney height increase, (for certain collector area), the output power increase too. And the output power increase, (for certain chimney height), as the collector area increase too. The value of output power increase as the ambient temperature increase from the values 10°C to 40 °C .

(Figure 10) shows the effect of the variation of outlet area on the power gained by the chimney with different solar chimney heights and collector areas for ($T\infty$=25 °C). it can shown as the chimney height increase, (for certain collector area), the output power increase too. And the output power increase, (for certain chimney height), as the collector area increase too. The value of output power increase as the chimney exit area reduced from 0.7 m^2 to 0.2 m^2.

Its demonstrated that the production of chimney power increases nonlinearly with the increase of collector area and the chimney height, it increases rapidly when the sizes of collector and the chimney are small, but the percentage growth in chimney power is reduced with an increase in their sizes as shown in (Figure 11) so any increase in sizes will be useless as economically cost.

CONCLUSIONS

1. The simulated results showed good agreement with calculated results.
2. The simulation convenient to predict the performance of the solar chimney and that can save the cost of the experimental procedures.
3. It is concluded that the mathematical model can predict the performance of the chimney equipment well, and this approach is also applicable to different-scale solar chimney thermal power generating systems.
4. For a required electric power output, It can obtain many combinations of chimney and collector dimensions by the simulation.
5. The chimney couldn't produce suitable power for low chimney height and small base area, for low chimney height it is preferred to the desirable enhancement for increasing the chimney power generation is reducing its exit area.
6. The optimum collector area and chimney height could be chosen for required output power, we only need to take some measurement at sites.
7. It is convenient to choose the chimney site within acceptable annual average ambient temperature.
8. The chimney power increases rapidly as the sizes of collector and the chimney are increases, but

the percentage development in chimney power is reduced with an increase in their sizes so that it will be useless economically .

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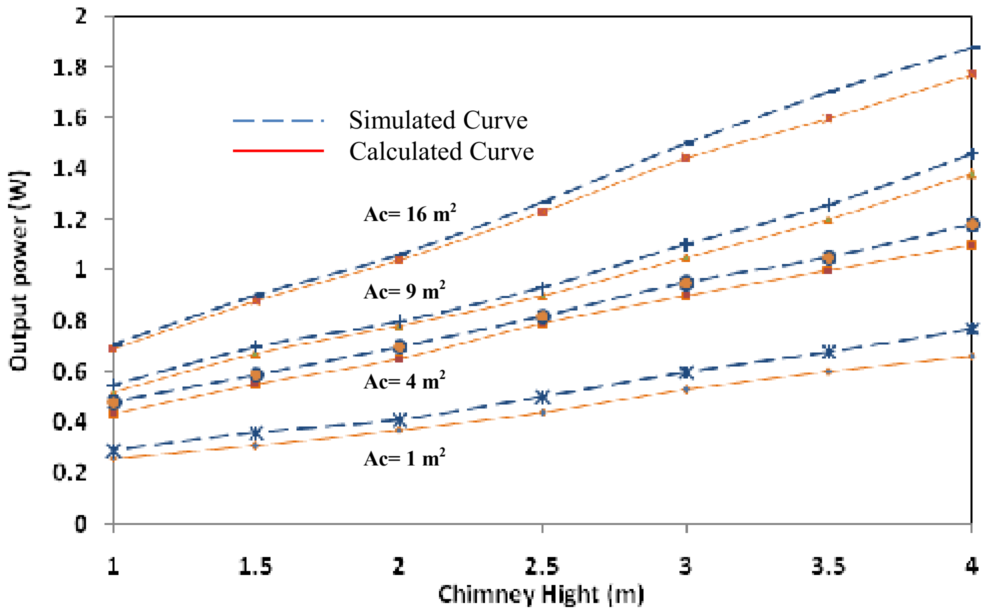
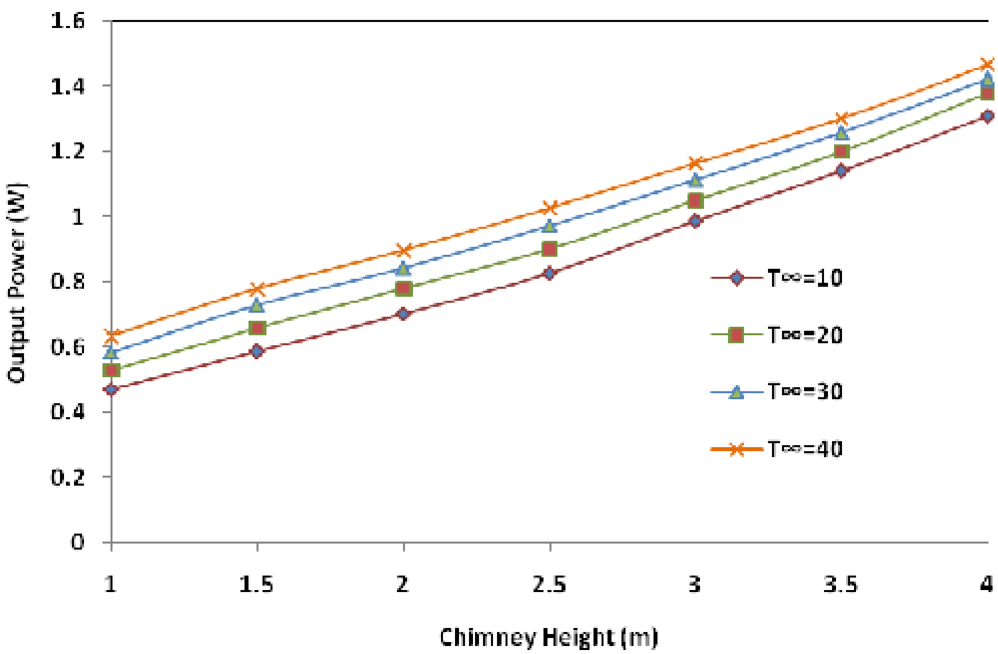
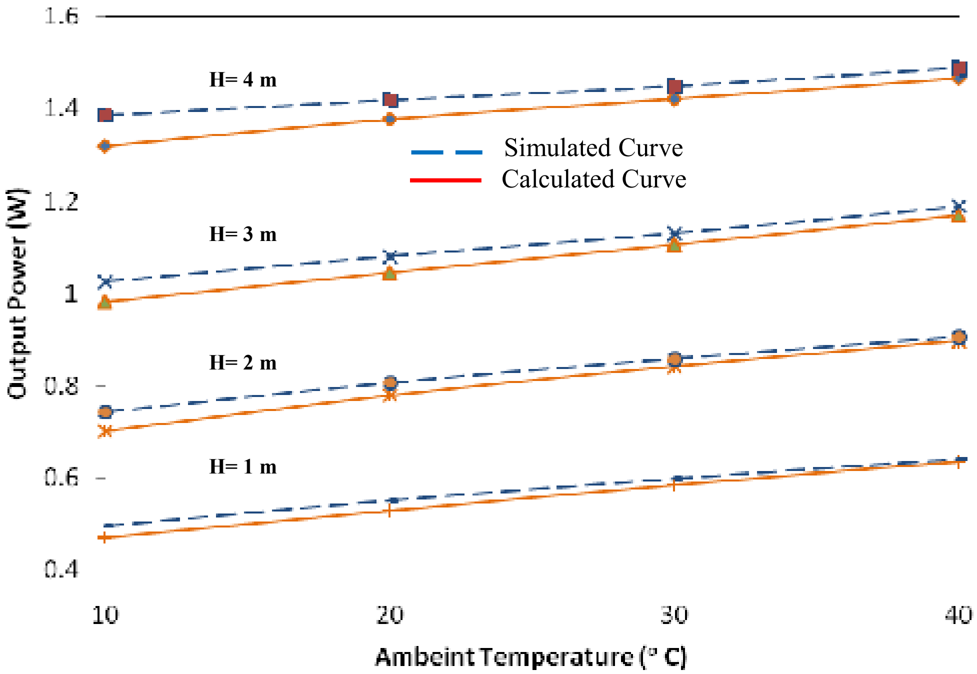


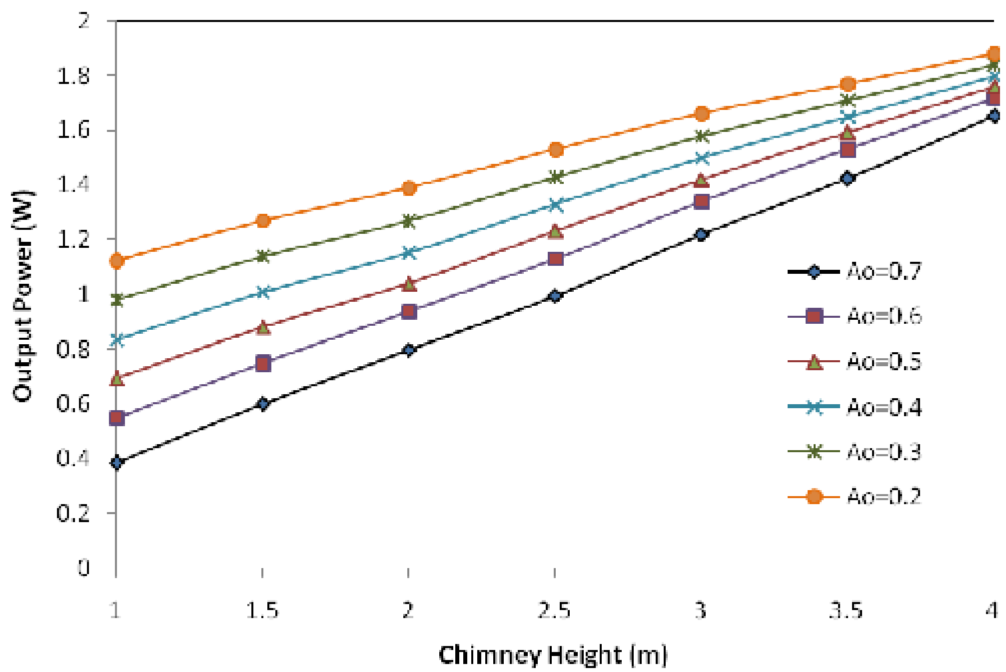
(Figure 3) Variation of the calculation and simulation output power with the variation of chimney height(m) for different collector areas Ac (m^2), and ambient temperature T_∞=25°C



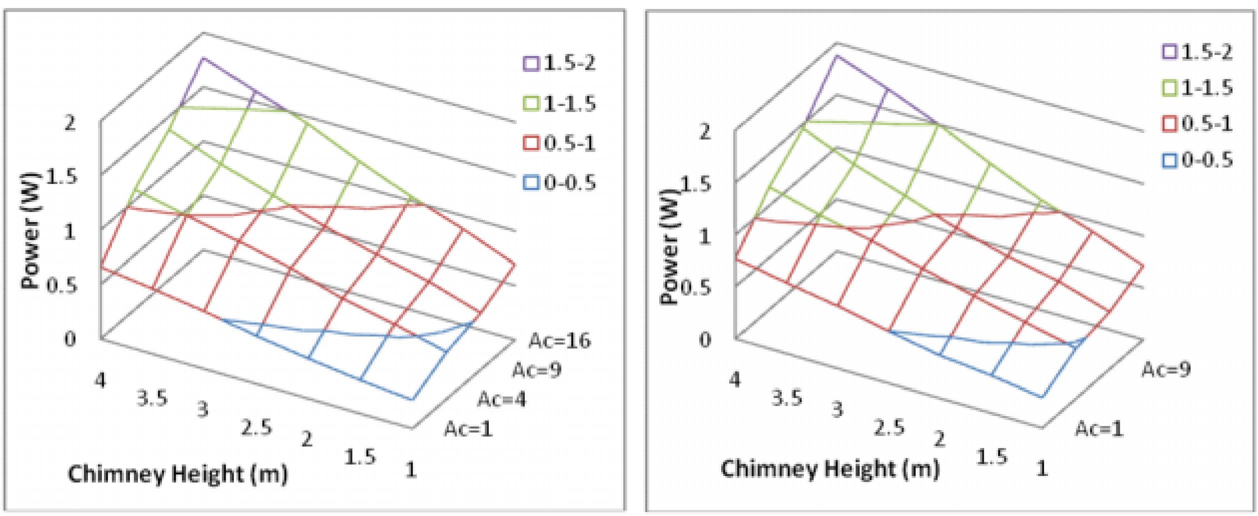
(Figure 4) Variation of output power (W) with the variation of chimney height and for different ambient temperature (T_∞ C^o), and collector area of 9 m^2.



(Figure 5) Comparison between calculated and simulated output power for different ambient temperature T_∞ (C^o) for different chimney height H (m).

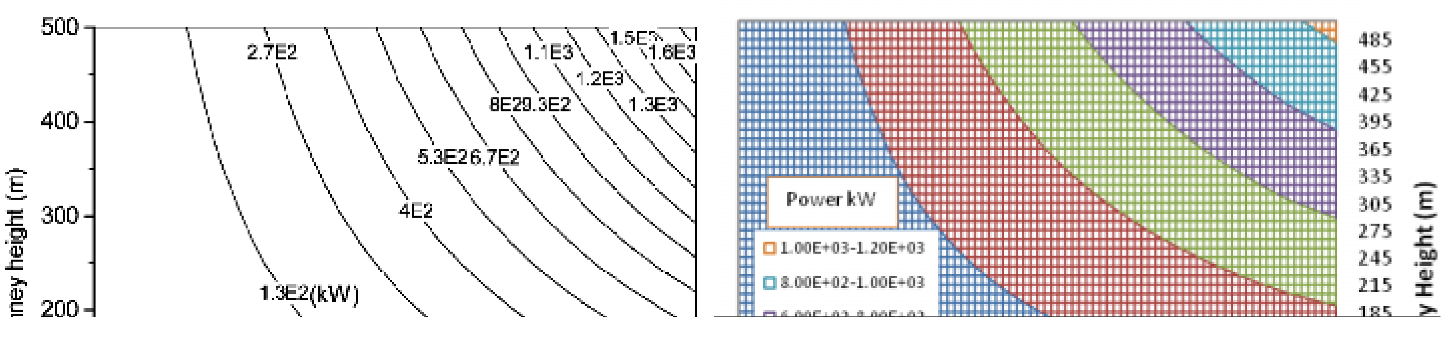


(Figure 6) Output power against chimney height for different exit area, and the collector area is 16m^2.



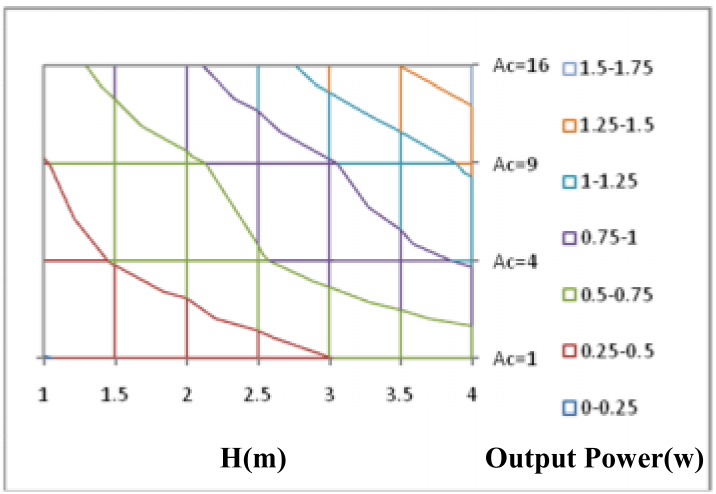
(a) Calculated **(b) Simulated**

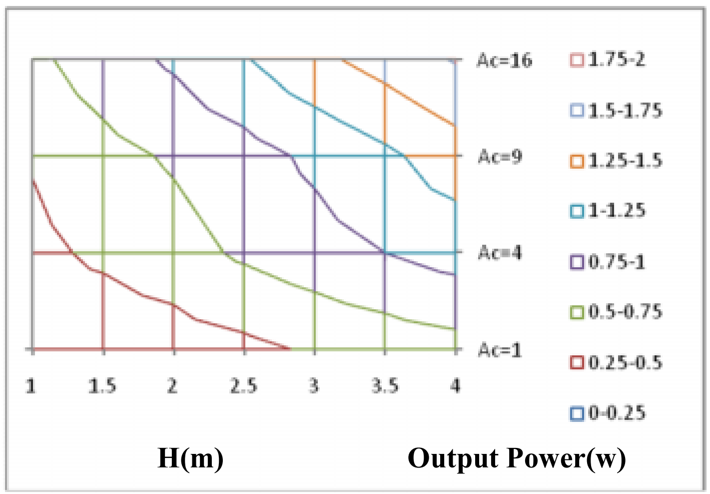
(Figure 7) Calculated and simulated power gained from the chimney for collector area (1,3,9,16) m^2 and chimney height (1,2,3,4) m .



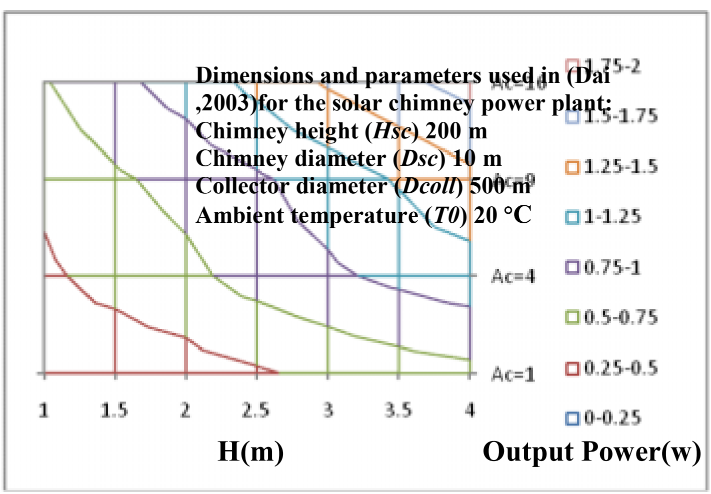
(a) Data (Dai ,2003) **(b) Simulation Study**

(Figure 8) The effect of solar chimney height and diameter of collector on the power generation comparison between data from (Dai ,2003) and the simulation present work.

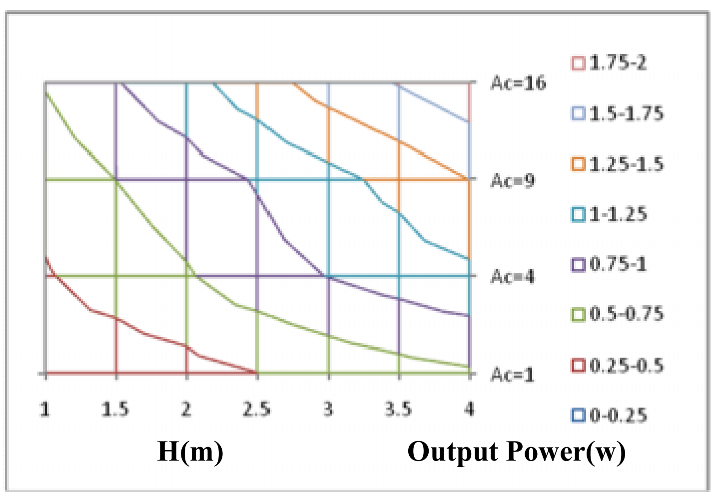




T∞=10 °C **T∞=20 °C**

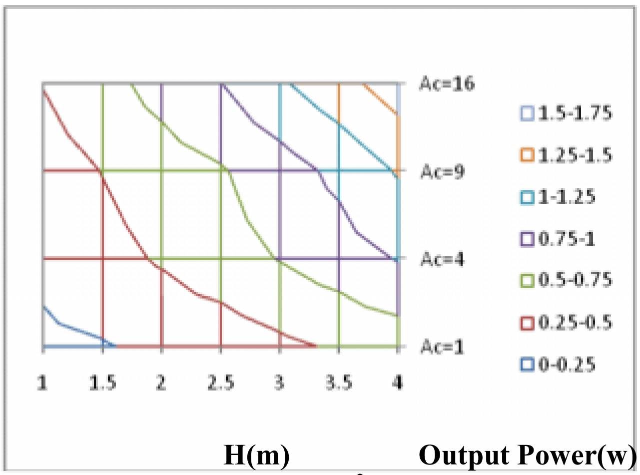


Dimensions and parameters used in (Dai ,2003)for the solar chimney power plant:
Chimney height (*Hsc*) 200 m
Chimney diameter (*Dsc*) 10 m
Collector diameter (*Dcoll*) 500 m
Ambient temperature (*T0*) 20 °C

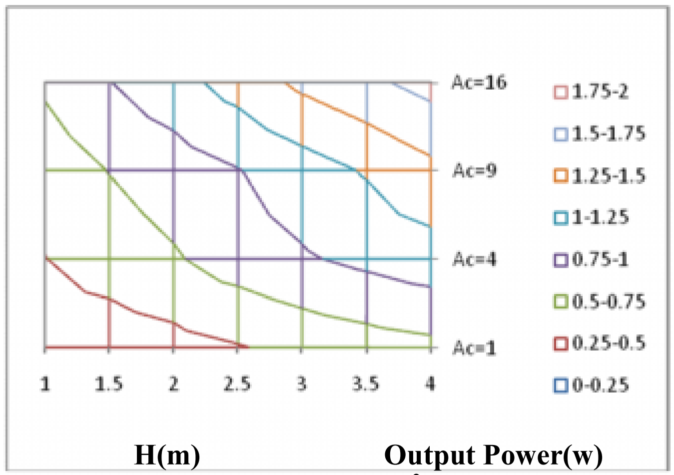


T∞=30 °C   T∞=40 °C

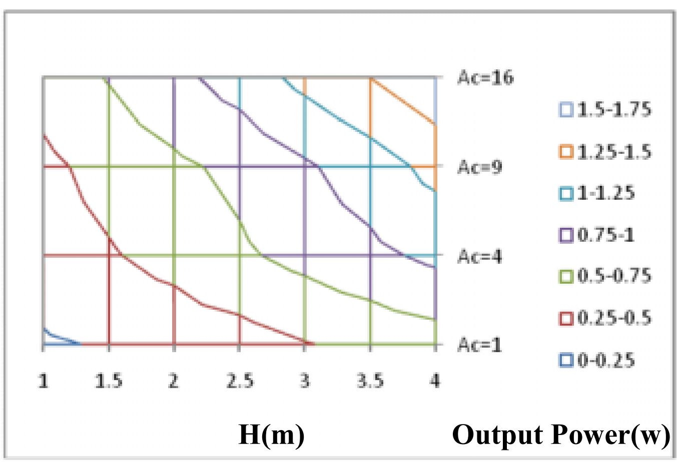
(Figure 9) Effect of the ambient temperature on the power gained by the chimney with different solar chimney heights and collector areas for (A_o =0.5 m²).



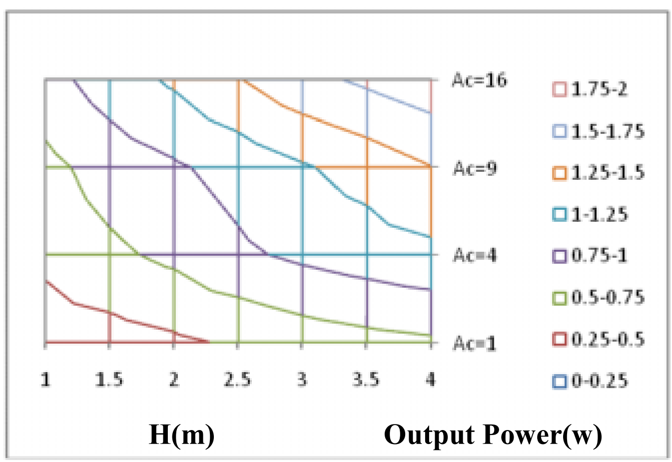
Ao=0.7 m²



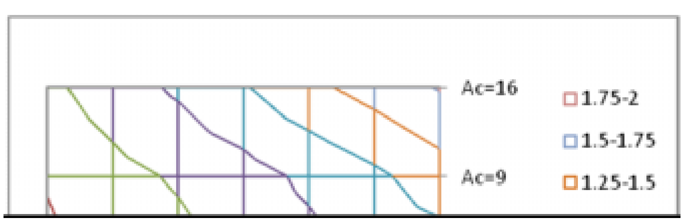
Ao=0.4 m²

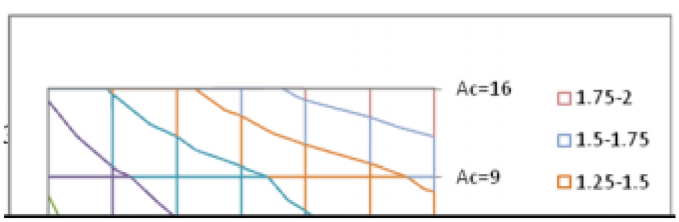


Ao=0.6 m²



Ao=0.3 m²

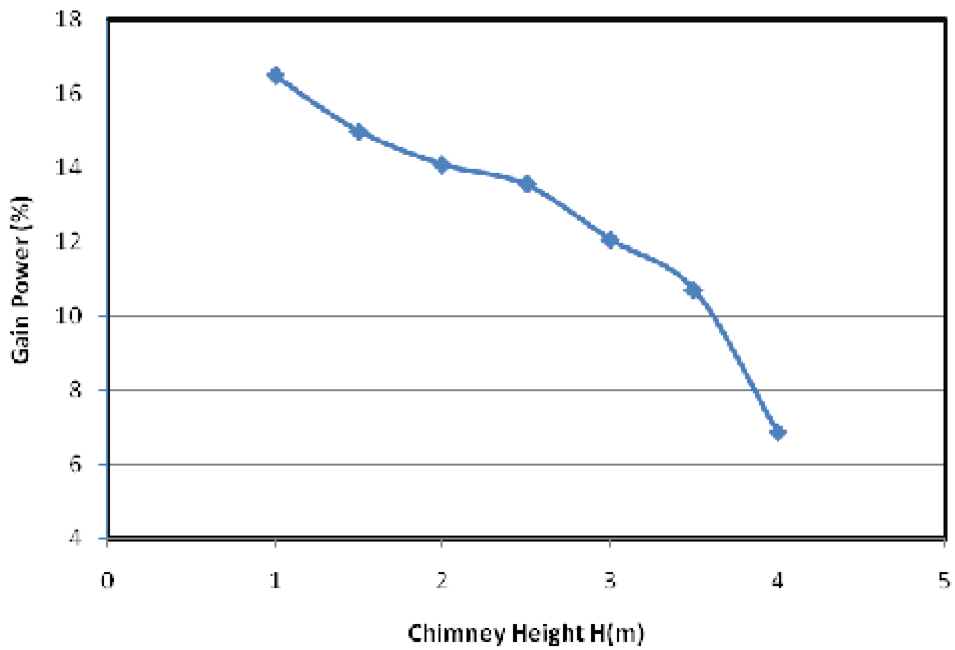




H(m) Output Power(w) H(m) Output Power(w)

Ao=0.5 m^2 Ao=0.2 m^2

(Figure 10) Effect of the outlet area on the power gained with different chimney heights and collector areas for ($T\infty=25^o$).



(Figure 11) The percentage of the gain output power variation with the chimney height.