International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 8 Aug 2023, pp: 578-583 www.ijaem.net ISSN: 2395-5252

Numerical Technique for Solar Tower System Secured With Flat Plate and Permeable For Tification

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Date of Submission: 15-08-2023 Date of Acceptance: 25-08-2023

ABSTRACT
Solar towers often integrate thermal storage using molten salts, usually nitrates, as the heat transfer fluid, which enables them to generate electricity around the clock. Others use direct steam systems. More complex pressurized gas systems have also been proposed that use a gas turbine in a hybrid generating system. The performance of solar updraft tower investigates numerically by comparing between two solar collectors with and without porous absorber flat plate. Copper metal foam (11 and 30) PPI at the same porosity (0.8) are used as an absorber plate. The effect of the absorbing porous medium is studied to increase the air flow towards the updraft tower by tilting of the porous absorber at an angle (2° and 6°) from the horizontal line for (11 and 30) PPI and compared with the horizontal absorber flat plate. To simulate the physical quantities inside the porous medium, at steady state, symmetry, three dimensional, Darcy model and energy numerical model with local thermal equilibrium (LTE) assumption are adopted and numerical models is approximated by a Re-Normalization Group k- ϵ turbulent model and discrete ordinates radiation model equations. The numerical study is analyzed by fluent software package to solve the governing equations. The results showed that the tilting of a porous absorber plate at an angle (2° and 6°) from the horizontal line lead to increase in the mass flow rate inside the solar updraft tower and the maximum performance is found by using 30 PPI at tilt angle 2°.A solar power tower system uses a large field of flat, sun-tracking mirrors called heliostats to reflect and concentrate sunlight onto a receiver on the top of a tower. Sunlight can be concentrated as much as 1,200 times. Some power towers use water as the heat-transfer fluid.

I.INTRODUCTION

One of the most important modern methods using the porous medium as an absorber flat plate that used to increase the thermal efficiency of the solar collector is based on the decreasing of flow flux density as well as increasing the area of heat transfer between the working fluid and solar collector .The basic working principle of SUT without and with the deviation of a porous absorber from the horizontal line. The best way to model the solar collector for all cases of the differential boundary condition was concluded that a no-slip, mixed convective and radiactive boundary, and the best model by using thermal storage layer of a porous material as a ground. Assembled the porous absorber with the tower for the indirect model dryer to analyze the effect of the material, porosity, and inclination of the absorber and the height of the dryer on the performance of heat transfer and airflow in the porous absorber. The heat and mass transfer models of the porous media in a solar tower system were applied by to investigate the effect of the porosity, diameter, thickness and inlet velocity of air, on the temperature, distribution by solving the convection heat transfer coefficient model numerically. The result showed that the bigger porosity is given a lower surface temperature and the higher in air temperature as well as the bigger particle diameter is given the high temperature for solid surface and air passing. Compared a porous absorber with composite flat plate absorber to find a more interface area and higher coefficients of heat transfer by using a porous absorber plate. The result showed that a more heat is supplied to the green house collector by air flow and heat flow in the porous absorber rapidly. Used dimensional analysis methodology to establish scaling law to simulate numerically for several plant models between the models and the prototype, by using the computational fluid dynamics (CFD).

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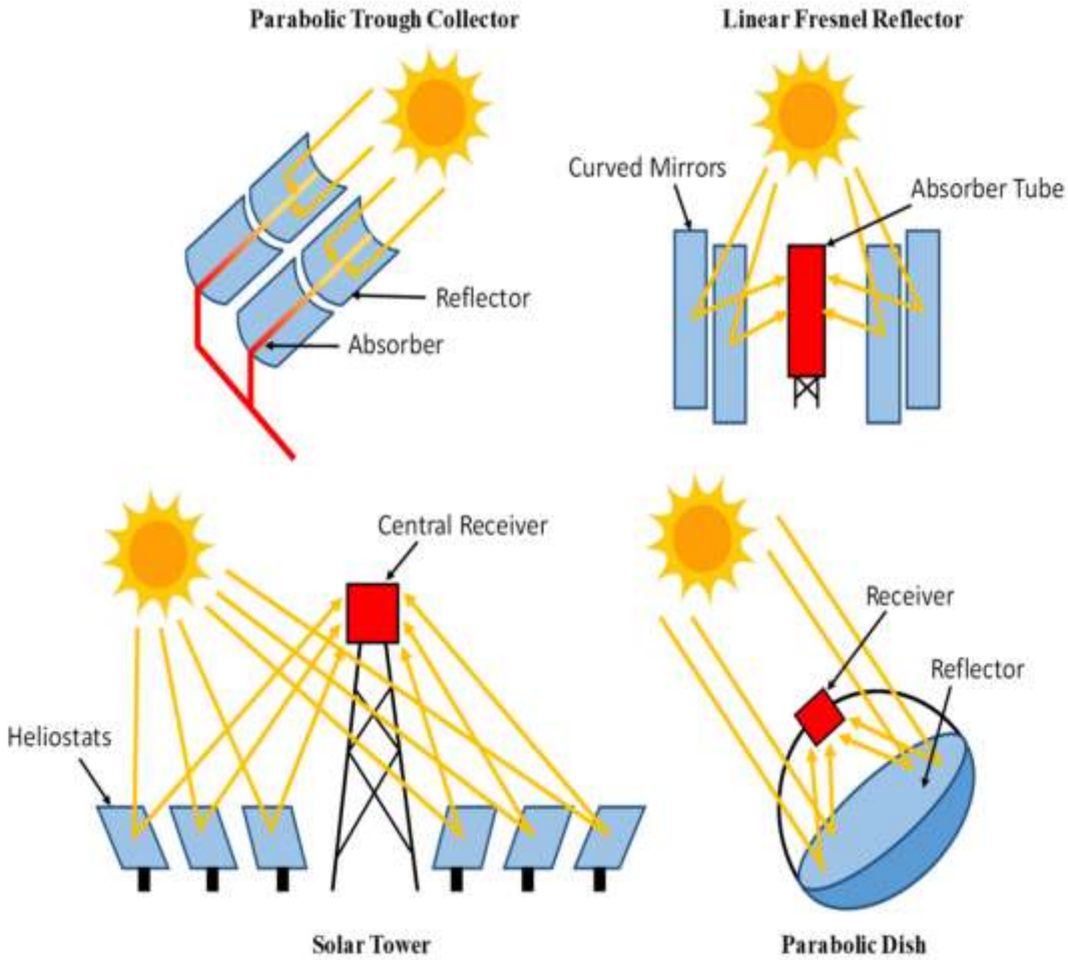


Eight primitive variables are combined into one dimension variable that governs similarity of model plants. The values of the suggested dimensionless variable were found to be nominally equal, indicating the validity of the variable. An analytical and numerical study was conducted by to investigate the energy generated by, a large scale solar tower power plant. The power produced of solar power plant was presented over 24 hours. The results showed that the height of the tower and the diameter of the solar collector was affected on the annual electricity output. At the same time, the energy production was increased by improving the shape and height of the collector roof. Summarized numerically the air flow in a solar chimney with a curved junction to examine the effect of system geometry on the heat transfer phenomenon in the solar, chimney. The result appeared that maximum velocities were obtained at the chimney entrance with curve junction when the difference between ground and cover of the collector for all Rayleigh numbers is increased. Analyzed the solar chimney power plant numerically to create two different models of numerical simulation by using the CFD software FLUENT. Second part of the simulation is showed the effect of varying plant parameters such as chimney diameter, chimney angle, collector height and collector angle under steady state condition for small range SCPP. Simulated the SCPP numerically by analyzing the air flow for SCPP generation in Baghdad / Iraq. A set of geometric parameters is assumed to solve the governing equations by Fluent software such as collector diameter and chimney height in different working conditions for the intensity of solar radiation (300,450,600,750 and 900 W/m2) to obtain the optimal structure designed. Results showed that changing the aggregate diameter and chimney height had a significant impact on system performance. The study showed that Iraqi weather was suitable for analyzing of the system.

In this paper, the performance enhancement of solar tower system is numerically investigated where the enhancement is achieved by using copper foam as a collector absorber plate.

II. NUMERICAL ENFORCMENT

The present study is intended to solve the equations of continuity, momentum and energy using ANSYS-FLUENT, a computer package that uses a finite volume method to model fluid flow and how to transfer the heat in simple and collector geometric shapes that are difficult to solve in other languages.

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

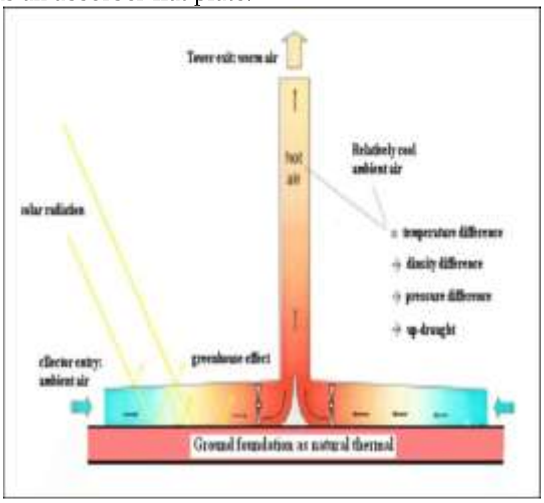
Where:

$$\Phi=2\mu[(\frac{\partial v_r}{\partial r})^2+(\frac{1}{r}\frac{\partial v_\theta}{\partial \theta}+\frac{v_r}{r})^2+(\frac{\partial v_z}{\partial z})^2+\frac{1}{2}(\frac{\partial v_\theta}{\partial r}-\frac{v_\theta}{r}+\frac{1}{r}\frac{\partial v_r}{\partial \theta})^2+\frac{1}{2}(\frac{1}{r}\frac{\partial v_z}{\partial \theta}+\frac{\partial v_\theta}{\partial z})^2+\frac{1}{2}(\frac{\partial v_r}{\partial z}+\frac{\partial v_z}{\partial r})^2-\frac{1}{3}(\nabla V)^2]$$

The numerical analysis is presented for three-dimensional, symmetry, steady state and natural convection heat transfer. Air is used as an ideal gas as the working fluid. Simulation of the buoyancy model is carried out by defining gravity -g in the (y) direction. Use 1atm. as a reference air pressure. Simulation is performed with and without porous metal foam. In this study two types of copper metal foams were used (11 and 30) PPI at the same porosity 0.9. In each type, the porous absorber is tilted from the horizontal line at angles (2° and 6°) at the middle of the height inlet opening air to reach a nearby center of the solar collector.

III.TEMPERATURE DISTRIBUTION

The porous copper foam as an absorber plate leads to increase the temperature distribution along the porous surface to reach a maximum value at tilt angle 6° of percentage 46.7 % for 10 PPI and 52.9 % for 40 PPI compared without porous metal foam. The working mechanism of the porous metal foam lead to increase the surface area of the rate of heat transfer from the hot surface to the air passing through it, which increases air temperature and decreases solid surface temperature in each case due to the increasing in Darcy number leads to increase the heat convection. The temperature distribution decreases with higher of the updraft tower because the updraft tower wall is insulated from the surroundings. The temperature increases when the tilting of porous copper foam closes from the inclination of solar collector roof because the porous copper foam as an absorber plate will be closer to the solar radiation incident on the collector roof .The temperature distribution for 40 PPI is greater than 10 PPI at the same porosity because the metal foam for 40 PPI has a large pore per inch that means a greater proportion of the metal skeleton (larger thermal contact area), which promotes a large heat transfer between the heating plate and the air passing, therefore the presence porous copper foam of 40 PPI is better than 10 PPI as an absorber flat plate.



Temperature contours with and without porous absorber. The air temperature is varied gradually along the radial direction of solar collector to reach a maximum value at the exit of updraft tower in the vertical direction. The air temperature at angle's tilt (6°) for 40 PPI is recorded a maximum value compared with other cases because the porous absorber will close to the solar radiation leading to increase the temperature of porous absorber surface that reduced the air density near the walls of porous absorber. In general, the temperature is increased along the solar collector, but the density and pressure of the air are decreased.

Air Velocity Distribution

Air velocity contours:

The velocity counters of airflow inside the solar updraft tower without copper metal foam, (11 and 30) PPI at tilting angles (2° and 6°) respectively. The presence of copper metal foam (11 or 30) PPI by the tilting of angles from the horizontal surface caused increasing in the air velocity slowly at a long surface of porous metal

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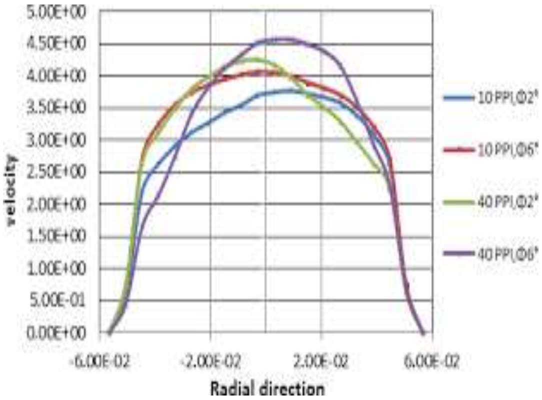
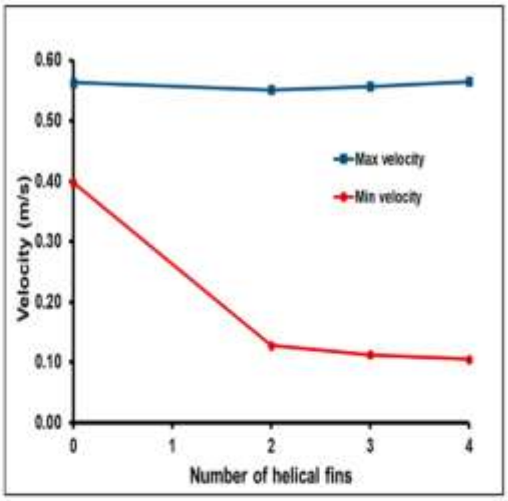
foam to rise smoothly inside the updraft tower. This is due to the increasing of buoyancy effect as the fluid temperature is increased and the strength of induced air (from the heated sections) is decreased and as a consequence a smaller eddies are formed to cause increasing in the pressure difference within the updraft tower in case the presence of porous metal foam compared without metal foam .

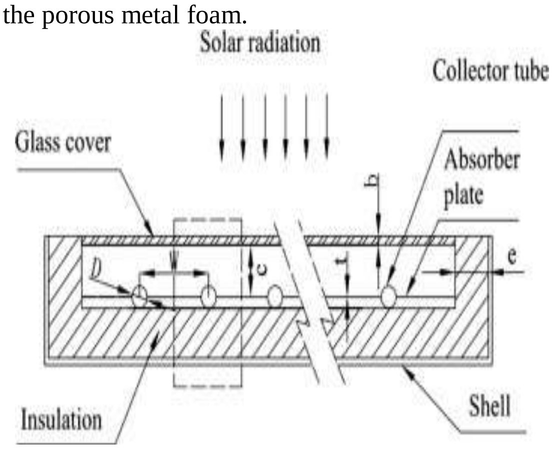


Air velocity vectors:

Velocity vectors without and with porous copper foam (11 and 30) PPI at tilting angles (2° and 6°) respectively. Effect the tilting angles of copper metal foam on the air velocity distribution inside the SUT can be analyzed. It shows that the velocity increases with increasing in the tilting angle of copper metal foam of 5.1 m /s for 11 PPI and 4.8 m/s for 30 PPI compared without porous medium of 2.4 m/s.



Air velocity is increased significantly with porous metal foam due to swirls are detected and then decreasing in the recirculate air inside the greenhouse. Thus, the air velocity increases gradually towards the updraft tower. The maximum air velocity is recorded by using copper metal foam (30 PPI) at an angle's tilt of 6° because the increasing of pores per inch leads to increasing in the difference between the solid surface temperature and air passing temperature through the porous metal foam.



Temperature Distribution along absorber plate surface:

The distribution of temperature along the surface by using flat Plate and Porous copper Absorber plate in the radial direction. It can be noted that the temperature of porous absorber medium (11 and 30) PPI at tilting angles (2° and 6) are increased from the air intake to reach to the maximum temperature at the center of solar collector and then begin to decline. The better temperature distribution along surface absorber can be seen by using porous copper foam (30 PPI at tilting angle 6°) because the porous absorber will be close to the solar collector roof, to absorb the largest quantity of solar radiation lead to improve in the air passing temperature.

Air Velocity along Up Draft Tower Distribution:

The aim of this study is to improve the performance of the solar updraft tower system by increasing the rate of air flow that enters the updraft tower. The distribution of air velocity at the base and the exit regions of the updraft tower respectively, compared without porous absorber. The air velocity reaches to the maximum at the center of the updraft tower in all cases and the reason that the pressure had a minimum value in this region. The maximum value of air velocity is recorded by using porous absorber medium (30 PPI at tilting angle 6°).

Static Pressure Distribution along Updraft Tower Distribution:

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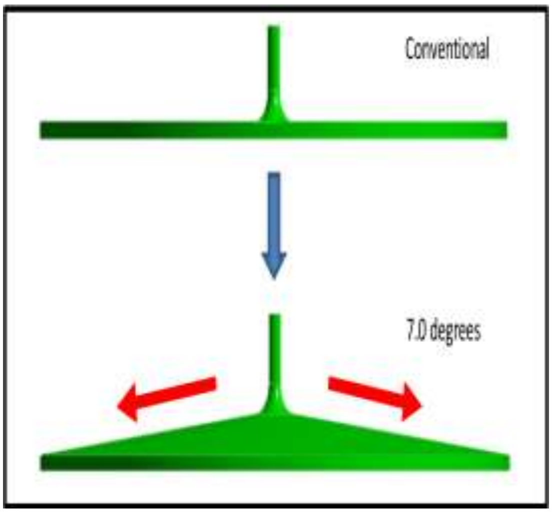
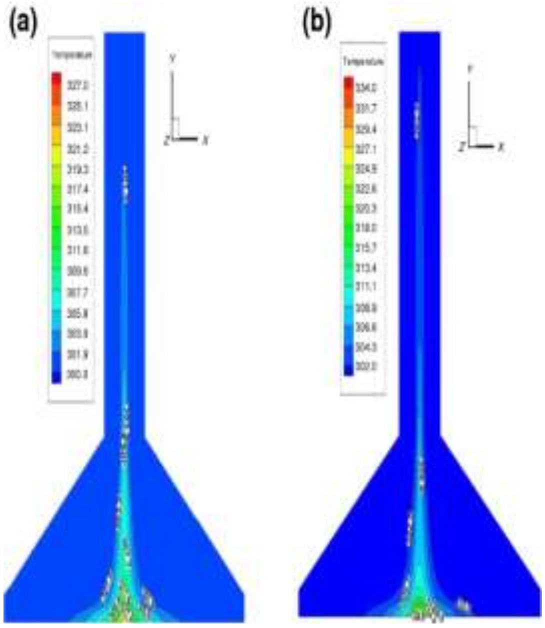
The static pressure distribution along the length of the updraft tower at different tilting angles for (11 and 30) PPI and without porous metal foam. In general, if the porous absorbing medium was present or not, the static pressure is reduced greatly at the base of the updraft tower due to the maximum airflow rate and the contact region between the exit of the solar collector and entering the updraft tower is a curve shape lead to reduce the process of separation of the fluid that occurs in this region. The presence of a porous absorber increases the pressure drop.



Thus, the air flow rate will be increased and the greater angle's slope of the horizontal line will be close to the solar collector roof to become a more decline. The static pressure at the base of updraft tower is dropped largely to reach a minimum value of –2.2 Pa. at tilting angle 6° for 30 PPI.

Dynamic Pressure Distribution Along Up Draft Tower:

The variation of the dynamic pressure along the updraft tower with and without porous copper foam as an absorber plate. The presence of porous absorber medium lead to increase the dynamic pressure clearly compared to the absence of porous copper foam, and began to gradually increase to reach a maximum dynamic pressure at the exit of air from the solar updraft tower. The highest value of dynamic pressure was recorded of 8.2 Pa. at tilting angle 2° for 30 PP. The equation was used to calculate the dynamic pressure.



Power Production:

The exit power is plotted with the mass flow rate for all cases with and without porous copper foams. It is observed that the maximum power is given when the maximum mass flow rate is reached at tilting angle 2° for 30 PPI because the height between the inclination of porous absorber and collector roof will be increased leading to decrease in the thermal contact resistance of the porous absorbing medium. Thus, the increasing with the passing of air flow rate from the bottom of a porous absorber towards the updraft tower. The following equation was used to calculate the power generated.

IV.CONCLUSION

Numerical test has been conducted to investigate the enhancement in the heat transfer, mass transfer characteristics and the performance of the solar tower system that was achieved by using porous copper foam (11 and 30) PPI at the same porosity as an absorber plate. The numerical tests are carried out on the natural convection heat transfer in an inclined collector roof at angle 22.5° with tilting metal foam absorber at an angle (2° and 6°) from the horizon and with horizontal absorber flat plate heated at constant radiation heat flux (750 W/m2). The important conclusions that extracted from the present work are:

- The fluid temperature with metal foam absorber, whether (11 or 30) PPI is higher than that in the case of without metal foam absorber.

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- The velocity of the air inside the updraft tower increases with thepresence of pores absorber and the highest value is recorded using 30 PPI compared with 11 PPI.
- Effect of the porous metal foam absorber tilted from the horizonshows clearly compared with horizontal absorber flat plate where the absorber temperature, balk temperature and air flow velocity increase with the tilt angle increases.
- Using 30 PPI porous copper foam absorber gives a betterenhancement in the performance of the solar tower system compared with 11 PPI and horizontal absorber flat plate.
- Mass flow rate increases as well as pressure drop of the updraft tower in case the presence of porous copper foam absorber compared with absorber flat plate. Thus, the power output increased by 6.7 % for 11 PPI and 9.97% for PPI 30.

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