# Research on Design and Simulation of Folded Baffle Solar Air Collector

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**Keywords:** Folded baffle solar air collector, Folded angle, Outlet temperature, Heat collection efficiency.

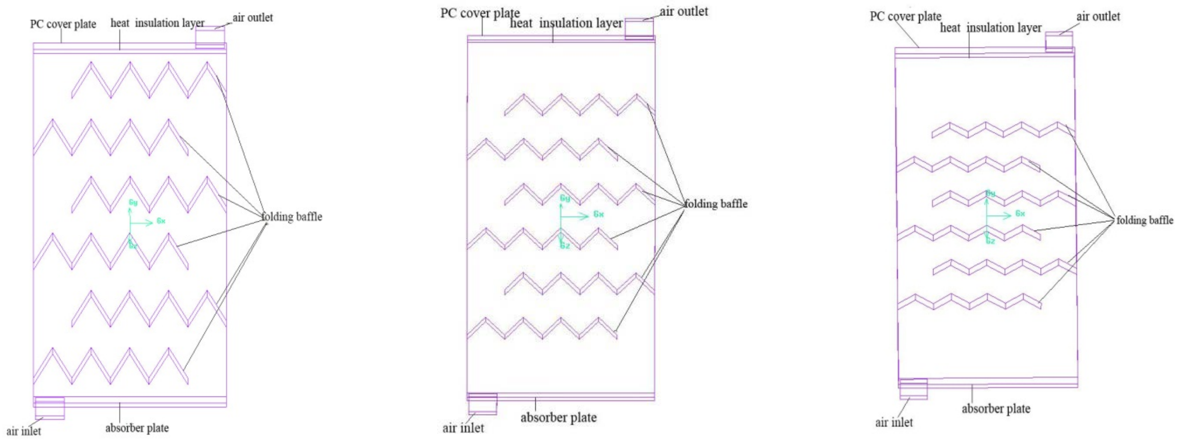
**Abstract.** In order to promote the outlet temperature and heat collection efficiency of solar air collector, this study puts forward a folded baffle solar air collector, which can improve the heat collection efficiency of the collector by enhancing the air turbulence inside the flow passage and increasing the heat exchange area. In this paper, the outlet temperature and heat collection efficiency of solar air collector with different baffle angles and different inlet flow velocities are simulated and calculated by the fluent software. The results show that under the conditions of inlet temperature of 278 K and ambient temperature of 274 K, the collector with inlet flow rate of 2 m/s and folding angle of 60° is more suitable.

## Introduction

Using clean energy such as solar energy for heating is an effective way to actively promote the national energy administration's *northern winter clean heating plan* ( 2017 - 2021 ), and the solar air collector heating system is simple in structure, free from frost protection problems, low in cost and convenient to maintain compared with the conventional solar water system [1,2]. In order to improve the heat collection efficiency of solar air collector, some efforts have done in this area. Cheng etc [3]. Proposed a new type of solar air collector with parabolic absorption plate structure. The instantaneous efficiency and pressure loss of different inclination angle are discussed. The crossed v-shaped solar air collector with wave plate proposed by Chen [4] changes the height of the air flow channel to enhance the heat conversion efficiency between air and the heat absorbing plate. In order to further improve the photo-thermal conversion efficiency of solar air collector, a folded baffle solar air collector with different baffle angles are designed and simulated in this paper.

## Physical Model of Solar Air Collector

The physical model of the folded baffle air collector designed in this article is shown in Fig. 1.




a. 60° folded b. 90°folded baffle c. 120°folded baffle

**Fig. 1** Model diagram of folded baffle type air collector

As shown in Fig. 1, the air flow channel is composed of the space between the PC cover plate, the folded baffle and the heat absorption plate. The height between PC cover and heat absorption plate is 50mm. There are six groups of baffle plates, each group is composed of eight aluminum baffle plates, and the baffle plate material is the same as the heat absorption plate material.

**Table 1** Size parameter and materials of designed collector

| | Length/mm | Width/mm | Thickness/mm | Material |
|---|---|---|---|---|
| PC cover plate | 2000 | 1000 | 4 | Polycarbonate |
| Heat absorbing plate | 2000 | 1000 | 3 | Aluminium+Al-N-Al coating |
| Baffle plate | 200<br>141.42<br>115.47 | 50 | 3 | Aluminium+ Al-N-Al coating |
| Insulation layer | 2000 | 1000 | 30 | Phenolic foam |

## Model Establishment

### Basic Assumptions

The heat loss of air at the inlet and outlet is ignored. Only the heat conduction between the cover plate and the baffle plate are considered. Radiation and convection heat exchange exist between air and the PC cover plate. Air flow inside air collector can be considered as the steady flow with constant physical parameters.

### Grid Division and Boundary Condition Setting

The gambit preprocessor is used to divide the established 3D model of collector into grids. The T-grid format is utilized, and the grids number is 550,000 through the grid independence test.

The simulation time is set at 12: 00 on March 1. The meteorological conditions are based on the typical meteorological year data. The location is set at 117°E and 36 °4′N. Using the solar calculator provided by fluent software, the azimuth vector of solar energy is obtained as follows: x=-0.690846, y=0.7152947, z=0.1052865.The air inlet and outlet adopt the coupling of velocity and pressure base, the air flow is not affected by the change of regional conditions, and the overall flow direction is along the negative direction of z axis. The air inlet temperature can be set to the same inlet condition according to different regional conditions. The atmospheric transparency is set at 0.7, which meets the local meteorological conditions. The setting of boundary conditions is listed in Table 2.

**Table 2** Boundary condition setting

| Border name | Boundary conditions |
|---|---|
| Import | Speed inlet |
| Export | Pressure outlet |
| PC cover plate | Mixed boundary conditions of convection and radiation, semitransparent medium, absorption rate 0.06, transmittance 0.83, and refractive index 1.5 |
| Heat absorbing plate<br>Baffle plate | Fluid-solid coupling couple boundary condition, opaque medium, absorptivity 0.9, emissivity 0.08 |
| Thermal insulation layer | Adiabatic boundary condition, opaque medium, wall |
| Shell | Adiabatic boundary condition, opaque medium, wall |

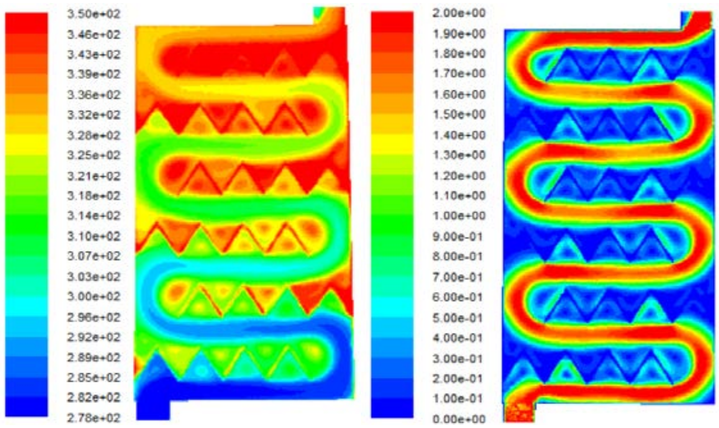
### Solution Method

The simulation process is solved by using a 3-D double-precision pressure base. The realizable k-ε model is selected, and a calculation equation about the turbulent viscosity of the fluid is added. Solar radiation is used as a local heat source, and the radiation model adopts the DO model. Simple algorithm is used for calculation. In order to obtain accurate results, the second-order upwind difference scheme is used for discretization.

## Simulation Results and Analysis

In the simulation, the inlet air temperature is set as 278K, the ambient air temperature is set as 274K, the inlet speed is set as 2 m/s, and the air mass flow rate is 0.011025 kg / s.

### Numerical Simulation of Collector with Baffle in 60° Folded Angle

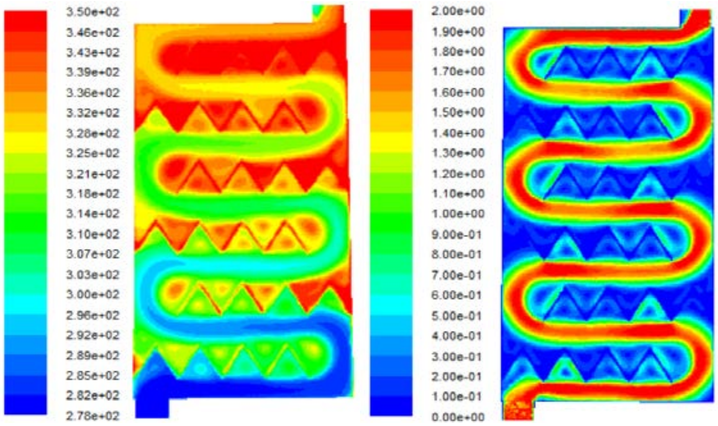



(a) Temperature distribution (b) Velocity distribution

**Fig. 2** Temperature and velocity distribution of collector with baffle in 60° folded angle

As can be seen from Fig. 2, due to the folded baffle plates, air flows in a serpentine shape in the flow passage, and air is in full contact with the baffle plates and the heat absorption plates. So the heat exchange is much more sufficient than that of the traditional flat plate air collector. Along the negative direction of the z axis, the air temperature increases, and the temperature difference between the air and the heat absorption plate decreases gradually, then the heat exchange efficiency decreases accordingly. Based on simulation results, the outlet air temperature is 325.21K and the collector heat collection efficiency is 47.54%. The heat loss coefficient is 5.014W/ ($m^2$·K), which does not exceed 9 W/ ($m^2$·K) required by the solar air collector technology [6], and the heat transfer factor is about 0.493.

**Numerical Simulation of Collector with Baffle in 90° Folded Angle**

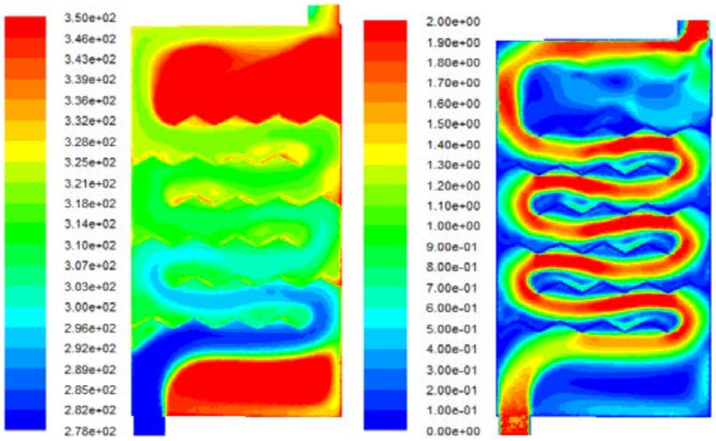



(a) Temperature distribution (b) Velocity distribution

**Fig. 3** Temperature and velocity distribution of collector with baffle in 90° folded angle

Based on simulation results, the outlet temperature of the collector with 90°folded baffle is 322.66K, the heat collection efficiency is 44.97%, the heat loss coefficient is 4.998W/(m$^2$·K), and the heat transfer factor is 0.467.

**Numerical Simulation of Collector with Baffle in 120° Folded Angle**




(a) Temperature distribution (b) Velocity distribution

**Fig. 4** Temperature and velocity distribution of collector with baffle in 120° folded angle

According to calculation, when the folding angle of the baffle plate is increased to 120°, the outlet air temperature is about 320.34K, the heat collection efficiency is 42.64%, the heat loss coefficient is 5.053W/(m$^2$·K), and the heat transfer factor is 0.443.

From comparison between Figure 2, Figure 3, and Figure 4, it can be seen that the air turbulence intensity of collector with baffle in large folded angle are lower than those in small folded angle. For the baffle in small folded angle, the convection heat transfer coefficient of air and absorption plate is higher, the air takes away more heat, and the temperature of baffle as well as heat absorption plate is relatively lower than which in large folded angle. Therefore, the heat dissipation of the collector with baffle in small angle is smaller, and its heat collection efficiency is higher than which in large angle. Therefore, 60° is selected as the folded angle of baffle for the solar air collector.

**Performance of Collector with Baffle in 60° Folded Angle at Different Inlet Flow Rates**

Keep the temperature of ambient air and inlet air constant, the operation performance of collector with baffle in 60°folded angle under condition of air inlet flow rate in 1.0, 1.5, 2.5, 3.0, 3.5 and 4m/s are simulated and plotted in Fig. 5.

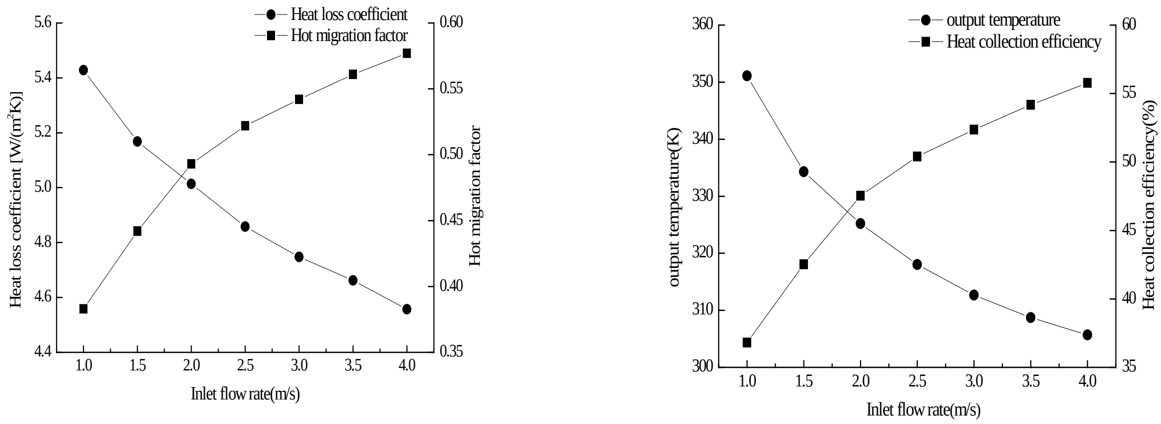



**Fig. 5** Operation performance of collector with baffle in 60° folded angle

Based on simulate results shown in Fig. 5, as the inlet flow rate increases, the outlet temperature and the heat loss coefficient decreases, besides, the heat collection efficiency and the heat transfer factor increases .When the inlet flow rate increases to a certain extent, the change rate of outlet temperature, heat collection efficiency, heat loss coefficient and heat transfer factor decreases gradually. According to the simulation data, 2m/s is more appropriate to selected as the inlet flow rate.

## Conclusions

In this paper, a folded baffle solar air collector is designed and its model is established with fluent software. Then the outlet temperature, the heat collection efficiency, the heat loss coefficient, and the heat transfer factor of solar air collector with baffle in different folded angle are simulated under different inlet flow rates conditions. Based on simulation and analysis, the following conclusions can be drawn:

(1) When the inlet flow rate is 2m/s, the performance of the collector with baffle in 60° folded angle is the highest, with the outlet temperature and the heat collection efficiency in 325.21K and 47.54% respectively;

(2) 2m/s are more appropriate to selected as the inlet flow rate for the collector with baffle in 60°folded angle.

In the further research, the number of baffle groups can be increased to enhance air turbulence and improve heat collection efficiency of the heat collector. Besides, the influence of air passage dimensions on the performance of the heat collector should be simulated and analyzed.

## Acknowledgement

This research was financially supported by a grant from Shandong Province Natural Science Foundation (No. BS2015NJ016), and a grant from Shandong Province Green Building Collaborative Innovation Centre Team Building Foundation (No. LSXT201502).

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