INVESTIGATION OF PHOTO-THERMAL PERFORMANCE OF COMPOUND PARABOLIC CONCENTRATOR SYSTEM FOR SOIL HEATING IN FACILITY AGRICULTURE

by

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Aiming at the large carbon emissions of facility agricultural heating in severe cold regions in winter, a compound parabolic concentrator based soil heating system was presented. The system integrated with novel trough compound parabolic concentrator and was used for soil heating in facility agriculture. Following the structure of the compound parabolic concentrator, TracePro software was selected to trace the light in the compound parabolic concentrator. The variation trend of the light escape rate of the compound parabolic concentrator with the different incident angles was analyzed. Based on the calculation results, the performance of the solar collector system was investigated, and the impact of circulating air velocity on the photo-thermal performance of the solar collector system was explored. Research results indicate that when the circulating air velocity is 1.4 m/s and the average ambient temperature is about 28.9 ℃, the temperature of the system outlet is up to 90.9 ℃. The average instantaneous heat collection, maximum photo-thermal conversion efficiency, and unit area heat collection of the system are 740.6 W, 27.83%, and 0.8 MJ/m^2, respectively. This research can effectively promote the efficient integration of the solar collector system in facility agriculture.

Key words: *facility agriculture, solar concentrator, soil, heating, circulating air velocity*

Introduction

As an important agricultural production method for anti-season crop production in northern China [1, 2], facility agriculture has played a positive role in ensuring a long-term and stable supply of vegetables for urban and rural residents in winter. At the same time, China has become the country with the largest vegetable planting area in the world, while its output is only 1/3 of the developed countries in the world. This phenomenon is directly related to the low temperature [3] and high humidity [4] in the microclimate environment [5] of facility agriculture in winter.

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Traditional facility agriculture needs to rely on coal-fired heating in winter. However, facility agriculture heating would lead to high energy consumption [6], low efficiency [7], large carbon emissions [8], and high operating costs [9]. The economic benefits of facility agriculture cultivation are restricted as well. Therefore, researchers combined facility agricultural heating with active solar thermal technology. Wu *et al.* [10] constructed a curved Fresnel solar concentrated system established on the inner top of the solar greenhouse. The test results showed that the system can increase the temperature of the soil ridge by 4.5~5.0 °C. Li *et al.* [11] researched the performance of a solar-heated greenhouse equipped with a seasonal thermal energy storage system, which utilized the underground soil to store the heat through *U*-tube heat exchangers. The results demonstrated that their system could make the interior air temperature 13 °C higher than the ambient temperature. A solar heated system in a greenhouse driven by the Fresnel lens concentrator was built by Li *et al.* [12]. They found that the greenhouse temperature was guaranteed above 8 °C in the coldest weather without additional energy supplements. Lu *et al.* [13] presented an active solar heat storage-release system that stored solar energy in a water storage tank, which could supply heat to raise the air temperature in solar greenhouses.

In order to improve the heating capacity of the solar concentrator system in facility agriculture, researchers explored the influence mechanism of different factors on the heat collection and heat collection efficiency of the system. Zhang *et al.* [14] designed a serpentine compound parabolic concentrator (CPC). The experimental results showed that when the working medium inlet temperature was 28.17 °C, the instantaneous efficiency was 62.36%. Chen *et al.* [15] proposed a solar multi-surface air collector with double receiver tubes as a part of the existing active-passive heating system of the greenhouse. The results showed that the solar collector increased the average temperatures of the greenhouse north wall inner surface by 7.5 °C, indoor air during the night-time by 1.8 °C, and indoor soil by 1.5 °C. Zheng *et al.* [16] presented a combined system of refrigeration and heating units with seasonal solar thermal storage. They found that when the total collector surface area equals 40 m^2 and the heat collecting temperature is 80 °C, the system can supply 76.28% heating load and 40.14% cooling load. Liu *et al.* [17] studied the thermal performance of the CPC used in the soil heating system of facility agriculture. The outcomes manifested that the radial deflective incidence angle had little effect on the optical performance of the concentrator when it was less than 14°. And when the radial incidence angle was 20°, the overall light receiving rate and concentrating efficiency were 46.5 % and 39.49 %, respectively.

Due to low solar energy flux density, short sunshine time, poor heating capacity on cloudy and snowy days, and strong dependence on other auxiliary heating technologies in winter in cold regions, a CPC based soil heating system used in facility agriculture is proposed. In addition, the solar collector system is the driving source of the CPC-based soil heating system, and it is the core part of the heat supply which affects the whole system. Therefore, the performance of the solar collector system used in soil heating of facility agriculture are analyzed in this paper. At first, the composition of the CPC-based soil heating system and the structure of the CPC are introduced. Then the TracePro software was used to simulate and calculate the influence of the incident angle on the optical performance of the CPC, and the installation angle of the CPC was determined. As the circulating air velocity affects the efficiency and the economy of the solar collector system, the influence of different circulating air velocities on the heat collection and the photo-thermal conversion efficiency of the solar collector system was explored through the experiments.

The CPC-based soil heating system used for facility agriculture

Composition and working principle of the CPC-based soil heating system

The CPC-based soil heating system is mainly composed of solar collector system, soil heat storage system, control system and draft fans and so on. The structure of the CPC-based soil heating system is shown in fig. 1. Among them, the solar collector system is composed of multiple trough CPC which are connected in series and built on the ground south of the facility agriculture.

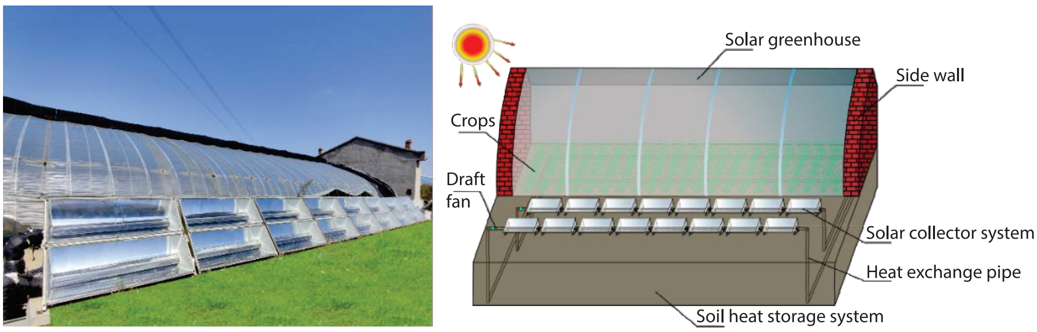

Figure 1. The CPC-based soil heating system applied to facility agriculture

The working principle of the CPC-based soil heating system is during the operation time, the CPC of the solar collector system receives sunlight and performs photo-thermal conversion generate heat, so that the temperature of the receiver in the CPC is increased. Then, the low temperature air driven by the draft fan flows through the receiver in turn. Convective heat exchange between the air and the receiver is conducted, making the circulating air temperature raised. At last, the high temperature air-flows through the planting soil of the facility agriculture. Through the means of heat convection and heat conduction, the heat is transported to the planting soil and stored in it. Therefore, the soil temperature is increased gradually and meets the planting needs of the facility agriculture in winter.

Compared with the traditional solar heating system, the CPC-based soil heating system applied to facility agricultural soil heating has the characteristics:

– The designed CPC has the advantages of a large receiving half-angle, low requirements for tracking accuracy, and can receive part of scattered radiation.
– The energy supply mode of the solar collector system adopts series and parallel multiple CPC, which can make the circulating air realize the step temperature rising and improve the energy quantity of the solar collector system.
– Using the planting soil in the greenhouse as the heat storage and heat transfer medium. Thus, not only can realize the isothermal heat exchange between the hot air and the soil, but also the uniform and stable heating of the soil can be realized.

Structure of the CPC

The structure and size of the CPC for the solar collector system are shown in fig. 2. The CPC is mainly composed of a glass cover plate, parabolic reflector, and receiver which includes a single-layer glass tube and an absorber, vertical reflection surface, and other components. The basic dimensions of the CPC are a length of 2 m, a height of 0.4 m, and the width of the light aperture is 0.7 m. The diameter of the single-layer glass tube is 110 mm. The installation height of the single-layer glass tube is 105 mm, which is the distance between the center of the single-layer glass tube and the bottom of the CPC. The 3-D co-ordinate system of the CPC is established as shown in fig. 2(b). The radial direction of the CPC refers to the *x*-direction along the glass tube, and the axial direction refers to the direction y perpendicular to the glass tube and points to the parabolic reflector.

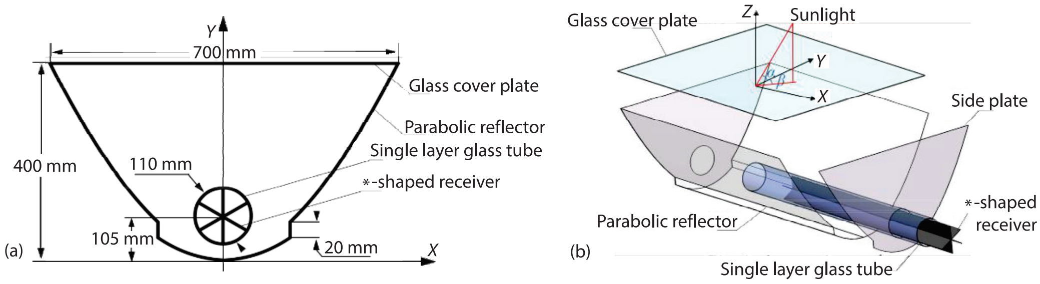

Figure 2. Structure of the CPC; (a) cross-section of the CPC and (b) assembly drawing of the CPC

Research methods and performance evaluation parameters

Optical simulation software TracePro

Using the optical simulation software TracePro, the process of light propagation and aggregation in the CPC can be visualized, and the optical performance of the CPC under different working conditions can be simulated. The light source was set as 500 × 200 parallel rectangular grid point lights, and the sun irradiance was set as 700 W/m^2. The geometric concentration ratio of the CPC is 2.03. The optical properties of the CPC are shown in tab. 1.

Table 1. Optical properties of the CPC

Unit of the CPC	Optical properties	
Parabolic reflector	Reflectivity	90%
Glass cover plate	Transmissivity	92%
Single-layer glass tube	Transmissivity	92%

Performance test system

Based on the results of the optical performance of the aforementioned CPC, a performance test system was built. Since the circulating air was driven and circulated by the draft fan. Therefore, different circulating air velocities would affect the energy consumption of the draft fan, as well as the heat exchange effect between the air medium and the CPC. Under actual weather conditions, the influence on inlet temperature and outlet of different air velocities were tested. In addition, the instantaneous heat collection, photo-thermal conversion efficiency, and heat collection per unit area of the solar collector system were obtained. It would provide data reference for the formulation of the system's operation plan in practical applications.

In order to explore and improve the heating capacity of the solar concentrator system in facility agriculture, the performance test system of the solar collector system is shown in fig. 3. The main part of the test system is a solar collector system integrated by multiple CPC. In addition, the test system also includes data acquisition instruments, *K*-type thermocouples, hot-wire anemometer, paperless recorders, solar irradiance meter, draft fans and circulation pipes, and so on. The solar collector system was arranged horizontally from east to west, the CPC are flush, and the light aperture was placed in the south direction. Considering the large receiving half-angle of the CPC, the conversion and utilization of scattered light, the cost of system operation, the difficulty of maintenance and other issues, the solar collector system was operated in a fixed installation mode. Through calculation, the installation inclination angle of the solar collector was 50° during operation.

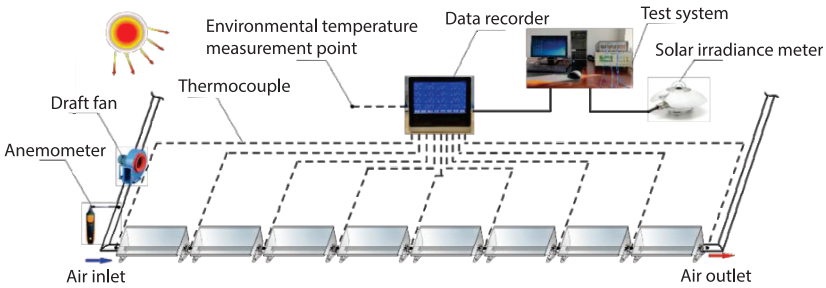

Figure 3. Test system of the solar collector system

During the experiment, the data that needs to be tested include solar irradiance, circulating air velocity, ambient wind velocity, ambient temperature, inlet temperature and outlet of each CPC, and air temperature in the CPC cavity. Among them, the centrifugal draft fan (JY5-47) was used to drive the solar collector system as the power device. The circulating air velocity was measured by a hotwire anemometer (Testo 405i). The solar irradiance was monitored and recorded in real time by a solar power monitoring system (TRMFD1). The temperatures at each measuring point were measured by K-type thermocouples, and the test data was collected in real-time by multi-channel data recorders (Sin-R6000C). The experiment was conducted in Hohhot, Inner Mongolia (N40°50′, E111°42′). The test instruments had been checked before experiment to improve the accuracy.

Performance evaluation parameters and error analysis

The TracePro software can simulate and calculate the optical performance of the CPC, and the calculation results can provide guidance and reference for the test of the CPC under actual weather conditions. In addition, the optical performance evaluation parameters selected include the light receiving rate and the light escaping rate.

– *The light receiving rate* η_0:

$$\eta_0(\alpha,\beta)=\frac{N(\alpha,\beta)}{N(0,0)} \tag{1}$$

where $\eta_0(\alpha, \beta)$ [%] is the lighting receiving rate, $N(\alpha, \beta)$ – the number of lights received by the receiver when the radial incidence angle is α and the axial incidence angle is β, and $N(0, 0)$ – the number of light when entering the light inlet of the CPC at normal incidence.

– *The light escaping rate* η_e:

$$\eta_e(\alpha,\beta)=\frac{M(\alpha,\beta)}{N(0,0)}=1-\frac{N(\alpha,\beta)}{N(0,0)} \tag{2}$$

where $\eta_e(\alpha, \beta)$ [%] is the lighting escaping rate and $M(\alpha, \beta)$ – the number of lights escape the CPC when the radial incidence angle is α and the axial incidence angle is β.

According to the optical simulation results, the photo-thermal characteristics test of CPC was carried out under the actual weather conditions. In the experiment, performance parameters such as instantaneous heat collection and photo-thermal conversion efficiency were selected to quantitatively evaluate the photo-thermal characteristics of the CPC [18].

– *The instantaneous heat collection per unit area*:

$$Q_i = \frac{mc_p\left(T_{\text{out}} - T_{\text{in}}\right)}{A_c} \tag{3}$$

where Q_i [Wm^{-2}] is the instantaneous heat collection of each CPC, i – the serial number of CPC in the solar collector system, m – the velocity of heat exchange air in the single-layer glass tube of the CPC [kgs^{-1}], c_p [Jkg^{-}1K^{-1}] – the air-specific heat capacity at a corresponding operating temperature, T_{out} and T_{in} are the outlet air temperature and inlet of each CPC, respectively, and A_c is the area of the CPC which is 1.4 m^2.

The qualitative temperature of the physical parameters is $(T_{\text{out}} + T_{\text{in}})/2$.

– *The photo-thermal conversion efficiency, which is the ratio of the heat collected by the CPC to the solar irradiance energy receiving by the CPC during the system operation*:

$$\eta = \frac{Q_i}{G_{\text{sun}}} = \frac{mc_p\left(T_{\text{out}} - T_{\text{in}}\right)}{G_{\text{sun}} A_c} \tag{4}$$

where η is the photo-thermal conversion efficiency of the CPC [%].

When the solar collector system was used in practical application, the influence mechanism of different factors on the thermal performance of the solar collector system was analyzed through the experiments. The conventional thermal performance evaluation parameters like the temperature rising and instantaneous heat collection of the solar collector system were calculated. In addition, the heat collection during operation period was chosen as a quantitative evaluation parameter of the solar collector system:

$$Q_{mi} = \sum\nolimits_{\text{start}}^{\text{end}} Q_i \tag{5}$$

where Q_{mi} [MJm^{-2}] is the heat collection per unit area of CPC, start and end are the time of the system start and stop operation, respectively.

In addition, direct measurement errors would occur when using instruments to test physical quantities such as solar irradiance, temperature, and circulating air velocity. The indirect measurement errors would be further generated when calculating performance parameters, such as instantaneous heat collection and photo-thermal conversion efficiency. Therefore, to improve the accuracy of the test, it is necessary to analyze the uncertainty of the test. Then the photo-thermal characteristics of the CPC can be accurately evaluated. The test error is shown in tab. 2.

Table 2. Testing instrument and error

Equipment	Type	Precision	Measurement error [%]	Measurand
Solar irradiance meter	TBQ-2	<5%	2	Solar irradiance
Thermocouple	*K*-type	±0.5 °C	0.4	Temperature
Paperless recorder	Sin-R6000C	–	–	
Hotwire anemometer	Testo 405i	±0.5(0.1m/s + 5%v)	0.7	Air velocity
Centrifugal fan	JY5-47	-	–	

According to eqs. (4) and (5) and the error analysis theory, the errors of instantaneous heat collection and photo-thermal conversion efficiency can be calculated [19]. The calculation formula is shown:

$$\Delta Q = \sqrt{\left(\Delta T\right)^2 + \left(\Delta v\right)^2} \tag{6}$$

where ΔQ [%] is the relative error of the instantaneous heat collection , ΔT [%] – the temperature measurement error, and Δv [%] – the measurement error of circulating air velocity:

$$\Delta\eta = \sqrt{(\Delta T)^2 + (\Delta v)^2 + (\Delta G_{\text{sun}})^2} \tag{7}$$

where $\Delta\eta$ [%] is the relative error of photo-thermal conversion efficiency and ΔG_{sun} [%] – the measurement error of solar irradiance.

After calculation, the relative errors of instantaneous heat collection and photo-thermal conversion efficiency are 0.8% and 2.2%, respectively, which can meet the test accuracy requirements.

Discussion and results

Optical performance of the CPC

The biggest feature of the CPC is that the receiving half-angle is large, and there is no need to track the sun in real-time. While the change of the incidence angle still affects the photo-thermal performance of the CPC, the influence mechanism can be obtained intuitively by using optical simulation software. The light tracing at normal incident of the CPC is shown in fig. 4. As can be seen in the fig. 4, the normal incident light is received by the receiver for photo-thermal conversion, so no light escapes.

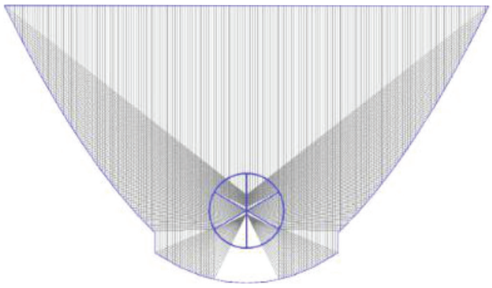

Figure 4. Light tracing at normal incidence of the CPC

During operation period, the axial incidence angle β caused by the solar azimuth angle has a great influence on the optical performance of the CPC, which is fixedly placed in the east-west direction. Through simulation, it is obtained the light transmission trajectory of the CPC when the axial incidence angle β is between 0° and 20°. At the same time, in order to better understand the influence of the axial incidence angle on the light tracing of the CPC, the red line at the bottom of the CPC is used to show the effective light-receiving length of the receiver, which is shown in fig. 5.

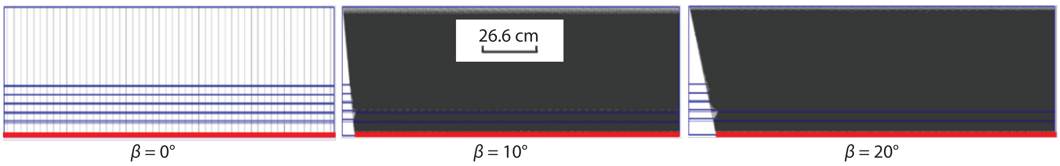

Figure 5. Influence of axial incidence angle on light tracing of the CPC

It can be seen in fig. 5 that when the light is normal incident, all light entering the CPC is received by the receiver, and the red line is the length of the CPC which is 2 m. When the axial incidence angle β increases to 10°, a little light escape and the light receiving rate decreases. When the axial incidence angle β is 20°, more light escapes from the CPC and reflected to the side plate. Therefore, when the light is obliquely incident, part of the light is reflected by the CPC and escape to the side plate to form the focal spot. What's more, with the axial incidence angle increases to 20°, the red line is 0.15 m shorter than the normal incident. When the effective light-receiving length shortened, it is not conducive to the efficient light-gathering of the CPC. In addition, the light receiving rate and focusing efficiency are decreased under

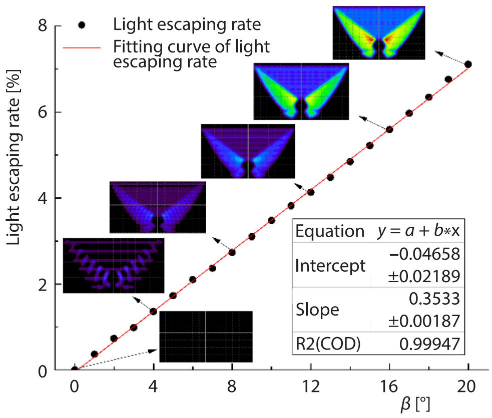

Figure 6. Influence of incidence angle on light escaping rate of the CPC

the influence of the *cosine effect* formed by axial incident angle. In order to further evaluate the influence of the axial incidence angle on the optical performance of the CPC, it is necessary to analyze the quantitative relationship between the optical performance and the axial incidence angle. Figure 6 shows that quantitative change of the light escaping rate of the CPC with the axial incidence angle and the data fitting.

In order to further predict the influence of the light escaping rate of the CPC on the axial incidence angle, a fitting analysis is carried out on the variation trend of the light escaping rate with the axial incidence angle. As shown in fig. 6, the light escaping rate increases with a linear relationship with a slope of 0.3533 and an intercept of –0.04658 as a function of the axial incidence angle. Figure 6 shows that the light escaping rate of the CPC increases with the increase of the axial incidence angle, and the energy flux density of the corresponding escaping light shows the same change trend. When $\beta = 0$ °, the light escaping rate of the CPC is 0. When β increases to 20 °, the light escaping rate of the CPC is the largest, which is 7.11%. The light escaping rate of the CPC is only 3.49% when the axial incidence angle is 0~20°, indicating that the light escaping rate of the CPC is less affected by the axial incidence angle.

Influence of circulating air velocity on performance of the solar collector system

The experiments were conducted on July 4-10 of 2021, and the operation time was 10:00 to 14:00. The circulating air velocity of the comparative test was 1.4 m/s on July 9th, 2.6 m/s on July 4th, and 3.5 m/s on July 7th. The variation of solar irradiance and ambient temperature with time on different test days can be seen in fig. 7.

Figure 7 shows that the solar irradiance and the ambient temperature are closer when the solar collector system was operated at different circulating air velocities. The solar irradiance increased first and then decreased during the operation, reaching the highest at noon. While the ambient temperature changed little with time, showing a slowly rising trend. The ambient temperature on different test days has no difference. During the test, the influence of circulating air velocity on the temperature difference between the inlet and outlet of the solar collector system is shown in fig. 8.

From fig. 8, the changing trend of the temperature difference between the inlet and outlet of the solar collector system under different air velocities is consistent with the solar irradiance. While the temperature difference between the inlet and outlet of the solar collector system and the circulating air velocity shows a negative growth trend. When the circulating air velocity is 1.4 m/s, the maximum temperature difference between the inlet and outlet of the system is 64.2 °C. It is 19.4 °C and 28 °C higher than the maximum temperature difference when the circulating air velocity is 2.6 m/s and 3.5 m/s, respectively. The main reason is that the change of circulating air velocity affects the convective heat transfer coefficient between the air and the receiver of the CPC, which in turn affects the heat transfer between the air and the receiver. At the same time, the solar collector system and the soil heat storage system are connected through the heat exchange pipe, so that the circulating air can achieve closed-loop operation. When the circulating air velocity is low, the air stays in the solar collector system for a long time to fully exchange heat with the receiver. Therefore, the temperature difference between the inlet and outlet increases. Similarly, the low circulating air velocity makes the heat exchange time longer of the heat exchange pipe and the soil heat storage system. Consequently, the circulating air temperature is lowered, because the heat carried by air can be fully released to the soil heat storage system.

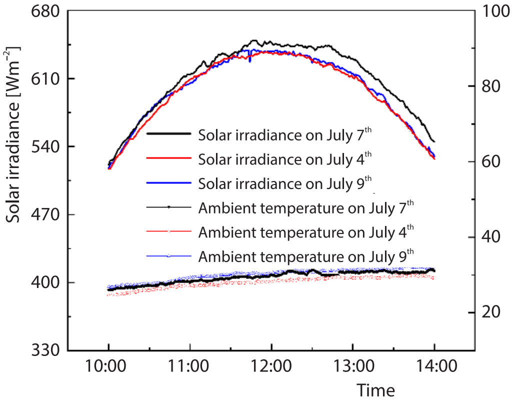

Figure 7. Solar irradiance and ambient temperature on different test days

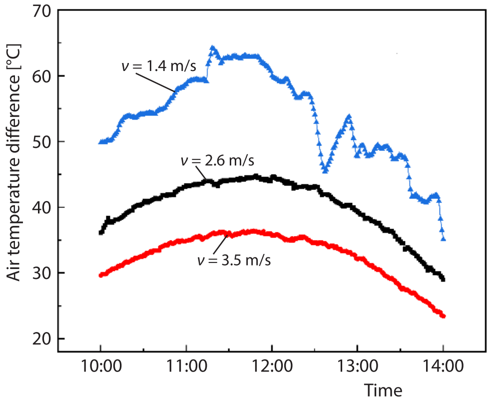

Figure 8. Influence of circulating air velocity on inlet and outlet air temperature of system

In order to obtain the variation law of the photo-thermal performance of each CPC in the solar collector system under different air velocities, the average heat collection and average photo-thermal conversion efficiency of each CPC were further calculated according to eqs. (4) and (5). Figure 9 shows average instantaneous heat collection per unit area of the solar collector system under the influence of circulating air velocity.

Table 3. Influence of circulating air velocity on the average photo-thermal conversion efficiency and average temperature rising of series CPC

CPC \ Circulating air velocity	1.4 m/s		2.6 m/s		3.5 m/s	
	Efficiency [%]	Temperature rising [°C]	Efficiency [%]	Temperature rising [°C]	Efficiency [%]	Temperature rising [°C]
1st	27.83	14.9	31.69	8.9	29.35	6.5
2nd	19.96	10.9	25.70	7.4	26.15	5.7
3rd	15.24	8.4	18.11	5.6	20.96	4.7
4th	13.04	7.2	19.69	5.8	19.48	4.3
5th	9.48	5.1	15.20	4.6	16.19	4
6th	5.99	3.3	10.31	3.1	12.83	3.1
7th	4.68	2.5	9.62	3.0	11.36	2.5
8th	2.50	1.5	5.99	1.9	9.17	2.1

Comparing fig. 9 and tab. 3, it can be found that the average instantaneous heat collection and the average photo-thermal conversion efficiency of each CPC increase with the circulating air velocity. When the circulating air velocity is 1.4 m/s, the lowest average instantaneous heat collection of the solar collector system is 529 $\mathrm{Wm^{-2}}$, which is 256.7 $\mathrm{Wm^{-2}}$ lower than the circulating air velocity of 2.6 m/s and 324.4 $\mathrm{Wm^{-2}}$ lower than the circulating air velocity of 3.5 m/s. In addition, when the circulating air velocity is 1.4 m/s, the average photo-thermal conversion efficiency of the solar collector system is 27.57 % and 32.14 % lower than when the circulating air velocity is 2.6 m/s and 3.5 m/s, respectively. The reason is that the average instantaneous heat collection and the average photo-thermal conversion efficiency are simultaneously affected by the temperature rising between the inlet and outlet of the solar collector system and the circulating air velocity. As the circulating air velocity increases, the time that the air stays in the receiver is shortened. Therefore, the heat dissipation loss of the circulating air is reduced, while the average instantaneous heat collection and the average photo-thermal conversion efficiency of the solar collector system are increased. As shown in fig. 10, the heat collection per unit area of the solar collector system is the cumulative heat collection during the test time from 10:00 a. m. to 14:00 p. m.

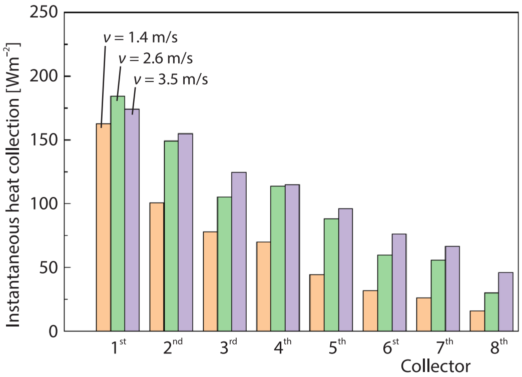

Figure 9. Influence of circulating air velocity on average instantaneous heat collection per unit area of the solar collector system

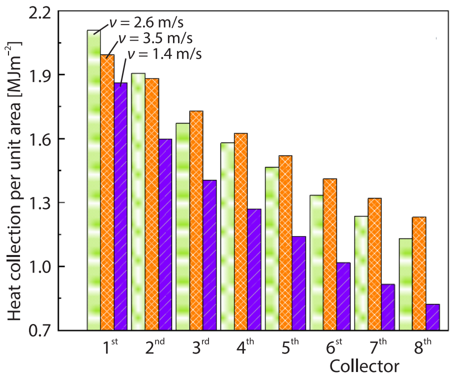

Figure 10. Influence of circulating air velocity on heat collection per unit area of the solar collector system

From fig. 10, with the decrease of the circulating air velocity, the heat collection per unit area decreases. Especially when the circulating air velocity is 1.4 m/s, the heat collection per unit area of the system is lower than the circulating air velocity of 2.6 m/s as well as 3.5 m/s. When 8 CPC are installed in the system and the circulating air velocity is 1.4 m/s, the heat collection per unit area is 0.8 MJm^{-2}, which is 0.3 MJ/m^2 and 0.4 MJ/m^2 lower than the circulating air velocity is 2.6 m/s and 3.5 m/s, respectively. To sum up, if the soil needs to obtain high grade heat energy, the solar collector system should be operated with a low circulating air velocity. And if the soil needs to obtain more heat energy, the solar collector system should be operated with a high circulating air velocity.

The economy of the solar collector system has become an important factor in determining whether it can be widely promoted. The price of heat collection per unit area is selected as the index for evaluating the system economy. When the circulating air velocity is 1.4 m/s, the system heat collection is 1.12 MJ, and the price of the device is 1400 yuan per unit. Therefore, the price of the heat collection per unit area is the heat collection/(heat collection area × price) = 1.12/(1.4 × 1400) = 5.71 × 10^{-4} MJ/m^2 Yuan per piece.

Conclusions

To increase the heating temperature of the solar collector system that can be used for soil heating in facility agriculture, a novel CPC was designed, which can realize fixed operation with a large half-angle of reception. Theoretical research was done on the variation of the light escaping rate of the CPC with the incident angle using the TracePro software. Under actual weather conditions, the performance of the solar collector system was tested. The effects of different air velocities on the heat output temperature, average instantaneous heat collection, and average photo-thermal conversion efficiency of the solar collector system were analyzed.

The main conclusions are as follows.

- The influence of the incident angle of the CPC was simulated and calculated. The results showed that with the increase of the incident angle, the number of light absorbed by the receiver decreased, and the number of escaping light through the parabolic reflector increased. Thus, the number of escaping light increased linearly. When the incident angle increases to 20°, the light receiving rate and light-gathering efficiency are still 92.89% and 77.91%, which indicates that the CPC can realize fixed installation and operation.
- Under actual weather conditions, the effects of different air velocities on the heat output temperature of the solar collector system were compared through experiments. With the increase of circulating air velocity, the outlet temperature of the solar collector system decreases, while the inlet temperature increases. When the circulating air velocity is 1.4 m/s, the average outlet temperature of the system is 90.9 °C, which is 10.6 °C, and 14.5 °C higher than when the circulating air velocity is 2.6 m/s and 3.5 m/s, respectively.
- The influence of circulating air velocity on the average instantaneous heat collection, average photo-thermal conversion efficiency and heat collection per unit area of the system was explored. When the circulating air velocity is 1.4 m/s, the average instantaneous heat collection and the average photo-thermal conversion efficiency of the CPC in solar collector system are the lowest, which are 256.7 W, 324.4 W, 27.57%, and 32.14% lower than those of the circulating air velocity of 2.6 m/s and 3.5 m/s, respectively. When eight collectors are installed in the solar collector system, the heat collection per unit area of the solar collector system at 1.4 m/s is 0.8 MJ/m^2, which is 0.3 MJ/m^2 and 0.4 MJ/m^2 lower than the circulating air velocities of 2.6 m/s and 3.5 m/s, respectively.

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