

Simulation Study of Thermal Performance on the Inner and Outer Surfaces of Semi-Transparent Photovoltaic (STPV) Glass with Different Transparency

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Abstract

This paper used the experimentally verified one-dimensional steady-state heat transfer numerical model of the semi-transparent photovoltaic (STPV) glass to simulate the influence of wind speed, ambient temperature and air gap thickness on the surface temperature of PV modules, and analyzed the thermal performance of the inner and outer surfaces of STPV glazing with different transparency. Results shows that for every 1m/s increase in wind speed, the outer surface temperatures of SL-STPV glass with transparency of 10%, DL-STPV glass with transparency of 20% and 40% decreased by 3 °C, 3.02 °C and 2.22 °C, respectively. For every 10 °C increase in ambient temperature, the outer surface temperatures of SL-STPV glass with transparency of 10%, DL-STPV glass with transparency of 20% and 40% increase by 8.45 °C, 7.6 °C, and 7.79 °C, respectively. For the DL-STPV glass with transparency of 20% and 40%, for every 2 mm increase in the thickness of the air gap, the outer surface temperature increases by 0.13 °C and 0.12 °C, respectively. The heat transfer between the inner surface of the glass and the indoor environment increases the heat gain through the glass into the room in summer, which will lead to an increase in refrigeration energy consumption. However, in winter, the heat exchange between the inner surface and the in-door air to heat the indoor air reduces the heating energy consumption to a certain extent, and achieves the effect of building energy conservation to a certain extent.

Keywords

STPV; One-dimensional Steady-state Heat Transfer Numerical Model; Transparency.

1. Introduction

With the development of economy and the acceleration of urbanization, building energy consumption has become a serious global problem that cannot be ignored, which accounts for about 40% of global energy consumption[1]. Building Integrated Photovoltaic (BIPV) combines PV modules with building materials and uses solar radiation to generate electricity[2]. By applying PV technology to roofs, walls and windows, the building has an aesthetic and modern appearance[3]. As a new type of building material, STPV glass not only allows solar radiation to enter the room through it, but also reduces lighting energy consumption by making full use of natural lighting[4], which has gradually attracted the attention of scholars. Fung et al.[5] studied the heat transfer characteristics of single-layer photovoltaic glass (SL-STPV) windows by establishing a numerical transient heat transfer model, and conducted experimental research in Hong Kong. The results show that the total indoor heat gain mainly comes from solar heat. Yang et al.[6] experimentally studied the influence of indoor airflow on the

performance of SL-STPV glass and double-layer photovoltaic (DL-STPV) glass curtain walls in Taiyuan. The results show that compared with the influence of indoor heat gain of facade photovoltaic window, the indoor air distribution has little effect on the operating temperature of photovoltaic modules. Karthick et al.[7] studied the performance of rooftop BIPV skylights under actual outdoor environmental conditions. The results showed that when the PV cell coverage was 0.62, the maximum daylight factor and indoor illumination were 4 % and 850 lux, respectively. Filippidou et al.[8] compared two different PV modules installed in North Eastern Greece, namely cadmium telluride (CdTe) thin film and poly. Si PV modules. Results are expected to help decision makers, investors and researchers interested in PV technological issues and their performance. Alarashidi et al. [9] conducted experimental studies on the visible light transmittance and daylight transmittance of STPV CdTe thin-film glazing in the UK, which were measured to be 25% and 12%, respectively, with a U value of 2.7 W/(m²•K). However, the combination of PV modules and building envelopes has changed the heat transfer process and radiation process of traditional building envelopes due to the existence of its cell layer. At the same time, the heat transferred from PV glass to the room due to its own temperature rise during the working process cannot be ignored. It is imperative to study the thermal performance of the inner and outer surfaces of STPV glass[10].

2. Material and Methods

2.1 Structure of STPV Glass

The structure of STPV glass and the heat exchange with the surrounding environment are shown in Figure 1(a) and Figure 1(b). The heat entering the room includes the solar radiation through the glass window and the heat flow caused by the temperature difference on the inner and outer sides.

The material of PV modules is cadmium telluride (CdTe) cells, which have the advantages of high power generation efficiency, simple manufacturing process and low cost. In recent years, they have become the PV cells with the highest market share after crystalline silicon (c-Si) cells[11].

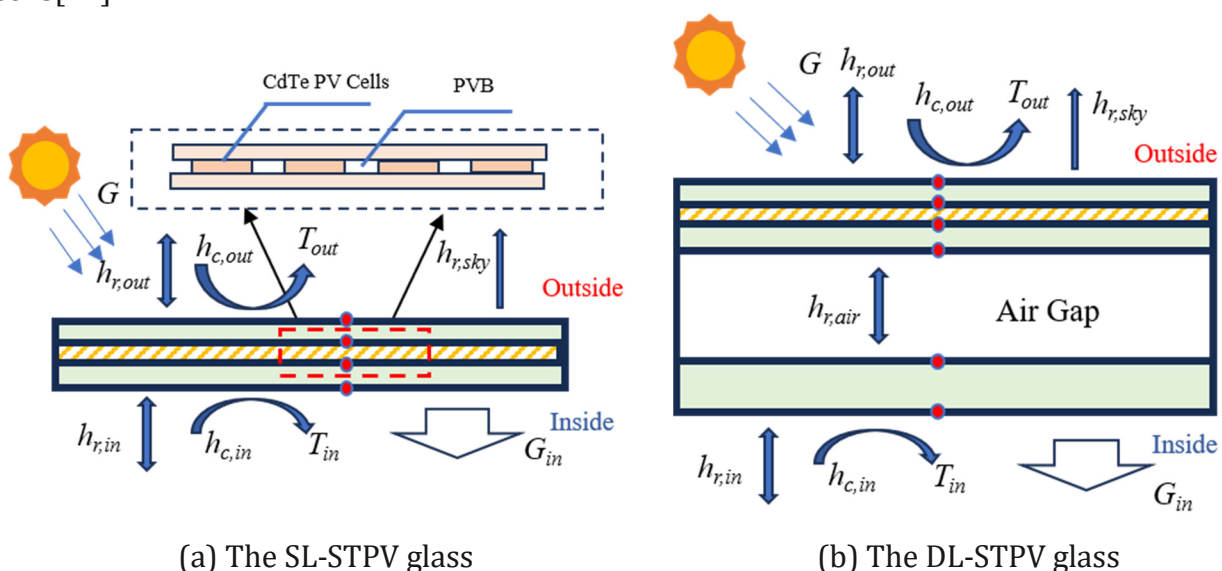


Figure 1. Structure and heat transfer diagram of the STPV glass

The SL-STPV glazing is mainly divided into three parts: outer glass, middle photovoltaic module and inner glass. Photovoltaic modules include PV cells and polyvinyl butyral (PVB adhesive layer). The DI-STPV glazing is based on the above SL-STPV window, and the middle air gap and

the inner layer of ordinary transparent tempered glass are added. The design information of the STPV glass is shown in [Table 1](#).

Table 1. Design information of the STPV glass

Types	Transparency (%)	Size (mm)	Structure			PV cells
			front	midst	backboard	
SL-STPV glazing	10	1200 (High) 600 (Width)	3.2 mm Tempered glass	0.018 mm CdTe film+ 0.76 mm PVB	3.2 mm Tempered glass	CdTe
DL-STPV glazing	20 40		SL-STPV glazing	12 mm air	5 mm Tempered glass	

2.2 Heat Transfer Model

A one-dimensional steady-state heat transfer model of STPV glass was established along the thickness direction of the glass. To calculate the temperature of each layer plane of the STPV glass, this paper establishes a heat transfer network for the structural characteristics of the SL-STPV glass and the DL-STPV glass, as shown in [Figure 2\(a\)](#) and [Figure 2\(b\)](#). When establishing the heat balance equation, the model does not consider the heat storage of the glass.

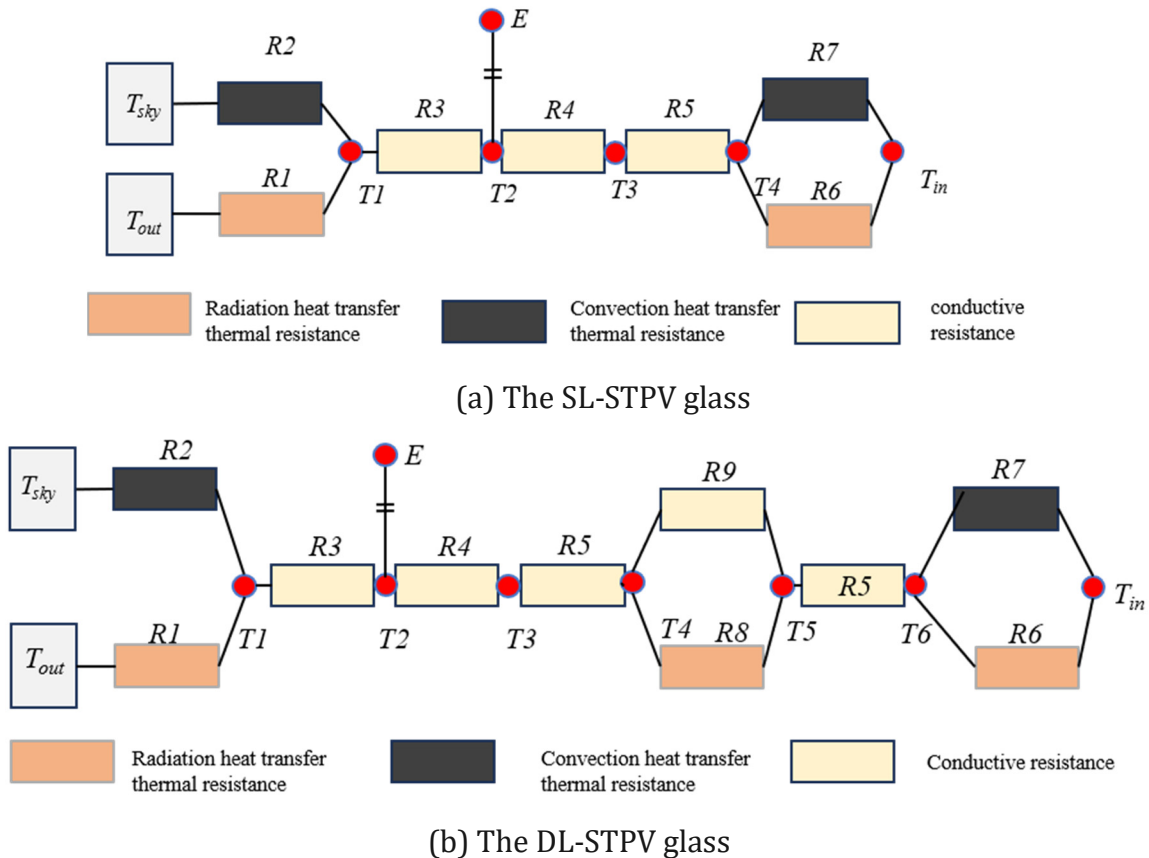


Figure 2. Heat transfer network diagram

For the SL-STPV glass, the heat balance equations of each heat transfer node are detailed below.

$$\alpha_{gl1} + h_{c,out}(T_{out} - T_1) + h_{r,sky}(T_{sky} - T_1) + \frac{\lambda_{gl1}}{d_{gl1}}(T_2 - T_1) = 0 \quad (1)$$

$$G\tau_{gl1}(\psi_{PV}\alpha_{PV} + \psi_{PVB}\alpha_{PVB}) + \frac{\lambda_{gl1}}{d_{gl1}}(T_1 - T_2) + \frac{\lambda_{PVB}}{d_{PVB}}(T_3 - T_2) - E = 0 \quad (2)$$

$$G\tau_{gl1}(\psi_{PV}\tau_{PV} + \psi_{PVB}\tau_{PVB})\alpha_{gl2} + \frac{\lambda_{PVB}}{d_{PVB}}(T_2 - T_3) + \frac{\lambda_{gl2}}{d_{gl2}}(T_4 - T_3) = 0 \quad (3)$$

$$\frac{\lambda_{gl2}}{d_{gl2}}(T_3 - T_4) = h_{c,in}(T_4 - T_{in}) + h_{r,in}(T_4 - T_{in}) \quad (4)$$

where, G denotes the horizontal solar radiation intensity, W/m^2 ; α_{gl1} , α_{PV} , α_{PVB} , α_{gl2} represents the solar radiation absorption coefficient of outer glass, PV cells, PVB adhesive layer and inner glass respectively; $h_{c,out}$, $h_{c,in}$ represents the convective heat transfer coefficients between the outer glass surface and the outdoor environment, and between the inner glass surface and the indoor environment respectively; $h_{r,sky}$, $h_{r,in}$ represents the radiant heat transfer coefficients of the outer glass surface and the outdoor environment, and the inner glass surface and the indoor environment respectively; τ_{gl1} , τ_{PV} , τ_{PVB} , τ_{gl2} , represents the radiation penetration coefficient of the outer glass and PVB adhesive layer respectively; λ_{gl1} , λ_{PVB} , λ_{gl2} represents the thermal conductivity of glass and PVB adhesive layer, $W/(m \cdot K)$; d_{gl1} , d_{PVB} , d_{gl2} represents the thickness of the outer glass, PVB adhesive layer and inner glass respectively, m ; ψ_{PV} , ψ_{PVB} represents PV cell coverage and PVB adhesive layer coverage respectively.

For the DL-STPV glass, the heat balance equations of the first to the third heat transfer nodes are the same as SL-STPV glazing. While The heat balance equations of the fourth to sixth heat transfer nodes are as follows:

$$\frac{\lambda_{gl}}{d_{gl}}(T_3 - T_4) + \frac{\lambda_{air}}{d_{air}}(T_5 - T_4) + h_{r,air}(T_5 - T_4) = 0 \quad (5)$$

$$G\tau_{gl1}(\psi_{PV}\tau_{PV} + \psi_{PVB}\tau_{PVB})\tau_{gl2}\alpha_{gl3} + \frac{\lambda_{air}}{d_{air}}(T_4 - T_5) + h_{r,air}(T_4 - T_5) = \frac{\lambda_{gl}}{d_{gl}}(T_5 - T_6) \quad (6)$$

$$\frac{\lambda_{gl}}{d_{gl}}(T_5 - T_6) = h_{c,in}(T_6 - T_{in}) + h_{r,in}(T_6 - T_{in}) \quad (7)$$

where, λ_{air} represents the thermal conductivity of air; d_{air} represents the thickness of air gap, $h_{r,air}$ represents the radiant heat transfer coefficients of air.

Experimental study and model validation have been completed by Ding et al [12]. The thermal properties of each heat transfer node are shown in [Table 2](#).

Table 2. Thermal properties of STPV glass

Materials	Thickness (mm)	absorption factor of solar radiation (%)	solar radiation transmission function (%)
glass	3.2	0.11	0.82
	5	0.13	0.8
CdTe PV cells	0.018	0.91	0.093
PVB	0.76	0.12	0.85

2.3 Numerical Model for Calculation of Heat Transfer on the Inner Surface

The absorption of solar radiation by photovoltaic cells will lead to an increase in the temperature of the outer surface of the glass, and then through the heat transfer of the glass, the temperature of the inner surface of the glass is also higher than that of the ordinary daylighting glass. The heat transfer through the temperature difference of the inner surface of the glass enters the room in the form of convective heat transfer and radiation heat transfer. The calculation method is as follows:

$$Q_h = h_{c,in}(T_g - T_{room}) + h_{r,in}(T_g - T_{room}) \quad (8)$$

where, Q_h is the heat transfer through the temperature difference of the inner surface of the

glass, W/m^2 ; T_g is the inner surface temperature of glass, K; T_{room} is the room temperature, K. The positive value of Q_h is the indoor heat gain, and the heat is transferred from the inner surface of the glass to the interior. The negative value of Q_h is the heat lost in the room, and the heat is transmitted from the indoor environment to the outdoor through the inner surface of the glass.

3. Results and Discussions

When STPV glass is applied to building roofs, due to the strong absorption of the sun by PV cells, part of the solar radiation is converted into electrical energy, and a large part is converted into heat energy, which will lead to the increase of the surface temperature of STPV windows. The surface temperature of the outer window is a key factor affecting the heat gain of the indoor environment. The higher the surface temperature is, the more heat it gets into the room, which is directly related to the energy saving of the building. The roof skylight adopts a STPV glass window, which can reduce the heat gain of solar radiation entering the room by reducing the transmittance of the glass. However, the temperature rise of the glass caused by the high absorption rate of STPV glass to solar energy will lead to the heat conduction and convection of the glass to the indoor environment. Therefore, this section has mainly studied the heat transfer characteristics of the inner and outer surfaces of STPV glass under different transparency.

3.1 Case Study of STPV Glass in Shanghai

This study focuses on the thermal performance of STPV applications on rooftop glazing, using the typical meteorological day (TMD) of Shanghai as an example. In this simulation, TMD data was used as input data, and the indoor temperature was set to be 26°C in summer and 20°C in winter.

The horizontal solar radiation intensity and temperature changes of TMDs in summer and winter in Shanghai are shown in Figure 3(a) and Figure 3(b), respectively. The typical daily temperature range in summer is from 26.2 °C to 32.1 °C. The solar radiation received on the horizontal plane reaches a maximum of 930.31 W/m^2 at about 12 a.m. The typical daily temperature range in winter is from 4.5 °C to 5.73 °C. The solar radiation intensity on the horizontal plane reaches the maximum value of 57.17 W/m^2 at about 11 a.m.

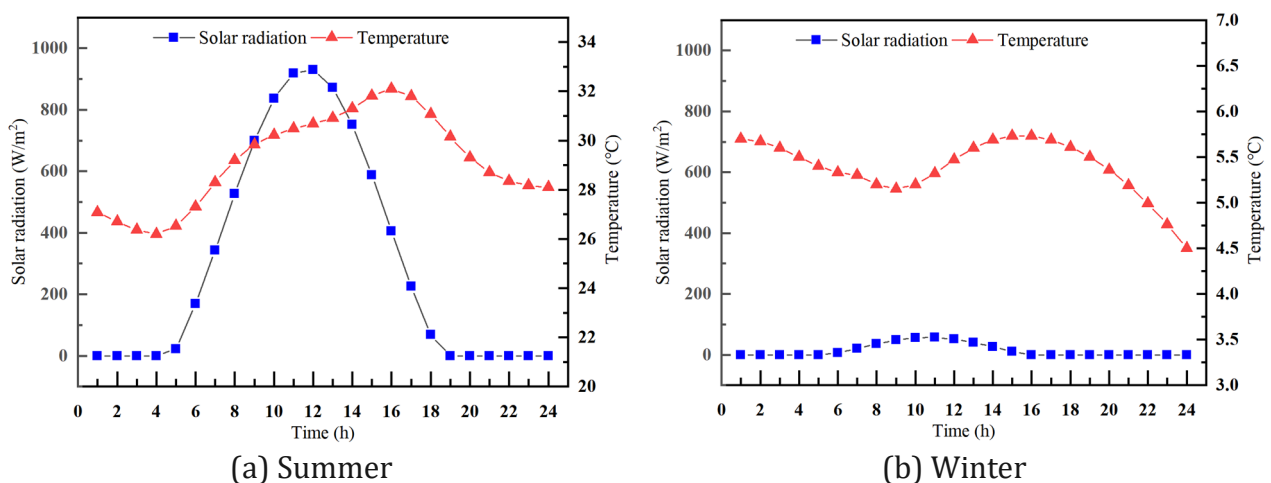


Figure 3. The horizontal solar radiation intensity and temperature on TMDs in Shanghai

3.2 The Influence Factors of STPV Module Temperature

In this section, the verified thermal models were used to simulate and analyze the influence of wind speed, ambient temperature and air gap thickness on the temperature of STPV modules.

3.2.1 Wind Speed

Assuming that the solar radiation intensity was set to 850 W/m^2 , the ambient temperature was $20 \text{ }^\circ\text{C}$, and the air gap thickness of the DL-STPV glass was 12 mm , the influence of wind speed on the component temperature was simulated and calculated.

It can be seen from [Figure 4\(a\)](#) that with the increase of wind speed, the outer surface temperature of STPV glass decreases, and shows a trend of rapid first and then slow. For every 1 m/s increase in wind speed, the outer surface temperature of SL-STPV glass with 10% transparency decreases by $3 \text{ }^\circ\text{C}$ on average. The average surface temperature of DL-STPV with transparency of 20% and 40% decreased by $3.02 \text{ }^\circ\text{C}$ and $2.22 \text{ }^\circ\text{C}$, respectively. This is due to the increase of wind speed, which enhances the convective heat transfer between the outer surface and the outdoor air.

The closed air layer of the DL-STPV module has a strong heat insulation effect, so the heat transfer from the outer surface temperature to the indoor surface is blocked, resulting in an increase in the outer surface temperature, while the SL-STPV glass is inward heat transfer faster, both sides heat transfer to the environment, and the outer surface temperature dissipates relatively fast. The absorption of solar radiation by STPV glass with high transmittance is relatively reduced under the same conditions, and the solar radiation entering the inner air through the glass is more, so the surface temperature of STPV glass is relatively low. The average temperature of the outer surface of the DL-STPV with 40% transparency is $6.7 \text{ }^\circ\text{C}$ lower than that of the DL-STPV with 20% transparency. Under the same outdoor parameters, the relationship between the outer surface temperature is 20% transparent DL-STPV > 10% transparent SL-STPV glass > 40% transparent DL-STPV glass.

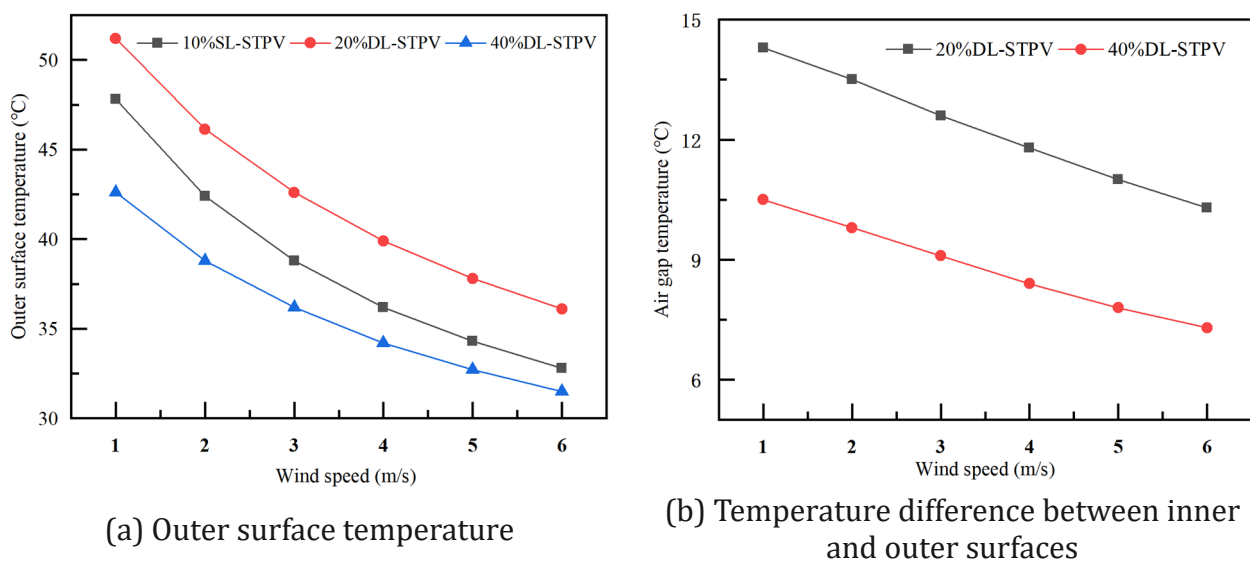


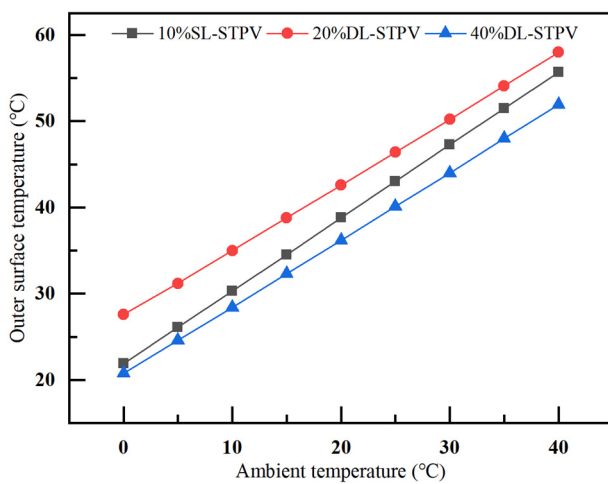
Figure 4. The influence of wind speed

As shown in [Figure 4 \(b\)](#), as the wind speed gradually increases, the temperature difference between the upper and lower sides of the air gap gradually decreases. For every 1m/s increase in wind speed, the temperature difference between the upper and lower surfaces of the air gap of DL-STPV glass with transparency of 20% and 40% decreases by $0.8 \text{ }^\circ\text{C}$ and $0.64 \text{ }^\circ\text{C}$, respectively. The results show that the increase of wind speed can greatly restrain the temperature rise of the component, change the thermophysical properties of the closed air gap, and weaken the heat transfer effect. The temperature difference between the upper and lower surfaces of the air gap also reflects the heat insulation capacity of the air gap to a certain extent. The larger the temperature difference is, the greater the heat insulation capacity is, which is

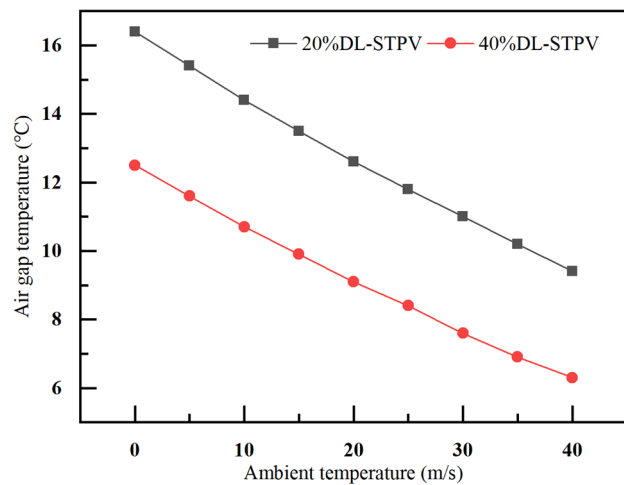
beneficial to reduce the heat gain from outdoor to indoor in summer and reduce the heat loss from indoor to outdoor in winter.

3.2.2 Ambient Temperature

When the wind speed was set to 3 m/s, the solar radiation intensity was 850 W/m², and the air gap thickness of the DL-STPV glass was 12 mm, the influence of the ambient temperature was simulated. It can be seen from [Figure 5\(a\)](#) that under the set conditions, the outer surface temperature increases linearly with the increase of ambient temperature. For every 10 °C increase in ambient temperature, the average temperature of the outer surface of SL-STPV glass with a transparency of 10% increases by 8.45 °C. The outer surface temperature of DL-STPV glass with transparency of 20% and 40% increased by 7.6 °C and 7.79 °C, respectively. The results show that the increase of ambient temperature will lead to the deterioration of heat transfer effect on the outer surface of the STPV glass. The smaller the heat dissipation trend of the glass surface to the surrounding environment, the higher the outer surface temperature.



(a) Outer surface temperature



(b) The temperature difference between the upper and lower surfaces of the air gap

Figure 5. The influence of ambient temperature

[Figure 5\(b\)](#) shows that as the ambient temperature gradually increases, the temperature difference between the upper and lower sides of the air gap gradually decreases. As the ambient temperature rises by 10 °C, the temperature difference between the upper and lower surfaces of the air gap of DL-STPV glass with transparency of 20 % and 40 % decreases by 0.875 °C and 0.775 °C, respectively. The results show that when the ambient temperature is low, the heat insulation ability of the air gap is obviously better than that of the high ambient temperature, which will enhance the heat transfer effect of the component to the room in summer and increase the heat gain through the glass into the room.

3.2.3 Air Gap Thickness

The closed air gap of the DL-STPV glass has excellent thermal insulation performance. Therefore, if the solar radiation intensity was set to 850 W/m², the ambient temperature was 20 °C, and the wind speed is 3 m/s, the influence of the thickness of the air gap on the temperature of the component was simulated.

Under the set conditions, the outer surface temperature of DL-STPV glass with two different transparency increases with the increase of air gap thickness, as shown in [Figure 6\(a\)](#). As the thickness of the air gap increases by 2 mm, the outer surface temperature of the DL-STPV glass with 20 % and 40 % transparency decreases by 0.13 °C and 0.12 °C, respectively. The reason is that the increase of the thickness of the air layer also increases the thermal resistance, and the heat transfer from the outer surface temperature to the inside of the glass is blocked. However,

it also reflects that the thickness of the air gap has a certain influence on the outer surface temperature, but the degree of influence is limited.

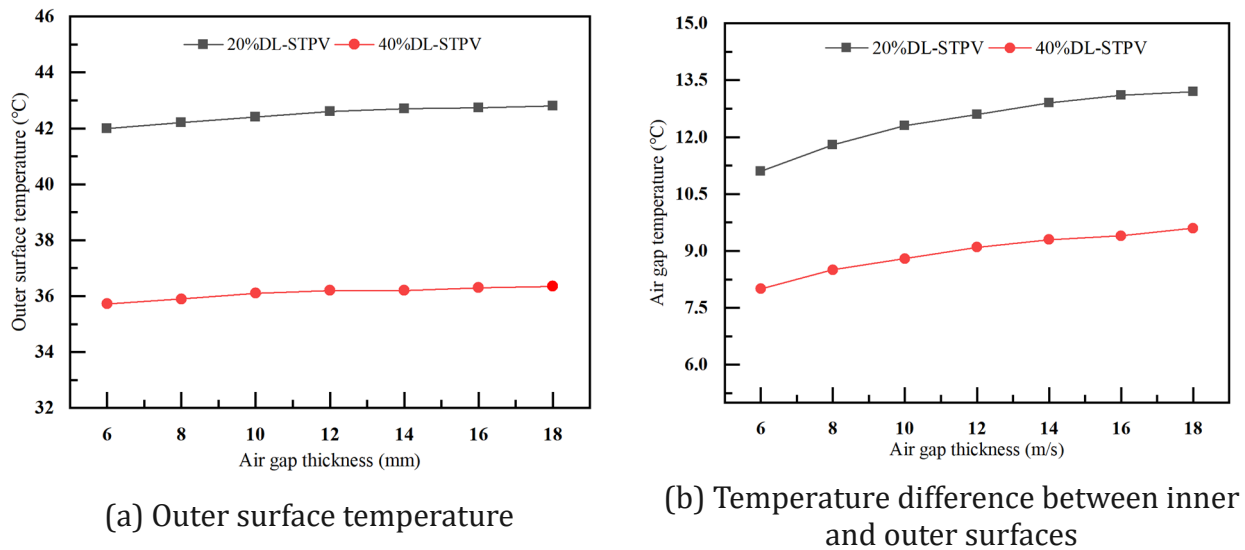


Figure 6. The influence of air gap thickness

As shown in Figure 6(b), the temperature difference between the upper and lower sides of the DL-STPV glass air gap increases with the increase of the thickness of the air gap. For every 2 mm increase in thickness, the temperature difference between the upper and lower sides of the air gap of the DL-STPV glass with transparency of 20% and 40% increases by 0.35 °C and 0.27 °C, respectively. It can be seen that increasing the thickness of the air gap is beneficial to optimize the thermal insulation performance of DL-STPV window.

3.3 The Temperature Change of the Outer Surface of STPV Glass

In this section, the real-time changes of the outer surface temperature of the above different transparency STPV glass in Shanghai have been studied.

3.3.1 Typical Summer Day

Figure 7 shows the hourly surface temperature of STPV glass with different transparency on a typical summer day. The temperature of the outer surface of the four kinds of STPV glass changes with the change of solar radiation intensity. The temperature of the DL-STPV glass with 20 % transparency (PV modules in the inside) reaches 62.53 °C. The temperature of the outer surface of the DL-STPV glass on the outer of the PV module is increased by 21.96%. Because of the structure of the PV module on the indoor side, the upper interface is the closed air gap, and the air gap has the heat insulation effect. At the same time, the next interface is the heat conduction to the indoor, and the heat exchange capacity between the inner surface and the indoor is also less than the heat exchange capacity of the PV plate on the outside and the surrounding environment. As a result, the outer surface temperature dissipates more slowly, resulting in a higher temperature.

The outer surface temperature of DL-STPV glass with 20% transparency (PV modules in the outside) is slightly higher than that of SL-STPV glass with 10% transparency. Although the SL-STPV glass with 10% transparency has a greater effective absorption capacity for solar radiation, due to the existence of no-closed air gap, the outer side dissipates heat to the external environment, and the inner side dissipates heat to the indoor environment. The more heat, the faster the cell layer cools down, resulting in a slightly lower outer surface temperature than the DL-STPV glass with 20% transparency. The DL-STPV glass with a transparency of 40% has the

slowest heating of the cell layer due to its low effective absorption rate. The SL-STPV glass with a transparency of 10% and the DL-STPV glass with a transparency of 20% (PV modules in the outside) have a temperature of more than 40 °C for 7 hours on a TMD, and the DL-STPV glass with a transparency of 40% is 5 hours. The maximum temperature of the outer surface of the DL-STPV glass with a transparency of 20% is 51.27 °C on a TMD, which is 12.38% higher than that of the DL-STPV glass with a transparency of 40%.

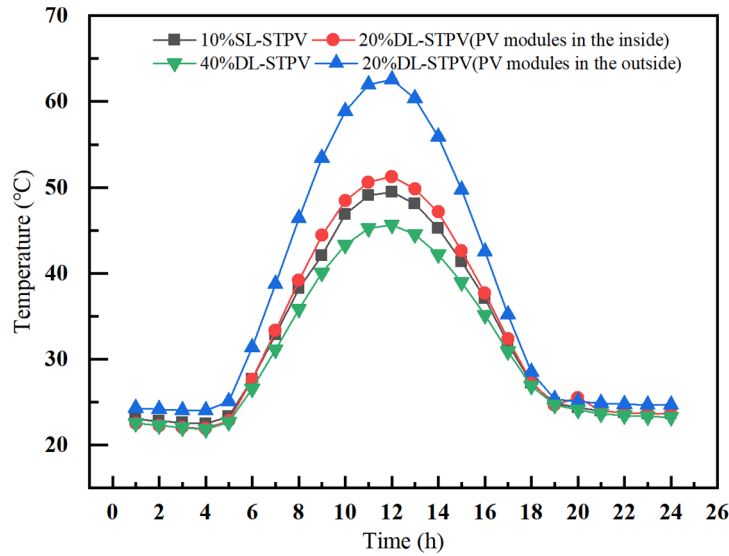


Figure 7. The temperature change of the outer surface of STPV glass in a typical summer day

3.3.2 Typical Winter Day

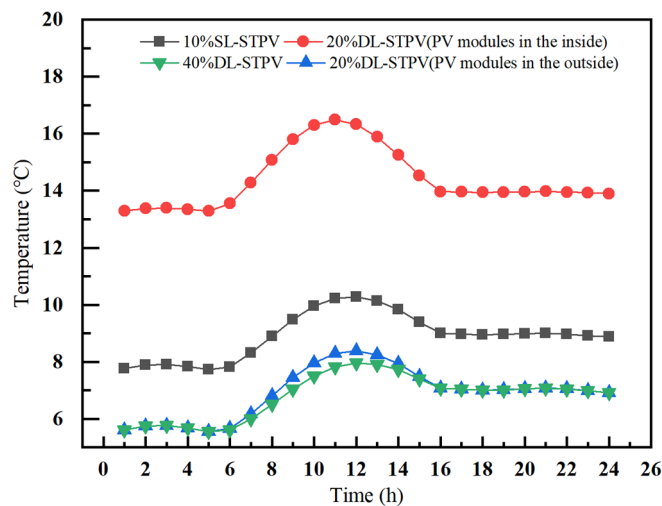


Figure 8. The temperature change of the outer surface of STPV glass in a typical winter day

Figure 8 shows the hourly variation of the surface temperature of STPV glass on a TMD in winter in Shanghai. Four kinds of STPV glass with the change trend of solar radiation intensity, four kinds of STPV glass transparency is 20 % of the DL-STPV glass (PV modules in the inside) the maximum temperature peak reached 16.49 °C, compared with the PV module in the outside of the glass of PV glass surface temperature increased by 61.19 %. Because the heat transfer direction is transferred from indoor to outdoor, and the PV module is on the indoor side of the STPV glass, the upper interface is the closed air gap, and the air gap has the heat insulation effect. The next interface is the heat conduction to the interior, and the heat exchange capacity between the inner surface and the interior is also smaller than the heat exchange capacity of

the PV module between the outer glass and the surrounding environment, resulting in a slower heat dissipation of the outer surface temperature, so the temperature is higher.

The outer surface temperature curves of DL-STPV glass with 20% transparency (PV modules in the outside) and DL-STPV glass with 40% transparency are basically coincident. During the daytime, the DL-STPV glass with 20 % transparency (PV modules in the outside) is slightly higher than the DL-STPV glass with 40% transparency. Because of the weak solar radiation, the absorption of solar radiation by PV glass has a certain impact on the temperature rise of the cell layer, but the gap is very small. The highest surface temperature of DL-STPV glass with 20% transparency (PV modules in the outside) on a TMD is 8.38 °C, which is 5.03% higher than that of DL-STPV glass with 40% transparency. The outer surface temperature of SL-STPV glass with 10% transparency is higher than that of DL-STPV glass with 20% transparency (PV modules in the outside) and DL-STPV glass with 40% transparency, up to 10.28 °C, 1.9 °C higher than that of DL-STPV glass with 20 % transparency (PV modules in the outside), 2.33 °C higher than that of DL-STPV with 40% transparency. On the one hand, it is because the glass with low transmittance has strong absorption of solar radiation. On the other hand, the indoor ambient temperature is higher than the outdoor ambient temperature. There is no closed air gap in the SL-STPV glass, and the heat dissipation from the indoor environment to the outdoor is faster, resulting in a faster temperature rise of the module, resulting in an increase in the external surface temperature. The phenomenon of higher surface temperature of SL-STPV glass with a transparency of 10%.

3.4 The Heat Transfer through the Inner Surface into the Room

This section mainly analyzed the transformation of heat transfer between the inner surface of the above four kinds of STPV glass and the indoor environment in Shanghai.

3.4.1 Typical Summer Day

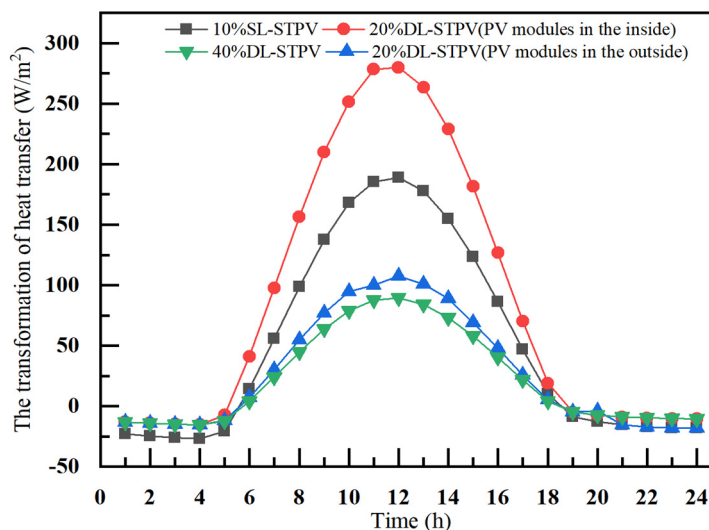


Figure 9. Heat transfer between inner surface and indoor environment on a typical summer day

Figure 9 shows the heat transfer between the inner surface of four kinds of STPV glass and the indoor environment on a TMD in summer. The relationship between the four kinds of STPV glass and the heat exchange capacity of the indoor environment is that the DL-STPV glass with a transparency of 20% (PV modules on the inside) > the SL-STPV glass with a transparency of 10% > the DL-STPV glass with a transparency of 20% (PV modules in the outside) > the DL-STPV glass with a transparency of 40%. The maximum heat exchange capacity on a TMD is 279.96 W/m², 188.99 W/m², 107.4 W/m², and 89.23 W/m² at 12 a.m., respectively. When the

outdoor parameter conditions are consistent, the inner surface temperature of the PV cell layer on the inner side is higher. Under the same light transmittance condition, the heat gain of the PV module inside the STPV glass from the inner surface to the interior in summer is more than that of the PV module outside, which increases the cooling load of the air conditioner.

The SL-STPV glass with a transparency of 10 % also has a relatively large heat transfer with the room. On the one hand, it has a strong absorption capacity for solar radiation. On the other hand, compared with the DL-STPV glass, the SL-STPV glass has no heat insulation effect of the closed air gap, and the temperature transfer trend to the inner surface is greater. The temperature difference between the inner and outer surfaces is small, and the inner surface temperature is close to the outer surface temperature, resulting in more heat transfer from the inner surface to the room.

3.4.2 Typical Winter Day

Figure 10 shows the heat transfer between the inner surface of STPV glass and the indoor environment in four different transparency on a typical winter day in Shanghai. During the day, of the four components, the internal surface of the DL-STPV glass with a transparency of 20% (PV modules in the inside) has the smallest heat flow into the room due to its structural form. The cell layer is inside the insulating glass. The heat flux of the inner surface of the SL-STPV glass with a transparency of 10% is the largest, because there is no closed air gap, and the heat transfer trend from the indoor environment to the outdoor environment is large. The total heat gain of DL-STPV glass with transparency of 20% (PV modules in the outside) and 40% is almost the same, because the solar radiation is weak on a TMD in winter, and the influence on the outer surface temperature of the two is also small.

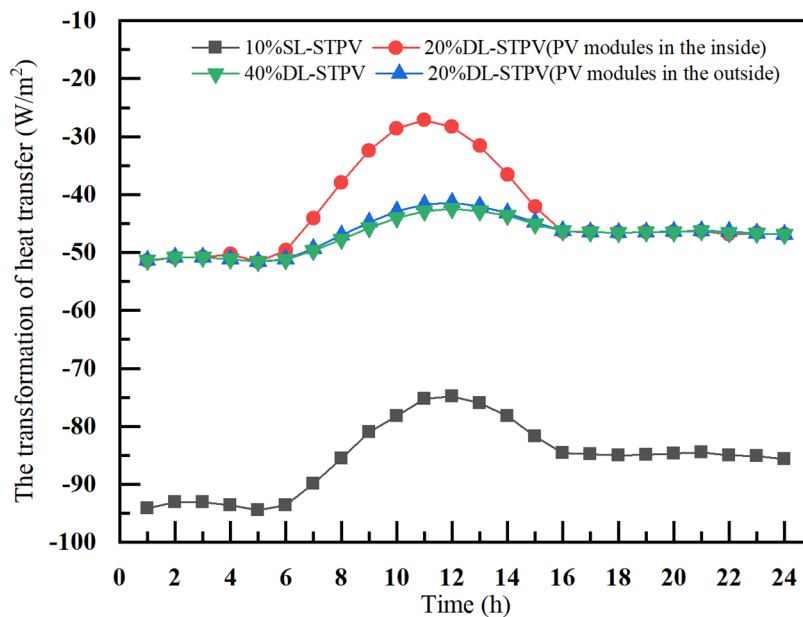


Figure 10. Heat transfer between inner surface and indoor environment on a typical winter day

4. Conclusion

Based on the thermoelectric characteristics of CdTe PV cells, this paper used the experimentally verified one-dimensional steady-state heat transfer numerical model of the STPV glass to simulate the influence of wind speed, ambient temperature and air gap thickness on the surface temperature of PV modules, and analyzed the thermal performance of the inner and outer surfaces of STPV glazing with different transparency. The conclusions are as follows:

(1) Under the set conditions, for every 1 m/s increase in wind speed, the outer surface temperatures of SL-STPV glass with transparency of 10%, DL-STPV glass with transparency of 20% and 40% decreased by 3 °C, 3.02 °C and 2.22 °C, respectively. The average decrease of the temperature difference between the upper and lower sides of the DL-STPV glass air gap is 0.8 °C and 0.64 °C, respectively. For every 10 °C increase in ambient temperature, the outer surface temperatures of SL-STPV glass with transparency of 10%, DL-STPV glass with transparency of 20% and 40% increase by 8.45 °C, 7.6 °C, and 7.79 °C, respectively. The average decrease of the temperature difference between the upper and lower sides of the air gap of the DL-STPV glass is 0.875 °C and 0.775 °C, respectively. For the DL-STPV glass with transparency of 20% and 40%, for every 2 mm increase in the thickness of the air gap, the outer surface temperature increases by 0.13 °C and 0.12 °C, respectively, and the temperature difference between the upper and lower sides of the air gap of the DL-STPV glass increases by 0.35 °C and 0.27 °C, respectively.

(2) In summer, the outer surface temperature relationship is 20% transparency of DL-STPV glass (PV modules in the inside) > 20% transparency of DL-STPV glass (PV modules in the outside) > 10% transparency of SL-STPV glass > 40% transparency of DL-STPV glass. In winter, the outer surface temperature relationship is 20% transparency of DL-STPV glass (PV modules in the inside) > 10% transparency of SL-STPV glass > 20% transparency of DL-STPV glass (PV modules in the outside) > 40% transparency of DL-STPV glass.

(3) The absorption of solar radiation by PV cells will lead to an increase in the temperature of the outer surface of the glass surface, and then the temperature of the inner surface of the glass will be higher than that of the ordinary daylighting glass through the heat transfer between the layer. The heat transfer between the inner surface of the glass and the indoor environment increases the heat gain through the glass into the room in summer, which will lead to an increase in refrigeration energy consumption. However, in winter, the heat exchange between the inner surface and the indoor air to heat the indoor air reduces the heating energy consumption to a certain extent, and achieves the effect of building energy conservation to a certain extent.

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