Research on a New Type of Solar Photovoltaic Solar Thermal Integrated Louver Curtain Wall

Y H Zhong\textsuperscript{1}, W J Zhang\textsuperscript{1}, J J Zhang\textsuperscript{1} and J W Zhou\textsuperscript{1}

\textsuperscript{1} Nanjing University of Science and Technology, No.200 Xiao Lingwei Street, Xuan Wu District, Nan Jing City, Jiang Su Province, China

zhangwenjie001@139.com

Abstract. This paper discusses the problem that the output efficiency of photovoltaic module decreases with the temperature rise of its environment. Combining photovoltaic power generation and photothermal technology, a new model of solar photovoltaic photothermal integrated louver curtain wall is proposed, which can not only have photovoltaic power generation function, but also create a good thermal environment for buildings and further reduce building energy consumption. The curtain wall model is established by computational fluid dynamics software. For the given initial parameters, the data of temperature field and flow field are obtained through simulation, and the influence of curtain wall system operation on the indoor thermal environment of the building is theoretically studied. It is found that the solar photovoltaic and photothermal integrated louver curtain wall not only has good thermoelectric benefits, but also improves the indoor thermal environment. Especially in summer and winter, the air conditioning load is reduced, which has a good building energy saving effect and provides a basis for actual building construction.

1. Introduction

At present, China's building energy consumption accounts for about 1/3 of the total energy consumption, so that high energy consumption has become synonymous with buildings. With the rapid development of solar technology, the successive discovery of a variety of photoelectric conversion materials, the urgent need for energy saving and emission reduction, and other factors, photovoltaic building integration has become the general trend of the development of the construction industry and the energy industry. The building curtain wall is one of the building's peripheral maintenance structures. As a barrier inside and outside the building, it has thermal insulation performance and has a large area that can fully accept the heat radiation of sunlight to be converted into electrical energy output. Modern curtain walls can alleviate the problem of excessive energy consumption in buildings to some extent, but there are still many areas that need to be improved. For example, in terms of building ventilation and lighting, the distribution of rooms in buildings today often only has one side leaning against the wall. Photovoltaics the curtain wall is generally installed on the south side of the building. Even if the amorphous silicon photovoltaic curtain wall is used to reduce the cell arrangement density and increase the light transmittance, the ventilation and lighting conditions in the south room are still poor, which means that it is used in buildings. As the energy consumption of lighting increases, it also does not meet people's requirements for building comfort. In terms of output efficiency, the best effect of photovoltaic cells at the appropriate temperature is monocrystalline silicon, and most of the remaining solar energy is converted into photovoltaics. The thermal energy of the module, and the photoelectric conversion efficiency of the photovoltaic cell will decrease as the temperature of the battery rises. In terms of the thermal environment in the room, a
simple photovoltaic glass curtain wall will exacerbate the greenhouse effect in the room, which will cause the building to increase energy consumption to actively cool down; in addition, the curtain wall is a facade, the photovoltaic glass and the facade will face the incident angle of the sun and too The battery can not vertically, which in turn reduces the power generation efficiency of the cell. In this regard, this paper investigated the problem of the decrease in the output efficiency of photovoltaic module power generation as the temperature of the environment in which it is located. Considering that photovoltaic curtain walls need to meet the requirements of architectural design in terms of aesthetics, lighting, ventilation, and thermal comfort, the existing Based on the photovoltaic curtain wall, a new type of solar photovoltaic light-heat integrated louver curtain wall is planned to be designed, so that it can not only have photovoltaic power generation function, but also create a good thermal environment for the building, and further reduce the building energy consumption [1-3].

2. Photovoltaic light-heat integrated shutter curtain wall model

2.1. Curtain wall overall structure model
The solar photovoltaic light-heat integrated louver curtain wall is made of aluminum alloy material as a whole frame, a single layer of toughened safety glass is installed outside the frame, and a double-layer insulating glass is installed inside. The outer glass is fixed on the aluminum alloy frame, the inner glass can be pushed, and the glass pieces that can be opened and closed are installed above and below the wall. At the same time, a 0.2m wide gap is left inside and outside the frame to serve as an air passage for the adjustable switch. There is a certain amount of space in the middle of the aluminum alloy frame. On the one hand, both ends of a box-like metal box or a material with good thermal conductivity (hereinafter referred to as a louver) are fixed to the outer part of the aluminum alloy frame through a rotating shaft. There are pipes, and the rotation axis can adjust the angle of the blades relative to the sun, and on the other hand, the air in the curtain wall can circulate [4]. One side of the louver board is equipped with crystalline silicon or amorphous silicon photovoltaic cells for photovoltaic power generation; a coil is buried inside, and the tube is filled with a heat exchange medium to absorb most of the thermal energy in the sunlight received by the photovoltaic cells, through the back panel The communication pipes between the louvers and the pipes in the building and the water heater perform heat exchange to produce domestic hot water. The curtain wall model is shown in Figure 1.

![Figure 1](image_url)

**Figure 1.** Solar photovoltaic light-heat integrated shutter curtain wall model.

2.2. Summer heat insulation
In summer, the temperature is high and the sun is abundant. Adjust the louver blades and the sun at the optimal angle to better convert photoelectricity and light and heat. The heat exchange medium flows in the louver to take away the heat of the photovoltaic cells. Close the heating channel, open the heat dissipation channel of the outer glass, use the chimney effect to take away the heat in the curtain wall channel, reduce the temperature in the curtain wall channel, and then realize the heat insulation function.
2.3. Winter heating signal
The outdoor temperature is low in winter and the sunlight is not strong enough. Adjust the louver blades to the optimal angle with the sunlight to better perform photoelectric and light-to-heat conversion. Invert the louver to make its back face the sun. The heat exchange medium flows in the louver to take away the heat of the photovoltaic cells. The cold air is heavy, sinking in the lower floor of the room, closing the heat dissipation channel, opening the inner heating channel, and using the greenhouse effect to heat the air in the curtain wall channel. The air expands and rises after being heated and enters the room through the heating channel [5-6]. Heating continues in the curtain wall. This forms a natural air heater that brings a more comfortable indoor thermal environment.

3. Calculation model establishment and analysis
3.1. Geometric model
The length, width and height of the simulation experiment room are 4.8m × 3.6m × 2.8m, the distance between the inner glass and outer glass is 0.6m, and the length, width and height of the heat dissipation channel and the heating channel are 4.6m × 0.2m × 0.1m. Because the changes in the interlayer temperature and the room temperature in the east-west direction are basically the same, the temperature changes in this direction were ignored during the simulation with Fluent, so the model was simplified to a two-dimensional model.

3.2. mathematical model
The gas in the room generally flows at a low speed, and this flow state conforms to the Boussinesq hypothesis. The corresponding turbulence model is the two-equation model of the renormalization group, namely the RNG k-ε turbulence model. The radiation model is a discrete coordinate (DO) radiation model. The PISO algorithm is used as the model's speed coupling algorithm. The pressure discrete format is BodyForce Weighted format, and the second-order upwind style and two-dimensional steady-state calculation method are used. In the room, a structured quadrilateral grid is
used to divide the grid, while in the curtain wall air sandwich, an unstructured triangular grid is used to divide the grid.

3.3. Setting of boundary conditions
The basic indoor and outdoor conditions during the simulation are summarized as follows: outdoor temperature of 35 °C in summer and indoor temperature of 30 °C, constant solar radiation intensity of 475w/m²; outdoor temperature of 5 °C in winter, indoor temperature of 10 °C, constant solar radiation intensity of 346w/m².

4. Simulation results of curtain wall influence on indoor thermal environment

4.1. Computational fluid dynamics simulation cloud image display
Using Fluent software to simulate, study the effect of solar photovoltaic solar thermal integrated louver curtain wall on the indoor temperature of the room during summer and winter operation, and obtain the velocity distribution map and temperature in the curtain wall channel and indoor under different environmental conditions in summer and winter Distribution.

![Figure 4. Computational fluid dynamics simulation cloud map](image)

Figure 4. Computational fluid dynamics simulation cloud map: (a) Summer speed cloud map (b) Summer temperature cloud map (c) Winter speed cloud map (d) Winter temperature cloud map.

4.2. Simulation analysis
The figure shows the velocity distribution diagram and temperature distribution diagram of the solar photovoltaic and photothermal integrated shutter curtain wall and the room after reaching a stable state in summer and winter.
It can be seen from the figure that the surface airflow near the outer glass and louvered photovoltaic cells in the hot aisle has the highest speed of airflow. This is because the high temperature of the outer glass surface causes the airflow temperature to change greatly, resulting in very high density changes. Large, obvious hot pressing effect. As a result, the air velocity is greater here than elsewhere. The direction of the airflow in the middle of the curtain wall hot aisle flows upward, which is consistent with the working principle of the double-glazed curtain wall.

It can be seen from the temperature cloud diagram obtained from the simulation calculation that the air temperature is highest on the side of the louver box where the photovoltaic cell is installed, which can reach about 60 °C in summer, but the temperature of the gas drops sharply along the normal direction of the photovoltaic cell. Then gradually flattened out. It can be seen from the figure that after the outdoor air enters the interlayer of the curtain wall, it absorbs the heat of the photovoltaic cells on the surface of the louver and mixes it with the hotter air in the channel of the curtain wall. The outflow, hot and cold circulation brings new air into the curtain wall channel and reduces the temperature in the curtain wall channel.

In the case of better sunshine in winter, it can be seen from the figure that the air temperature in the upper part of the room is higher and the air temperature in the lower part is lower. In addition, the maximum temperature of the side of the louver box equipped with photovoltaic cells can reach about 40 °C, and the heating channel in the lower part of the indoor cold air curtain wall enters the curtain wall channel. The gas in the channel of the curtain wall has a high temperature due to the effect of solar radiation. At this time, the indoor cold air in the channel absorbs the heat and expands and rises, and then enters the room from the heating channel above to circulate to heat the room, improving the thermal comfort of the room.

5. Conclusions
This model uses photovoltaic-photoelectric integration to collect excess heat that affects the efficiency of photovoltaic cells, which can both generate domestic hot water and be used for heating in winter. Photovoltaic cells are arranged in the form of adjustable louvers, and the inclination angle of the leaves can be combined with manual control and electronic induction control to adjust the angle of solar radiation to the photovoltaic cell to improve the photovoltaic cell's power generation efficiency. The combination of adjustable backplane light and hot water louver, double-layer combined glass, and low-power fan can create three modes: corresponding to natural ventilation, high-temperature insulation, and low-temperature heating. The use of phase-change materials improves the heat storage capacity of the water heater, which makes heat insulation and heating faster. At the same time, the combination of adjustable louvers and double-layer glass has flexibly realized the lighting and ventilation requirements of the building. The existing photovoltaic curtain wall has improved the lighting and ventilation conditions in the building to a certain extent, which can better meet people's needs. In a sense, such a curtain wall combines the common characteristics of walls and windows. And for the given initial parameters, the temperature field and flow field data are obtained through simulation, the obtained data are analyzed, and the mapping is made. The effect of the curtain wall system operation on the indoor thermal environment of the building under different environmental conditions in summer and winter is studied in theory. Because the nature of the building maintenance structure is changed, the role of a solar house is formed, which has a good effect on improving the indoor thermal environment. This greatly reduces the energy consumption of the building and provides reference value for the design of the modern building curtain wall.

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