Indoor Thermal Environment Test of Six Prism Terrace Greenhouse

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Abstract. Solar greenhouse occupies a large proportion of greenhouse types in China and is the most widely used agricultural facility in northern China. The application of solar greenhouse in agriculture is mainly to cultivate fruits, vegetables and flowers, and the bottom surface of greenhouse is mainly rectangular. So in this paper, based on regular hexagon, a greenhouse with hexagonal structure is designed, and a miniature model is constructed according to the scale. Then select some reasonable components and install them inside the structure for temperature test. By measuring the temperature inside the greenhouse at a fixed point, the temperature change inside the greenhouse in a day is obtained. Through the analysis of the longitudinal temperature comparison and the horizontal temperature field inside the greenhouse, the rationality of the structure model is verified.

1 Introduction

Solar greenhouse occupies a large proportion of greenhouse types in China and is the most widely used agricultural facility in northern China. The main application of solar greenhouse in agriculture is greenhouse, and the bottom surface of greenhouse is mainly rectangular. Greenhouse in accordance with the direction of division can be divided into east-west greenhouse and south greenhouse, greenhouse in Shandong Province is mainly south, south greenhouse east, west, north three directions are thermal insulation wall, the general front roof design angle is about 60°, the design angle of the whole shed surface is about 30~34°, the back angle according to latitude generally between 44~46°. The aim is to improve the efficiency of lighting inside the greenhouse as much as possible[1,2].

The greenhouse designed by us is different from the traditional greenhouse. It adopts the hexagonal bottom surface design to maximize the utilization of land area. The greenhouse structure with the shape of hexagonal platform makes the lighting surface more reasonable and higher lighting efficiency, so that the greenhouse can receive as much light area as possible at any time throughout the day. At the same time, the bottom structure of the six-pyramid greenhouse is matched with the top six-pyramid photovoltaic bracket, which makes the appearance more beautiful and the structure more reasonable.

2 Greenhouse design

The greenhouse model is an isometric miniature model, and the greenhouse as a whole has a hexagonal platform structure. Fig.1 shows the actual photo of the greenhouse miniature model, and Fig.2 shows the actual size of the greenhouse miniature model. The overall support part of the model adopts 60mm*60mm*2mm steel pipe material, the greenhouse roof covering material adopts 5mm toughened glass, the light transmittance is above 88%. The entrance and exit of the greenhouse are located on the north side of the greenhouse. The top of the greenhouse is a six-prism solar PV complementary power generation system. Except for the north side, the other five sides are covered with customized triangular photovoltaic panels to provide enough electricity for the whole greenhouse, which is also the power source of our temperature sensor[3].

Fig. 1. Real photos of greenhouse miniatures
In order to study the internal temperature changes of the greenhouse miniature model, six RS-WS-WIFI-Y4 temperature and humidity sensors are used, and the temperature measuring points are arranged on three horizontal planes, a total of 21. The specific temperature measuring points are distributed as shown in Fig.3[4,5].

Number 1 to 7 are located 0.2m above the ground, and number 8 to 14 are located 0.8m above the ground, and number 15 to 21 are 1.5m above ground level. The temperature measuring points of number 1 to 6, number 8 to 13 and number 15 to 20 are all located 20cm inside the adjacent side column, and number 7, number 14 and number 21 are located in the center of the horizontal plane.

3 Test data analysis

The test time of this study was April 15, 2023, when the outdoor temperature was 4-20℃ and the outdoor air humidity was 55%-65%. The greenhouse miniature model was placed in a farm in Decheng District, Dezhou City, Shandong Province. There was no obvious shelter around the farm, and the ground was ordinary land. The temperature measurement system collects data every 1 hour. Since this test only considers the temperature change inside the greenhouse when there is sunlight, a total of 10 hours of test data from 8 am to 18 PM is selected for analysis[6,7]. By sorting out the temperature of 21 points, it can be analyzed from two angles:

3.1 Longitudinal temperature distribution

Sensor 1, 8 and 15 can collect the temperature changes in the southeast direction inside the solar greenhouse miniature model, and the specific situation of its temperature is shown in Fig.4. Sensors 2, 9 and 16 can collect temperature changes in the southwest direction inside the solar greenhouse miniature model, as shown in Fig.5. Temperature changes in the due west direction inside the solar greenhouse miniature model can be collected by sensors 3, 10 and 17, and the specific temperature situation is shown in Fig.6. Sensors 4, 11 and 18 can collect temperature changes in the northwest direction inside the solar greenhouse miniature model, as shown in Fig.7. Temperature changes in the due east direction inside the solar greenhouse miniature model can be collected by sensors 5, 12 and 19, and the specific temperature situation is shown in Fig.8. Temperature changes in the central position of the solar greenhouse miniaturized model can be collected by sensors 7, 14 and 21, and the specific temperature situation is shown in Fig.10.
As can be seen from the figure, with the gradual enhancement of solar radiation in the morning of a sunny day, indoor temperature rises rapidly until it reaches the highest point around 14:00.

The trajectory of the sun moves from east to west, and the temperature inside the greenhouse presents an obvious rule. During 08:00 to 10:00, the temperature measurement points in the due east and southeast directions warm up faster. From 10:00 to 14:00, temperature points in the southeast and southwest directions showed the fastest temperature rise. After 14:00, the ambient temperature decreases and the surface temperature begins to drop. At this time, the southwest direction and due west direction receive more sunlight radiation, so the decrease range is the lowest in the same time period. The longitudinal temperature in the northeast and northwest directions is relatively low due to the short time of solar radiation and the proximity to the north entrance and exit.

The temperature inside the greenhouse shows an obvious trend of lower upper and lower levels. The upper temperature is generally 2-4°C higher than the lower temperature, which accords with the characteristics of temperature distribution[8].

3.2 Horizontal temperature distribution

It can be seen from the above content that 14:00 is basically the time when the temperature of each measuring point inside the greenhouse is the highest. The temperature of each point on the same horizontal plane during this time period is selected to carry out the distribution statistics of the temperature field inside the greenhouse[9].

The horizontal plane temperature distribution diagram of the solar greenhouse miniature model at a height of 0.2m above the ground can be collected by sensor number 1 to 7, as shown in Fig.11. The horizontal plane temperature distribution diagram of the solar greenhouse miniature model 0.8m above the ground can be collected by sensor number 8 to 14, as shown in Fig.12. The horizontal temperature distribution diagram of the solar greenhouse miniature model at a height of 1.5m above the ground can be collected by sensor number 15 to 21, as shown in Fig.13[10].
distribution inside the traditional greenhouse. In addition, compared with the traditional greenhouse, the six-prism greenhouse structure makes the lighting surface more reasonable and higher lighting efficiency, so that the greenhouse can receive as much light as possible at any time throughout the day. Therefore, the distribution of the indoor temperature field of six Prism greenhouse is more uniform. With the change of time, the temperature growth rate of all places is relatively stable, and has obvious rules, which is more convenient for us to control the indoor temperature.

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**References**

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