THE THERMAL MEASUREMENT SYSTEM

Yanzheng Liu [1,2], Guanghui Teng [1,*], Chengwei Ma [1], Shirong Liu [3]
[1] *College of Water Conservancy and Civil Engineering China Agricultural University, Beijing, China, 100083;*
[2] *Beijing Vocational College of Agriculture, Beijing, China, 102442;*
[3] *Yantai Research Institute China Agricultural University, Yantai,264670;*
[*] *Corresponding author, Address: P. O. Box 195, College of Water Conservancy and Civil Engineering, China Agricultural University, 17 Tsinghua East Road, Beijing, 100083, P. R. China, Tel:+86-10-62737583, Fax:+86-10-62736413, Email:futong@cau.edu.cn*

Abstract: The K-value (the overall heat transfer coefficient) is an important factor to reflect thermal performance of the covering material in a green house. The measuring process of K -value was burdensome in labors, low accuracy, complicated in dealing with data that is difficult to meet the development of modern agriculture. New testing methods need to be developed, and specially designed for greenhouse covering materials.

Keywords: greenhouse, virtual instrumentation, thermal measurement system

1. INTRODUCTION

The K-value (the overall heat transfer coefficient) is an important factor to reflect thermal performance of the covering material in a green house. In general, we test the K-value in the nature environment condition or simulated real environment in lab. Mihara and Hayashi kept the constant temperature inside of the room using the control instrument, and calculated the electricity quantity to get the K-value (Mihara and Hayashi, 1970). P.Feuilloley and G.Issanchou compared thermal performance between the glass and the plastic covering materials (P.Feuilloley and G.Issanchou, 1996). Xinqun Zhou tested the thermal insulation of honeycomb covering materials with plastic sheets, and he got the K-value using multi-conversion switch and the direct current potentiometer (Xinqun Zhou, 1998). The measuring process of K -value was burdensome in labors, low accuracy, complicated in dealing with data that is difficult to meet the development of modern agriculture. New testing methods need to be developed, and specially designed for greenhouse covering materials.

2. MATIERIALS AND METHOD

2.1 Geography and meteorology

In our study, we measured the cover material of a Static Hot Box to simulate the real condition, and we used the testing platform for protected agriculture cover material (Fig.1).

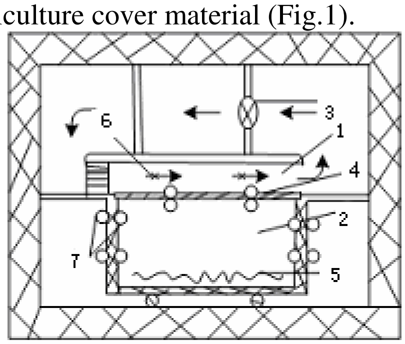

Fig.1: The cross-section diagram of the testing platform.

The box is airproof and is not subject to the sun radiation, $Q_t = Q_s = 0$; there are neither soil nor plants, $Q_r = Q_e = Q_p = Q_d = 0$; there are no lights on during the test, $Q_a = 0$; the temperature is kept constant during the test, $\Delta Q = 0$. With these conditions, the equation (1) is simplified as:

$$Q_w = KA_w(t_i - t_0) = Q_g - \sum_{j=1}^{5} Q_j \quad (2)$$

$$K = \frac{Q_c}{A_c(t_i - t_o)} = \frac{Q - \sum_{j=1}^{5} Q_j}{A_c(t_i - t_o)} = \frac{Q - \sum_{j=1}^{5} A_j(t_{wij} - t_{woj}) / R_{wj}}{A_c(t_i - t_o)} \quad (3)$$

where Q_w is the heat conducted through the cover material per second; Q_j is the heat through the other five walls of the heating box; Q_g is the overall heat given by the box (power of heating when the system is at balance); K is the heat transfer coefficient; A_w is the area of the cover; A_j

is the area of the other five walls; t_i , t_0 is the inside and outside temperatures of the cover respectively; R_{wj} is the thermal resistance of the other five walls. Based on the studied conditions (K.V. Garzoli and J. Blackwel, 1981), we can calculate the K -value of the cover in the testing platform.

2.2 The hardware components of the virtual measurement system

The virtual instrument consists of computer hardware, an instrument module, and a measurement and control unit with software for data analysis, process communication, and graphic interface. The flow diagram of this system is shown in Fig.2.

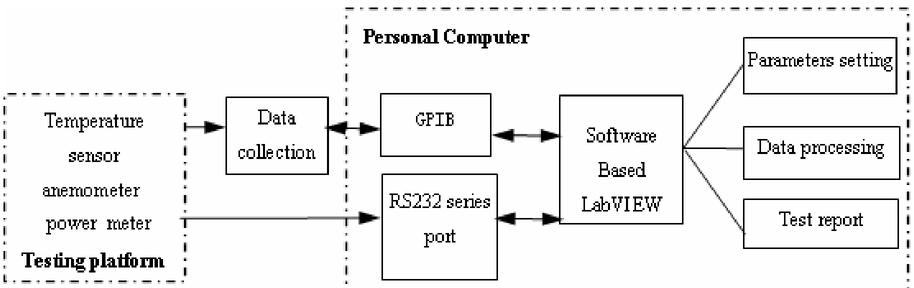

Fig.2: System structure block diagram

3. RESULTS AND DISCUSSION

We tested the K -value of a 5mm thick flat glass in the TMS. The power of heating is 55±1 W, and the airspeed is 3.0±0.125 m/s and the temperature of sky radiation board is -30±2℃, (These values are based in the weather information of Beijing), so the testing platform simulates the real condition. The measurement results are shown in Table 1. Form the Table 1 we can see that the testing K -value of glass is $7.59\,W \cdot m^{-2} \cdot ℃^{-1}$, and the deviation compared with the reference value （Qin Midao, 2004）is between 0.7% and 1.1%, that shows that the precision of the measurement system is accurate. There are only a few standard testing methods used for thermal performance of covering materials for greenhouses. The values presented are found to vary considerably among the materials considered. The heat transfer coefficient of different covering materials are not the same, for example, the K -value of 3mm thick of flat glass is from 6.29 to 6.86 (Zhou

Changji, 2003). These variations are attributed mainly to the testing method employed and also to the type of materials.

Table 10. Result of measurement

Testing cycle	Heat loss/W	Heat flux of glass/W	K testing/W·m-2·℃-1	K reference/W·m-2·℃-1
1	38.4	232.1	7.60	7.54
2	38.6	231.4	7.63	7.56
3	38.7	231.3	7.59	7.51
4	38.6	230.7	7.53	7.49
5	38.5	231.5	7.60	7.58
Average	38.6	231.36	7.59	7.54

4. CONCLUSIONS

Virtual Instrument technology is successfully applied to the study of cover material thermal performance measurement system with advantage of graphic interface and simple operation. After one month in use, the system provided accuracies and the measurement results are close to the reference value and validated that the virtual instrument technology can reduce costs of traditional testing methods. The accuracy of this measurement and experiment efficiency are improved. The effects of airspeed, temperature on both sides of the material and etc on the K-value need more experiments and studies.

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