DEVELOPMENT OF A SIMPLIFIED METHOD FOR MEASURING SOLAR SHADING PERFORMANCE OF WINDOWS

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ABSTRACT
Various window systems have been proposed and developed for the purpose of improving energy-saving properties and comfort. We are developing a simple and practical measuring system in order to determine the solar shading performance of advanced windows, such as airflow windows, windows with exterior blinds or double skin using low-E glass, thermotropic glass, and so on. Experimental set-ups with heat flow meter, a Peltier device, and a vacuum insulation box were made. Firstly detection accuracy of the measurement boxes was verified as preliminary measurement, then tested for some conventional window units, and they were applied to window systems in office buildings in Japan. The results showed that this compact system provided a simple on-site method to evaluate solar shading performance of various windows under the actual conditions of buildings in practically sufficient accuracy. Another experimental set-up was also made in order to cope with larger elements such as slats of exterior blinds.

1. Introduction
In order to realize solar shading and the utilization of natural light by windows, various window systems using blinds, such as airflow windows, double-skin windows and external blinds, have been proposed and developed. However, it is not well known whether these window systems exhibit the desired performance under actual conditions of use. In this study, the authors developed a simple technique for measuring the thermal performance of a window system with blinds, conducted preliminary experiments, and checked the effectiveness in the actual thermal performance.

2. Measuring Technique
In a previous paper, we reported about comparatively simple measuring system. As shown in Fig. 1, the measurement box comprises large-size heat flow meters (300 x 300mm) on all five surfaces of its cubical inside, and detects heat gain from its opening with these heat flow meters. The outline of the system is shown in Fig. 2. Since the temperature inside the measurement box rises by solar radiation, it is necessary to cool the measurement box from the outside of the heat flow meters so that the temperature inside is adjusted to room temperature.

As a more compact and easy technique for measuring solar shading performance, we proposed and developed the measuring device shown in Fig. 3.
1) Outline of the measuring device

Figure 4 shows an outline of the measuring device assumed for the simple measurement of a window. The structure of the device consists of vacuum insulation panels having a high thermal insulation (thermal conductivity: 0.0025 W/m/K) positioned on four internal faces. One of the remaining open faces is pressed against the window to detect the inflow heat using a heat flow meter located at opposite side. Since solar radiation heat increases the internal temperature of the device, a Peltier unit is adhered outside the heat flow meter and the internal air in the device is circulated using fans. Thus, this device controls and uniformly maintains the internal temperature almost at room temperature.

2) Accuracy evaluation

The authors conducted a verification experiment by assuming the measurement on a window surface. In the experiment, the opening of the measuring device was sealed with a heat insulation panel. Heat was then generated from a heating element of known heat radiation inside the device and the detection ratio was obtained as the ratio of the detected value to the input energy. Three kinds of heating elements were used to ascertain different heat generation values. Figure 5 shows the relationship between input energy and detected values based on the experimental results. The detection ratio was computed using Eqn. (1) in Fig. 5. The results show that the detection accuracy was comparatively high, judging on the fluctuation of only several percent from 100%.
3) Solar shading performance on window surface

The measuring device was installed on double-glazed windows and the solar heat gain coefficient (SHGC) was computed from the detected value by using Eqn. (2) in Fig. 6. Figure 6 shows the time series transition of SHGC and solar radiation on a typical summer day on the west facade. The SHGC shows variation under the influence of the time interval of the device’s internal temperature control, but is almost stable at about 0.8. This verified practical accuracy for thermal performance measurement.

\[ \eta = \frac{Q - q_f - q_{out}}{q_{in}} \]  
\[ (1) \]

\[ \eta = \frac{Q - q_f - K(t_o - t_o)}{I_{v}} \]  
\[ (2) \]

- \( \eta \): SHGC [-]
- \( Q \): Detected value [W]
- \( q_f \): Fan [W]
- \( q_{in} \): Input energy [W]
- \( q_{out} \): Heat loss through insulation panel [W]
- \( K \): Thermal transmittance [W/m²/K]
- \( t_o \): Room air temp. [°C]
- \( t_o \): Outdoor air temp. [°C]

Figure 5: Comparison of input energy and detected value

3. Application to High-performance Window System

In measuring the thermal performance of a window system with blinds, the relationship between the position of the measuring device and the slat position may impede the detection of the average thermal performance of a window. To measure the average thermal performance of such a window system independent of the positional relationship with the slats, the authors made an experimental measuring device for the vertical opening, shown in Fig. 7.
1) Outline of the measuring device

Figure 8 shows an outline of the measuring device. Like the measuring device shown in Fig. 3, this device has vacuum insulation panels with high thermal insulation on its four internal faces and the remaining face is pressed against the window to be measured. Considering that air heated by solar radiation heat tends to gather at the top, a Peltier unit is installed in the upper part of the device and the device’s internal air is circulated by two fans to control and uniformly maintain the internal air temperature almost at room temperature.

2) Accuracy evaluation

The detection ratio was computed in the way described in the previous section. For the purpose of measuring a high-performance window system, the input energy was smaller than that in the preceding section. Figure 9 shows the results. A rather high detection accuracy was verified by the small fluctuation of the detection ratio. As Fig. 10 shows, no remarkable vertical temperature distribution is observed in the measuring device. It was confirmed that temperature control was working appropriately.

3) Preliminary measurement on windowpane

The measuring device was adhered to the window surface and SHGC was measured. The shading type Low-E glass was measured on the west facade. Figure 11 shows the time series transition of SHGC and solar radiation on a typical winter day on the west facade. The SHGC did not change significantly from 0.45 under the stable condition of solar radiation. This
confirmed practical thermal performance measurement for the window with comparatively high thermal performance.

4. Application to the airflow window under actual conditions of use

1) Subject Building and Window System

The new device was tested on a high-rise office building (30 floors above ground with a total area of 180,000 m²) in Tokyo. This building uses an airflow window (AWF) and double-skin window with built-in automatic control blinds. It is suitable for measuring the optical and thermal performance around the windows since there are no obstacles that block the solar radiation on its western side. The AFW uses double-glazing on the outside and single glass on the inside. This window system sucks indoor air from below the window frame and ventilates it through a hollow layer to discharge the solar radiation heat received by the blinds from above the window frame.

2) Measured results

Figure 12 shows the time series transition of the outdoor condition and temperature on a typical winter day. The average internal temperature of the device fluctuated almost equally with the room temperature, indicating good temperature control. Figure 13 shows the time series transition of SHGC obtained from the detected value of the measuring device. The SHGC value ranges 0.15-0.2, indicating an SHGC measurement with practical accuracy. Figure 14 shows the results of SHGC measurement of the AFW, shading type Low-E glass, and double-glazing. According to the results, it seems that windows with high solar shading performance allowed the average measurement of SHGC with practical accuracy.
5. Conclusion

The authors proposed and developed a simple technique using a Peltier unit and vacuum insulation panels for measuring the solar shading performance of a high-performance window system with blinds, and verified the comparatively high accuracy of the technique.

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