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ScienceDirect
Solar Energy 110 (2014) 71–82
SOLAR ENERGY
www.elsevier.com/locate/solener

Heat transmission through a glass window with a curved venetian blind installed

Somsak Chaiyapinunt [a,*], Nopparat Khamporn [b]

[a] Department of Mechanical Engineering, Faculty of Engineering, Chulalongkorn University, Phayathai, Bangkok 10110, Thailand
[b] Department of Mechanical Engineering, Faculty of Engineering, Siam University, Petkasem, Bangkok 10160, Thailand

Received 9 January 2014; received in revised form 23 July 2014; accepted 30 August 2014

Communicated by: Associate Editor Mario A Medina

Abstract

This article reports a study on the effect of installing a curved venetian blind to a glass window on the solar heat transmission into the space. The mathematical model of the combined glass window and venetian blind is developed. Predicted results from the developed mathematical model are compared with the previous experimental ones to verify their accuracy. The variation of the solar heat gain coefficient (*SHGC*) with the related blind parameters (optical properties of venetian blind, slat spacing, distance between the blind and glass window, slat angle and solar profile angle) are studied. The variation of the *SHGC* in the shortwave part (*ShW SHGC*) and in the longwave part (*LoW SHGC*) with the related blind parameters are also studied. The understanding of their variation will provide the important information for the study of the thermal comfort for a person who stays near the glass window with blind. The *SHGC* can be further classified as the *SHGC* for direct solar radiation ($SHGC_D$) and the *SHGC* for diffuse solar radiation ($SHGC_d$). From the study it is found that installing a curved venetian blind to the glass window causes a significant reduction in solar heat gain compared to the plain glass window. The $SHGC_D$, $ShW\ SHGC_D$ and $LoW\ SHGC_D$ are all dependent on the slat angle and solar profile angle. The slat reflectance of the venetian blind has direct effect on the $ShW\ SHGC_D$. The slat absorptance of the venetian blind has direct effect on the $LoW\ SHGC_D$. The glass window and blind with high slat reflectance gives a lower value of $SHGC_D$ compared to the glass window and blind with low slat reflectance. The slat curvature also affects the $SHGC_D$ of the fenestration system (glass window with blind installed). The slat with more curvature (lower value of slat radius of curvature) causes more reduction in the value of $SHGC_D$ compared to the slat with less curvature. The blind with lower slat spacing yields a lower value of $SHGC_D$ compared to the blind with higher slat spacing. The effects of slat emittance and distance between the blind and the glass window on the $SHGC_D$ of the fenestration system are only appeared on the $LoW\ SHGC_D$ and such effects are quite small.

Keywords: Venetian blind; Glass window; Solar heat gain coefficient; Shortwave radiation; Longwave radiation; Thermal performance

1. Introduction

Glass windows are a common type of building envelope for most commercial buildings. They receive a plenty of heat gain into buildings from the incident solar radiation, especially in countries that are located in the tropic zone near equator. To reduce this solar heat gain and maintain thermal comfort for the occupants in the building, a large air conditioning system is usually required. The best way to reduce the solar cooling load is to prevent solar radiation from entering into the building inner space. Certain types of external shading devices such as roof overhangs, horizontal and vertical projections are preferred for

* Corresponding author.

http://dx.doi.org/10.1016/j.solener.2014.08.041
0038-092X/

preventing the solar radiation from entering into the building. But for certain types of buildings such as high rise office buildings, external shadings are not preferred due to the external wind load. In that case, using an expensive energy efficient glass (i.e. double pane reflective glass, double pane low-e glass and triple pane low-e glass, etc.) as a building envelope is the preferred way to reduce the solar heat gain. However, when the building is actually used, occupants often install a venetian blind as an indoor shading device to reduce the glare and to maintain the privacy. The building envelope to be analyzed becomes the glass window together with blind instead of the plain glass window alone. The venetian blind is considered as diathermanous (i.e. it transmits both shortwave and longwave radiation) and nonspecular optical element. Much work has been done on heat transmission through the glass window with venetian blind installed. But most of the works (Klems, 1994a,b; Klems et al., 1996; Klems and Warner, 1997; Collins and Harrison, 2004; Pfrommer et al., 1996; Chantrasrisalai and Fisher, 2004; EnergyPlus, 2005; Yahoda and Wright, 2004) dealt with the flat slat blind. Kuhn (2006a,b) has studied the solar control system including the venetian blind with arbitrary shapes of slat and their specular properties. Wright et al. (2008) through the ASHRAE sponsored research developed a simplified method to calculate the thermal performance of the glass window with a shading device system. Chaiyapinunt and Worasinchai (2009a,b) have developed a mathematical model to calculate the shortwave optical properties for a curved slat venetian blind with thickness and a mathematical model to calculate the longwave optical properties for a curved slat venetian blind by including the effects of both the slat curvature and the slat thickness in the mathematical model. Chaiyapinunt and khamporn (2013) have investigated the thermal performance of a glass window with a curved venetian blind installed in the shortwave part. It is found that the solar heat gain coefficient in the part of shortwave radiation (*ShW SHGC*) is mainly affected by the slat properties, slat angle and solar profile angle. The glass window using blind with a lower value of slat reflectance, will have a smaller value of *ShW SHGC*.

In this article, the complete study of the thermal performance of the glass window with a curved venetian blind installed in term of total solar heat gain and the solar heat gain in the part of shortwave and longwave radiation is performed. The effect of certain parameters on the thermal performance of the fenestration (glass window with a curved venetian blind installed) is performed. It is believed that with a clearly understanding of the thermal performance of the glass window with a curved venetian blind installed, the need of using the expensive energy efficient glass as the building envelope can be avoided. For an energy efficient building, besides minimizing the solar heat gain through the building envelope, the thermal comfort for the occupants in the building must be maintained. Chaiyapinunt et al. (2005) and Khamporn and Chaiyapinunt (2014) have shown that the thermal discomfort for a person who sits near glass window can be classified as the discomfort from the solar radiation striking on his body (shortwave effect) and the discomfort from the glass surface temperature (longwave effect). The thermal discomfort of a person who sits near the glass window with a curved venetian blind installed can also be classified as the discomfort from the solar radiation striking on his body (shortwave effect) and the discomfort from the glass surface temperature (longwave effect), as well (Khamporn, 2012). Without a thoroughly understanding about the *ShW SHGC* and *LoW SHGC* (solar heat gain coefficient in the part of longwave) of the fenestration, it is quite possible that though the total solar heat gain is minimized, but the occupants may need more extra cool air from the air conditioning system to compensate the local discomfort from either the shortwave effect or the longwave effect (depends on which component of the solar heat gain is dominated). Therefore, the understanding about the *ShW SHGC* and *LoW SHGC* of the fenestration is also important.

2. Mathematical model for the glass window with a curved venetian blind installed

Heat transmission through the system of glass window with a curved venetian blind installed can be expressed as the summation of the solar heat gain and the conduction heat gain. The expression of the heat gain can be written as:

$$q = \{SHGC(\theta, \psi)\}I + U\Delta T \quad (1)$$

where q is the heat gain (W/m^2), *SHGC* is the solar heat gain coefficient, U is the overall heat transfer coefficient (W/m^2 K), ΔT is the temperature difference between the indoor and outdoor condition (K), I is the incident solar radiation, (W/m^2), θ is the solar incident angle (degree), and ψ is the azimuth angle (angle of the incident radiation measured from the horizontal axis on the plane of the glass window as shown in Fig. 1) (degree). The heat gain from solar radiation can be further classified as the heat gain from the direct solar radiation (beam solar radiation) and

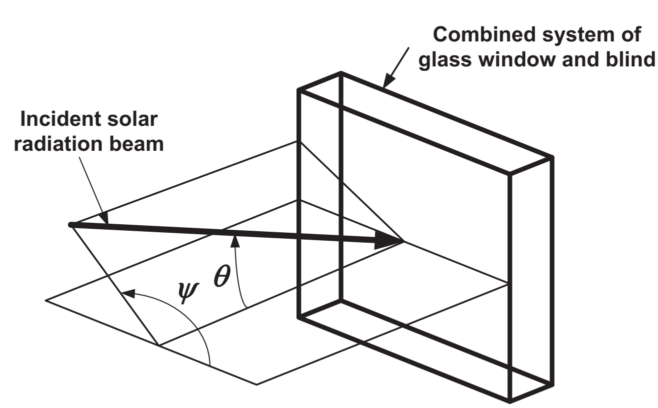

Fig. 1. The system of glass window with a venetian blind installed and the incident solar radiation. θ is the solar incident angle. ψ is the azimuth angle.