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Summer performance of ventilated windows with absorbing or smart glazings

Michael Cain Skaff, Louis Gosselin *

Department of Mechanical Engineering, Université Laval, Québec City, Québec, Canada

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Abstract

This work investigates the benefits of ventilated fenestration on the energy performance through the analysis of ventilated windows in skycrapers and commercial buildings with criteria such as the U-factor and the SHGC. Fenestration considered are double glazing units made of exterior glazings with different absorption properties. In particular, a more in-depth analysis is performed with ventilated glazings integrating electrochromic filters which are known to have high absorbing properties. A numerical model is implemented in a CFD commercial software to determine the total heat gain reduction provided by ventilated glazing units compared to insulated units used under hot climates. An operating design is proposed as well as an optimal spacing between glazings in order to obtain best performances.

Keywords: Smart windows; Ventilated windows; Optimal spacing; Solar heat gain; Absorbing glazings

1. Introduction

Building energy consumption is a major concern, both for environmental and financial reasons. Many research efforts are devoted to improving energy performance of buildings. In particular, these efforts are often dedicated to improving HVAC systems. However, the envelope is often at the heart of the problem. Although some interesting envelope innovations have been proposed (Yun et al., 2007; Shen et al., 2007), the outer shell of modern buildings is more and more made of glass. The indoor-to-outdoor heat exchange is therefore more important due, on one hand, to the low R-factors (~0.4 m^2 K/W) of typical curtain walls compared to full walls (~1.3 m^2 K/W), and on the other hand, to the amount of solar radiation passing through the glass. Over the years, windows performance has been improved through the use of double and triple glazings, low-e coatings, as well as noble gases such as argon to fill the pane-to-pane spacing. More recently, active glazing technologies have emerged as a promising approach to improve further windows performance. Chow et al. (2010) proposes a review of these emerging technologies, such as smart windows made with liquid crystals or electrochromic filters, PV glazings or waterflow windows.

Window ventilation is another concept with interesting overall performance improvement at a relatively low cost. In Ismail and Henríquez (2006), a simplified model was created in order to simulate the energy performance of a ventilated double window under forced convection while in Ismail and Henríquez (2005) a two dimensional model was developed to simulate the ventilated window performances under natural convection. Both studies showed improved performances of ventilated windows compared to a simple clear glass window by analyzing the total heat gain and other energy performance criteria such as the SHGC. However, no comparison of ventilated glazing

* Corresponding author. Address: Pavillon Adrien-Pouliot, Local 1508-D 1065, Avenue de la Médecine, Québec, QC G1V 0A9, Canada. Tel.: +1 418 656 7829; fax: +1 418 656 7415.

E-mail address: Louis.Gosselin@gmc.ulaval.ca (L. Gosselin).

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Nomenclature

a	solar absorptance
A	area, m^2
c	heat capacity, J/kg K
D	spacing between glass panes, m
g	gravity, m/s^2
G	solar radiation, W/m^2
h	heat transfer coefficient, W/m^2 K
H	height, m
IGU	insulated glazing unit
k	thermal conductivity, W/m K
$\dot{m}$	mass flow rate, kg/s
N	fraction of solar radiation absorbed redirected to the interior
P	pressure, Pa
q	heat gain per unit area of fenestration, W/m^2
q'''	volumetric heat generation, W/m^3
Q	total heat gain, W
Ra	Rayleigh number
SHGC	solar heat gain coefficient
SM	simplified model
t	thickness, m
T	temperature, K
u,v	velocity components, m/s
U	U-factor, W/m^2 K
VGU	ventilated glazing unit
x,y	cartesian coordinates, m

Greek letters

α	thermal diffusivity, m^2/s
β	thermal expansion coefficient, 1/K
δ	boundary layer thickness, m
ε	emissivity
ν	kinematic viscosity, m^2/s
ρ	density, kg/m^3
σ	Stefan–Boltzmann constant, W/m^2 K^4
τ	solar transmittance

Subscript

1	surface 1, wall 1
2	surface 2, wall 2
3	surface 3
4	surface 4
c	cavity
ch	channel
f	fenestration
g	glass
G	solar radiation
H	height
s	surface
sol	solar
trans	transmitted
vent	ventilation
w/	with
w/o	without

units (VGU) with double insulated glazing units (IGU) was presented, and no optimal window design was proposed. In Lollini et al. (2010), a ventilated window prototype combined with integrated active blinds was tested experimentally and simulated in two different building types. Results showed an overall reduction of the building energy consumption. The prototype eventually led to a commercial product. In Carlos et al. (2011), a model of ventilated double window has been developed and validated with test facilities proving the efficiency of ventilated windows. The ventilated window was used to naturally ventilate the inside zone with outside air, and thus reduce the heating loads due to ventilation. However, cooling loads reduction was not studied. In Etzion and Erell (2000), a ventilated window with an absorptive glazing was tested and a design proposed to easily rotate the window. This rotation is required when passing from the heating to the cooling period, or vice versa, in order to direct the airflow heated in the window appropriately either inside or outside depending on whether heating or cooling is required in the conditioned space. A single absorbing glazing was tested.

Highly absorptive properties can be found in glazings such as low-e's (Saidur et al., 2008; Ebisawa and Ando, 1998) which are commonly used nowadays. These glazings have a reflective metallic coating applied on a specific glass surface either to reduce the solar heat gain or to prevent heat from escaping the building. Often, this results in an augmented amount of solar radiation absorbed in the coated glass. Another emerging window technology with absorptive properties is the electrochromic smart window, the opacity of which can be adjusted in order to control the solar radiation transmitted to the building (Granqvist et al., 1998). In electrochromic windows, the absorptivity of an active film is varied in order to control the solar heat gain. The increase of the film absorptivity results in a temperature increase of the glazing. Typically, temperature as high as 60 °C can be reached (Fang and Eames, 2006; Piccolo, 2010) in fully tinted state. Such a high temperature means that a significant portion of the absorbed solar radiation will be discharged in the conditioned space due to conduction through the window. Therefore, we saw an opportunity to combine the positive effects of windows ventilation as reported above to the advantages of absorptive glazings. The high temperature of the glazing can enhance natural convection in the spacing between panes of a ventilated window, which in turn will reduce the portion of the absorbed solar radiation released in the building.