



Computational fluid dynamics for thermal evaluation of a room with a double glazing window with a solar control film



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ABSTRACT

The thermal analysis of a Room (R) coupled with a Double Glazing Window (DGW) with/without solar control film (SCF) for warm and cold climate conditions of Mexico City is presented. The right vertical surface of the room is considered partially adiabatic and with a DGW. The DGW consists of two vertical semitransparent walls: glazing-1 facing the room, and glazing-2 facing the external environment; there is a SCF attached to glazing-1 for cold climate condition, or glazing-2 for warm climate condition. During one day, the hourly simulations of the R-DGW were done in an in-house code based on the finite volume method. To carry out the thermal analysis of the R-DGW, three cases were defined: Case C1 corresponds to the R-DGW without SCF; Case C2 and C3 correspond to the R-DGW with SCF for warm and cold climate condition, respectively. For warm climate condition the use of a SCF is highly recommended, since Case 2 reduces the amount of energy gained in $\approx 67.7\%$ compared to Case 1. When using the SCF on the R-DGW for cold climate condition case C3, the average temperature inside of the room is similar to case C1.

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1. Introduction

Comfort inside a building is determined by parameters such as humidity, temperature, air velocity, etc. In many cases, mechanical systems are required to achieve thermal comfort inside a building, which results in a high cost of operation and maintenance to provide thermal comfort to people. Most of the heat gains or losses in a building are through the roofs and walls, mostly on walls with large windows or glazing which in some cases covers the whole facade. Windows are responsible for a disproportionate amount of unwanted heat gain and heat loss between buildings and the environment. The above issue has motivated the study and development of new technologies focused on reducing the gains or losses of energy in tower type buildings. Among these technologies, we can find the use of tinted, reflective, low-emittance coatings or high extinction coefficient (absorbent) glasses, and even the use of

solar control films, double glazing windows or multiple facades.

Double glazing windows are closed systems that encapsulate mainly air or a low conductivity gas (inert gas) such as krypton, in order to diminish heat transfer. On the other hand, solar control films are designed to absorb or reflect the incident solar radiation, in order to diminish solar heat gains through the glass. Lampert [1] presented an extensive review on this technology. Rubin [2] presented a methodology for analyzing the heat transfer in multiple glazing with or without solar control film, considering environmental variables such as temperature and wind speed. The author determined that the overall thermal conductance for a double glazing window with clear glass will have an approximate value of $3 \text{ W/m}^2\text{K}$ and if a solar control film of plastic (polyester film) adheres on one of the glasses this value is reduced to $2 \text{ W/m}^2\text{K}$. A short review on the thermal performance of windows with multiple glasses (as closed systems) for thermal comfort follows below.

Among the studies to find the optimal width of the fluid layer between glasses of windows with multiple glazing we can find the work developed by Ref. [3]. Gan (2001) carried out a numerical study to predict the total energy transmitted through a window with multiple glazing. The author concluded that the thermal resistance of the window, as well as the global heat transfer

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Nomenclature			
b	width of the cavity between glasses, cm	β	thermal expansion coefficient, K^{-1}
C_p	specific heat, $J\ kg^{-1}\ K^{-1}$	ε	rate of dissipation of κ , $m^2\ s^{-3}$
$C_{1\theta}, C_{2\theta}, C_{3\theta}, C_\mu$	coefficients of the turbulence model	ε^*	emissivity
g^*	gravitational acceleration, $9.81\ m\ s^{-2}$	κ	turbulence kinetic energy, $m^2\ s^{-2}$
G	solar radiation, $W\ m^{-2}$	λ	thermal conductivity, $W\ m^{-1}\ K^{-1}$
h_{ext}	convective heat transfer coefficient at the outside glass wall, $W\ m^{-2}\ K^{-1}$	μ	Dynamic viscosity, $kg\ m^{-1}\ s^{-1}$
H	height of the room, m	μ_t	turbulent viscosity, $kg\ m^{-1}\ s^{-1}$
H_2	height of the glass, m	ρ	density, $kg\ m^{-3}$
P	pressure, Pa	ρ^*	reflectivity
q	heat flux, $W\ m^{-2}$	σ	Stefan-Boltzman constant, $5.670 \times 10^{-8}\ W\ m^{-2}\ K^{-4}$
q_{ext}^{conv}	convection heat flux towards the exterior of the room, $W\ m^{-2}$	σ_T	turbulent Prandtl number
q_{int}^{conv}	convection heat flux towards the interior of the room, $W\ m^{-2}$	σ_k	Prandtl number for κ .
q_{ext}^{rad}	radiation heat flux towards the exterior of the room, $W\ m^{-2}$	σ_ε	Prandtl number for ε
q_{int}^{rad}	radiation heat flux towards the interior of the room, $W\ m^{-2}$	τ^*	transmissivity
q_{int}^{trans}	transmitted heat flux through the double glazing window, $W\ m^{-2}$	Subscripts	
S_g	extinction coefficient, m^{-1}	conv	convection heat transfer
T	temperature, C	ext	external ambient
T_f	solar control coating temperature, C	f	solar control film
u, v	horizontal and vertical velocities, $m\ s^{-1}$	g	glass
W	width of the room, m	glass	glass
x, y	dimensional coordinates, m	int	internal ambient
Greek symbols		rad	radiation heat transfer
α^*	absorptivity	Room	room quantities
		total	total quantities
		1, 2	glass number
		Acronyms	
		DGW	double glazing window
		R-DGW	room – double glazing window
		SCF	solar control film
		SHGC	solar heat gain coefficient

coefficient depend on the thickness of the air layer, and from the numerical results he found an optimal width of 25 mm. Gueymard and DuPont [4] presented a compilation of 37 different glass systems: single, double and triple glass pane windows. In addition, the analysis was performed with and without solar control film. The authors used the software WINDOW 5.2.17 and OPTICS 5.1 for the calculation of the thermal parameters (U and SHGC). Among the results, they found the SHGC in a range from 24.7 to 67.8% for systems with double glazing and low emittance. Afterwards, Arici and Karabay [5] extended their work of 2010 taking into account double, triple and quadruple pane windows considering various gap widths together with different emissivity coatings. Numerical results showed that the most reasonable gap width is 12 mm for all cases considered in this study. The effect that the gas filling has on the U-value is more pronounced for the windows coated with low emissivity materials.

Among the studies on windows with double glazing with natural convection, we can find the work carried out by Ref. [6]. Álvarez et al. (1999) studied double glazing unit with and without solar control film, the temperatures on the inside and outside environment considered for the study were 24 and 32 °C, respectively. The authors concluded that the glass with a solar control film increases its temperature, but reduces the energy passing through it by 30% towards the interior of the cavity. Aydin [7] presented a study to determine the optimal width of a closed double glass; the system was analyzed as a tall differentially heated cavity. Aydin considered four average gradient temperatures typical for Turkey $\Delta T = 19, 25, 34$ and 49 °C and the temperature of the cold wall was

fixed at 21 °C. Optimal widths of 18–21, 15–18 and 12–15 mm, were obtained respectively for each ΔT . Afterwards, Aydin [8] extended his work taking into account heat conduction on the glasses in one dimension and analyzed the effect of the exterior convective coefficient varying from 15 to 30 $W/m^2\ K$. The author concluded that this increment has no significant effect on the heat transfer towards the interior cavity. Ismail et al. [9] carried out a comparison on three different systems: single glass, double glazing unit filled with an absorbent gas and a double glass unit with natural ventilation; they concluded that the second configuration was the most effective. Arici and Karabay [10] determined the optimal gap width of a double pane window using the degree-day method. The study was conducted for four different climates zones of Turkey and the heating cost was calculated for five types of fuels. The base temperatures were 18, 20 and 22 °C and the optimal gap width varied between 12 and 15 mm, according to the climate zone, fuel type and base temperature. The results showed that it is possible achieve up to 60% of energy saving. Rongxin et al. [11] analyzed a double glazing window with a solar control film on the exterior; the results showed that using the solar control film reduces the SHGC value. The most recent results reported about double pane window are focused on the effect of varying the gap width between the glasses, the indoor temperature, solar radiation [12,13], entire wave length heat radiation [14] and emissivity and gas fill [15].

From the literature review it can be concluded that there are plenty of studies related to thermal performance of multiple glasses, particularly double pane windows with and without solar

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