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Environmental, economic and energy analysis of double glazing with a circulating water chamber in residential buildings

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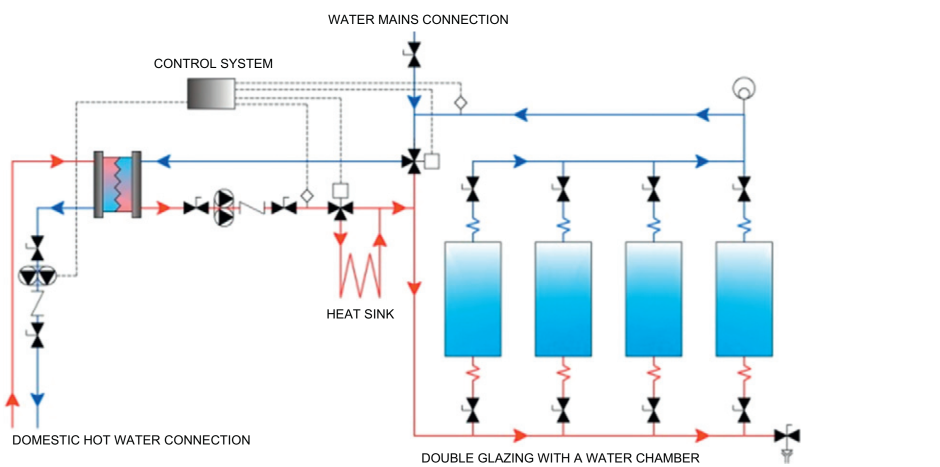
HIGHLIGHTS

- ▶ Glazed façade area is the part that produces greatest energy losses and gains.
- ▶ A potential for energy savings has been detected in residential buildings.
- ▶ Active glazing comprising two laminated glass panels with a circulating water chamber.
- ▶ Analysis of energy performance, economic viability and impact on carbon footprint.
- ▶ Natural gas condensing boilers is the less contaminating and more efficient option.

GRAPHICAL ABSTRACT



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ABSTRACT

In general, the glazed façade area of a building is the part that produces the greatest energy losses and gains. The basic aim of this work is to achieve a more efficient heat control in closed spaces. To this end, an exhaustive study has been made of active glazing comprising two laminated glass panels with a circulating water chamber. Not only has the energy consumption been analysed but also the energy efficiency according to fuel type, the amount of CO_2 emitted into the atmosphere and the economic cost. The results of this study, from the points of view of economic feasibility and energy efficiency, show that the solution of double glazing with a circulating water chamber is a less polluting and more efficient option than the systems currently used. This solution is able to reduce the energy losses and gains that are produced through the glazed façade of a building by 18.26% for calorific and frigorific energy compared to the total consumption of the building. The layout of the proposed installation facilitates its integration into any type of residential building, either under construction or being renovated. Moreover, its zero visual impact means it can even be implemented in places with strict town-planning regulations.

1. Introduction

Various studies have shown that, during a large part of the year, the windows available (either dynamic or static), do not help to achieve the thermal efficiency currently demanded [1,2].

The Adaptation of the European Directive 2010/31/EU on the Energy Efficiency of Buildings [3] aims to introduce the concept

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of "Passive Building" or "Almost Zero Consumption Buildings", and limit the maximum annual energy consumption to 15 kW h/m^2 for heating and cooling. It is also believed that the Directive will rule that all new buildings will be required to have almost zero consumption by the 31 December 2020[1].

Due to the low emission requirements for CO_2, glazed façades are being subjected to extensive continuous research, as indicated by Chow et al. [4].

Diverse techniques are capable of transforming static windows into dynamic windows, called chromogenic windows, the most marked of which are liquid crystal, electrochromic, gasochromic or suspended particle windows [5,6].

Since the 1970s, various researchers, the most outstanding being from the LBNL (Lawrence Berkeley National Laboratory), one of whom is Stephen Selkowitz, have been studying the thermal and luminous performance of electrochromic windows (the most commercially developed technology), and state that they perform better from both a luminous and a thermal point of view [7].

Weather-resistant electrochromic windows are capable of controlling infrared or thermal radiation (long wave-length $\lambda > 0.7$ μm), which to a large extent is responsible for heating the interior environment [8]. Being able to regulate thermal radiation leads to lower cooling costs in the summer and lower heating costs in the winter [9]. On the other hand, regarding luminosity, glare is reduced and the entry of visible light can be controlled if there is exposure to direct sunlight, thus reducing the need for solar protections. However, the high marketing cost of these windows, the difficulty in adapting them to the user [10], and the long colour correction time (often minutes), makes it difficult to find an opening on the market. In short, these kinds of windows have failed to satisfactorily meet their purpose.

Other researches indicate that advanced transparent super insulation materials could satisfy both requirements, which are a high thermal insulation and a high light transmittance. Aerogel is a promising transparent insulating material, due to its low thermal conductivity (down to 0.010 W/m^2 K), high solar factor, high daylight transmittance and remarkable light weight, and could be interesting especially in very cold areas where it is necessary to reduce heat transmission [11,12].

Another system that is still in its early stages commercially, that can be placed in the category of dynamic or smart windows, is a window comprising two laminated glass panels with fluid circulating in the chamber between both panels. This solution leads to better thermal comfort due to the way this fluid is processed. Of all the fluids that can be used, water has the following benefits: low cost, it is easily available (on new construction sites as well as in renovation work), it is highly opaque to infrared radiation and highly transparent. In the same way that some authors have analysed the visual comfort and daylighting designs in different glazing systems [13–15], Fig. 1 clearly shows the transparency of the glazing as well as the undistorted image achieved by the proposed system [5].

Various researchers have developed test methods to evaluate heat gain and heat loss in indoor spaces, and more specifically in the field of the energy efficiency of different types of glazing. Grimmer states that small test boxes can be a very useful tool for the thermal modelling of buildings [16]. Álvarez, Palacios, and Flores developed a test method to measure the thermal performance of glazed windows [17]. They propose a laboratory-developed procedure that lets any glazing composition be compared with another. Around 1990, the Lawrence Berkeley National Laboratory (LBNL) of the University of California (USA) developed a mobile system for

Fig. 1. Transparency of the glazing.

the outdoor testing of advanced glazing called MoWiTT (Mobile Window Thermal Test), aimed at making exact measurements of the thermal performance over time of different glazing types when exposed to real weather conditions [18]. Basing his opinion on analytical calculations and various tests, Chow concludes that windows with a circulating water chamber are able to reduce heat gain, and therefore, energy consumption [19,1,20].

Given the complexity of its analysis, there is currently no comparative research on the economic and energy feasibility of this system compared to more conventional solutions like windows with an air chamber. It would appear that new models need to be produced that allow analysing the energy and cost savings over a representative period of time, as well as the environmental impact.

The aim of this research is to compare a conventional double glazing system with an air chamber with another system with a water chamber, the purpose of which is to check its energy efficiency, its repercussion on the environment and its economic feasibility. The two types of glazing compared are: 6 mm thick double glazing with an 8 mm thick air chamber (due to its being one of the most common in the building industry) and glazing comprising two 6 mm thick glass panels (stadip 3 + 3 glass) with water circulating through an 8 mm thick chamber between the panels.

2. Material and methods

2.1. Description of the proposed system

A glazing solution that is standard in the building industry was chosen, which, by incorporating circulating water in the chamber considerably reduces thermal transmittance (U), increases the capacity to block infrared radiation (responsible for interior overheating) and preserves the transparency of the glass.

As the water circulates inside the chamber, the transmittance and the solar factor of the assembly vary, among other properties, depending to a large extent on the temperature of the circulating water. The finite element method used specifically takes account of this variation in the model's properties according to temperature.

The heating system and water circulation system through the chamber, which is made of two glass panels, consists of two circuits: primary and secondary (Fig. 2).

– The primary circuit comprises the inlet and outlet connections from the mains corresponding to the building's domestic hot water supply and the circulation pumps.

[1] For buildings belonging to public administrations, this date will be brought forward to 31 December 2018; and for existing buildings, the deadline will be 31 December 2050.