Fluid Glass Façade Elements: Influences of dyeable Liquids within the Fluid Glass Façade.

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Abstract

In this paper a glass façade system is proposed, which controls the energy flows within the transparent building envelope [1].

Yearly energy consumptions of an office space are calculated in Munich and Dubai [2]. The office space is calculated with a theoretical glazing share of 100% within the south-west oriented façade area. A standard solar-control glazing unit (SCGU) is adopted as benchmark for the fluid glass. Three fluid glass scenarios are considered: two with adjustable transparency (dyed) and one with constant properties of a clear fluid. One of the adjustable scenarios is simulated with white glass (low iron).

The cooling demand is strongly connected to the g-value of the glass unit. Without coloring the fluid, the cooling demand with fluid glass is approximately 39% higher than with SCGU in Munich, and approximately 25% higher in Dubai. While colored fluid glass nearly halves the cooling demand compared to the SCGU. Colored fluid glass show an overall saving in the energy demand of approximately 23% in Munich, and approximately 44% in Dubai, compared to the SCGU. Thus, using dye to control the solar transmission is crucial for successful implementation of the fluid glass concept. By coloring the outer liquid layer, a huge fraction of the solar radiation is absorbed in the fluid. As a result, the temperature of the liquid layer rises, but not the room temperature.

To optimize the fluid glass system, white glass (low iron) is investigated. The visual transmission of the clear fluid glass rises by 38% compared to standard glass panes, the solar transmission even by 84%. Contrary to expectations the energy demand of the office space in Munich rises by around 70%, which is due to the poor absorption behaviour within the near infrared spectrum of the actual used dye.

The current study showed the high potential of fluid glass façades for reducing the energy demand of an office space, mainly for cooling purposes. An important function of the fluid glass façade is the dyeing of the liquid with to actively control the solar transmittance. Further investigations are required to optimize the spectral transmission behaviour of the fluid glass system.

Keywords: Renewable energy, energy efficiency, adaptive facades, solar thermal facades

1. Introduction

Since transparency is an important element of architecture, also large-scale buildings often are equipped with a high proportion of areas with transparent façades. This can lead to major problems from an energetic and comfort point of view, especially in high-rise buildings, where conventional external overheating protection cannot be used due to the wind loads. Nevertheless, glass façades need to be adjustable to different climate conditions and internal needs. One way of doing so is the dynamic transparency adjustment of the glass itself. Today adjustable transparency of windows is achieved using electro-chromic materials, liquid crystals and electrophoretic or suspended-particle devices [3].

Another approach is the fluid glass façade proposed in this paper [1]. It is a glass façade system which controls the energy flows within a transparent building. Two fluid-filled layers are set into the glass façade. These two layers regulate all energy flows within the facade. The inner fluid layer keeps the inside surface temperature just below or above room temperature for heating and cooling, while the outer liquid layer controls the energy transmission by absorption of the solar radiation. The inside and outside fluid layers are thermally separated. Two basic operating modes for summer and winter are illustrated in *Figure 1*.

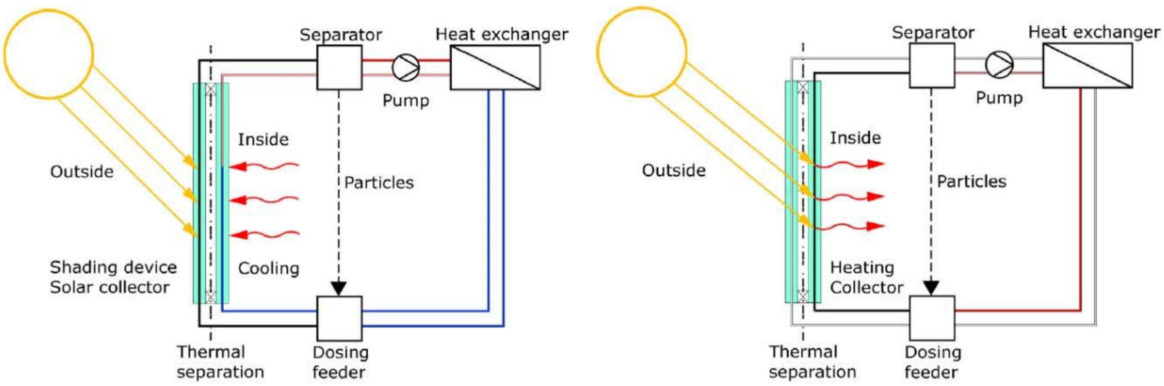


Figure 1: Basic operating modes of the fluid glass in summer (left) and winter (right) [1].

The absorption of solar radiation within the façade can be controlled by coloring or decoloring the fluid [1]. In summer mode, the outer fluid layer will be dyed to increase the absorption – it protects against overheating. The solar energy will be absorbed in the fluid and can be transported by fluid circulation where needed. In winter mode, the outer fluid layer will be clear to allow solar radiation entering the insulated perimeter to reduce the heating demand of the building.

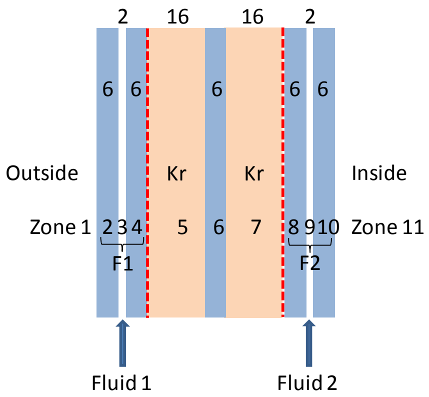
This system works as a shading device, solar collector, cooling ceiling, floor heating system, and insulating façade of a building within a thickness of a few centimetres, and it replaces equivalent common systems. The transparent façade can help to increase the energy efficiency of buildings in every climate zone and enables the use of renewable solar energy throughout the whole façade area.

2. Materials and Methods

A basic physical model of the façade system was developed and validated with the results of prototype testings as descripted in [4], [5] and [6]. The prototype features two fluid layers separated by a thermal barrier of a commercial triple-glazed insulation unit as shown in *Figure 2*. It consists of three layers of 6mm thick glass with gaps of 16mm each. The glazing gap is filled with the inert gas krypton. Low-E coatings are on the inside surface of the outer pane (position 4) and on the outside surface of the inner pane (position 7) of the insulation glazing unit. On both sides of the insulation glazing unit, a 6mm thick glass is placed to form the chambers for fluid 1 (outside) and fluid 2 (inside). The fluid chamber width is 2mm, resulting in a total thickness of the glazing system of 66mm. The complete glazing system is illustrated in *Figure 2*. The clear glass is PLANILUX® (zone 2, 6, 10) and the coated glass is PLANITHERM® ONE II (zone 4 and 8), both from

Saint-Gobain Glass.

Figure 2: Fluid glass system consisting of two fluid chambers separated by an insulation glass unit [2].



A standard solar-control glazing unit (SCGU) is adopted as benchmark for the fluid glass. Three fluid glass scenarios are considered: two with adjustable transparency (dyed) and one with constant properties of a clear fluid. One of the adjustable scenarios is simulated with white glass (low iron) DIAMANT with two Low-E coatings (position 4 and 7) PLANITHERM® MAX II from Saint-Gobain Glass. The parameters of the tested glazing scenarios are shown in *Table 1.*

Table 1: Parameters of investigated glazing scenarios.

No.	Titel	g-value	τ_{sol}	τ_{vis}	U-value [W/m²K]
1	Solar-control glazing unit (SCGU)	0.25	0.22	0.53	0.4
2	Fluid glass PLANILUX® without dyed fluid (fluid glass clear)	0.34	0.25	0.50	0.44
3	Fluid glass PLANILUX® with dyed fluid (fluid glass dyed)	0.34 – 0.06	0.25 – 0.02	0.50 – 0.00	0.44
4	Fluid glass DIAMANT with dyed fluid (fluid glass DIAMANT dyed)	0.55 – 0.14	0.47- 0.09	0.70 - 0.00	0.5

Static calculations of the yearly energy consumption of an office space in Munich and Dubai are made on an hourly basis. The office space is calculated with a theoretical glazing share of 100% within the south-west oriented façade area. The settings and assumptions of the calculation method are described in detail in [2] and [6].

3. Results and Discussion

The simulations for Munich and Dubai show, that the cooling demand is strongly connected to the g-value of the glass as shown in *Figure 3*. In Munich without coloring of the fluid, the fluid glass (No. 2) has a 39% higher cooling demand than the SCGU. While colored fluid glass (No. 3) nearly halves the cooling demand compared to the SCGU. Colored fluid glass (No. 3) shows an overall saving in the energy demand of approximately 23% compared to the SCGU in Munich.

In Dubai, the energy demand increases substantially compared to Munich. There is no heating demand but an enormous cooling demand during the entire year. The energy demand for lighting and pumping is very small compared to the cooling demand. Compared to a highly advanced SCGU, the cooling demand increases by approximately 25% with the fluid glass without colored fluid (No. 2); however by coloring the fluid (No.3), the overall energy demand decreases by approximately 44%.

To optimize the visual transmittance of the clear fluid glass system, white glass (low iron) DIAMANT with different coatings is investigated. The visual transmission of the clear fluid glass rises by 38% compared to fluid glass system with standard glass panes. The solar transmission increases even by 84%. Contrary to expectations the energy demand of the office space in Munich rises by around 70% for the fluid glass DIAMANT.

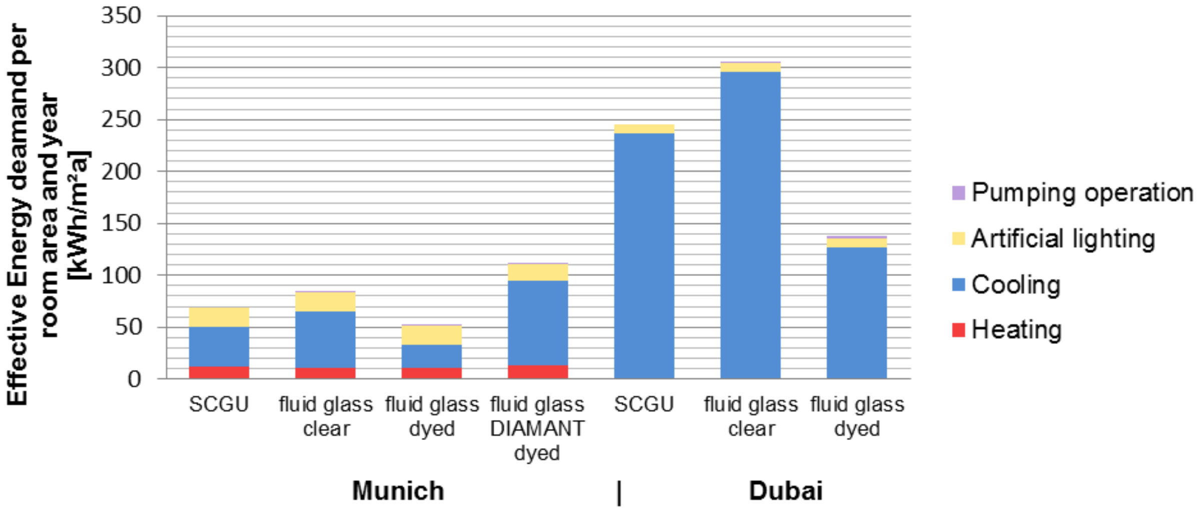


Figure 3: Munich (Left, first 4 columns) and Dubai (right, last 3 columns) south-west orientation: Yearly effective energy demand for the seven scenarios listed in Table 1.

Based on spectral measurements, calculations of the visual and solar transmission of the fluid glass system with different coloring saturations of the outer fluid layer were made as shown in *Figure 4.*.

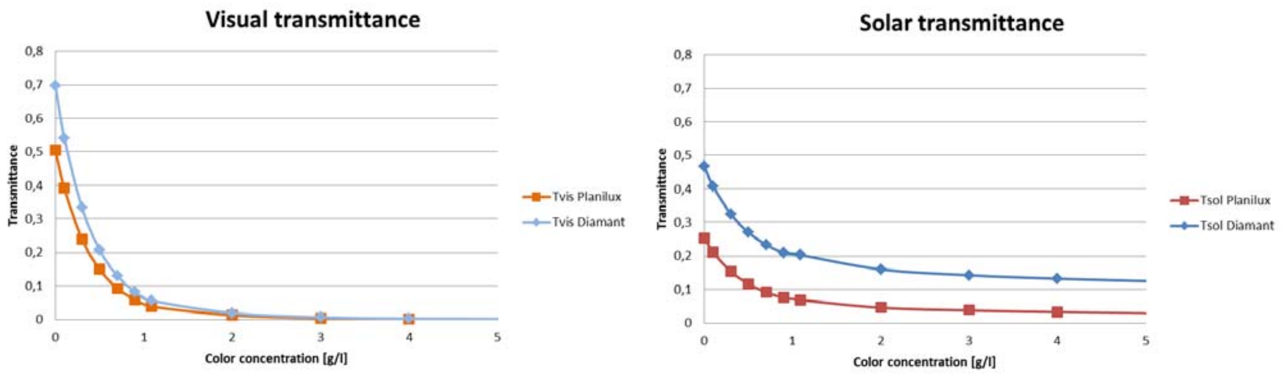


Figure 4: Visual transmittance (left) and solar transmittance (right) according to the color concentrations of the outer fluid layer of the fluid glass PLANILUX® and fluid glass DIAMANT [6].

While the visual transmission of the fluid glass DIAMANT can also be reduced up to 0% like the fluid glass PLANILUX, the solar transmission remains at 9% at the maximum concentration of 11g/l. This is due to the relatively high transmission coefficient within the near infrared spectrum compared to the transmittance within the visual spectral range of the actual used dye. Therefore the cooling demand of the office space in Dubai rises by 86%. Furthermore the heating demand increases little because of the slightly higher U-value of the fluid glass DIAMANT. Only the demand for artificial lightning decreases by 15%.

4. Conclusion

The energy demand for cooling, heating and lighting were determined for a standard office room in Munich and Dubai with a complete glass façade on one side oriented south-west. Three scenarios of fluid glass were compared to one reference scenario. The operation of the fluid glass was performed with clear and dyed fluid in the outer liquid layer in order to control the solar energy transmission. The reference scenario consisted of a highly advanced solar-control glazing units with a low U-values of 0.4 W/m²K. The fluid glass with regular float glass (PLANILUX®) with coatings and adjustable dyeing showed the best overall thermal behavior, resulting in the lowest energy demand in both climates. Compared to the SCGU, a reduction of energy demand up to 23% in Munich and 44% in Dubai was achieved. The reduction of the total energy demand is mainly due to the reduction of the cooling energy demand by reducing the solar gains through the transparency adjustment of the fluid. By coloring the outer liquid layer, a huge fraction of the solar radiation is absorbed in the fluid. As a result, the temperature of the liquid layer rises, but not the room temperature. The energy savings potential of the fluid glass façades increases in hot climates with higher cooling demands. Without dye, the net energy demand for fluid glass is higher than for the solar-control glazing. An attempt to further improve the performance fluid glass system using white glass did not lead to the expected reduction of the energy demand. Thus, using an appropriate dye to control the solar transmission is crucial for successful implementation of the fluid glass concept.

The current study showed the high potential of fluid glass for reducing the energy demand, mainly for cooling. Additional energy savings potential of the fluid glass concept is expected for optimized spectral transmission characteristics of the fluid.

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