Aspects of Heat Insulation Efficiencies for Modern Windows

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Abstract – Requirements on performance characteristics of windows as building elements are continually increasing as demands on energy-efficiency of buildings are growing. It becomes more and more evident that thermal performance of windows of "traditional" design, i.e. using frame constructions of improved thermal insulation and low-e coated glass panes with inert gas filling between them cannot be further improved. Investigating the potentials that intelligent products may offer are coming to the fore. In this paper the author identifies which physical processes related to the functioning of a window has to be controlled in order that the thermal performance could be further improved. In the light of these findings the technical possibilities of imparting intelligent features to windows are surveyed. These include the use of smart materials, sensor and actuator techniques as well as energy gains. The author gives his suggestions for development of intelligent windows in three directions: improvement of energy utilisation, influencing the internal climate and enhancement of database on boundary conditions.

Keywords: smart window/smart glazing/energy-saving window

1. INTRODUCTION

The energy-efficiency of the existing stock of buildings in Hungary is rather low; the consumption index is twice as high as the average of the EU countries. The continuous decline of supplies of energy and the increase of their price justify the progress in thermal insulation of buildings. The European Union regulates the energy consumption of buildings through directives. From these follows the decree of 7/2006 that contains the requirements on the heat transfer coefficient of fenestration products

Besides the more and more rigorous building regulations it is the financial interest of the occupants to use up the least possible amount of energy while maintaining the comfort of indoor environment. As a consequence, more and more attention is to be paid to the enhancement of windows' thermal performance. This can be achieved by decreasing thermal losses through the window on the one hand and increasing the solar gain on the other.

In the case of buildings, windows have a great impact on the aesthetics and play an important role in the general condition of those staying inside. Being transparent building elements, windows let sunshine in, which provides free source of energy; at the same time they allow visual contact with the outside world. In the course of using a building there appear basically two conditions that determine the occupants comfort: quality of air and indoor climate. Therefore architects have to make provision for sufficient light and fresh air to obtain access to the rooms. Windows generally make a smaller proportion of a building's façade, yet they are responsible for a high proportion of the total heat loss since even a well-insulated

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window's thermal performance is inferior to that of the walls. In this sense windows are the most important week points of a building's envelope; it would be ideal to enhance their thermal insulation to the level that wall systems provide. However, with the materials and structural solutions currently used with the window products of best technical parameters we are approaching the upper limits of attainable thermal performance. Further increase of the windows' performance cannot probably be realised unless by using smart materials, intelligent solutions and control technique.

2. PERFORMANCE OF WINDOWS

The heat transfer characterised by the *U*-factor of a window is defined by the glazing system, the material and profile of the frame and casement(s), way of fitting the casement(s) to the frame and by the method of jointing the window to the wall. The heat flow directed outwards through a window is composed of the heat transfer by transmission, and the convective flow due to the air permeability of the window (KOVÁCS 2000). The heating energy consumption of a household is largely contributed to by ventilation and by thermal bridging caused by the geometry and material of joining elements. Heat flow is higher, inside surface temperature is lower at these locations of higher thermal conductance. Quantification of the heat flow through the frame and casement members including the effect of thermal bridge effect is stipulated in the standard ISO 10077-1:2000.

The complexity of the problem of glazed units is further contributed to by the fact that they often have to comply with contradictory requirements depending on the geographical environment they are used in. In winter it would be ideal to use a glazing system that lets the highest possible amount of solar heat in, minimising at the same time the outward heat transfer from the inside. On the contrary, in summertime the alleviation of heat load through sunshine is of concern. Heat radiation from the sun arriving to the glazed surface will partially reflect, the rest is transmitted into the room and absorbed in the glass then transmitted inward and outward by convection and radiation. Different technical solutions are aimed at favourably influencing these proportions and visible light transmission. Special coatings can be used for lowering the transmission of solar radiation.

In the course of the last few years the development in information technology sped up very importantly. Customers are not fully satisfied by products that are aesthetic and functional only; expectations are growing and invoke certain extra functions. In any case, windows have to satisfy the standard requirements set with regards to the performance characteristics as below:

- air permeability
- water tightness
- resistance to wind load
- sound insulation
- thermal insulation
- resistance to burglary

3. SMART WINDOWS

An intelligent product, as its name implies, provides the customer more than an average everyday product does. It fulfils certain extra tasks most often by the application of special materials or information technology. Smart materials and intelligent products are able to sense several parameters of their immediate environment's physical and chemical state, they

proceed these signals then give a quick and unequivocal respond to the environmental changes by significantly changing their own state. In order to use them in the case of windows, we need measurable physical quantities (temperature, relative humidity, light intensity etc.), signal sensor and means of signal transmission, as well as a control unit.
Today, digital technology penetrated into the windows, between the frame and the sash.

To use it in the proper way integrated into a building control system, an all-over regulation can be provided, be it either savings in heating energy or optimising natural illumination. Control, or eventually self-control of the individual performance characteristics can essentially be achieved in two ways. One is to apply smart materials; the second possibility, not excluding the former one is the application of digital technology for automation. It is not absolutely necessary to invent new solutions in order to designate something as intelligent; it is enough to complement the known solutions or equipment with a control system that is capable of sensing and responding to the changes in certain parameters of the environment.To achieve this we need a specific measuring instrument for sensing the environmental parameter involved, as well as a tool for steering the corresponding accessory device built into the window system. Most often these tools can be accessed from remote places, and by sending an SMS or e-mail; the system can react and produce the required parameters of the indoor environment.

Applying currently available accessory devices for windows complemented with control system and sensors it can be achieved that:

- by sensing the inside temperature part or the whole of the shading equipment starts operating;
- by sensing the inside temperature glazing changes its properties;
- by sensing rain the roller blind starts operating, the window closes;
- controlled, automatic ventilation is in operation.

The control of a window and its accessory devices can be examined from different points of view. We are considering the categories as follows:

3.1 Automatic ventilation.

Today windows are closing more and more airtight. This is true for roof windows as well, where the required rate of ventilation can be solved with built-in ventilating systems. The ventilating device built in the window frame is no more a novelty, but the kind of device responding to the outside air pressure and decreasing the aperture with the increase of wind speed is less widespread. Thanks to it the airflow from the outside can be kept at constant rate, independent of the weather conditions. The integrated electrical remote control system is comfortable to handle, which can be used for operating several shading apparatuses and different sensing devices (rain and wind sensing).

3.2 Glasses of changing performance.

Changing performance is typical to the photochromic glasses, the light transmission of which decreases by the effect of UV radiation. Such solutions of the smart windows were blocked in the development phases by a number of obstacles, despite of the successfully application of this technology in the case of sunglasses. The principle working in small surfaces could not be adapted to large window glasses.

3.3 Glasses of changeable performance.

The first available smart window was based on liquid crystal technology (Figure 1). When the apparatus is switched off liquid crystals have random orientation. Sunshine can only go

through in the oriented state of the crystals after switching on. This solution was not energy-efficient enough, therefore the search for further solutions continued.

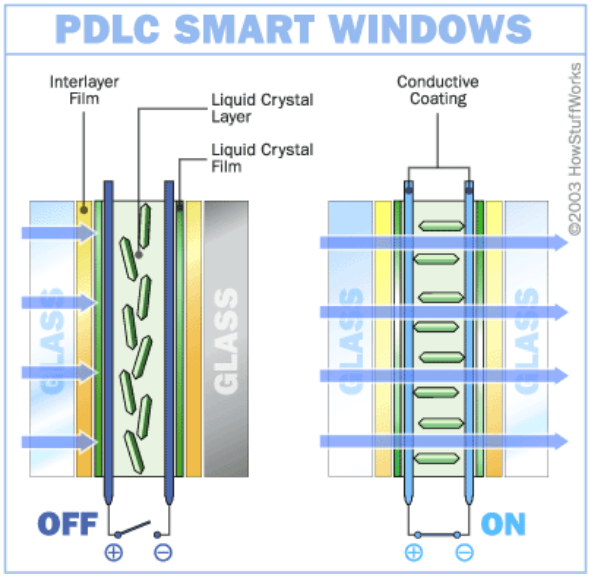

Figure 1. http://www.consumerenergycenter.org

Thermochromic windows, as their name implies alter their properties under the effect of heat. Researchers experimented with several technologies among which the gel-based coatings appeared the most promising. This thin synthetic foil that changes its properties according to the environmental temperature can be applied virtually on all window parts.

Electric field cause to change the transparency of electrochromic glasses (Figure 1). Chemical reaction induced by electric voltage changes the properties of the material. Due to the moving ions the material reflects or absorbs light, turning the glass temporarily darkened. The multi-layer assembly has to be kept under voltage to maintain the opaque state. As soon as the voltage is released the ions leave the electrochromic layer and the glass regains its transparency.

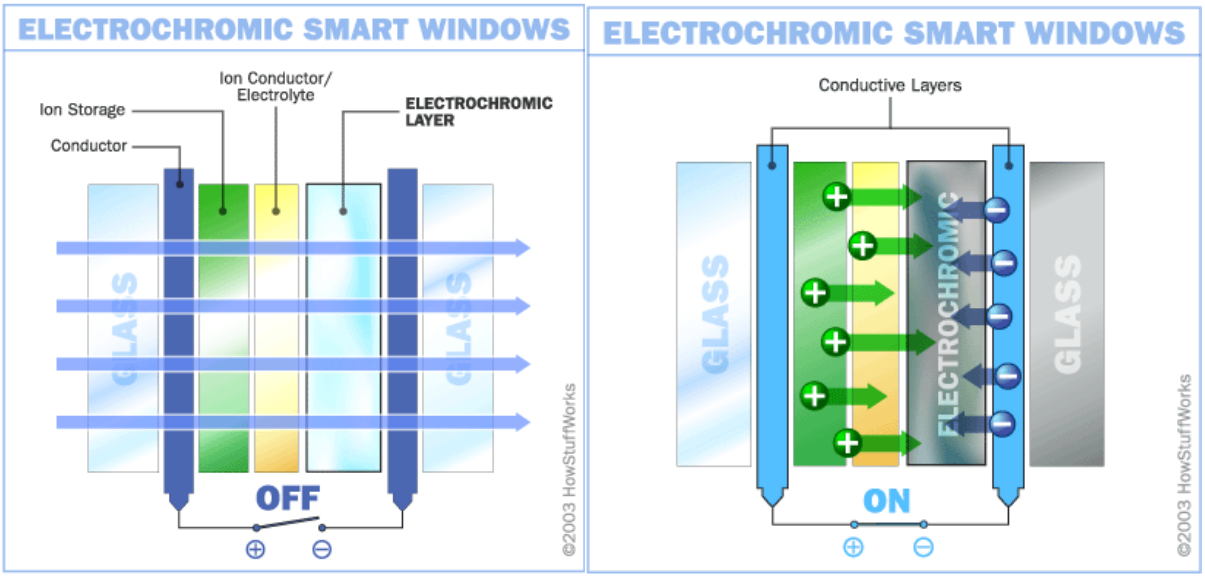

Figure 2. http://home.howstuffworks.com

The tinted version of Sage's elektrochromic smart window blocks 98% of solar radiation (Figure 3).

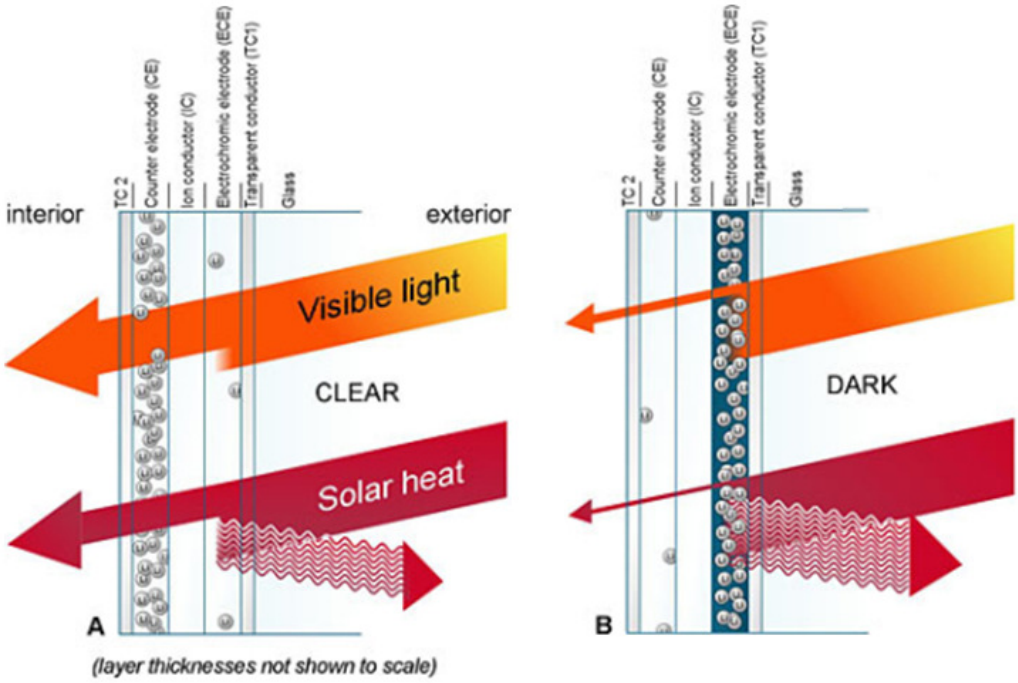

Figure 3. http://news.cnet.com

4. PROPOSALS OF DEVELOPMENT

We are making proposals of development for the enhancement of energy utilisation and improvement of interior climate:

- heating of the glass spacer and glass pane in winter to mitigate thermal bridging and reduce surface transmittance;
- replacement of glazing by transparent solar cell;
- utilisation of nano-technology on the surfaces of window parts and shading units
- control of artificial illumination according to the amount of light from the outside;
- Low-E coating responding to environmental effects;
- reflective coating on the outside surface of shading device;
- coating the glass surface with foil that is transparent but becomes reflective from a certain angle of light incidence;
- pre-heating of the air flowing inward through the built-in ventilator in winter;
- sensing the pollution level of inside air for the control of ventilation system.

In all cases a data management system is an important supplement for the acqusition, recording and storing of data, since the stored information, after thorough proceeding, can be utilised in a number of areas such as tracing changes in climate, number of sunny hours, intensity of sunshine etc.

5. CONCLUSIONS

Properties of commercially available glazings for windows relating transparency and thermal performance vary in a wide range; however, such windows or glazings that comply with the extreme requirements dealt with are currently not available. This problem can probably be solved through the continuous development of smart glazing and shading devices of altering or alterable properties. It should be noted that costs related to automation are rather high, and the return of investments is questionable; therefore their propagation cannot be expected within a short time. The primary objective of developments remains unchanged: a window system should transmit the lowest possible amount of heat. The window system that is able to adapt to the changing conditions, will be capable of optimising the heat and energy utilisation of the building through the control of heat flow. For the development of smart glazings it is important to take into consideration that in our country glazings of at least 60% of solar energy transmission are recommended, otherwise their use can not be economical because of the diminishing solar gain and the need for increased artificial lighting.

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References

KOVÁCS, Zs. (2000): Basics of Building physics; requirements. in: Engineered wood construction I. edit.:Dr. Gyula Wittmann; in Hungarian. Agricultural knowledge Publishing, Budapest. pp.160-197.

http://www.consumerenergycenter.org/home/windows/windows_future.html (March 10 2012)

http://home.howstuffworks.com/home-improvement/construction/green/smart-window4.htm (March 10 2012)

http://news.cnet.com/8301-11128_3-20087428-54/window-and-insulation-experts-the-next-plumbers/ (March 10 2012)