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Location based study of the annual thermal loads with microstructured windows in European climates

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Abstract

Glazed envelopes can cause significant thermal energy gains or losses. The installation of a novel design of Complex Fenestration Systems (CFS), such as embedded mirrors, could significantly contribute to reduce the energy consumption. In order to determine the influence of this glazing technology on thermal loads, a parametric study considering twenty-two European locations has been carried out. Simulations were performed for each location, to evaluate the range of latitudes for which the installation of the microstructures is advantageous. Optical microstructures found to be a valid solution to increase energy savings up to 20% when compared to a sun protective glazing.

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Keywords: embedded microstructures, climate, thermal loads, energy savings.

1. Introduction

Glazing is a key material in building façades for aesthetic and energetic motivations in modern constructions. At the same time the attention to the environment is increasing, and buildings are designed to be more and more sustainable. About 20% to 60% of all energy used in buildings is affected by the design and the construction of the building envelope [1]. Therefore the need to focus on the role that windows can play from the energetic point of view is growing. The installation of Complex Fenestration Systems (CFS) can be an interesting solution to reduce the energy demand. In particular, a novel design of embedded microstructures [2] can be used to find a compromise between daylighting, glare protection and seasonal thermal control. Such a CFS could significantly contribute to the

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reduction of energy consumption in buildings: in winter the heating loads can be reduced by exploiting solar gains, while in summer the gains can be moderated to avoid overheating and excessive cooling loads. This seasonal dynamic effect can be achieved by embedded mirrors combined with a second reflector as described in [3]. For a given configuration of such reflectors, the geometry of the microstructure is characterized, among other properties, by the blocking angle and the width of the blocking range. The transmittance depending on the elevation angle of the sun is illustrated in Figure 1. During the winter period, when the solar elevation is low (21,4° is the winter solstice in Turin), the total transmittance of the microstructured glass is high (around 70%). In summer, for a range of incidence angle from 50° to 68°, the transmittance reaches low values, mainly between 10% and 20%. This seasonal variation of the transmittance enables solar gains in winter and reduces them during the hot months.

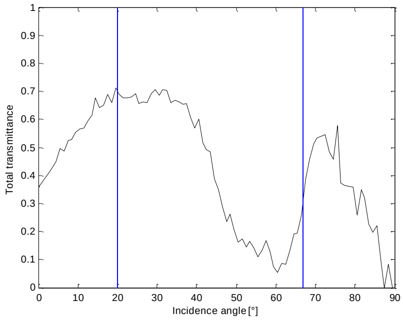

Fig. 1. Total transmittance of the embedded microstructured glazing at different incidence angles on the vertical window plane. Vertical blue lines indicate the solar elevation at noon on solstices for Turin.

Numerous parameters influence the performance of the embedded micro-mirrors for glazing envelopes: microstructure design, site, orientation, climatic conditions as well as geometry and thermal properties of the considered room. However one of the most interesting points is to evaluate how thermal loads vary for changing latitudes, fixing the blocking angle and the blocking range of the microstructure and the type of room, to assess the range of latitude for which a particular microstructure is suited.

The frame for the present study is to analyze the impact of the local climate, in order to evaluate its influence on the thermal loads for a reference office room. Using a ray tracing program, simulations for each location have been performed.

2. Methodology

The parametric study was performed in order to investigate the thermal loads for different glazed façades as a function of the latitude. A standard double glazing and a sun protective glazing were considered as reference cases; an advanced CFS [2] comprised of micro-mirrors was studied. The blocking angle and blocking width of the micro-mirrors have been defined in order to optimize the thermal loads for one location: Lausanne. On the other hand, the geometry and the thermal properties of the considered office room are maintained for all the simulations. The aim is to evaluate the reachable energy savings during the year, in comparison with the two reference glazing.

The simulations have been performed with a ray tracing program based on a Monte Carlo method for the statistical evaluation of the bidirectional transmission distribution function of CFSs [4]. This program allows to model the path taken by light through the microstructured glass. The thermal performance depends on the CFS geometry but also on the location and time dependent variations of the irradiance distribution of the sky [4]; for accuracy, direct and diffuse irradiance are computed separately. A realistic sky luminance distribution is considered for diffuse irradiance, according to the Perez model [5]. The location dependence on the hourly solar path is considered for the direct radiation.

Energy savings for different latitudes have been derived, in order to quantify the advantages of the embedded microstructures from the energetic point of view.