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Evaluation of models for the angular variation of solar absorptance in windows

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Abstract

An empirical model to predict the angular variation of solar absorptance in window panes has been evaluated in terms of errors in maximum absorbed solar power. The input to building simulation programs is usually the near normal optical properties of a window, and the angular variation has to be predicted by some kind of algorithm. This may lead to an incorrect estimate of the solar optical properties. In this study, Fresnel formalism and international standards for the solar irradiation were used when calculating the error in the total solar absorptance in window panes using different approximations. The absolute error in maximum absorbed solar power was then calculated for a standard Stockholm climate and for four different orientations (N, E, S, W) for the incidence angle intervals $0-10^{\circ}$, $10-20^{\circ}, \ldots, 80-90^{\circ}$. Typically, the highest values for maximum incident power on a vertical facade in the Stockholm climate are found for incidence angles around 20° for all four orientations, whereas the absorptance of many types of window panes peaks at about 70–80°. Together, the two effects give a maximum absorbed solar power at an angle between these two values. The empirical model requires that the window composition is known and thereby to which of the nine groups the window belongs. A set of polynomial fits for the angular absorptance is used; one set for each window group (one polynomial fit for each window pane). It is shown that the error with the empirical model, which distinguishes between

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different window configurations, is on average about a factor of ten lower than with two other models where the same approximation is used indiscriminately for all windows.

Keywords: Angular variation; Window absorptance; Optical properties

1. Introduction

1.1. Background

Solar radiation reaches a window from all possible angles of incidence. On a clear day, most of the radiation is direct and its incidence angle against a vertical surface varies with time of day and season. Radiation coming from different directions is affected differently by the window panes, and since the reflectance always approaches 100% when the incidence angle approaches 90°, the transmittance and absorptance both approach zero. This angle dependence could be tailored for specific applications, such as future angular selective windows [1], but it also leads to problems when the heat flux through windows is estimated. Building simulation programs have to use some kind of algorithm to estimate the angular variation of the optical properties since the available input parameters are usually limited to the properties at normal incidence. These near normal properties are available from the manufacturers and from the European database which is part of the public software tool Advanced Window Information System (WIS) [2]. A building simulation program can thus use window data from WIS or from some equivalent source, such as International Glazing Database (IGDB) [3]. Routines for the angular variation of the total solar transmittance are included in these tools but they do not distinguish between products with different coatings. The European collaborative project Angular Dependent Optical Properties of Coated Glass and Glazing Products (ADOPT) [4], has suggested an empirical formula to estimate the angular variation of the total solar transmittance based on the different material categories in different types of coatings. In this way it is possible to improve the accuracy in the prediction of the angular variation by recognizing the fact that different types of coatings have different angular variation functions. It is not possible to accurately take these differences into account without identifying the actual products used in the window. The ADOPT project showed, however, that it is not necessary to know the exact composition of the coatings, which the manufacturers would never reveal. Based on the near normal optical properties the coated pane can be placed in the right product category and thus be associated with the corresponding purely empirical angular variation function for the total solar energy transmittance, g. Some building simulation programs, such as Derob-LTH [5], do not use the complete window data as input but use the properties of the individual panes as input and then calculate the properties of the window according to EN 410 [6], ISO 9050 [7] or some equivalent calculation procedure. This way the absorptance in each pane can be obtained, but