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Heat parameters of multi-sash windows in residential buildings

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HIGHLIGHTS

- Thermal characteristics of multi-sash windows are difficult to find.
- The degree of influence of fundamental factors of heat transfer were analysed.
- Only the surface area of the window has a positive effect on the U_w factor.
- The number of sashes in the window corrects the impact of other factors.
- A minimum value of coefficient $U_{w,\min}$ = 0.722 W/(m^2 K).

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ABSTRACT

The article presents the analysis of heat transfer coefficient values for multi-sash windows in residential buildings according to the surface area of the window, the number of sashes in the window, the width of the frame and the heat transfer coefficient values of glazed surfaces and frames. The analysis was made in compliance with the deterministic mathematical model of the discussed dependency, based on the results from the computational experiment. The optimum values for the tested parameters for multi-sash windows are: A_o = 2.664 m^2; r = 1; b_f = 0.08 m; U_g = 0.40 W/(m^2 K); U_f = 1.20 W/(m^2 K). They allow for a minimum value of coefficient $U_{w,\min}$ = 0.722 W/(m^2 K). The information may be useful for students, scientists, designers and window buyers.

1. Introduction

For several years, scientists have been considering the problem of optimizing the parameters of windows for Polish conditions. Some researchers focused on the economic aspect. According to the author [1], the optimal window is the one for which the sum of window costs and operation divided into loan time will be the lowest. In addition, the author takes into account the influence of external blinds on the heat take off results through the window for the average heating season. The results in this aspect are so surprising that even in the case of modern windows with low heat transfer coefficient using shutters, more than 10% of heat can be saved, which escapes through the window [1].

Other work [2] refers to two methods for calculating the energy balance of glazing, used in the current optimization procedure and subjected to modification. Both relate to obtaining specific economic effects, however the modified variant additionally takes into account heat gains from solar radiation. The example of optimization provided by the author [2] concerns the calculation of the simple payback time of SPBT financial expenditures and does not take into account the limitations of the energy parameters of window joinery. Although the solar effect was taken into account, none of the significant indicators ensuring thermal protection of the windows have been analysed.

Another example is the development of Ref. [3], whose main assumption was to calculate the energy consumption of a residential building for variable share of window frames in external partitions. In addition, an attempt was made to optimize window surfaces for the heating season, taking into account different orientations towards the world sides. In this case, the focus was not on the variable thermal parameters of the window joinery. The only thing that changed was the window area and the percentage of the transparent part of the window.

Thermal characteristics of multi-sash windows are difficult to find, whether in the specialized literature [1–4] or marketing materials. Usually, information for the Polish standard window (sometimes singular calculations) is given, that is for a 1.23 × 1.48 m single-sash window.

It is very likely for window distributors not to inform consumers about the thermal parameters for the windows with a

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larger number of sashes since such products are characterized by a higher (or less favourable) rate of thermal transmittance than single-sash windows. This is mainly due to the increase in the surface area of the window frame and the length of the thermal bridge at the glass-frame contact and the reduction of the glass surface of the window. However, this thesis could be ultimately confirmed by a properly scheduled and implemented study.

The main structural element that distinguishes the single-sash windows from the multi-sash windows is the mullion. This could be called a characteristic feature of the window's divide. When the windows are opened it is the mullion that shows precisely how the window-frame is divided (vertically or horizontally). For the multi-lite windows (when the window is divided into horizontal or vertical and horizontal areas), the muntins or glazing bars are characteristic. They are transverse elements fixed in the window-frame dividing the sashes into smaller areas.

In the window joinery, several adjacent window sashes may be separated from each other by a fixed or floating mullion, and there is also a one-to-one option when the window sash closes overlapping another. In the case of windows with a frame made of wood without a fixed mullion, it is possible to distinguish the following types of sash: awnings (opening outward) and also hopper windows (opening inward thanks to a special profile called a sash stop). Used in the multi-lite windows, muntins can be divided into two main groups: structural muntins or imitations. The first play a role similar to the vertical members, and the other are used to achieve aesthetic effects – they are installed in two ways, either by sticking them onto the glass pane, or mounting inside the glazing.

It is extremely difficult to find data on coefficient U_w for the multi-lite window in the literature on the subject. Below there is a table (Table 1) from the resources of the Lower Silesian Energy and Environment Agency [5], which presents the data for the multi-lite windows measuring only 1.80 by 2.40 m.

The first row of the table shows the scheme of the window described in the second line. The immediately preceding line indicates the value of heat transfer coefficient for this window. The last row gives the percentage of the heat transfer coefficient of a single-chamber profile window used to analyse the window with a correspondingly increased number of chamber profiles. The listed data show that at constant values *Ug*, U_f and *y* the *U* value increases with the increasing number of chamber profiles. For a single-chamber profile window, under specified conditions, it is 1.1 W/(m^2 K), and for an eight-chamber profile window of the same size it increases to 1.38 W/(m^2 K), which is up to 25% more [5].

However, these data are discrete, indicative only and very approximate for other conditions as there is no dependency or information on the interaction and nature of the effect of many other important factors on the *U* value. This fact motivated the authors to try to close the existing gap.

Due to the fact that a number of research works on the optimization of windows parameters for Polish conditions were created and none of these works takes up the problem of multi-sash windows, there was a need for such tests. Moreover, in the above-mentioned studies [1–3] no attempt was made to estimate the influence of variable thermal parameters of window elements, and according to the authors, this is crucial and cannot be omitted from the analysis. Therefore, the aim of this paper is to analyse the heat transfer coefficient values for multi-sash PVC windows in residential buildings, with respect to the surface area of the window, the number of sashes, the width of the frame elements and the glazed surface heat transfer coefficient as well as the heat transfer coefficient of the frame, along with the assessment of the degree and nature of influence of these factors, and determination of their optimal values based on the deterministic mathematical model developed.

2. The examined variants of multi-sash windows

In residential building the size of the windows is limited by the size of rooms and security conditions. As a consequence, the height of the windows does not usually exceed 1.50 m. The width of the windows ranges from 0.60 to 2.40 m. Horizontal bolts are rarely used in these types of windows. What can be found are vertical mullions only, forming several sashes in the window. Taking into account the most commonly used window sizes and the aim of the study, the following window frames were selected: height (fixed) – 1.48 m; width (variable) – from 1.20 to 1.80 m; with a number of window sashes from 1 to 3. The diagrams for the tested variants of windows are given in Fig. 1.

3. The method of calculating heat transfer coefficient of multi-sash windows

To calculate the heat transfer coefficient of multi-sash windows the best idea is to use the evaluation method described in Ref. [7] used by window manufacturers. This method divides part of the baffle into surface areas of different thermal properties and the total heat transfer coefficient is calculated by means of surface-weighted U-values of components with additional corrections, taking into account the mutual heat interactions between these elements. According to this method, for the adopted variants of multi-sash window joinery, the coefficient of heat transfer U_w should be calculated in accordance with the following equation:

$$U_w = \frac{A_g \cdot U_g + A_f \cdot U_f + A_m \cdot U_m + l_{f,m} \cdot \psi_{f,m} + l_{g,f} \cdot \psi_{g,f} + l_{g,m} \cdot \psi_{g,m}}{A_g + A_f + A_m} \quad (1)$$

where:

U_g, U_f, U_m – heat transfer coefficients: glazing; frame; window mullions, respectively;

$\Psi_{f,m}$, $\Psi_{g,f}$, $\Psi_{g,m}$ – linear heat transfer coefficients resulting from the combined heat effects of the glass and frame components, glazing and window mullion; window frame and mullion, respectively;

$l_{g,f}$, $l_{g,m}$, $l_{f,m}$ - the length of the linear thermal bridge formed at the contact of glass and frame; glass and mullion; frames and mullion, respectively

Table 1
Heat transfer coefficient for a window consisting of different numbers of lites [5]

								
Eight	Seven	Six	Five	Four	Four	Three	Two	One
Multi-lite windows 1800 mm × 2400 mm								
1,38	1,35	1,33	1,31	1,31	1,27	1,26	1,2	1,1
125%	123%	121%	119%	119%	115%	115%	109%	100%