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THE IDENTIFICATION OF SELECTED WINDOW ENERGY PARAMETERS IN WINTER AND SUMMER PERIODS IN THE GREATER POLAND REGION

Summary

The simulation research results of gains, losses and heat balance of two-, three- and four-paned windows positioned at 30, 60 and 90° angles relative to a surface for climatic conditions in Poznań and the Greater Poland region expected in the eco-power industry have been presented. It has been shown that in a summer period the increase in a number of panes and the angle of widows decreases high solar heat gain which determines similar alternations of heat balance at low losses. Particularly high window heat balance occurs from May to August due to high sun exposure at low heat losses. In winter, window heat balance is generally positive, apart from December, when it is minor and negative due to the lowest solar radiation at not the lowest outdoor temperature. Increasing a number of panes and a window angle does not change significantly window heat balance in a winter period.
***Key words**: windows, panes, window angle, gains, losses, heat balance, summer, winter*

IDENTYFIKACJA WYBRANYCH PARAMETRÓW ENERGETYCZNYCH OKIEN W OKRESIE ZIMOWYM I LETNIM W REGIONIE WIELKOPOLSKI

Streszczenie

Przedstawiono oczekiwane w ekoenergetyce wyniki badań symulacyjnych zysków, strat i bilansu cieplnego okien 2-, 3- i 4-szybowych ustawionych pod kątami 30, 60 i 90° względem podłoża, dla warunków klimatycznych Poznania i regionu Wielkopolski. Wykazano, że w okresie letnim wzrost liczby szyb i kąta ustawienia okien zmniejsza wysokie zyski ciepła, które przy niskich stratach determinują podobne zmiany bilansu cieplnego. Szczególnie wysoki bilans cieplny okien występuje w okresie od maja do sierpnia wskutek wysokiego nasłonecznienia przy niskich stratach ciepła. W okresie zimowym bilans cieplny okien jest ogólnie dodatni z wyjątkiem grudnia, kiedy jest nieduży i ujemny z powodu najniższej emisji promieniowania słonecznego przy nie najniższych temperaturach zewnętrznych. Zwiększanie liczby szyb i kąta ustawienia nie zmienia znacząco bilansu cieplnego okien w okresie zimowym.
***Słowa kluczowe**: okna, liczba szyb, kąt ustawienia, zyski, straty, bilans cieplny, okres letni, okres zimowy*

1. Introduction

Better determination of energy parameters contributes to the reduction of energy consumption and costs thus limiting numerous negative consequences for environment. In building structures, windows constitute an important element and their parameters influence considerably heat balance and energy demand for both heating in winter and cooling in summer.

In Western literature, conducting research on the effect of local climate parameters on heat balance of building structures and their elements [1, 2, 3] is substantiated. In order to do such research, there have been marked climate zones in Poland characterised by various temperature and radiation conditions changing throughout a year (according to PN-EN 12831: 2006). According to the studies [4, 5] in some regions, for Lublin [7, 8] or Rzeszów [9], locally different climate conditions influence general energy demand for heating and cooling buildings. Energy research on windows has concerned a various number of panes, their emissivity and frame structure and it has been conducted for a typical meteorological year in Poland [4, 5, 6] or for the selected locations mentioned above [7, 8, 9]. The gathered heat balance results regard comprehensively rooms or buildings, which hampers conclusions about individual structure elements, including windows [4, 6, 7]. Extensive window energy parameter results have been determined for Rzeszów so far [9].

There are expected window energy parameter results for Poznań and the Greater Poland region located in Polish climate zone 2 (PN-EN 12831: 2006). The climate of Poznań is characterised by high temperature in summer, quite high air temperature in a heating period and high annual temperature amplitude. Sums of insolation – of solar energy falling on a horizontal surface (in $kWh \cdot m^{-2}$) – differ from other locations. It may differ in various locations in Poland even up to approximately 30%, average ± 10%. Solar transmittance into a building through a window is determined by incident resulting from the azimuth of the Sun's position and local climate conditions (e.g. clouds) throughout a year and also depends on *inter alia* a number of panes and a window angle. Conducting heat out of a window depends to a great extent on a number of panes and outdoor air temperature during a year. Those factors result in determining window local energy parameters expected in eco-power industry.

This paper presents the results of simulation research, the aim of which was to determine the selected energy parameters for windows with a various number of panes and angles, for summer and winter periods, conditioned by climate parameters of the Greater Poland region.

2. Materials and methods

There have been investigated heat gains and losses as well as heat balance for typical, commonly used Tilt Turn windows of overall measurements: 1230 x 1480 mm. Two-, three- and four-paned windows (one-chambered, two-chambered and three-chambered), respectively, exposed to the South were analyzed. Three angles of window positions relative to a surface: $\alpha 1=30°$, $\alpha_2=60°$ and $\alpha_3=90°$ were considered. It was assumed that research results would be gained for possible solar transmittance and heat conduction coefficients for windows meeting new technical requirements determined for buildings and their location specified in the directive of Ministry of Transport, Construction and Marine Economy on 5th July 2013 (Dz. U. 2013 item 926) [12]. Other window parameters were adopted as constant.

Gain, loss and heat balance (in kWh) were determined with a simplified method according to the methodology recommended in the directive of Minister of Infrastructure and Development on 27th February 2015 [10] as well as in Polish standards. The calculations were conducted separately for a summer period, from 1st April to 30th September, and a winter period, from 1st October to the end of March and for consecutive months in a year. Long-term average outdoor temperature for Poznań [11], observations of central heating operation dates and indications of standard PN-EN ISO 13790: 2009 led to adopting the periods.

Heat gains were determined on the basis of average monthly values of solar radiation energy I_i ($kWh \cdot m^{-2}$), for the studied α angles, specified experimentally in the years 1971-2000 by the Institute of Meteorology and Water Management (*IMGW*), placed and shared on the website of the Ministry of Infrastructure and Construction (*MIiB*) [10]. Window heat gains [10) resulting from solar radiance $Q_{solb,H}$, in kWh, were calculated using the following formula:

$$Q_{solb,H} = C_i \cdot A_i \cdot I_i \cdot F_{sh,gl} \cdot F_{sh} \cdot g_{gl} \qquad (1)$$

where: C_i – glazing surface area share to total window surface area (averaged value is 0.7) [-], A_i – window surface area [m^2], F_{sh} – reducing factor for mobile shading devices according to standard PN-EN ISO 13790:2009, $F_{sh,gl}$ – reducing factor due to shading according to standard PN-EN ISO 13790: 2009, g_{gl} – total solar radiation transmittance for panes.

Total window heat loss $Q_{tr,ie}$ was calculated for average outdoor temperature $\theta_{e,n}$ (K) from the last 29 years [11] taken from the weather station in Poznań (Hydrological-Meteorological Station (*SHM*) and Airport Meteorological Station (*LSM*), no 123300). The data were adopted as representative for the Greater Poland region located in Polish climate zone 2 (according to PN-EN 12831: 2006) (Table 1). Total heat loss $Q_{tro,ie}$, in kWh, was determined by a simplified method using the following formula:

$$Q_{tr,ie} = H_{tr,ie} \cdot (\Theta_{int,s,H} - \Theta_{s,n}) \cdot t_M \cdot 10^{-3}, \qquad (2)$$

where: $\Theta_{int,s,H}$ – average indoor temperature in heating area [K], t_M – the number of hours for a period [h], Coefficient $H_{tr,ie}$ of heat transfer through a window from a heating area (i) directly to outdoor environment (e) [$W \cdot K^{-1}$] determined according to PN-EN 12831:2006:

$$H_{tr,ie} = f_k \cdot U_w \cdot A_i, \qquad (3)$$

where: f_k – temperature correcting factor in accordance with PN ISO 13831: 2006 [-], U_w- coefficient of heat transmittance for a window [$W \cdot m^{-2} \cdot K^{-1}$].

It was assumed in the calculations that: A_i=1.82m² (according to PN-EN ISO 10077-1:2017-10); C_i = 0.7; $F_{sh,gl}$ = 1, F_{sh} = 0.9, $\theta_{int,s,H}$ = 295.16 K (22°C); f_k = 1. A number of hours t_M was determined on the basis of dates marking summer and winter periods and a number of days in months. The coefficient values g_{gl} and U_w for windows are shown in Table 2.

Heat balance was determined in accordance with the standard PN-EN ISO 13790; 2009 by deducting defined heat losses $Q_{tro,ie}$ from heat gains $Q_{solb,H}$.

3. Results and discussion

There have been presented the results of heat gains and losses and heat balance for windows of a various number of panes, positioned at various angles which were analyzed in terms of potential benefits resulting from energy savings for central heating in the winter period and cooling in the summer period.

Table 1. Average outdoor temperatures $T_{śr}$ for Poznań from the last 29 years [11]
Tab. 1. Średnie temperatury zewnętrzne $T_{śr}$ dla Poznania z okresu 29 lat [11]

Month	1	2	3	4	5	6	7	8	9	10	11	12
$T_{śr}$ [°C]	0.2	-1.8	2.7	8.3	13.0	16.8	18.3	18.4	13.5	7.0	2.2	-0.1

Table 2. Adopted coefficients of solar transmittance and heat conduction of the analysed windows
Tab. 2. Przyjęte w obliczeniach współczynniki przenikania promieniowania słonecznego i przewodzenia ciepła analizowanych okien

Coefficient	Units	Value		
		Double-glazed window	Triple-glazed window	Quadri-glazed window
U_w	$W \cdot m^{-2} \cdot K^{-1}$	1.3	1.0	0.7
g_{gl}	-	0.8	0.7	0.6

Source: own work / Źródło: opracowanie własne

3.1. Summer period

Heat gains and heat balance for the summer period depending on window angles and a number of panes as well as heat losses for a number of panes are shown in Fig. 1. The figure depicts that in climate conditions of the analysed region, heat gains and heat balance decline along with an increase in a number of panes and a window angle (Fig. 1). Heat gains for still commonly used and found in buildings windows with two panes amount to approx. 707 kWh, heat losses approx. 256 kWh and heat balance approx. 964 kWh in the summer period. Heat gains decline along with an increase in a number of panes by average approx. 88 kWh/pane for each of the studied window angles.

Heat gains decrease parabolically along with a rise in window angles (Fig. 1). The change of an angle from 60 to 90° decreases heat gains approx. threefold more than from 30 to 60°. Approx. 32 kWh (approx. 4%) less radiation energy is transmitted through a window positioned at an angle of 30° than through a window positioned at 60° and approx. 119 kWh less than through a vertical window (approx. 16%). The drop is similar to the analysed windows with a various number of panes.

Heat losses for windows in the summer period are generally low, mainly due to high outdoor temperature in the analyzed region (Table 1). Heat losses for a two-paned window are approx. 284 kWh and decrease along with an increase in a number of panes only by approx. 17.5 kWh/pane.

The values and changes of window positive heat balance in the summer period are similar to the values and changes of heat gains due to prevailing heat gains at very low losses (Fig. 1). Window heat balance decreases parabolically along with a rise in window angles. Heat balance for a window with two panes is approximately 632 kWh and declines along with an increase in a number of panes by approx. 32 kWh/pane. The change of a window angle from 60 to 90° decreases heat balance approx. 2.7 times more than the change from 30 to 60°. A vertical window has approx. 87 kWh (approx. 14%) lower heat balance than a window positioned at 30° and a window positioned at a 60° angle has a lower heat balance by approx. 32 kWh (about 5%) than a window positioned at 30°. The drops are similar to the analysed windows with two, three and four panes.

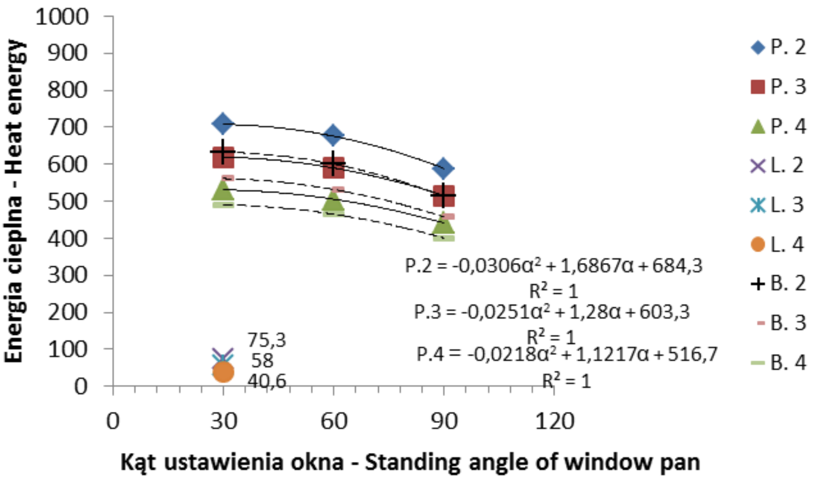
Fig. 3 depicts that high values of window heat balance occurring primarily from May to August result mainly from high and similar insolation [11] at low heat losses determined mostly by high and similar outdoor temperature in these months (Table 1). A vertical four-paned window (for α_3) in comparison with a two-paned window positioned at a 30° angle reduces gained heat energy (heat balance) by more than 30% in these months.

3.2. Winter period

Heat gains and losses in winter depending on a window angle and a number of panes as well as heat loss for a number of panes are shown in Fig. 2. In general, the effect of a number of panes and window angles on heat gains and heat balance conditioned by the Greater Poland climate in this period is relatively slight. Heat gains in winter are low and change also slightly with the change of a number of panes and window angles. Gains for a double-paned window are the highest at a 60° window angle and amount to approx. 280 kWh. Window angles affect heat gains to a minor extent, changes range merely from approx. 10 to approx. 22 kWh. Heat gains decline with an increase in a number of panes on average by approx. 32 kWh/pane (approx. 12%/pane) and at the analysed window angles alike.

Heat losses are from 209 kWh for a window with two panes to 112 kWh for a four-paned window in winter. They decrease along with an increase in a number of panes on average by 48 kWh/pane.

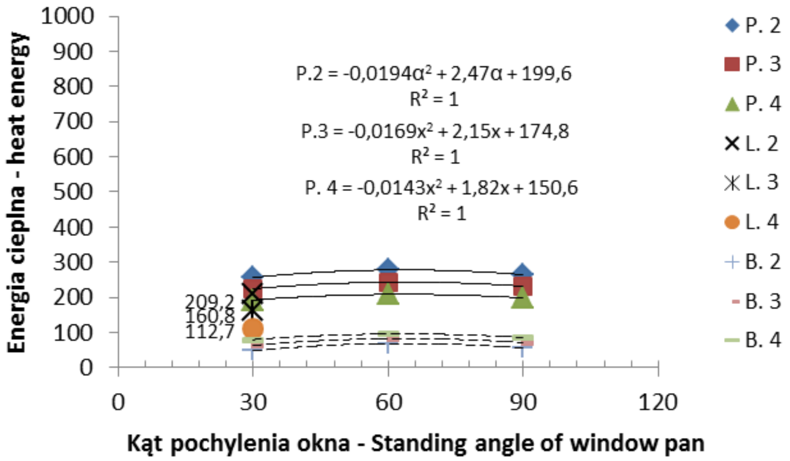
Heat gain values higher than heat losses in the winter period result in positive, albeit low, values of heat balance ranging from approx. 50 to approx. 95 kWh. Heat balance for a double-glazed window is approx. 50 kWh. Applying additional panes improves heat balance slightly, merely by approx. 15-16 kWh/pane, as heat conductivity to the outside air and solar transmittance to the indoor both decrease similarly. Heat balance values barely change, from 5-7 kWh depending on window angles, for a 60° angle being the highest.



Source: own work / Źródło: opracowanie własne

Fig. 1. Heat gains (P) and losses (L) and heat balance (B) depending on a window angle and a number of panes in the summer period

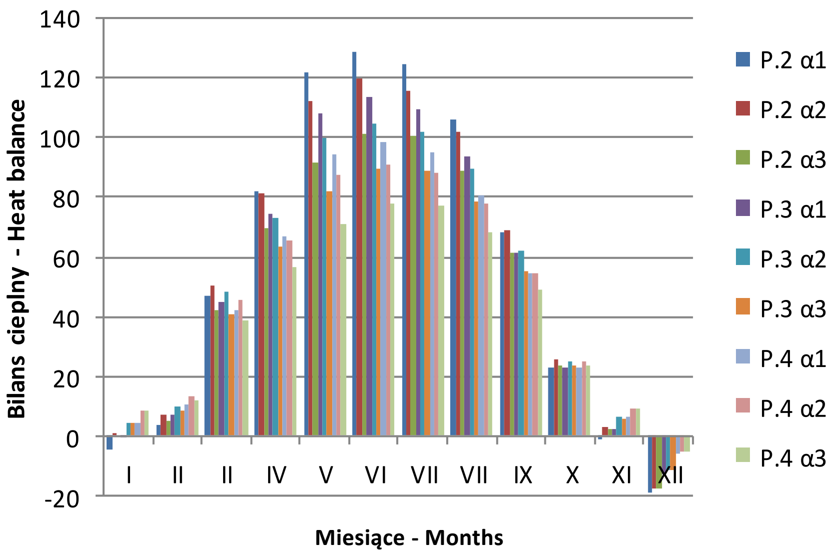
Rys. 1. Zyski (P) i straty (L) ciepła oraz bilans ciepła (B) w zależności od kąta ustawienia okien i dla liczby szyb w okresie letnim



Source: own work / Źródło: opracowanie własne

Fig. 2. Heat gains (P) and losses (L) and heat balance (B) depending on window angles and a number of panes in the winter period

Rys. 2. Zyski (P) i straty (L) ciepła oraz bilans cieplny (B) w zależności od kąta ustawienia okien i liczby szyb w okresie zimowym



Source: [11] / Źródło: [11]

Fig. 3. Heat balance in consecutive months for a number of panes and window angles (notes: P – panes, 2, 3, 4 – a number of panes, α – window angle)

Rys. 3. Bilans cieplny w kolejnych miesiącach roku dla liczby szyb i kątów ustawienia okien (oznaczenia: P – szyba, 2, 3, 4 – liczba szyb, α – kąt ustawienia)

Fig. 3 shows that windows have negative heat balance only in December mainly because of the lowest solar radiation emission [11] despite not the lowest outdoor temperature and heat loss (Table 1).

4. Results

Simulation research results have been presented considering the paper's assumptions regarding heat gains and losses as well as heat balance of windows for climate conditions in the Greater Poland region. The results can be helpful to design with a greater precision more energy- and cost- effective heating and cooling systems for rooms and buildings.

– In summer, an increase in a number of panes and window angles results in a significant decrease in high heat gains, which affects predominantly the change of window heat balance in this period.

– Windows from May to August have the highest and similar heat balance, mainly due to high and similar insolation at low heat losses.

– In the winter period, heat gain values higher than heat losses lead to heat balance of the analysed windows being low but generally positive.

– Window heat balance is negative only in December mostly due to the lowest solar radiation emission at not the lowest outdoor temperature and heat losses.

– In the winter period, the influence of a number of panes and window angles on heat gains and heat balance is very little. Heat balance changes slightly along with an increase in a number of panes as little heat loss declines are accompanied by similar declines of heat gains.

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Standards

PN-EN 12831: 2006. Instalacje ogrzewcze w budynkach. Metoda obliczania projektowego obciążenia cieplnego.

PN-EN ISO 13790: 2009. Energetyczne właściwości użytkowe budynków. Obliczanie zużycia energii na potrzeby ogrzewania i chłodzenia.

PN-EN ISO 10077-1: 2017-10. Cieplne właściwości użytkowe okien, drzwi i żaluzji. Obliczanie współczynnika przenikania ciepła.