DOI 10.34185/1562-9945-5-162-2026-11
УДК 536.212: 699.059
O.V. Кravets, К.V. Makhonina

STUDY OF THE NON-STATIONARY TEMPERATURE FIELD ALONG THE THICKNESS OF A MULTILAYER EXTERNAL WALL PANEL OF A RESIDENTIAL BUILDING IN WINTER

Abstract. Solved the relevant problem of studying the non-stationary temperature field along the thickness of a multilayer external wall panel of a residential building with daily fluctuations in ambient temperature in the winter period.
Key words: multilayer external wall panel, temperature field, non-stationary calculation, insulation of a residential building, enclosing structure.

Introduction. In winter, the problem of heating residential buildings and storing heat in them becomes relevant. The main problem is taking into account the daily change in ambient temperature, which requires non-stationary calculations of the temperature field of enclosing structures that have a multilayer structure. The study of the non-stationary temperature field and heat fluxes of multilayer wall panels of buildings will allow for the correct design of the geometric parameters of the layers of their external wall panels and the optimal selection of insulation materials. This direction is dedicated to the study of the problem of energy conservation – a relevant problem of modern times in Ukraine.

Analysis of recent research and publications. Residential, cultural, administrative and industrial buildings are large consumers of thermal energy. According to experts, up to 50% of energy consumed can be saved annually in the stock of residential and non-residential buildings through energy-saving measures. Considering the fact that heat loss through building envelopes accounts for up to 80% of all total heat losses [3], thermal calculation of building envelopes becomes relevant.

Calculating the temperature field in the enclosing parts of buildings is also relevant for the implementation of many factors, including:

– energy efficiency: thermal calculation allows you to determine the geometric parameters of enclosing structures and optimally select thermal insulation material, which leads to minimizing heat loss and, as a result, reducing heating costs;

– preventing destruction: the calculated temperature field prevents the formation of condensation and mold in the rooms, which can lead to the gradual destruction of structures;

– endurance: extending the endurance of building structures is possible by taking into account the heat resistance and strength of their materials, which is based on the calculation of the thermal field of enclosing structures;

– thermal protection and accordance with building codes: thermal calculation ensures accordance of enclosing structures with the requirements of modern building codes and regulations in terms of thermal protection and safety;

– comfort: maintaining optimal indoor temperatures without sudden changes is critically important for creating comfortable living or working conditions for people.

In work [4], a study of heat flows and an analysis of heat losses of opaque external enclosures of heated premises was conducted, taking into account various methods for assessing the heat-shielding properties of external walls: without taking into account heat-conducting inclusions (external walls in the heat engineering calculation are a homogeneous opaque enclosure); taking into account heat-conducting inclusions according to the standards in force in Ukraine and according to the European standard, as well as instrumental determination of the characteristics of thermal protection. It has been shown that taking into account heat-conducting inclusions, even for a building without complex structural solutions for enclosures, leads to an increase in heat loss of up to 14%, which may change the energy efficiency class of the building.

In paper [5], a simplified discrete analogue, presented in a dimensionless form, was developed for the numerical solution of unsteady heat transfer problems. This was achieved by using a one-dimensional initial model. The use of such a model is sufficient for solving most practically important problems. The stability of numerical calculations at large time discretization steps and high accuracy of calculations on extremely small computational grids are shown.

The article [6] is devoted to the study of unsteady heat conduction in a solid wall and contains mathematical modeling of asymmetric heating and cooling of the wall due to imperfect heat transfer from both sides. The method used to obtain an analytical solution in a long-time process is presented. The solution method allows to obtain the temperature distribution in the heated (cooled) wall using the Laplace transform. Its validity is verified by numerical calculation using the COMSOL Multiphysics software. In the example that was tested, the maximum difference between the analytical and numerical solutions was about 3.5%, taking into account the possible maximum and minimum temperatures in the wall under given conditions.

The thermal response of a building's envelope has a significant impact on the overall comfort conditions in the room, as well as on the energy efficiency of buildings. Most Central and Northern European countries focus mainly on optimizing the efficiency of buildings during the heating season. However, future projections show the potential for a significant increase in cooling demand due to building overheating. In this context, the focus of the paper [7] was on assessing the transient performance of different facade walls (light and heavy building systems) during typical Central European summer conditions. In addition to the influence of wall composition, the effects of orientation and high-intensity passive cooling on thermal response were also investigated. The results showed significant differences in the thermal behavior of east-, south-, and west-facing walls.

ISSN 1562-9945 (Print)
ISSN 2707-7977 (Online)

Thus, the review of recent studies shows that, despite the significant influence of many factors on the thermal state of building structures, the issue of conducting non-stationary thermal calculation of a multilayer enclosing structure remains relevant, especially in the winter period.

The purpose of the study: to investigate the non-stationary distribution of the temperature field along the thickness of a four-layer wall panel of a residential building depending on the daily change in ambient temperature in the winter period.

Presentation of the main material of the study. Calculated cases of the location of building materials in the layers of the wall panel and their coefficients of thermal conductivity are presented in the table 1.

Table 1

The location of building materials in the layers of the wall panel
and their thermal conductivity coefficients λ, $\text{kcal}/(\text{m} \cdot \text{h} \cdot \text{grad})$

	Wall panel layers			
Material of a layer	**Concrete inner textured layer**	**Cement fibrolite**	**Mineral wool plate**	**Concrete outer textured layer**
Layer thickness, mm	**80**	**70**	**55**	**40**
Number of a layer	**1**	**2**	**3**	**4**
λ, $\frac{\text{kcal}}{\text{m} \cdot \text{h} \cdot \text{grad}}$	**1,400**	**0,130**	**0,060**	**1,400**

The scheme of the arrangement of layers in a multilayer wall panel in relation to the interior and the environment is shown in Fig. 1.

Fig. 2 shows a graph of the temperature of a four-layer wall panel each layer depending on time, taking into account changes in ambient air temperature.

The non-stationary calculation of the temperature field in a four-layer flat wall, illustrated by the lines in Fig. 2, was obtained using the methodology that described in [3].

Analysis of the graph in Fig. 2 shows that lines 3-4 and 4 have a noticeable effect of decreasing ambient temperature (the lines have a clearly expressed temperature minimum). Lines 1-2 and 2-3 almost do not contain such minima, which indicates sufficient thermal insulation properties of layer 3 – mineral wool plate. The line 1, which models the temperature on the inner surface of a residential building, has an almost rectilinear shape and proves that comfortable temperature conditions inside the building by this model of the arrangement of layers in the wall panel are ensured.

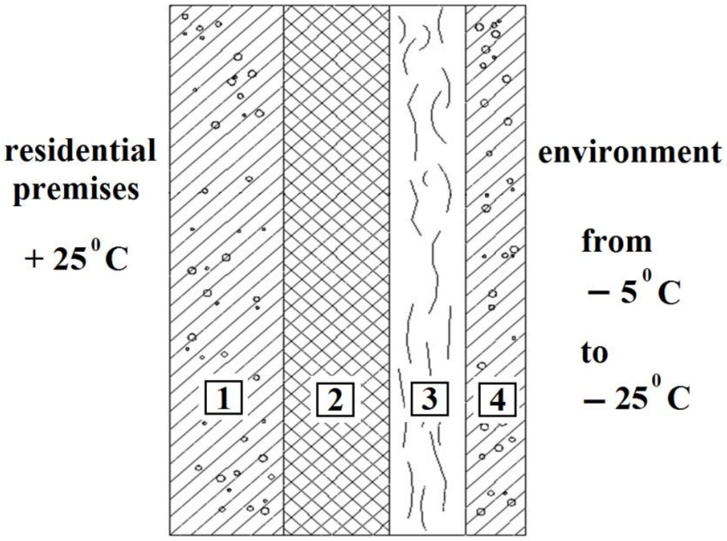

Figure 1 - Scheme of a multilayer external wall panel:
1 – concrete inner textured layer; 2 – cement fibrolite;
3 – mineral wool plate; 4 – concrete outer textured layer

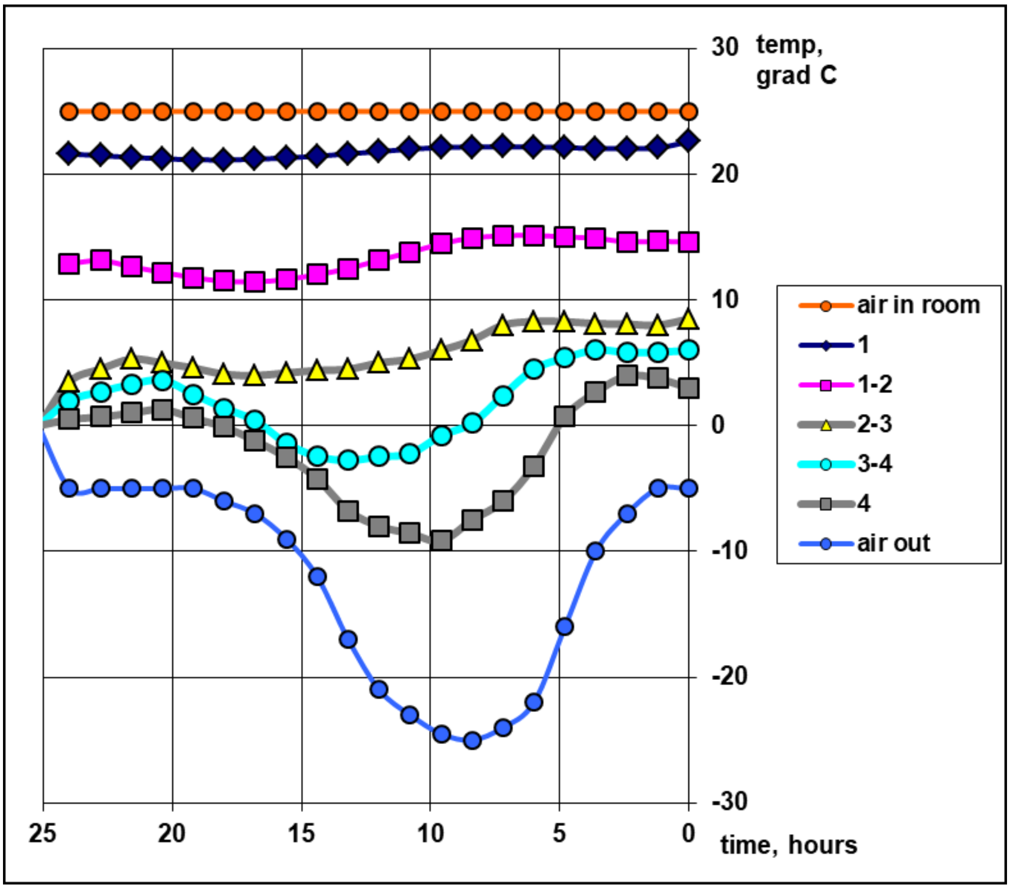

Figure 2 - Distribution of the temperature field along the thickness
of a four-layer external wall panel depending on the ambient air temperature:
air in room – indoor air; 1 – the inner surface of a wall indoors;
1-2, 2-3, 3-4 – contact surfaces of layers 1 and 2, 2 and 3, 3 and 4
respectively; 4 – outer surface of the outer layer; air out – ambient air

ISSN 1562-9945 (Print)
ISSN 2707-7977 (Online)

Analysis of calculations shows that the effect of low ambient air temperature on the temperature inside the room when it passes through a multilayer enclosing building structure can be reduced by one or both of two methods:

– firstly, by increasing the thickness of the thermal insulation layer;

– secondly, by choosing a thermal insulation material with the lowest possible thermal conductivity coefficient.

The presented results were tested at the 20th and 21st International Conferences "Man and Space" [1-2].

Conclusions. In the course of the task, the following types of work were carried out and the following conclusions were obtained:

1) the problem of heat saving and the need to use thermal insulation coatings are considered;

2) the methodology and basic principles of conducting non-stationary thermal calculations of a multilayer flat wall were studied;

3) non-stationary calculations of temperatures through a four-layer flat wall taking into account the daily change in ambient temperature in the winter period were carried out;

4) a graph of the temperature through thickness of the multilayer wall depending on time has been constructed, which allows determining the geometric parameters of each layer of the multilayer external flat wall of a residential building and optimally selecting the type of thermal insulation material;

5) ways to reduce the impact of daily fluctuations in air temperature in winter on indoor temperature are proposed.

LITERATURE

1. Кравець О.В. Тепловий захист поверхонь в нестаціонарних умовах / О.В. Кравець, К.В. Махоніна. – XXI Міжнародна наук.-практ. конф. „Людина і космос”. – Дніпро. – 10-12 квітня 2019. – С. 32.

2. Кравець О.В. Тепловий розрахунок багатошарової стінової панелі / О.В. Кравець, К.В. Махоніна. – XX Міжнародна наук.-практ. конф. „Людина і космос”. – Дніпро. – 11-13 квітня 2018. – С. 35.

3. Фокин К.Ф. Строительная теплотехника ограждающих частей зданий / К.Ф. Фокин. – М.: Стройиздат, 1973. – 287 с.

4. Шовкалюк М.М. Аналіз тепловтрат через огородження з урахуванням різних методів оцінки теплозахисних властивостей / М.М. Шовкалюк, С.В. Зіменко // Енергетика: економіка, технології, екологія. – 2017. – № 4. – С. 73-82; ISSN 2308-7382 (Online)

5. Brunetkin O. A Simplified Method for the Numerical Calculation of Nonstationary Heat Transfer Through a Flat Wall / O. Brunetkin, M. Maksymov, O. Lysiuk // Eastern-European Journal of Enterprise Technologies. – N. 2/5 (86). – 2017. – P. 4-13; DOI: 10.15587/1729-4061.2017.96090.

6. Charvátová H. Mathematical Model of Non-stationary Heat Conduction in the Wall: Asymmetric Problem with the Boundary Conditions of Imperfect Heat Transfer / H. Charvátová, M. Zálešák // Journal MATEC Web of Conferences. – N. 76. – 2016. – P. 89-94; DOI: 10.1051/matecconf/2016760 2016 6.

7. Košir M. Non-stationary thermal performance evaluation of external façade walls under central European summer conditions / M. Košir, L. Pajek, B. Hudobivnik, M. Dovjak, N. Iglič, D. Božiček, R. Kunič // Journal of Solar World Congress. – N. 11. – 2017. – P. 11-22; DOI: 10.18086/swc.2017.15.03.

REFERENCES

1. Kravets O.V. Teplovyy zakhyst poverkhon′ v nestatsionarnykh umovakh / O.V. Kravets, K.V. Makhonina. – XXI Mizhnarodna nayk.-prakt. konf. „Ludina i kosmos” – Dnipro. – 10-12 kvitnya 2019. – P. 32.
2. Kravets O.V. Teplovyy rozrakhunok bahatosharovoyi stinovoyi paneli / O.V. Kravets, K.V. Makhonina. – XX Mizhnarodna nayk.-prakt. konf. „Ludina i kosmos” – Dnipro. – 11-13 kvitnya 2018. – P. 35.
3. Fokin K.F. Stroitelnaya teplotekhnika ograzhdauschikh chastey zdaniy / K.F. Fokin. – M.: Stroyizdat, 1973. – 287 p.
4. Shovkalyuk M.M. Analiz teplovtrat cherez ohorodzhennya z urakhuvannyam riznykh metodiv otsinky teplozakhysnykh vlastyvostey / M.M. Shovkalyuk, S.V. Zimenko // Enerhetyka: ekonomika, tekhnolohiyi, ekolohiya. – 2017. – N 4. – P. 73-82; ISSN 2308-7382 (Online)
5. Brunetkin O. A Simplified Method for the Numerical Calculation of Nonstationary Heat Transfer Through a Flat Wall / O. Brunetkin, M. Maksymov, O. Lysiuk // Eastern-European Journal of Enterprise Technologies. – N. 2/5 (86). – 2017. – P. 4-13; DOI: 10.15587/1729-4061.2017.96090.
6. Charvátová H. Mathematical Model of Non-stationary Heat Conduction in the Wall: Asymmetric Problem with the Boundary Conditions of Imperfect Heat Transfer / H. Charvátová, M. Zálešák // Journal MATEC Web of Conferences. – N. 76. – 2016. – P. 89-94; DOI: 10.1051/matecconf/2016760 2016 6.
7. Košir M. Non-stationary thermal performance evaluation of external façade walls under central European summer conditions / M. Košir, L. Pajek, B. Hudobivnik, M. Dovjak, N. Iglič, D. Božiček, R. Kunič // Journal of Solar World Congress. – N. 11. – 2017. – P. 11-22; DOI: 10.18086/swc.2017.15.03.

Received 06.01.2026.
Accepted 13.01.2026.

Дослідження нестаціонарного поля температури за товщиною багатошарової зовнішньої стінової панелі житлового будинку в зимовий період

На сучасному етапі розвитку енергетики, в умовах енергетичної кризи на перший план виходить розробка та впровадження енергозберігаючих технологій, які зменшують споживання енергоносіїв, знижуючи, тим самим, шкідливі викиди в атмосферу. Одним зі шляхів втілення в життя цього напрямку є теплозбереження – комплекс заходів, спрямованих на зменшення втрат тепла з приміщень, що веде до зниження витрат на опалення та підвищує комфорт. Теплова реакція огороджувальних конструкцій будівлі має суттєвий вплив на формування загальних умов комфорту в приміщенні, а також на енергетичну ефективність будівель. Особливо актуальним стає питання при великому перепаді температур повітря всередині приміщення та в навколишньому

ISSN 1562-9945 (Print)
ISSN 2707-7977 (Online)

середовищі зовні, тобто в зимовий період. Одним зі шляхів розв'язання цієї проблеми стає вибір матеріалів та геометричних параметрів прошарків багатошарових огороджувальних стінових панелей приміщень. Робота присвячена дослідженню нестаціонарному розподілу поля температури за товщиною чотиришарової зовнішньої огороджувальної стінової панелі житлового будинку в зимовий період при добовому коливанні температури навколишнього повітря від -5^0C до -25^0C. В якості матеріалів шарів стінової панелі досліджено: бетонний внутрішній фактурний шар, фіброліт цементний, мінераловатна плита, а також бетонний зовнішній фактурний шар. Метою роботи є визначення впливу добового коливання температури повітря зовнішнього середовища на розподіл температур шарів чотиришарової стінової панелі. В процесі виконання поставленої задачі було проведено нестаціонарні розрахунки температур крізь чотиришарову плоску стінку з урахуванням добової зміни температури навколишнього середовища у зимовий період; побудовано графік залежності температури за товщиною багатошарової стінки від часу, що дозволяє визначити геометричні параметри кожного шару багатошарової зовнішньої плоскої стінки житлового будинку та оптимально підібрати різновид теплоізоляційного матеріалу; запропоновано шляхи зменшення впливу добового коливання температури повітря навколишнього середовища в зимовий період на температуру всередині приміщення при проходженні його крізь багатошарову огороджувальну будівельну конструкцію.

Кравець Олена Володимирівна – к.ф.-м.н., доцент, доцент кафедри аерогідромеханіки та енергомасопереносу, Дніпровський національний університет ім. Олеся Гончара.
ORCID: https://orcid.org/0000-0002-3428-2232
Махоніна Карина Володимирівна – магістр, кафедра аерогідромеханіки та енергомасопереносу, Дніпровський національний університет імені Олеся Гончара.
ORCID: https://orcid.org/0009-0003-8666-9556

Kravets Olena Volodymyrivna – candidate of physical and mathematical sciences, docent, docent of the Department of AeroHydro Mechanics and Energy and Mass Transfer, Oles Honchar Dnipro National University.
ORCID: https://orcid.org/0000-0002-3428-2232
Makhonina Karina Volodymyrivna – master, Department of AeroHydro Mechanics and Energy and Mass Transfer, Oles Honchar Dnipro National University.
ORCID: https://orcid.org/0009-0003-8666-9556