

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

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**INFLUENCE OF ACTIVE HEAT CAPACITY ON
MICROCLIMATE AND ENERGY DEMAND OF
A BUILDING**

Summary of Doctoral Dissertation
Technological Sciences, Energetics and Thermal Engineering
(06T)

Doctoral dissertation was prepared at Vilnius Gediminas Technical University in 2000–2006 year.

The dissertation is defended as an external work.

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The summary of the doctoral dissertation was distributed on 15 February 2007.

A copy of the doctoral dissertation is available for review at the Library of Vilnius Gediminas Technical University (Saulėtekio al. 14, Vilnius, Lithuania).

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**PASTATO AKTYVIOSIOS ŠILUMINĖS TALPOS
ĮTAKA PATALPŲ MIKROKLIMATUI BEI
ENERGIJOS POREIKIAMS**

Daktaro disertacijos santrauka
Technologijos mokslai, energetika ir termoinžinerija (06T)

Vilnius  LEIDYKLA
TECHNIKA 2007

Disertacija rengta 2000–2006 metais Vilniaus Gedimino technikos universitete.
Disertacija ginama eksternu.

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Disertacija bus ginama viešame Energetikos ir termoinžinerijos mokslo krypties tarybos posėdyje 2007 m. kovo 16 d. 13 val. Vilniaus Gedimino technikos universiteto senato posėdžių salėje.

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Disertacijos santrauka išsiuntinėta 2007 m. vasario 15 d.

Disertaciją galima peržiūrėti Vilniaus Gedimino technikos universiteto bibliotekoje (Saulėtekio al. 14, Vilnius, Lietuva).

VG TU leidyklos „Technika“ 1357 mokslo literatūros knyga.

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General Characteristic of the Dissertation

Topicality of the problem

Heat transfer processes in buildings are always unsteady at real conditions. On the other hand practical calculations of heat exchange processes in buildings are based on steady-state process equations. In spite of modern microclimate system management, according to practical observations and theoretical investigations, undesirable changes of indoor heat behaviour occur. Such changes have negative influence on indoor heat comfort and misrepresent real energy demands of a building.

Usually, especially during the period of building exploitation, unreasonably installed heat power is noticed. Unevaluated heat inflows cause too big heating power and overheating of a building and, contrarily, intermittent heating arises from too low installed power and is the consequence of too long preheating time. That is why, wrong building maintenance is observed, that is, indoor climate does not satisfy hygiene requirements. Usually, energy saving is performed at the expense of human health.

The problem is influenced by factors, which have impact on thermal mode of a building. Solving of this problem involves identification and quantitative analysis of these factors. This might be useful in predicting and minimising negative influence of these factors on building microclimate and energy use.

The main factors, which alteration disturbs steady-state thermal behaviour of a building, can be divided into two general groups:

Outdoor (uncontrolled) – external air temperature, wind speed and solar radiation.

Indoor (controllable) – heating power of a building and internal heat gains.

The first group of factors mainly depends on geographical situation and climate conditions. Exact change and influence prediction of these factors is difficult enough. Investigations can be made only on the basis of previous air temperature records, wind speed and solar radiation intensity data.

It is noticed that namely factors of the first group are considered to be more important to unsteady building thermal behaviour and were investigated by many authors. Nevertheless, results of practical and theoretical investigations show that unsteady heat transfer processes are mainly caused by indoor factors: change of heating power and heat inflows. Influence of outdoor factors – wind and sun – can usually be solved by architectural means. In modern buildings with higher consumption of electricity and intermittent heating, influence of indoor factors influence on thermal behaviour of a building comes out during the comparatively short period of time.

Object of the research

Estimation of temperature and heat power (heat flow) change interaction's influence on unsteady thermal regime of a building is the object of the research (Fig. 1).

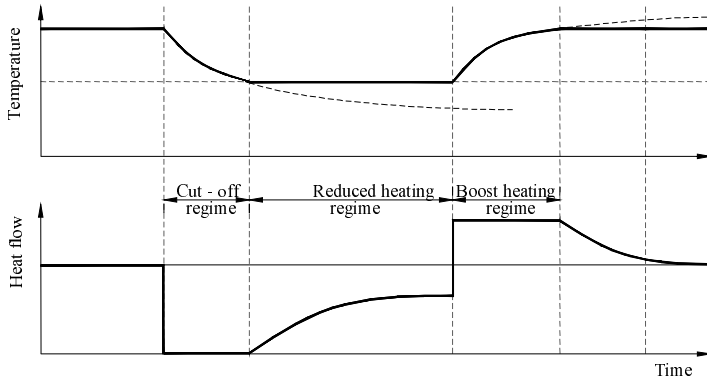


Fig 1. Unsteady heat regime of a building

The aim and tasks of the work

The main aim of the work is to investigate unsteady indoor thermal factors' influence on premises microclimate, energy demand and installed heat power.

Tasks of the work:

1. To investigate evaluation methods of thermal characteristics of a building which have influence on unsteady heat transfer, and to point out the main and determining factors.
2. To investigate dynamic thermal characteristics of a building in an experimental way.
3. To describe unsteady heat transfer processes in buildings on the basis of energy conservation law for a control volume with the help of active heat capacity conception and to adapt calculation methods for practical use.
4. To estimate the influence of active heat capacity on premises microclimate, design heat power and energy use.

Methodology of the research

The method is based on building's temperature evolution calculation when it falls below its normal set-point. This evolution is calculated with the use of the model of a building with three nodes representing internal and external

environment and building structure. The internal thermal inertia of a building is represented by capacitance which temperature is the structure temperature. Heat exchanges between the structure and external environment, between the structure and internal environment and directly between the internal and external environments are taken into account separately.

While extending the thermal scheme and combining it with conservation of energy law for a control volume we can define the scheme of thermal energy balance for a building (Fig. 2).

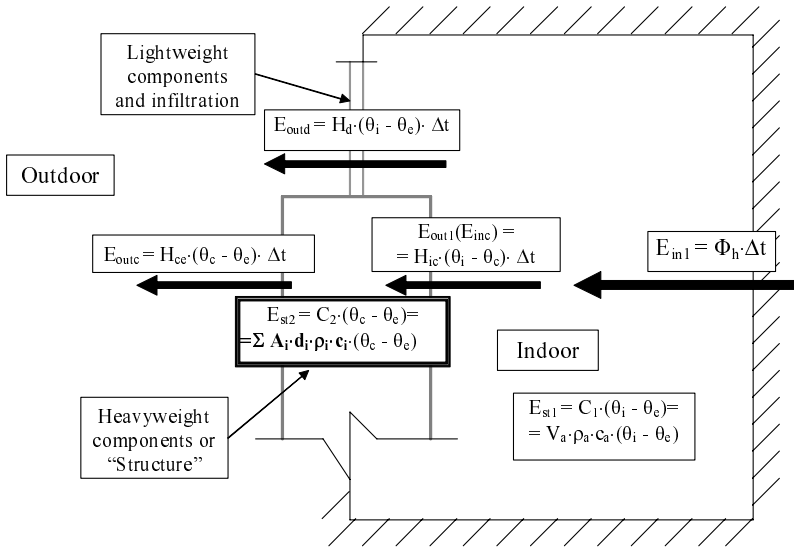


Fig 2. Thermal energy balance scheme for a building

Novelty of the dissertation

Unsteady thermal factors' influence on multi-layer wall and premise heat regime was investigated in an experimental way.

The problem of finding the solution for unsteady heat transfer was defined on the basis of energy conservation law for a control volume by using active heat capacity conception and taking active thickness of a building component as a constant.

The way of unsteady heat transfer problem solution together with finite difference method was applied for practical estimation of indoor thermal factors' influence on premises microclimate and energy demand.

Practical value of the work

Quantitative estimation of indoor thermal factors' influence on premises microclimate and energy demand allows to choose the most effective way of microclimate systems control and to estimate the exact energy use during the chosen period of time. This kind of analysis lets improving thermal microclimate of a building and saving energy resources.

Approval of dissertation's results

12 scientific publications and conference materials were published on the basis of the work. The main statements of the work were presented and discussed at international and national conferences in Lithuania, Russia and Spain.

The scope of the scientific work

This scientific work consists of the general characteristic, 4 chapters, conclusions, the list of literature and the list of publications. The dissertation takes 95 pages and contains 38 pictures and 4 tables.

1. Theoretical Aspects

Known methods of unsteady heat transfer calculations in buildings are mostly inflexible and hardly applicable for engineering analysis. The need of new ways of unsteady thermal processes in buildings still exists.

The solution of unsteady heat transfer problems can be made on the basis of thermodynamic laws, especially conservation of energy law for a control volume.

The subject of thermodynamics and heat transfer is highly complementary. The subject of heat transfer may be viewed as an extension of thermodynamics, because it treats the rate at which heat is transferred. Conversely, for many heat transfer problems, the first law of thermodynamics (the law of conservation of energy) provides a useful, often essential, tool.

Energy balance scheme for a building (Fig 2) consists of two thermodynamic related systems with inflow outflow and stored thermal energies.

Exploring Fig. 2 expression of inflow energy to indoor air:

$$E_{inl} = \Phi_h \cdot \Delta t, \quad (1)$$

where Δt – time step (s) and Φ_h – heating power or other energy source (W).

Outflow energy from indoor air and inflow energy to structure:

$$E_{out1} = E_{inc} = H_{ic} \cdot (\theta_i - \theta_c) \cdot \Delta t . \quad (2)$$

Outflow direct (through lightweight structures and infiltration) energy from indoor air to exterior:

$$E_{outd} = H_d \cdot (\theta_i - \theta_e) \cdot \Delta t . \quad (3)$$

Outflow energy from structure to exterior:

$$E_{outc} = H_{ce} \cdot (\theta_c - \theta_e) \cdot \Delta t . \quad (4)$$

Where, θ_e , θ_c , θ_i , – respectively, external air, structure and internal air temperatures ($^{\circ}\text{C}$); H_{ce} , H_{ic} , H_d – respectively, heat loss coefficient (W/K) between the structure and the external environment, heat loss coefficient between the structure and the heated space and direct heat loss coefficient, which is $H_d = H_w + H_v$. H_w – sum of all heat loss coefficients of windows and doors, H_v – the ventilation heat loss coefficient.

Indoor air stored energy:

$$E_{st1} = C_1 \cdot (\theta_i - \theta_e) . \quad (5)$$

Structure stored energy:

$$E_{st2} = C_2 \cdot (\theta_c - \theta_e) . \quad (6)$$

Heat capacity of internal air:

$$C_1 = V_a \cdot \rho_a \cdot c_a . \quad (7)$$

Active heat capacity of the structure:

$$C_2 = \sum_{i=1}^n A_i \cdot d_i \cdot \rho_i \cdot c_i , \quad (8)$$

where, $\theta_e = \text{const.}$; d_i – effective thickness of the structure (heavy weight construction); A_i , ρ_i , c_i , – respectively, area, density and specific heat capacity of the structure.

Energy balance for both systems is defined as follows:

$$E_{m1} - E_{out1} - E_{outd} = \Delta E_{st1}, \quad (9)$$

$$E_{inc} - E_{outc} = \Delta E_{st2}. \quad (10)$$

Change of stored energy ΔE_{st1} and ΔE_{st2} equals zero under steady-state conditions.

On the basis of 9 and 10 Eq, we can explore temperature change after time step Δt for unsteady conditions:

Indoor air temperature after time step Δt :

$$\theta_i(\Delta t) = \frac{E_{st1} + \Delta E_{st1}}{C_1} + \theta_e = \theta_i + \frac{[\Phi - H_{ic} \cdot (\theta_i - \theta_e) - H_d \cdot (\theta_i - \theta_e)] \cdot \Delta t}{C_1}. \quad (11)$$

Structure temperature expression after the change of indoor temperature and the same time step Δt :

$$\theta_c(\Delta t) = \frac{E_{st2} + \Delta E_{st2}}{C_2} + \theta_e = \theta_c + \frac{[H_{ic} \cdot (\theta_i - \theta_e) - H_{ce} \cdot (\theta_c - \theta_e)] \cdot \Delta t}{C_2}. \quad (12)$$

Eq 11, 12 allow to investigate exact temperatures change of unsteady process at any time period.

2. Active Heat Capacity and Thickness of a Building Components

The term *active heat capacity* (in EN ISO “effective heat capacity”) is actually a quantification that corresponds to the part of the total heat capacity of a building component that participates in dynamic heat exchange between the component and the environment:

$$C_2 = \Sigma \chi_j A_j = \Sigma_j \Sigma_i \rho_{ij} c_{ij} d_{ij} A_j. \quad (13)$$

Where active thickness of a building component:

$$\Sigma_i d_{ij} = d_{active}. \quad (14)$$

And it is the function of:

$$d_{active} = f(T, c, \rho, \lambda), \quad (15)$$

where T is time period of the unsteady thermal process, which is not well-defined or/and arbitrary. The theoretical investigation results of the interplay of an active thickness of various building components and time period of the unsteady thermal process is presented in Fig 3.

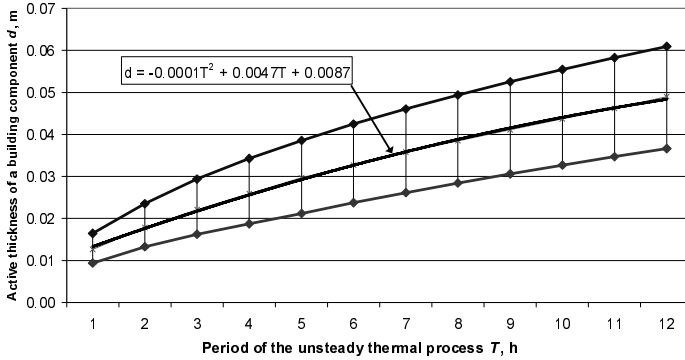


Fig 3. Interplay of active thickness of a building component and time period of unsteady thermal process

Theoretical analysis shows that active (or violent temperature oscillations) thickness can vary from 0.5 to 12 centimetres according to arbitrary time period of unsteady thermal process, or/and can be estimated by streamlined expression introduced in Fig. 3.

3. Experimental Investigation of Unsteady Heat Transfer Process in a One-cell Building

The experimental investigation was carried out at the Solar energy investigation centre *Platforma Solar De Almeria* (PSA) in Spain. This project was made under the financial support of EU-DGXII “Improving Human Potential” programme.

The aim of the experiment was to investigate unsteady heat transfer process in a one-cell building under natural conditions. Preparation and the main part of the experiment were carried out during the stay in PSA for more than a one-month period of time.

The paper presents methods and results of one-dimensional unsteady heat process experimental investigation in a one-cell building under the impact of solar radiation on one surface and unequal boundary conditions.

The obtained experimental data may be put into practice and can be useful

in developing unstable heat transfer theory in multi-layers using various methods of analysis.

3.1. Equipment and methods of the investigation

The LECE (Laboratorio de ensayos Energéticos para Componentes de Edificación), located on the south side of the PSA, forms the part of European PASLINK laboratories' network for energy testing of buildings' components. It consists of four test cells with complete instrumentation for testing thermal performance of building conventional and passive components under real outdoor conditions (Fig. 4).

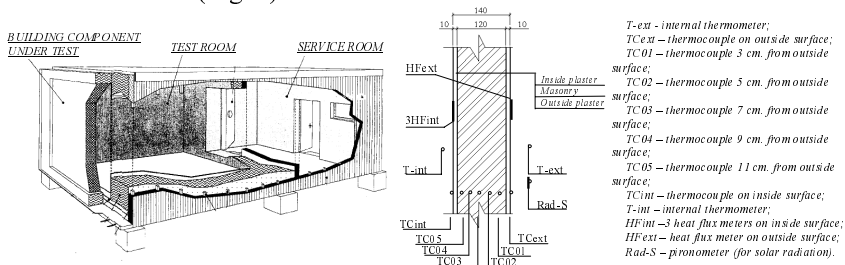


Fig 4. Scheme of a test room and a test component section with installed measuring equipment

A test cell of approximately the same size as a standard room was used in the experiment. The opposite wall to the service room is interchangeable with the test specimen. A test component was a multi-layer wall (Fig. 4) of three different layers, i.e. 2 cm of plaster from the outside, 12 cm of brick wall and 2 cm of plaster from the inside.

Thermocouples were installed in separate layers of the wall. Two thermo-resistant thermometers were installed to meter inside and outside air temperature. A pyrometer was installed on the outside surface to meter the total solar radiation. Heat flux meters were installed to investigate the heat flow – 1 on the outside surface and 3 on the inside surface.

All equipment was connected to a computer. The computer was fixing the test data each 10 minutes.

Orientation of the test's component was to the south, and the experiment was carried out in May of 2003.

3.2. Results of the investigation

Experimental data including the inside and outside air temperatures, temperatures of different layers of the testing wall, solar radiation and heat flow

densities through the boundary densities was being collected for a period of longer than a month. The characteristic data of temperature distribution for three days is presented (fig. 5).

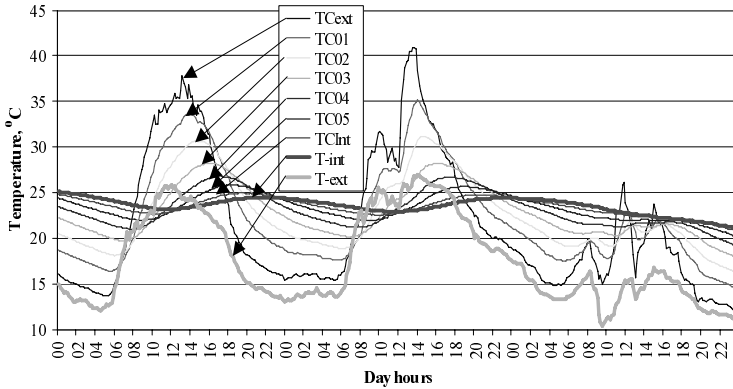


Fig 5. Temperature distribution

The outside air temperature maximum – 27–28 °C appears at about 1 o'clock PM at midday, and minimum – 13–14 °C at 2–4 o'clock AM at night. The third day sticks out because of temperature fluctuation at the bright period of day. The external surface temperature change is parallel to the outside air.

During the sunny days (1st and 2nd day) temperature curves even moves from external surface to internal. “Temperature wave’s” – temperature curves’ movement – time from external surface to internal is about 7 h, and from outside air to inside air – near 12 h.

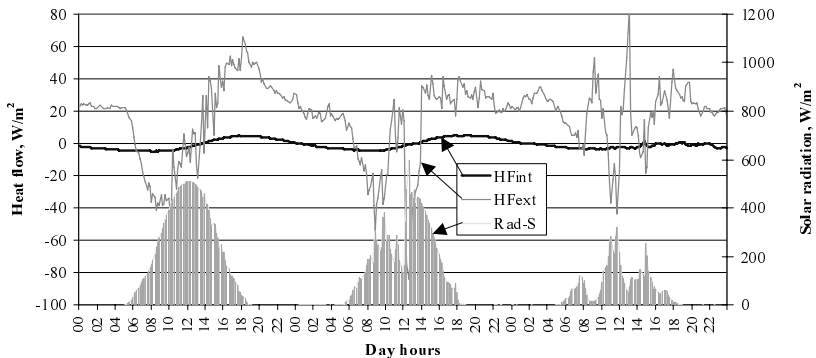


Fig 6. Heat flow densities and solar radiation

Here, “Rad-S” is solar radiation’s reading by the pyronometer, “HFext” and “HFint” are the heat flow densities’ readings by the flux meters that were installed on the external surface.

The first day sticks out because of no parallel between solar radiation intensity and external surface heat flow density change. High speed of wind at the time of experiment data measurement can be the result of such phenomenon.

3.3. Comparison of data results and theoretical calculations

The theoretical calculations were carried out using the method presented in Chapter 1.

Inside air temperature is calculated by the Eq 11.

$$\theta_{l-calculated}(\Delta t) = \frac{E_{stl} + \Delta E_{stl}}{C_l} + \theta_e = \frac{C_l \cdot (\theta_i - \theta_e) + HF_{int} \cdot A \cdot \Delta t}{C_l} + \theta_e, \quad (16)$$

where $\theta_e = T_{ext}$ (measured), $\theta_i = T_{int}$ (measured at the start point) (°C); HF_{int} – measured heat flow density on the inside surface (W/m²); $A = 8.1 \text{ m}^2$ – area of inside surface; $C_l = V \cdot \rho \cdot c$ (J/K) – heat capacity of internal air (J/K), here $V = 44 \text{ m}^3$ – inside room (inside air) volume, $\rho = 1.15 \text{ kg/m}^3$ – air density and $c = 1 \text{ kJ/kg} \cdot \text{K}$ – air specific heat; $C_l = 50420 \text{ J/K}$. Time step Δt equal to data fixing step 10 min (600 s).

Original analysis, i.e. without any assumptions, has shown a big discrepancy between experimental and calculation results.

If we make an assumption that the method of analysis and the primary data are correct, as well as air density and specific heat dependence on temperature change is insignificant, the main reason of discrepancy can be influenced by two (three) dimensional temperature and heat flow fields in the test component, i.e. wall. The assumption is that the measured heat flow density, measured in the central part of the wall, is not the same as on the whole surface area and it is likely that the most intensive heat flow appears exactly on the measured part.

Keeping to this point of view, the measured heat flow density HF_{int} cannot be attributed to whole surface area A of the wall. Additional calculations using a new value called “conditional heat exchange area” A^* (m²) were carried out.

Results of “conditional heat exchange area” A^* analysis are presented below (Fig. 7).

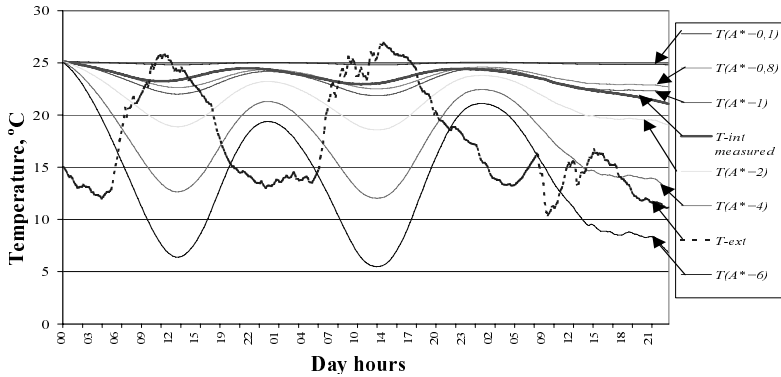


Fig 7. Comparison of the experimental results and theoretical calculations using the “conditional heat exchange area” A^*

The analysis results show that the “conditional heat exchange area” A^* is much less than real inside surface area A of the investigated wall. It means that an assumption of a more intensive heat flow density on the investigated (central) part of test component was made correctly.

The best correlation of the analysis results is evident when the “conditional heat exchange area” A^* is near 1 m^2 .

Also the lag of calculated inside air temperature curve behind the measured temperature curve appears. The most important cause of the curves’ lag would be the influence of inside room boundaries’ admittance. For further experimental investigations of this kind of processes the temperature of all inside surfaces must be taken into account. Another factor of the lag can be air density and specific heat dependence on temperature change. In order to get the most exact results’ correlation functional dependence of above mentioned values must be taken into account.

4. Investigation of an Unsteady Thermal Regime of the Building

A real building was chosen for practical calculation. Heated area of the building was 9144 m^2 , heated volume was 30176 m^3 , design indoor temperature was $+20^\circ\text{C}$, design average outdoor temperature of heating period was -0.7°C lowered heating period was 10 hours, heat loss coefficient of the building was $H = 9395 \text{ W/K}$, heat loss per heated area of the building was 44 W/m^2 , lowered heating period was 10 hours per day.

Necessary for the investigation data was calculated according to national regulations and energy audit results.

The results of building intermittent heating investigation with 3 °C lowered heating for 10 hours period are presented in Fig. 8. It is evident, that the same heating power re-creation after lowered heating period is insufficient to reach design indoor temperature. Anytime, after lowered heating period boost heating phase – heightened heating period – it is necessary to re-create design indoor temperature.

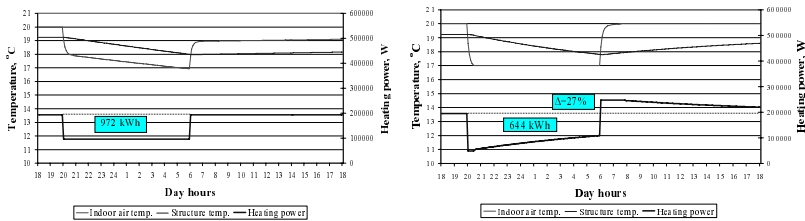


Fig 8. Investigation results of unsteady thermal regime of a building

Boost heating phase is the heating-up capacity of heated space and requires compensation effects of intermittent heating in a heated space. It could be estimated by using the re-heat factor which varies from 2 to 45 W/m², depending on the type of building, building construction, re-heat time and assumed drop of internal temperature during setback. Fig. 9 represents additional heating-up capacity (additional heat power) needs for compensation effects of intermittent heating according to comparative heat losses of a building.

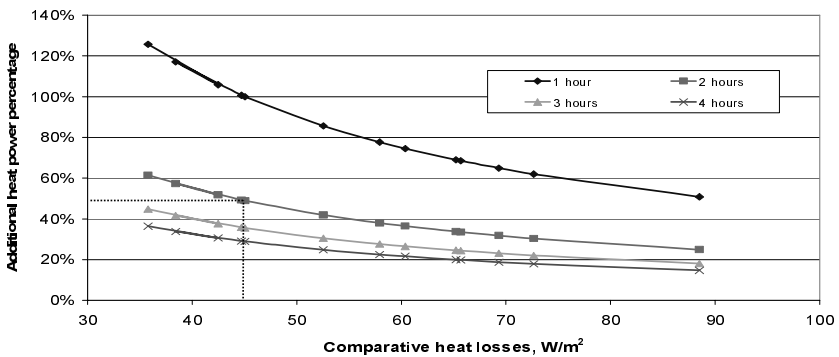


Fig 9. Additional heat power percentage for temperature change 3 °C

The heating power increase on behalf of intermittent heating effect is ranging from 18 % to 125 % according to temperature drop and re-heating period of time for particular buildings.

General Conclusions and Proposals

1. Detailed analysis of intermittent heating use possibility and other unsteady thermal factors' influence must be performed for a new design and existing buildings, especially connected to city heat network. The problem of finding the solution for unsteady heat transfer can be referred to the basis of energy conservation law for a control volume by using active heat capacity conception and taking active thickness of a building component as a constant, as presented in this work. These practical results are obtainable by using the finite difference method and choosing the appropriate time step.

2. The boost heating period is always required for intermittent heating use to achieve the design indoor temperature during the fixed period of time without influence of internal heat gains. The heating power increase on behalf of intermittent heating effect is ranging from 18 % to 125 % according to temperature drop and re-heating time period for particular buildings. Heating-up capacity on behalf of intermittent heating influence must be optimally chosen according to possible savings and investments.

3. The major part of building's thermal energy which is acting in dynamic heat exchange is accumulated in high weight building envelopes. Therefore the master's task is the estimation of stored (accumulated) thermal energy here. The main figure is thickness of massive structure where unsteady thermal processes appear and influence building microclimate and energy demands. Theoretical analysis shows that – active (or violent temperature oscillations) – thickness can vary from 0.5 to 12 centimetres according to arbitrary time period of unsteady thermal process.

4. The results of experimental investigation, which was carried out at natural conditions, show the display of violent temperature oscillations thickness till 7.5 centimetres, and unsteady thermal process of 12 hours on the average. A period of 12 hours for arbitrary unsteady thermal process and 5 centimetres of active thickness are recommended to use as a practical unsteady heat transfer problems' solution. Active thickness of the component can be estimated by a streamlined expression introduced in this work if another period of time for unsteady thermal process is chosen.

List of Published Works on the Topic of the Dissertation

In the reviewed scientific periodical publications

1. VALANČIUS, K.; SKRINSKA A. K.; PAULAUSKAITĖ S. Investigation of Unsteady Heat Transfer Process in an One-cell Building. *Journal of Civil Engineering and Management*, Vol XII, No 1, 2006, p. 97–101. ISSN 1392-3730
2. VALANČIUS, K.; PAULAUSKAITĖ S.; SKRINSKA A. Heat Transfer Processes in the Multilayer Wall of the Building under the Influence of Solar Radiation. *Energetika*, Nr. 3, 2002, p. 30–34 (in Lithuanian). ISSN 0235-7208

In other editions

3. PAULAUSKAITE, S.; VALANCIUS, K. Aspects of the Analysis of an Unsteady Heat Transfer Processes in the Building. In *Proceedings of the International Conference “Theoretical Backgrounds of Heat and Gas Supply and Ventilation Systems”* (Теоретические основы теплогазоснабжения и вентиляции). MGSU, Moscow, 2005, p. 57–60 (in Russian). ISBN 5-7264-0361-4
4. VALANCIUS, K.; PAULAUSKAITE, S. Energy Conservation Law Appliance for Intermittent Heating Analysis. In *Proceedings of the 6th International Conference “Energy for buildings”*. Vilnius: Technika, 2004, p. 540–547. ISBN 9986-05-771-X (ISI Proceedings).
5. PARFENTJEVA, N.; SAMARIN, O.; PAULAUSKAITE, S.; VALANCIUS, K. Temperature Field Design of Exterior Walls with Flexible Braces. In *Proceedings of the 6th International Conference “Energy for buildings”*. Vilnius: Technika, 2004, p. 479–486. ISBN 9986-05-771-X (ISI Proceedings).
6. VALANČIUS, K.; SKRINSKA, A. An Intermittent Heating Influence to the Building Reheating Time and Design Heat Load. In *Proceedings of the 4th International Baltic Heat Transfer Conference “Advances in Heat Transfer Engineering”*. Begel House, Inc. New York, 2003, p. 277–282. ISBN 1-56700-198-1
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About the author

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Many thanks to Assoc. Prof. Dr Sabina Paulauskaitė for the support and help.

PASTATO AKTYVIOSIOS ŠILUMINĖS TALPOS ĮTAKA PATALPŲ MIKROKLIMATUI BEI ENERGIJOS POREIKIAMS

Darbo aktualumas

Realiomis sąlygomis šilumos mainų procesai pastatuose visada yra nestacionarūs. Tuo tarpu praktiniams šilumos perdavimo procesų pastatuose skaičiavimams dažniausiai naudojamos metodikos remiasi stacionarių procesų lygtimis. Dėl to, kaip rodo praktiniai stebėjimai ir teoriniai tyrimai, nors ir esant pažangiam šiuo metu mikroklimato sistemų (MKS) valdymui, dažnai stebimi nepageidaujami patalpų šiluminio režimo pokyčiai, kurie neigiamai veikia patalpų šiluminį komfortą, iškreipia realius pastato energijos poreikius.

Neįvertinus pastato nestacionaraus šiluminio režimo neįmanoma palaikyti pastovias šiluminio komforto sąlygas ir efektyviai jame vartoti energiją. Dažnai, ypač pastato eksploatavimo metu, pastebima ir neracionaliai instaliuota šiluminė galia, t. y. neįvertinus šilumos pritekėjimų kartais ji esti pernelyg didelė, kita vertus, taikant protarpinį šildymą ji nepakankama norimam patalpų prišildymui. Dėl šių priežasčių dažnai pasitaiko atvejų, kai pastatai yra neracionaliai eksploatuojami, patalpų mikroklimato sąlygos neatitinka higienos reikalavimų, o energijos taupymas kartais vykdomas žmonių sveikatos sąskaita.

Problemą lemia veiksniai, įtakojantys nestacionarų pastato šiluminį režimą, o jos sprendimas susideda iš šių veiksnių identifikavimo ir kiekybinio įvertinimo. Tai leistų numatyti ir sumažinti nepageidaujamą minėtų veiksnių įtaką pastato šiluminiam komfortui ir energijos sąnaudoms.

Pagrindinius veiksnius, kurių pokytis iškreipia stacionarų šiluminį režimą patalpose, galima skirstyti į dvi pagrindines grupes:

Išoriniai – nevaldomi:

- išorės oro temperatūra
- vėjo greitis
- saulės spinduliuotė

Vidiniai – valdomi (numatomi):

- pastato šiluminė galia
- vidiniai šilumos išsiskyrimai.

Pastebima, kad būtent išorinių veiksnių įtaka kaip svarbiausia pastato nestacionariam šiluminiam režimui yra nagrinėjama daugelio autorių darbuose. Tiek praktika, tiek teoriniai tyrinėjimai rodo, kad didžiąją dalį pastato šiluminio nestacionarumo sudaro būtent vidiniai veiksniai – šiluminės galios ir šilumos išsiskyrimų pokytis. Išorinių – vėjo ir saulės – veiksnių poveikis dažnai yra išsprendžiamas architektūrinių priemonių ar sprendimų pagalba, o išorės oro

temperatūra per kelias ar daugiau paros valandas kinta palyginus nežymiai. Šiuolaikiniuose pastatuose, padidėjus elektros instaliuotai galiai, naudojant periodinį šildymą, vidinių veiksnių poveikis patalpų vidaus šiluminiam mikroklimatui pasireiškia per pakankamai trumpą laiko tarpą ir sudaro didesniąją įtakos dalį.

Darbo tikslas

Pagrindinis darbo tikslas yra išnagrinėti vidinių nestacionarių šiluminių veiksnių įtaką patalpų vidaus mikroklimatui, pastato energijos suvartojimui bei instaliuotai šiluminei galiai.

Darbo uždaviniai

1. Išnagrinėti pastato šiluminių charakteristikų, įtakojančių nestacionarius šilumos mainus, nustatymo metodus, išskiriant pagrindinius ir lemiamus veiksnius.
2. Ištirti pastato dinamines šilumines charakteristikas eksperimentinių tyrimų būdu.
3. Aprašyti nestacionarius šilumos mainus pastatuose remiantis energijos tvermės dėsniu uždaram tūriui ir naudojant aktyviosios šiluminės talpos sąvoką pritaikyti skaičiavimo metodus praktiniam naudojimui.
4. Įvertinti aktyviosios šiluminės talpos įtaką patalpų mikroklimatui, pastato energijos poreikiams bei skaičiuotinai šiluminei galiai.

Darbo mokslinis naujumas

Eksperimentiškai ištirta nestacionarių šilumos veiksnių įtaka daugiasluoksnės atitvaros ir patalpos šiluminiam režimui.

Naudojant aktyviosios šiluminės talpos sąvoką ir pasirenkant aktyvųjų sluoksnio storį kaip nekintamą dydį, nestacionarių šilumos mainų uždavinių sprendimas yra aprašytas, remiantis energijos tvermės dėsniu uždaram tūriui pagrindu.

Baigtinių skirtumų metodo pagalba toks nestacionarių šilumos mainų analizės būdas pritaikytas praktiškai nustatant vidinių šiluminių veiksnių įtaką pastato mikroklimatui ir energijos poreikiams.

Darbo praktinė vertė

Kiekybinis vidinių šiluminių veiksnių įtakos pastato mikroklimatui ir energijos poreikiams įvertinimas leidžia pasirinkti efektyviausią mikroklimato sistemų valdymo būdą bei nustatyti racionalų energijos suvartojimą pasirinktu laiko periodu. Tai leidžia pagerinti šiluminį mikroklimatą patalpose bei taupyti energetinius resursus.

Darbo aprobavimas ir publikavimas

Disertacijos tema paskelbta 12 publikacijų: 2 MII sąrašo leidiniuose (ISI Proceedings), 2 tarptautinėse duomenų bazėse referuotuose žurnaluose, 5 tarptautinių konferencijų leidiniuose kitomis kalbomis ir 3 kituose recenzuojamuose mokslo leidiniuose.

Remiantis darbo rezultatais perskaityta 10 pranešimų: 5 tarptautinėse konferencijose, 3 respublikinėse konferencijose ir 2 tarptautiniuose renginiuose.

Darbo apimtis. Darbą sudaro įvadas, 4 skyriai, išvados, literatūros sąrašas ir autoriaus publikacijų sąrašas. Bendra disertacijos apimtis – 95 puslapiai, 38 iliustracijos ir 4 lentelės.

Įvade aprašoma darbo problematika ir aktualumas, nustatomi darbo tikslai ir uždaviniai, identifikuojamas darbo naujumas ir praktinė vertė

Pirmame disertacijos skyriuje apžvelgiami nestacionaraus šilumos režimo pastate tyrimai, išskiriant pagrindinius ir lemiančius veiksnius.

Antrame disertacijos skyriuje pateikiama aktyviosios pastato šiluminės talpos nustatymo bei panaudojimo būdai.

Trečiajame skyriuje pateikiamas apibendrintas nestacionarių šilumos mainų pastatuose analizės metodas.

Ketvirtajame skyriuje aprašomi dviejų eksperimentinių tyrimų, atliktų Europos Saulės energijos tyrimų centre Ispanijoje, objektai, tikslai, metodai, prietaisai ir rezultatai.

Bendrosios išvados

1. Naujai projektuojamiems ir esamiems pastatams, ypač gaunantiems šilumą iš centralizuotų šilumos tinklų, turi būti atlikta detali protarpinio šildymo naudojimo galimybės bei kitų nestacionarių šiluminių veiksnių įtakos analizė. Nestacionarių šilumos mainų uždavinio sprendimui siūloma naudoti energijos tvermės dėsnį uždaram tūriui, panaudojant aktyviosios šiluminės talpos sąvoką ir priimant aktyvųjų sluoksnio storį kaip nekintamą dydį. Tokiu būdu skaitiniai rezultatai gaunami baigtinių dydžių metodu, pasirenkant atitinkamą laiko žingsnį.

2. Nustatyta, kad naudojant protarpinį šildymą ir, norint pasiekti komfortinę vidaus oro temperatūrą per nustatytą laiko tarpą be vidinių šilumos pritekėjimų įtakos, visada reikalingas padidintos galios šildymo periodas. Šiluminės galios padidėjimas dėl protarpinio šildymo, priklausomai nuo temperatūrų perkryčio ir komfortinės temperatūros „atstatymo“ laiko skirtingiems pastatams, gali kisti nuo 18 % iki 125 %. Todėl skaičiuotinos

šiluminės galios padidėjimas dėl protarpinio šildymo įtakos turi būti optimaliai parenkamas atsižvelgiant į galimus energijos sutaupymus bei investicijų dydį.

3. Didžioji pastato šiluminės energijos, dalyvaujančios dinaminiuose šilumos mainuose, dalis yra sukaupta masyviose išorės atitvarose. Todėl pradinis uždavinys yra įvertinti pastato sukauptos (akumuluotos) šiluminės energijos kiekį šiose konstrukcijose. Pagrindinis, kintamasis šiuo atveju, dydis yra atitvaros (masyvios) storis, kuriame vyksta nestacionarūs šiluminiai procesai, įtakojantys pastato šiluminį mikroklimatą bei energijos poreikius. Teoriniai tyrimai rodo, kad šis – aktyvusis (arba ryškių temperatūrinių svyravimų) – sluoksnio storis, priklausomai nuo pasirinkto skaičiuotino periodo per parą gali svyruoti nuo 0,5 centimetro iki 12 centimetrų.

4. Eksperimentinių tyrimų rezultatai rodo, kad ryškių temperatūrinių svyravimų sluoksnio storis pasireiškia atitvaros sluoksnyje iki 7,5 centimetrų, o nestacionarių šiluminių veiksnių įtakos periodas natūraliomis sąlygomis vidutiniškai trunka apie 12 valandų. Sprendžiant praktinius nestacionarių šilumos mainų uždavinius siūloma aktyvųjų sluoksnio storį pasirinkti 5 centimetrus prie skaičiuotino periodo – 12 valandų. Pasirenkant kitą skaičiuotiną periodą aktyviojo sluoksnio storis gali būti skaičiuojamas pagal supaprastintą išraišką pateikta darbe.

Trumpos žinios apie autorių

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Autorius dėkoja doc. dr. Sabinai Paulauskaitei už palaikymą ir pagalbą rengiant šį darbą.

Kęstutis Valančius

**INFLUENCE OF ACTIVE HEAT CAPACITY ON MICROCLIMATE
AND ENERGY DEMAND OF A BUILDING**

Summary of Doctoral Dissertation

Technological Sciences, Energetics and Thermal Engineering (06T)

Kęstutis Valančius

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PATALPŲ MIKROKLIMATUI BEI ENERGIJOS POREIKIAMS**

Daktaro disertacijos santrauka

Technologijos mokslai, energetika ir termoinžinerija (06T)

2007 02 12. 1,5 apsk. leid. I. Tiražas 100 egz.

Vilniaus Gedimino technikos universiteto

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