heat transfer, technical storages, physical modeling, control process

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ANALYSES OF HEAT TRANSFER THROUGH WALLS OF THERMAL TECHNICAL SPACES WITH COMPUTER HELPING

Abstract

The paper describes research work on methods concerning heat transfers through walls of thermal technical chambers. This paper is focused on the new concept of thermal analysis derived from harmonic character of temperature changes in building environment with aspect on conductive heat transfers through walls.. The paper presents exemplary measurement results taken in Lublin region during various periods throughout a year. The purpose for the research is to point out areas subjected to the highest energy losses caused by building's construction and geographical orientation of walls in the aspect of daily atmospheric temperature changes emerging on chamber exterior.

1. INTRODUCTION

Conduction take place when a temperature gradient exists in a solid (or stationary fluid) medium. Energy is transferred from the more energetic to the less energetic molecules when neighboring molecules collide. Conductive heat flow occur in the direction of decreasing temperature because higher temperature is associated with higher molecular energy. The equation used to express heat transfer by conduction is known as Fourier's Law. The article presents the physical model of heat transfer through chamber walls by means of a mathematical model suitable for sine waveform of internal temperature changes.

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2. MODELS OF HEAT TRANSFER THROUGH WALL

The purpose of this paper is to describe the design of control systems of cooling and air conditioning systems in storage spaces. For a control systems its necessary to use only three elements: sensor, controller and controlled device. The main of those elements is temperature sensor which shows the picture of thermal decomposition in cold store. The very important are also devices, which provide control of humidity and cyclic potential motion of air in space. It must be noted, that all the control actions depend mainly on measurement of a controlled variable. It is, therefore, necessary to analyze very carefully what is actually being measured, how it may vary with time and which degree of accuracy is necessary in the measurement. Mostly, the temperature of the surfaces on which the sensors are mounted is different from the air temperature. Observations of the ambient air temperature in Lublin are showing that the variations of the temperature from the heat by day to the cold by night and yearly changes from the cold of winter to the heat of summer may vary harmonically – figures 1-4. These variations of external temperature have influence upon the internal temperature, which depending upon the conductive heat transfer through walls of thermal technical spaces. By the suitable construction of the enclosure walls composed of several slabs of different thickness and conductivities we can obtain phase angle displacement (when the time lag attains twelve hours it is the best situation), which reduce the amplitude of internal temperature inside buildings.

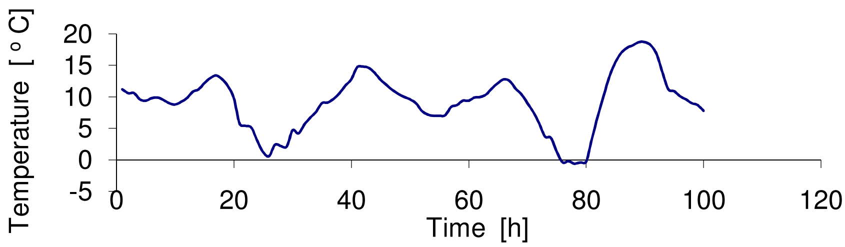

Fig.1. Diagram of atmospherics temperature in the four days of April [source: own study]

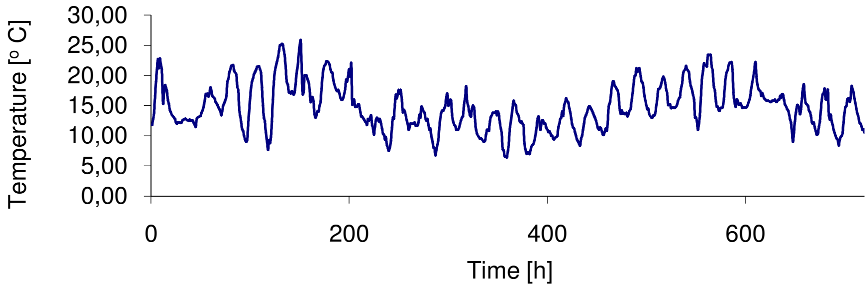

Fig. 2. Diagram of atmospherics temperature in the month of June [source: own study]

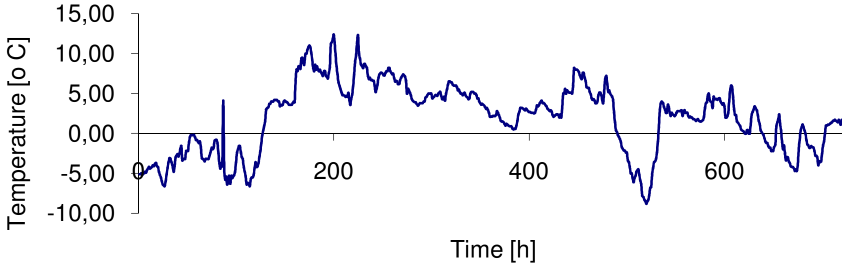

Fig. 3. Diagram of atmospherics temperature in the month of December [source: own study]

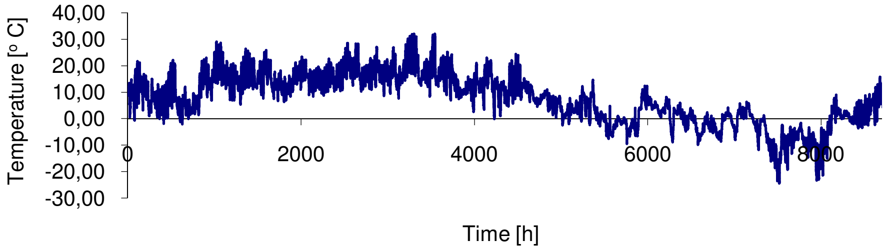

Fig. 4. Diagram of atmospherics temperature of the year in Lublin [source: own study]

The analysis has been performed on the basis of original numerical algorithms. They take into consideration hourly changes of ambient temperature in the central – eastern region of Poland. The accepted methodology of performance takes advantage of temperature dynamics which is necessary to solve physical and mathematical problems related to heat transfer processes occurring in chambers.

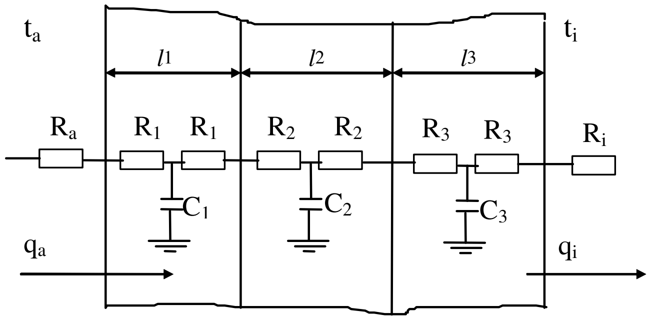

Fig. 5. Model of wall composed of three layers in electrical analogy [source: own study]

From it we can get matrix notation (eventually for n – layers of wall) and the final result of this calculation is a pair of linear relations between the temperature and fluxes at the two surfaces of the composite slabs.

$$[\Delta t_i(p),\Delta q_i(p)]=$$
$$[\Delta t_a(p);\Delta q_a(p)]\begin{bmatrix}1 & 0\\ -R_1 & 1\end{bmatrix}\begin{bmatrix}1 & -pC_1\\ 0 & 1\end{bmatrix}\cdots\begin{bmatrix}1 & -pC_n\\ 0 & 1\end{bmatrix}\cdot\begin{bmatrix}1 & 0\\ -R_{n+1} & 1\end{bmatrix} \quad (1)$$

The relation is precisely analogous to Ohm's law for the steady flow of electric current: the flux corresponds to the electric current and the drop of temperature to the drop of potential. Thus R may be called the thermal resistance of the slab (Figure 5). Next suppose we have a composite wall composed of n slabs of different thickness and conductivities. If the slabs are in perfect thermal contact mat their surfaces of separation, the fall of temperature over the whole wall will be the sum of the falls over the component slabs and since the flux is the same at every point, this sum is evidently.

This is equivalent to the statement that the thermal resistance of a composite wall is the sum of the thermal resistance's of the separate layers, assuming perfect thermal contact between them. Finally, consider a composite wall as before, but with contact resistances between the layers such that the flux of heat between the surfaces of consecutive layers is H times the temperature difference between these surfaces. The differential equation to be solved is Fourier's equation. These models we can confront with computer program Modelica, which allow to construct the walls of technical chambers. The diagram of the process of heat transfer through the wall under the program Modelica is shown in Figures 6 and 7.

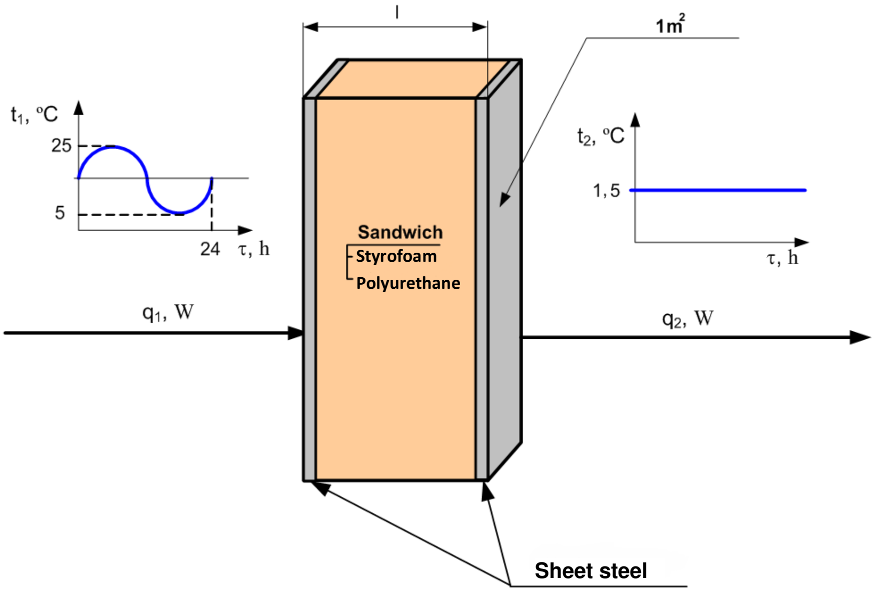

Fig. 6. Ideal model of wall [source: own study]

Below shows a universal electric scheme uses an analogy to Ohm's law for three layers wall.

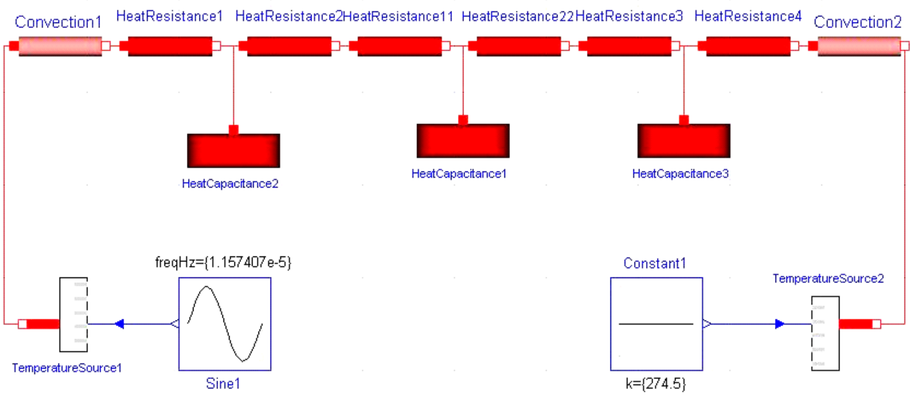

Fig. 7. Block schema using electrical analogue [source: own study]

By this modeling, we can simulate any temperature regime and heat flow both inside and outside of the chamber, for example in Figure 8 we can see periodically temperature signal on the outside surface of the wall. In Figure 9 we can obtain suppressed the course of the internal temperature.

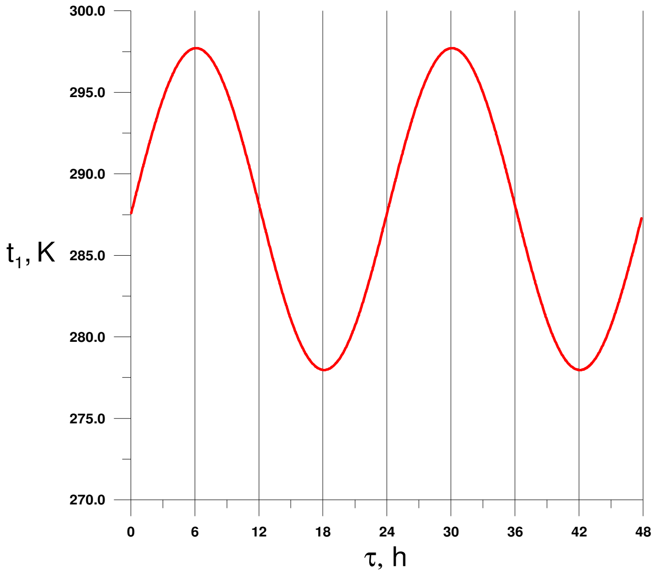

Fig. 8. Periodically temperature signal on the wall – t_1 [source: own study]

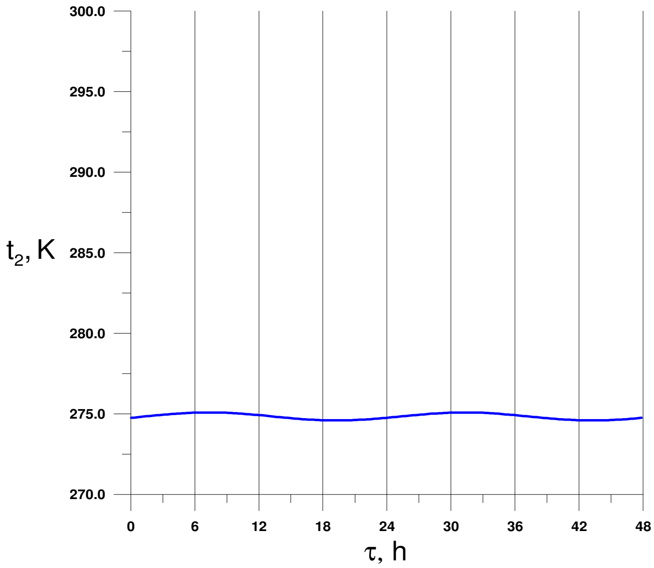

Fig. 9. Periodically temperature signal on the wall – t_2 [source: own study]

Below shows a universal electric scheme uses an analogy to Ohm's law for three layers wall.

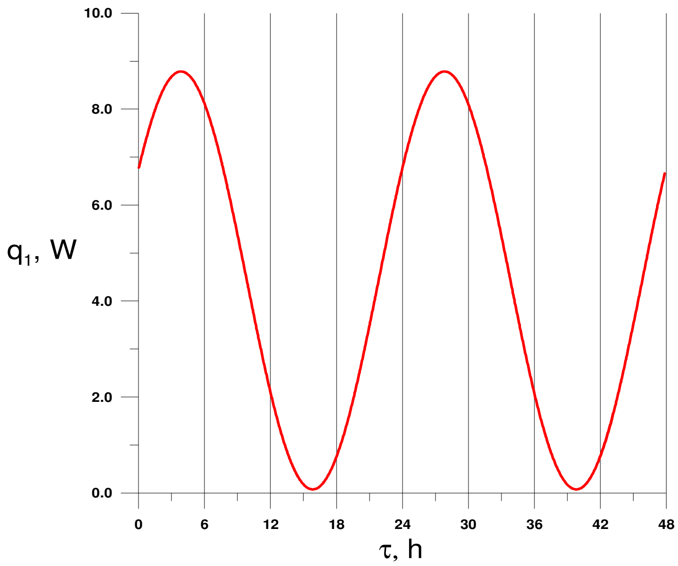

Fig. 10. Periodically heat flux flow signal on the wall – q_1 [source: own study]

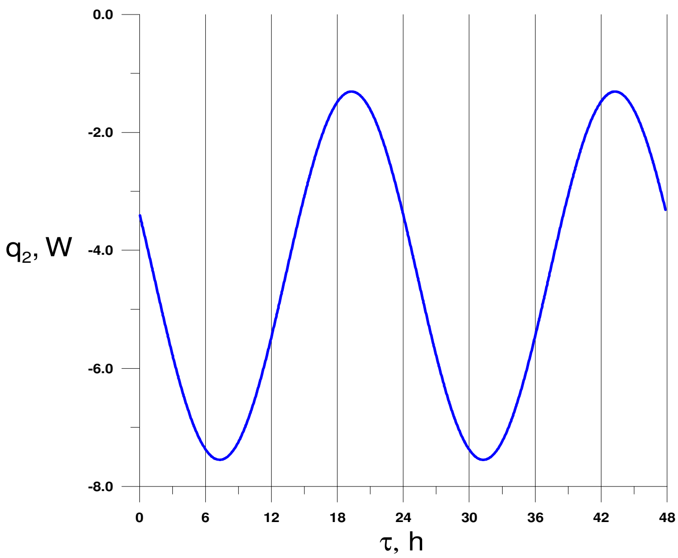

Fig. 11. Periodically thermal flow signal on the wall – q_2 [source: own study]

Analogous of the temperature process we can get the course of the heat flux (Figure 10 and 11) on the both surfaces of the wall.

3. CONCLUSION

The paper describes atmospheric temperature analysis and their variability in time in aspect of their influence upon the thermal technical chambers with the with the help of computer program Modelica. This analysis shows the periodic variability of outside temperature, changing in periods of each day and also in the year with maximum value in the afternoon or in summer and minimum value in the night or winter time. The influence of this periodically changing temperature on the inside storages climate is depending on thermal inertia of technical spaces. It is also show the periodically thermal flow signal on the wall and its influence to the inside of object. The proper construction of an object with prescribed thermo-stability characteristic can use the phase difference between internal and external temperature and allow to lower costs of energy, necessary for cooling or heating the technical spaces. By the suitable construction of the enclosure walls composed of several slabs of different thicknesses and conductivities, we can obtain phase shift, which reduce the amplitude of internal temperature inside technical chamber and in consequence, give equivalent of using energy. The influence of this periodically changing weather temperature upon the inside storages climate is depending on the material of walls and inertial property of thermal technical spaces.

REFERENCES

[1] CARLSLAW H., JAEGER J.: *Conduction of heat in solids*. Oxford University, 1959.

[2] TAKAHASHI Y., RABINS M., AUSLANDER D.: *Sterowanie i systemy dynamiczne*. WNT, Warszawa, 1976.

[3] JANCZAREK M. M.: *Methods concerning conductive heat transfers through walls of thermal technical spaces*. MATAR'92, Prague, 1992, pp. 166-170.

[4] BULYANDRA O. F., YANCHAREK M. M.: *Analiz peredachi teploti kriz zownischniu stinku skladskowo primischenia z urahowaniam dinamiki zmin atmosfernoi temperature.* Harchowa Promislowist, no. 4, Kyiv, 2005.

[5] JANCZAREK M., SKALSKI P., BULYANDRA A., SOBCZUK H.: *Przewodność cieplna zewnętrznych ścian budynków w aspekcie wilgotności i oszczędności energii.* Rynek Energii, no. 4(65), Lublin, 2006.

[6] WIDOMSKI M., SOBCZUK H: *Retentional abilities of soils in eroded environment*, in Pawłowski L., Dudzińska M., Pawłowski A.*: Environmental Engineering*, Taylor & Francis, New York-Singapore, 2007, p. 459-464.

[7] JANCZAREK M. M.: *Energooszczędność eksploatacji obiektów budowlanych w aspekcie zmiennej temperatury atmosferycznej.* Rynek Energii, no. 1(68), Lublin, 2007.

[8] PAVLÍK Z., Application of Time-Domain Reflectometry Method for Measuring Moisture Content in Porous Building Materials In: Trends in Applied Sciences Research. 2007, vol. 2, no. 3, pp. 188-200.

[9] JANCZAREK M. M., BULYANDRA O. F.: *Charakterystyki dynamiczne wpływu atmosferycznych zmian strumieni cieplnych na powierzchnie przegród komór obiektów technicznych*. Informatyka w technice, Lubelskie Towarzystwo Naukowe, Lublin, 2008, pp. 124-128.

[10] ВИНОГРАДОВ-САЛТЫКОВ В. А., ЯНЧАРЕК М., ФЕДОРОВ В. Г., КЕПКО О. И.: *Теплометрическое Исследобание Теплозащитных Свойств Ограждений*. Indus-trial Heat Enginneering – International Scientific And Applied Journal, vol. 31, no. 4, 2009.
[11] SUCHORAB Z., SOBCZUK H., ROŻEJ A., ŁAGÓD G.: *Comparison of Reflectometric and Gravimetric Methods for Examination of Sewage Sludge Additions Influence on Water Properties of Reclamated Soils*. Ecological Chemistry and Engineering, vol. 16, no. 4, 2009, p. 257-264.
Stępniewski W., Sobczuk H., Widomski M.: *Diffusion In soils.* Encyclopedia of Agrophysics, Encyclopedia of Earth Series, Springer, 2011, pp. 214-220.
[12] JANCZAREK M. M., ŚWIĆ A.: *Scientific and technological description of heat and mass transfer processes in chambers*. Acta technical convinieties – Bulletin of Engineering, vol. 10, 2012.
[13] JANCZAREK M. M.: *Analiza matematyczno-fizyczna cieplnych komór technicznych*. Technologie informacyjne w technice i kształceniu, Politechnika Lubelska, Lublin, 2013, pp. 127-137.
[14] SUCHORAB Z.: *Noninvasive moisture measurement in building materials*. Environmental Engineering IV, Taylor & Francis Group, London, pp. 433-439.