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Method of a Building Object Thermophysical Property Determination

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Abstract: This study is devoted to the experimental studies of Thermo Physical Properties (TPP) of objects. The existing methods of TPP determination are analyzed. They presented the algorithm developed by the researcher for TPP determination of the object under study. They described the operation of the unit for TPP (heat transfer coefficient, heat transfer resistance and specific thermal characteristic) determination of the object under study. The formulas are given required for TPP calculation. The experimental results of the study are presented. The main advantages of the developed unit are described.

Key words: Heat transfer, heat transfer coefficient, resistance to heat transfer, energy efficiency, method, operation

INTRODUCTION

One of the existing problems in the study of energy savings is the use of simple and reliable methods which determine heat losses to the environment through the enclosing structures of an object and the analysis of TPP which significantly affect the thermal regime. Nowadays, there are various methods and devices to determine the TPP of the object under study (Anonymous, 2003a, b, 2012; Golovnev and Mozgalev, 2014; Verkhovsky and Shubin, 2010; Pokhodun and Sokolov, 2011; Bogoyavlensky *et al*., 2008; Sergeev, 2011; Vavilov and Grigoriev, 2012; Datsyuk and Isakov, 2005; Lavrov *et al*., 2004; Varfolomeev and Orlova, 1998; Chernyshov and Slonova, 2005; Budadin and Abramova, 2005; Kabanov *et al*., 2015a, b; Panfilov and Kabanov, 2016a, b).

The methods used to determine the TPP of an object are divided into 3 main types, non-stationary, stationary and complex ones. Non-stationary methods to determine the TPP of an object are the most promising ones, due to the simplicity, a short time of research and so on. During the determination of TPP they require less time and heat energy in contrast to stationary ones. The leading place is occupied by TMNDT (Temperature Methods of Non Destructive Testing) among the above mentioned methods. At the same time, the existing methods have some limitations which include complex equations for thermophysical property calculation, the difficulty of real boundary condition determination in the process of the study, a long duration of the TPP determination procedure (at least 2 days), a possible beginning of experiments only after a stationary regime achievement and other limitations.

MATERIALS AND METHODS

The existing methods of heat transfer resistance determination and the coefficient of heat transfer establish these coefficients only for a certain section of the structure under study. It takes a considerable amount of time in order to determine the given thermo physical properties of the whole object. The cost of time has a significant impact on the cost of research. In the course of the study, it is also necessary to ensure the creation of special conditions (a stable temperature on the inner and outer surfaces of the object under study) during the entire study period which as the consequence, determines the high energy intensity of the study. The analysis of existing techniques has shown that it is possible to develop a unit that will determine the TPP of a MS object using modern information processing tools in a shorter period of time. Ametistov (2000), Belov *et al.* (1986), Bogoslovsky (1982), Vavilov (1991), Tabunshchikov and Khromets (1986), Panfilov *et al.* (2015), Anonymous (2012) and Panfilov and Kabanov (2016a, b) noted that non-stationary methods for TPP determination are the most promising ones, due to the simplicity and the reduction of time for a study. Based on the analysis, the algorithm was developed to study the TPP of an object.

The block diagram of the algorithm contains 16 blocks. The input of initial data is performed in 1, the heat source power, the total area of an object under study by external measurement, the volume of the object under study by external measurement, the maintained temperature inside an object under study, the range of temperature variation within an object under study, the delay time until the unit is turned on. The timer is started

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in 2. The check of the term concerning the starting time of an experiment is performed in 3. If the term is satisfied, the control is transferred to the heating unit 4 of the object under study. The 5 records the ambient temperature outside the object under study. Block 6 calculates the unit operation time in the active mode. The analysis is carried out concerning the condition "the time of the study is greater than or equal to the current time of the study". If the condition is fulfilled, the condition of the object heating to the set temperature is checked. If the condition is not fulfilled, the return to 6 takes place. If the condition is fulfilled, the unit 9 stops the supply of heat, the ambient temperature is recorded in 10. Then, the operation of the unit in the active mode for a preset time is performed. The condition "the test time is greater than or equal to the set study time" is checked in 12. If the condition is met, the condition of heating to the set temperature is checked in 13. If the condition is not met the return to 4 takes place. Otherwise, the transition to the unit 14 the calculation of the operation time in the active mode. In 15 they register the temperature outside the object under study and the TPP values (heat transfer coefficient, heat transfer resistance and specific thermal characteristic) of the object under study are recorded as a whole in 16.

Here is the description of the unit operation. Before the beginning of the study to determine the TPP of the object, temperature sensors 3 and 4 are installed along the inner and the outer perimeter of the object, at equal distance from each other. When the set temperature is reached, the programmable relay 1 records the time of the heat supply source 2 active research during the whole period of the study. The temperature readings of the environment are taken from the sensors, after a set interval of time. At the end of the experiment, the calculation of TPP (heat transfer coefficient, heat transfer resistance and specific thermal characteristic) for the object under study is performed according to the following formulas (Panfilov *et al*., 2015; Anonymous, 2012).

The studies were carried out to approbate this unit with a preset algorithm of actions (Panfilov *et al*., 2015; Anonymous, 2012) on the object model. Figure 1 demonstrates the model of the object. Figure 2 shows the type of experimental study object with installed equipment.

The object of the study is performed in the form of a cube. It consists of the foam polystyrene PSB-C25 and has the manufacturer's declared thermal conductivity of 0.039 W/(m°C), the area of one surface equal to 1.09 m^2 and the layer thickness of 0.1 m (Fig. 3). After the performance of the preparatory procedures, the given temperature was maintained in the object, the ambient

Fig. 1: The model of the object under study

Fig. 2: The type of experimental study object with installed equipment

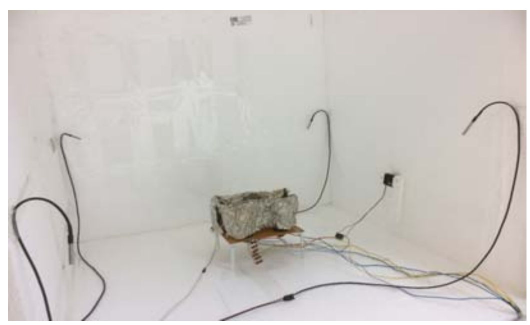

Fig. 3: Object view with installed equipment

temperature was determined using the manufactured portable module. Figure 4 shows the appearance of the module for the ambient temperature measuring by sensor signals, located along the perimeter of the object under study.

The unit for ambient temperature measurement consists of ArduinoNano 3.0 microcontroller (ATmega328), DS18D20 temperature sensors connected to the microcontroller and TF Cardreader module to record the data obtained during the experiment. Figure 5 demonstrates the module for a heat source control of a heated object.

The heat source control module installed inside a heated object consists of Arduino Mega 2560 on the basis of the Atmega 2560 microcontroller, 4 temperature sensors DS18D20 connected to the microcontroller, the TF cardreader module, the relays switching on and off of the heat supply source during the experiment algorithm performance.

Figure 6 shows the appearance and connection diagram of the Cicutor AR6 energy quality analyzer and consumed current, voltage and power during the experiment. Figure 7 shows the graph of voltage variation during the experiment time. Figure 8 shows the graph of current strength change during the experiment. Figure 9 shows the graph of active power consumed by the heat supply source. In order to confirm the thermal characteristics of the object material the procedure was performed to determine the thermal conductivity of the material used for the foam polystyrene PSB-C 25. IPP-2 instrument was used to measure the heat flux density.

The sample with the thickness of 0.032 m was placed in a special compartment, shown in Fig. 10. Temperature sensors were mounted on both sides of the PSB-S 25 foam polystyrene sample. One side had the probe to measure the heat flux. After a long period of time during which the heat flux ceased to change, the temperature values from the hot and cold sides as well as the heat flow were recorded.

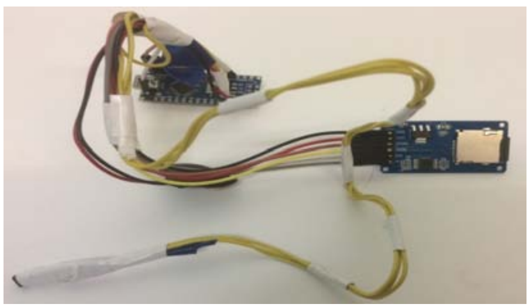

Fig. 4: Ambient temperature measuring unit

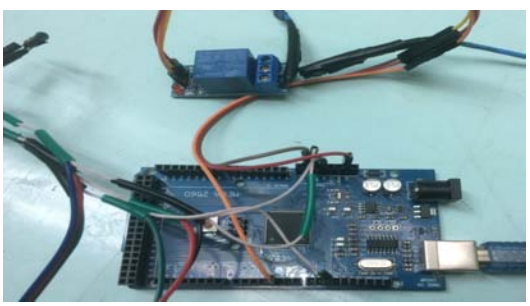

Fig. 5: Heat source control module

Fig. 6: Appearance and connection scheme of electrical energy quality analyzer CicutorAR6 to the unit according to the determined TPP of building objects

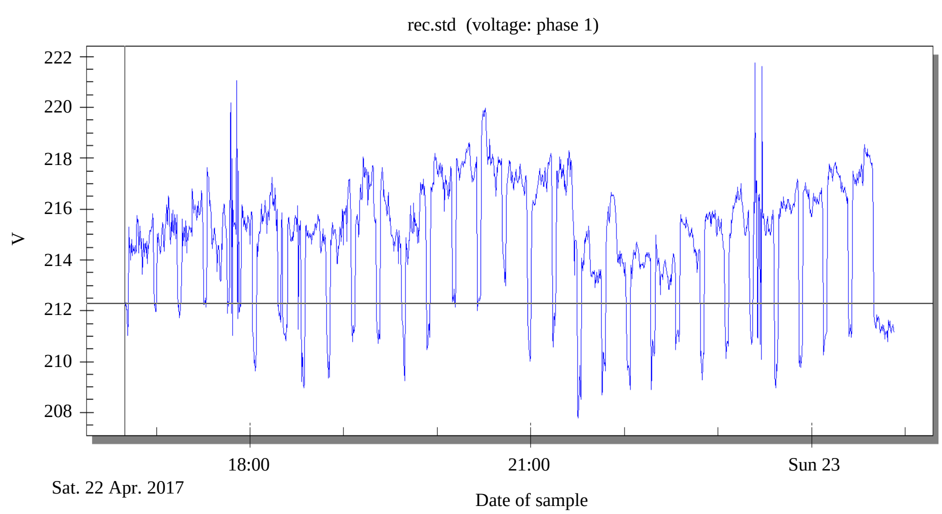

Fig. 7: The graph of power supply voltage change in a heat supply unit during the experiment

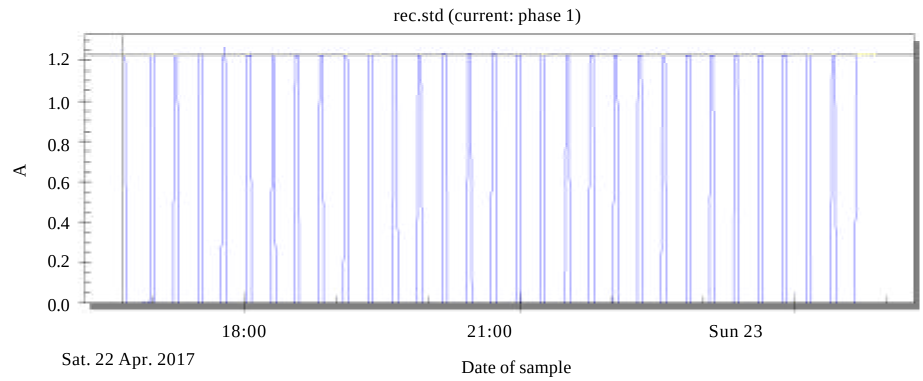

Fig. 8: The graph of current change during the experiment

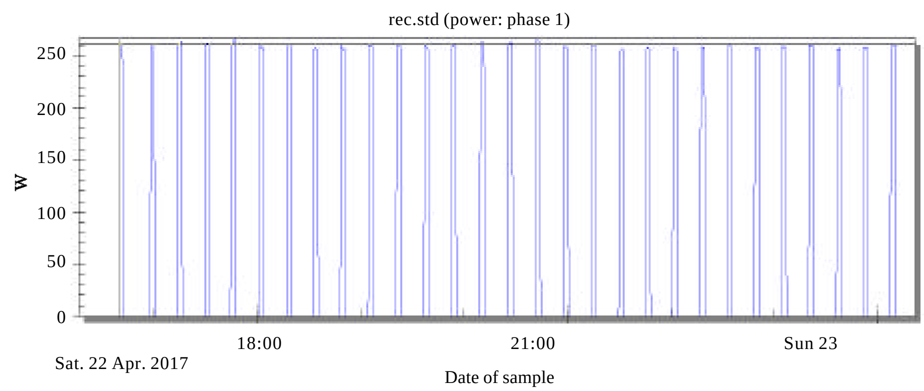

Fig. 9: Consumed power graph

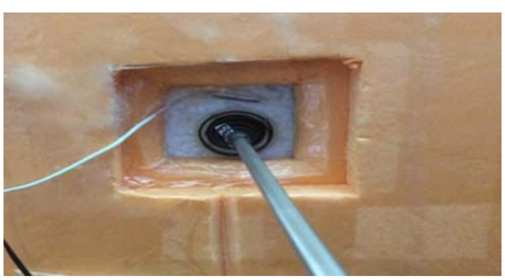

Fig. 10: The studied sample of foam polystyrene PSB-S 25

Fig. 11: The measurement of foam polystyrene thermal characteristics PSB-S 25

The results of temperature measuring for the sides of foam polystyrene PSB-S 25 sample as well as the heat flux are shown on Fig. 11.

RESULTS AND DISCUSSION

The thermal conductivity of the material is determined by the formula W/(m°C):

$$\lambda = \frac{Q \times \delta}{\Delta t}$$

Where:

Q = The heat flux passing through the sample of the material being studied

Δt = The temperature on different sides of a test sample

The thermal conductivity λ of foam polystyrene PSB-S 25 made 0.0395 W/(m°C) according to the experiment results. The analysis of the conducted experiment results allows us to conclude if the proposed portable automated unit and the method for object TTP determination are applicable.

CONCLUSION

In comparison with the known technical solutions, the proposed one allows you to set the heat transfer coefficient, the specific thermal characteristic, the resistance to heat transfer for the object under study as a whole, taking into account all the heterogeneities of the protective structures and also to reduce the duration and energy intensity of the experiment significantly.

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