

## METHOD OF NONDESTRUCTIVE CONTROL OF THERMOPHYSICAL PROPERTIES OF EXTERNAL THERMAL INSULATION OF CYLINDRICAL PRODUCTS

A. G. Filatova, A. A. Churikov, A. G. Divin

*Department "Mechatronics and Technological Measurements",  
TSTU; Filang90@mail.ru*

**Keywords:** a set of thermal and physical properties; automatic control system; ceramic materials; curved surface; inhomogeneous materials; integral characteristic; measuring instruments; metrological support; non-destructive testing; optimal parameters; specific heat; temperature; thermal conductivity; thermal diffusivity.

**Abstract:** The paper proposes a comprehensive method for evaluating non-uniform materials of products with cylindrical shape and a large radius of curvature. Using the solution of the inverse thermal conductivity problem to the following case, we can obtain formula for the time-integral characteristic of temperature or heat current and the surface time-integral characteristic. A short duration of the experiment is the main requirement in the study of thermal and physical properties of thermal insulation materials of new products and existing products of cylindrical shape. This requirement is especially important when it is necessary to investigate thermal and physical properties in a wide range of temperatures. Non-destructive testing is ideal for the study of thermal and physical properties of the material samples or finished products. Non-destructive testing of thermal physical properties is related to the ever-increasing range and volume of various artificial polymeric products and thermal protection materials. Rapid thermal control over properties of newly developed materials in the laboratory significantly reduces the time of creation and adjustment of manufacturing technology of these materials. We propose a complex method of evaluation of non-homogeneous materials with a cylindrical shape and a large radius of curvature. Using the solution of inverse heat conduction problem, we can obtain a formula for the Time Integral Characteristics of temperature or heat flow and Surface Time Integral Characteristic. We developed a methodology for the search and correction of experimental parameters (temperature, time, geometry) and computational procedures to ensure the lowest possible accuracy of the measurement for a given product.

---

### Introduction

In industry, various materials with a cylindrical shape and a large radius of curvature are often used for product development. Assessment of the state and characteristics of materials and structures using non-destructive testing methods (NDT) is a priority need in the world. NDT of thermal-physical properties (TPP) of products with curved surface have to be tested for detection of defects of those materials.

We consider the inverse thermal conductivity problem, i.e. the problem of finding thermal constants  $a$  and  $\lambda$  for the following case: knowing the density of the heat-flux  $q_c(t)$  directed inside the cylindrical body with radius  $R$  though the side's

section between two generators with expansion angle equal  $2\varphi$  (Fig. 1). The thermal process in the test body is described by the following boundary value problem of heat conductivity:

$$\frac{\partial U(r, \varphi, t)}{\partial t} = a \left( \frac{\partial^2 U(r, \varphi, t)}{\partial r^2} + \frac{1}{r} \frac{\partial U(r, \varphi, t)}{\partial r} + \frac{1}{r^2} \frac{\partial^2 U(r, \varphi, t)}{\partial \varphi^2} \right), \quad (1)$$

$$t > 0, \quad 0 \leq r \leq R, \quad 0 \leq \varphi \leq 2\pi;$$

$$U(r, \varphi, 0) = 0; \quad (2)$$

$$\frac{\partial U(r, \varphi, t)}{\partial r} = \begin{cases} q(\varphi, t) / \lambda, \\ 0, \end{cases} \quad (3)$$

$$r = R, \quad |\varphi| \leq \bar{\varphi},$$

$$r = R, \quad |\varphi| > \bar{\varphi};$$

$$\left. \frac{\partial U(r, \varphi, t)}{\partial r} \right|_{\varphi=0} = 0; \quad U(0, \varphi, t) < \infty. \quad (4)$$

Note that the temperature distributes symmetrically inside the cylinder with respect to planes  $\varphi = 0$  and  $\varphi = \pi$ , then consider the solution of problem for  $\varphi \in [0; \pi]$ .

Continuing this line of reasoning, we see that the solution of problems (1) – (4) according to Laplace and Fourier Transform are as follows

$$U_c^*(R, s, p) \equiv U_c^*(s, p) = \frac{q_c^*(s, p)R}{\lambda \Phi(g_c)}. \quad (5)$$

Here  $\varphi \in [0; \pi]$ ,  $r = R$  and  $g_{\bar{n}} = R\sqrt{(p/a)}$

$$\Phi(g_c) = \frac{g_c I_{s+1}(g_c)}{I_s(g_c)} + s, \quad (6)$$

where  $I_s(g_c)$  is the modified Bessel function of the first kind of  $s$ -order;  $p$  is Laplace's parameter,  $p > 0$ ;  $s$  is Fourier's parameter,  $s \geq 0$ .

Hence, solution (5) is according to Laplace

$$U_c^*(\varphi, p) = \frac{2R}{\lambda \pi} \sum_{s=0}^{\infty} \frac{q_c^*(s, p) \cos(s\varphi)}{\beta_s \Phi(g_c)},$$

where

$$\beta_s = \begin{cases} 2, & \text{if } s = 0; \\ 1, & \text{if } s \neq 0. \end{cases} \quad (7)$$

The time-integral characteristic (TIC) of temperature or heat current has the form

$$F^*(p) = \int_0^{\infty} \exp(-pt) f(t) dt,$$

if  $p > 0$ .

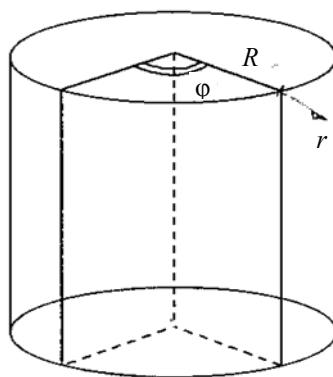


Fig. 1. Physical model of the object of study

In addition, the surface time-integral characteristic (STIC) is given ( $s > 0, p > 0$ )

$$F_c^*(s, p) = \int_0^\pi \cos(s\varphi) \int_0^\infty \exp(-pt) f(\varphi, t) d\varphi dt,$$

We can calculate these two characteristics experimentally.

Let  $U_c^*(s, p_2), U_c^*(s, p_1), q_c^*(s, p_2), q_c^*(s, p_1)$  be known for two value  $p_1$  and  $p_2$  of the parameter  $p$  taking into account formula (5) we obtain

$$\frac{U_c^*(s, p_1)}{U_c^*(s, p_2)} = \frac{q_c^*(s, p_1) \Phi(g_{c2})}{q_c^*(s, p_2) \Phi(g_{c1})}, \quad (8)$$

where  $g_{ci} = R\sqrt{p_i/a}, i = 1, 2$ .

Therefore  $\lambda = \frac{q_c^*(s, p_i)R}{U_c^*(s, p_i)\Phi(g_{ci})}, i = 1, 2$ . Substituting  $q_{ci}$  and  $\Phi(g_{ci})$  from formulas (8) and (6) respectively in formula for  $\lambda$  we can calculate it.

In general, we say that TIC has the next form:

$$U_c^*(\varphi, p) = \frac{q_c^*(p)R}{\lambda} V(\varphi, g_c); \quad (9)$$

$$V(\varphi, g_c) = \frac{2}{\pi} \sum_{s=0}^{\infty} \frac{\sin(s\varphi) \cos(s\varphi)}{s\beta_s \Phi(g_c)}.$$

if heat current doesn't depend on coordinates  $\varphi$  inside area heating.

We claim that values  $a$  and  $\lambda$  can be identified by formula (9) according to two methods.

On the one hand, if we have the value of the TIC at two random points  $\varphi_1$  and  $\varphi_2$  then we obtain:

$$\frac{U_c^*(\varphi_1, p)}{U_c^*(\varphi_2, p)} = \frac{V(\varphi_1, g_c)}{q_c^*(\varphi_2, g_c)},$$

$$\lambda = \frac{q_c^*(p)R}{U_c^*(\varphi_1, p)} V(\varphi_i, g_c), \quad i = 1, 2.$$

On the other hand, if we have the value of the TIC at one point  $\varphi = 0$  and two different values of the parameter  $p$  ( $p_1$  and  $p_2$ ) then we say that:

$$\frac{U_c^*(\varphi, p_1)}{U_c^*(\varphi, p_2)} = \frac{q_c^*(p_1) V(g_{c1})}{q_c^*(p_2) V(g_{c2})},$$

$$\lambda = \frac{q_c^*(p_i)R}{U_c^*(\varphi, p_i)} V(g_{ci}),$$

where  $V(g_c) = \frac{2}{\pi} \sum_{s=0}^{\infty} \frac{\sin(s\varphi)}{s\beta_s \Phi(g_c)}$ ;  $g_{ci} = R\sqrt{p_i/a}, i = 1, 2$ .

Value of STIC is identified by the formula

$$S_c^*(p) = \frac{1}{2\varphi} \int_{-\varphi}^{\varphi} U_c^*(\varphi, p) d\varphi = \frac{1}{\varphi} \int_0^{\varphi} U_c^*(\varphi, p) d\varphi.$$

If we combine integrator [3] and  $\varphi \leq |\varphi|$ , we get

$$S_c^*(p) = \frac{q_c^*(p)R}{\lambda} V(g_c),$$

where

$$V(g_c) = \frac{2}{\pi\varphi} \sum_{s=0}^{\infty} \frac{\sin^2(s\bar{\varphi})}{s^2 \beta_s \Phi(g_c)}.$$

Indeed, we define conditions of adequate two expressions  $S_n^*(p)$  and (1). The accuracy of  $S_n^*(p)$  and  $S_c^*(p)$  is estimated by relative error  $\delta_s \leq 0.01\%$ .

Fig. 2 shows that the width of heated band  $L$  depends on parameter  $g_c$  for different cylindrical bodies with radius  $R$ . Therefore, if measuring

device has a heater with width of  $2L$  and the cylindrical body with radius  $R$ , we can use methodologies [2, 4] for half-closed and flat surface of the sample. In addition, we can obtain optimal amount of time for conducting an experiment. On the other hand, if we know experimental parameter  $p$  [2, 6] and thermal diffusivity  $a$ , then we can find geometric sizes of the heat surface and the measuring device.

The fast performance of the NDT method or device usually means a relatively short duration of the active part of the experiment, for which heating is applied to obtain experimental information. However, the process of measuring the TPP always consists of preparation and working (active) stages. Most of the known methods of measuring the TPP assume uniform and stationary distribution of the beginning temperatures in studied samples. Therefore, during preparation thermostetting of the thermal system is made of test sample and the measuring device. The duration of this process for NDT method is longer than the length of the working stage of measurement. For our method of determining the TPP of shielding massive cylindrical solids of polymer materials, wherein the heat source used is a flat electric heater formed in the shape of a narrow rectangle, the length of the active stage is 2 to 5 minutes, while the time needed for thermostetting is 20 to 40 minutes. Decrease in the thermostetting time leads to errors in TPP measurements.

Reliable determination of the TPP by one result and even from a carefully conducted experiment is almost impossible. This is due to the presence of random error components, which can be eliminated by conducting several measurements. During the series of experiments, the basic parameters that determine the performance of the method include the necessary time for a single measurement, to provide the opportunity and accuracy of the TPP, and the continuation the preparatory phase of the experiment. Thus it is obvious that to get the best productivity and improved results of the NDT method is linked with calculation dependence, allowing, first, to extract maximum information from experimental thermal images, and, secondly, find the initial, not reached steady state temperature, of temperature distribution in tested sample. This will allow for the same type measurements of TPP on the same surface of the tested sample, without changing the position and design of measuring system, for example to carry out multiple identical measure by the same method.

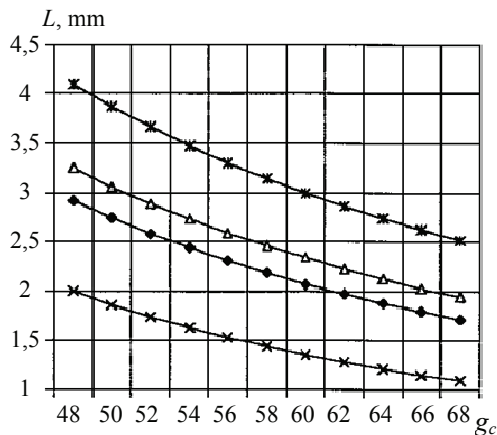


Fig. 2. Shows that width of heated band  $L$  dependence on parameter  $g_c$  for different cylindrical bodies with radius  $R$ :

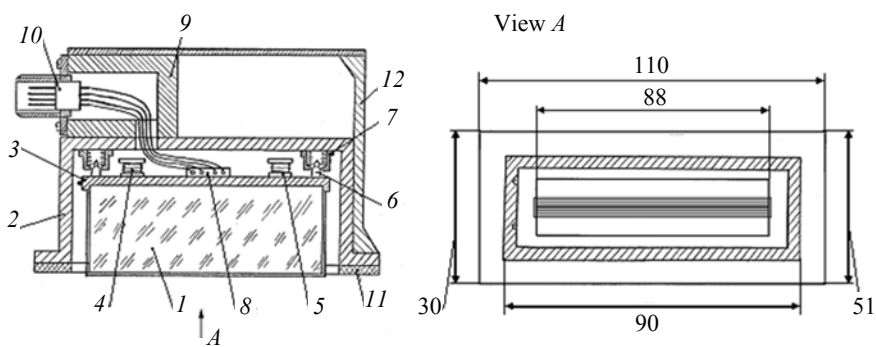
—●—  $R = 160$  mm; —△—  $R = 200$  mm;  
—×—  $R = 50$  mm; —\*—  $R = 300$  mm

The remote probe was used for the implementation of the thermal mode adequate to the mathematical model; the description of its construction is given below. The probe consists of two main elements: the body and the reference substrate with a heater and integrator of temperature or thermocouple.

When designing the probe we took into account two main components. First, the probe should be small. This requirement is caused by the need to have a relatively weightless probe, able to move effortlessly, and with reasonable accuracy at any place of the surface of the sample. Second, when fixating the probe to the target area we must create a pressure in the reference substrate with a heater and thermocouple on the surface of the material to avoid contact thermal resistance. For this purpose, we used a custom made weight, ensuring tight pressing of the probe to the test material. Based on the calculations of maintaining adequateness of the temperature field of that sample, induced by heating of the surface through its endless strip, the temperature field of the same sample, but heated through the rectangular portion of the surface, we obtained measures of the substrate:  $(80 \times 30 \times 20) \text{ mm}^3$ .

The NDT method provides zero initial distribution of heat in the standard and the tested body and, therefore, if an experiment with the same substrate is carried out, then for the experiment with the use of that substrate, we need to maintain a certain time to restore the initial conditions of the uniform temperature distribution. Therefore, there is a need for a change of identity in the probe substrates to increase the productivity measurement and their quality (due to lack of measurement error due to uneven pace of dimension  $e$ -temperature field in the standard). An important factor in the design of the temperature probe was the cold junctions (CJ) of the central thermocouple. During the experiment, the heating of the tested sample did not exceed  $10 \dots 15 \text{ }^\circ\text{C}$ , and therefore there was a sufficiently minor relative change in temperature of the CJ of thermocouples, for the error of measurement to become noticeable. Therefore, there was a need for temperature stabilization of the CJ coil, for these purposes we used the CJ coils 4 and 5 (Fig. 3). When using temperature integrators we used coil bridge measuring circuits instead of CJ coils 4 and 5 as shown in [3, 5].

Structurally, the substrate is attached to the housing with the metal support 3 (Fig. 3) which, in turn, is attached inside the probe via push clamps, which allows the change of the sensor quickly and simply, as the substrate is fixed in the housing with 4 clip-buttons 6 of the support in nests 7. The probe body is shaped as a parallelepiped with the dimensions  $(40 \times 50 \times 90) \text{ mm}^3$ , open on one side. Inside the probe a pad from the reference material (here polymethylmethacrylate) is mounted on resilient springs, on the outside of which a flat heater made of constantan wire is glued. On the central axis of the heater a chromel-copel or chromel-alumel thermocouple is attached with the work junction located in the center of the heater to record the temperature  $U(0, 0, t)$ . Between the turns of the heater by measuring the integral characteristic  $Sn(t)$  copper strands of temperature integrator are arranged. Fig. 3 shows a detailed structure of the probe. The casing or housing 2 of the probe is a hollow parallelepiped made from metal. Inside the probe on a special platform a substrate 1 made of a reference material is mounted. On the substrate (Fig. 3) a flat heater 2 made of constantan wire is mounted. The heater is thinned, i.e. each of its separate wires, running on the surface of the substrate does not touch the other adjacent to it; between the turns of the heater is a temperature integrator  $t$ . This is done so that the heat flow is not passed on to the heater (the wires are much bigger than the investigated polymeric materials) and it does not violate the temperature field under actual heater. The use of the cold junction coils (for each thermocouple electrode) made it possible to avoid the growth of errors in the measurement of temperature from one experiment to another due to the outflow of heat of the thermocouple. The substrate has a width greater than the heater. This meets the conditions of unboundedness of the tested body. Calculations have shown that it is sufficient to have a polymathic methacrylate substrate 30 mm wide and 20 mm thick.



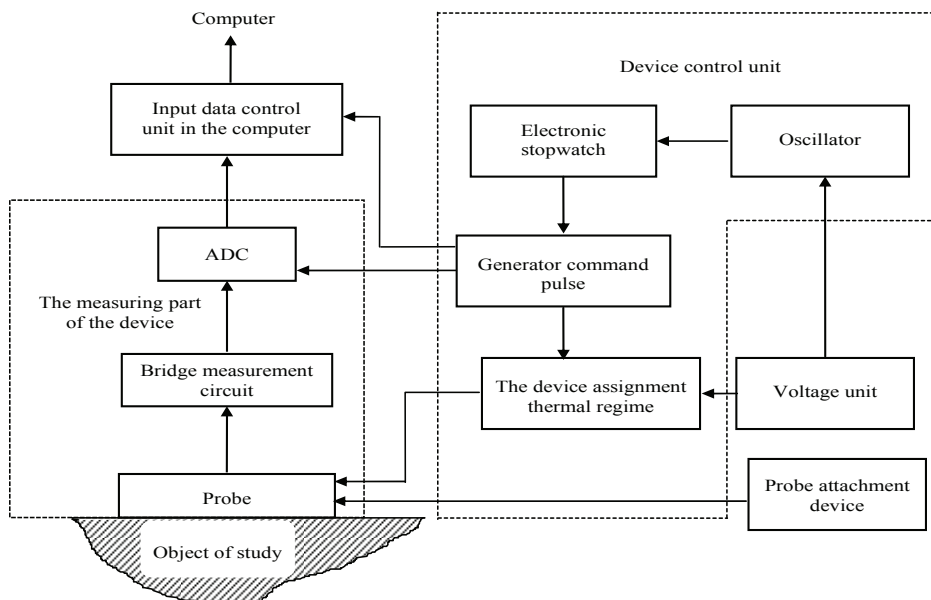
**Fig. 3. Probe design**

Lower base substrate is attached at the bottom 3 on the inner side of the coil which is fixed to cold junctions 4, 5 and connector 8 to connect the temperature transmitter to the measuring unit and the heater unit to the power supply. Four bearings 6 easily fit into the nests 7. This allows for quick replacement of the substrate from experiment to experiment.

At the edge of the open side of the probe casing, a wide flange with bonded rubber gasket 11, preventing the slide along the surface of the tested sample, was welded. The load resting on the edge ensures that the substrate together with the heater are tightly pressed to the tested surface. The tight hold eliminates contact thermal resistance and reduces the error in determining the thermal characteristics of the materials. For convenience, the probe has a handle 12, attached to the top end of the probe from the outside.

### Conclusions

Using the proposed method we have developed and built the device, a block diagram of which is shown in Fig. 4.



**Fig. 4. Block-diagram of the portable mobile microprocessor measuring device**

The device consists of the following units and devices:

1) *the measuring part of the instrument* is used to obtain experimental data and convert them into BCD. It consists of a probe, coil cold junctions (bridge measurement circuit) and analog-to-digital converter;

2) *the control unit* is used to control the course of the experiment, i.e. to set the heat mode for the tested sample, to control the procedure of data collection and recording as well as automated processing of the experimental results by sending command pulses into a computer.

Since the temperature measurement should be carried out at specified times [2, 6], the device contains a built in stopwatch with an accuracy of 0.01 seconds. At specified times the stopwatch sends trigger pulses to the ADC, which records the signals of the temperature converter;

3) *input data control unit* is used to check parameters of output signals of the device for nondestructive testing of TPR with the input parameters of the input data.

*The research was supported by the Ministry of Education and Science of RF within the basic part of the state order 539.*

#### References

1. Shatalov Yu.S. *Funktsional'no-integral'nye uravneniya teplofizicheskikh kharakteristik* [Functional integral equations of thermal characteristics], Moscow: Nauka, FIZMATLIT, 1996, 256 p. (In Russ.)

2. Vlasov V.V., Shatalov Yu.S., Churikov A.A. [Method and apparatus for non-destructive control of thermo-physical properties of materials massive bodies], *Izmeritel'naya tekhnika* [Measuring equipment], 1980, no. 6, pp. 42-46. (In Russ.)

3. Churikov A.A. [Integrating surface contact transducers for nondestructive thermal control], *Transactions of Tambov State Technical University*, 1998, vol. 4, no. 2-3, pp. 283-290. (In Russ.)

4. Burenina N.A., Churikov A.A. [Integral transforms and measuring devices in the thermophysical nondestructive testing of orthotropic materials], *Trudy TGTU : Sb. nauch. statei molodykh uchenykh* [Transactions TSTU : Collection of scientific papers of young scientists], 1999, issue. 4, pp. 44-46. (In Russ.)

5. Vlasov V.V., Kulakov M.V., Fesenko A.I., Gruzdev S.V. *Avtomaticheskoe ustroystvo dlya opredeleniya teplofizicheskikh kharakteristik materialov* [Automatic device for determining the thermal properties of materials], Moscow: Mashinostroenie, 1977, 192 p. (In Russ.)

6. Platunov E.S., Buravoi S.E., Kurepin V.V., Petrov G.S. *Teplofizicheskie izmereniya i pribory* [Thermal measurement and instrumentation], Leningrad: Mashinostroenie, Leningr. otd-nie, 1986, 256 p. (In Russ.)

---

### Метод неразрушающего контроля теплофизических свойств внешней теплоизоляции изделий цилиндрической формы

А. Г. Филатова, А. А. Чуриков, А. Г. Дивин

Кафедра «Мехатроника и технологические измерения», ФГБОУ ВО «ТГТУ»;  
Filang90@mail.ru

**Ключевые слова:** автоматизированная система управления; измерительные приборы; изогнутая поверхность; интегральная характеристика; керамические материалы; комплекс теплофизических свойств; метрологическое обеспе-



чение; неоднородные материалы; неразрушающий контроль; оптимальные параметры; температура; температуропроводность; теплоемкость; теплопроводность.

**Аннотация:** Представлен комплекс теплофизических свойств теплоизоляционных материалов как новых, так и эксплуатируемых изделий цилиндрической формы. В случае, когда необходимо проводить работу в широком диапазоне изменения температуры, решающим требованием к методу измерения комплекса теплофизических свойств является кратковременность проведения эксперимента. Такой вид и характер исследования дает неразрушающий контроль теплофизических свойств материала исследуемых образцов или готовых изделий. Проведение данного контроля в области научных исследований связано с возрастающим ассортиментом и объемом производства различных искусственных, полимерных, теплозащитных материалов. Быстрый теплофизический контроль свойств вновь разрабатываемых материалов в лабораторных условиях значительно сокращает время создания и корректировки технологии изготовления. Предложен комплексный метод оценки неоднородных материалов цилиндрической формы, которая имеет большой радиус кривизны. Используя решение обратной задачи теплопроводности можно получить формулу для временной интегральной характеристики температуры или теплового потока и поверхностно-временной интегральной характеристики.

#### *Список литературы*

1. Шаталов, Ю. С. Функционально-интегральные уравнения теплофизических характеристик / Ю. С. Шаталов. – М. : Наука : ФИЗМАТЛИТ, 1996. – 256 с.
2. Власов, В. В. Метод и устройство неразрушающего контроля теплофизических свойств материалов массивных тел / В. В. Власов, Ю. С. Шаталов, А. А. Чуриков // Измер. техника. – 1980. – № 6. – С. 42 – 46.
3. Чуриков, А. А. Интегрирующие поверхностные преобразователи для контактного неразрушающего теплофизического контроля / А. А. Чуриков // Вестн. Тамб. гос. техн. ун-та. – 1998. – Т. 4, № 2–3. – С. 283 – 290.
4. Буренина, Н. А. Интегральные преобразования и измерительные устройства в теплофизическом неразрушающем контроле ортотропных материалов / Н. А. Буренина, А. А. Чуриков // Тр. ТГТУ : сб. науч. статей молодых ученых. – 1999. – Вып. 4. – С. 44 – 46.
5. Автоматические устройства для определения теплофизических характеристик материалов / В. В. Власов [и др.]. – М. : Машиностроение, 1977. – 192 с.
6. Теплофизические измерения и приборы / Е.С. Платунов [и др.] ; под общ. ред. Е. С. Платунова. – Л. : Машиностроение, Ленингр. отд-ние, 1986. – 256 с.

---

### **Method der nichtzerstörenden Kontrolle der wärmephysikalischen Eigenschaften der äußerlichen Wärmeisolierung der Erzeugnisse der zylindrischen Form**

**Zusammenfassung:** Bei den Forschungen der Komplex der wärmephysikalischen Eigenschaften der thermoisolierenden Materialien, sowohl der neuen als auch der betreibenden Erzeugnisse der zylindrischen Form, und für den Fall, wenn man die Arbeit im breiten Umfang der Veränderung der Temperatur durchgeführt werden soll, ist die entscheidende Forderung zur Methode der Messung der Komplex der wärmephysikalischen Eigenschaften die Kurzzeitweiligkeit der Durchführung des



Experimentes. Solche Art und der Charakter der Forschung gibt uns die nichtzerstörende Kontrolle der wärmephysikalischen Eigenschaften des Materials der untersuchenden Muster oder der Fertigwaren. Die Durchführung der nichtzerstörenden Kontrolle der wärmephysikalischen Eigenschaften auf dem Gebiet der wissenschaftlichen Forschungen ist mit dem wachsenden Sortiment und dem Produktionsumfang der verschiedenen Kunst-, Polymer- und Wärmeschutzmaterialien verbunden. Die schnelle wärmephysikalische Kontrolle der Eigenschaften der wieder entwickelnden Materialien in den Laborbedingungen verringert wesentlich die Zeit der Bildung und der Korrektur der Technologie der Erzeugung der gegebenen Materialien. Es wird die komplexe Methode der Einschätzung der ungleichartigen Materialien mit der zylindrischen Form, die den großen Radius der Krümmung hat, vorgeschlagen. Die Lösung der Rückaufgabe der Wärmeleitfähigkeit verwendend, kann man die Formel für die vorübergehenden Integralcharakteristik der Temperatur oder des Wärmestroms und der oberflächlich-vorübergehenden Integralcharakteristik bekommen.

---

### **Méthode du contrôle non destructif des propriétés thermophysiques de l'isolation thermique extérieure des produits de la forme cylindrique**

**Résumé:** Lors de la recherche du complexe des propriétés thermophysiques des matériaux d'isolation thermique qui étaient déjà exploités, des matériaux nouveaux et ceux de la forme cylindrique, y compris les cas de la nécessité d'une large gamme de variations de température, l'élément décisif de la méthode de mesure du complexe des propriétés thermophysiques est la courte durée de l'expérience. C'est le cas du contrôle non destructif des propriétés thermophysiques de la matière étudiée des échantillons ou des produits finis. La réalisation du contrôle non destructif des propriétés thermophysiques dans le domaine de la recherche est liée à l'augmentation de l'assortiment et du volume de la production de différents produits artificiels, polymères, de protection thermique. Le contrôle rapide réduit considérablement le temps de la création et du réglage de la technologie de la fabrication de ces matériaux. Est roposée une méthode complexe d'évaluation des matériaux hétérogènes de la forme cylindrique, avec un grand rayon de courbure. En utilisant la solution du problème inverse de conductibilité thermique, on peut obtenir une formule pour une caractéristique intégrée Temporaire de la température ou du flux thermique et de la caractéristique superficielle-temporelle intégrée.

---

**Авторы:** *Филатова Анастасия Геннадьевна* – аспирант кафедры «Мехатроника и технологические измерения»; *Чуриков Александр Алексеевич* – доктор технических наук, профессор кафедры «Мехатроника и технологические измерения»; *Дивин Александр Георгиевич* – доктор технических наук, доцент, заведующий кафедрой «Мехатроника и технологические измерения», ФГБОУ ВО «ТГТУ».

**Рецензент:** *Чернышов Владимир Николаевич* – доктор технических наук, профессор, заведующий кафедрой «Уголовное право и прикладная информатика в юриспруденции», ФГБОУ ВПО «ТГТУ».