$$q'_y\left(A_x, A_y, \omega, \varphi, b_x, b_y, U_x, U_y\right) = \frac{2}{\pi A_y}\left[\left(U_1 - U_2\right)\left(\cos\varphi\sqrt{1-\frac{b_x^2}{A_y^2}}+\sin\varphi\frac{b_x}{A_y}\right)+(3U_2-U_1)\frac{b_y}{Ay}\right]. \tag{6}$$

Висновки

Таким чином, якщо в процесі роботи автоматичної системи управління при зміні параметрів об'єкту управління в широких межах змінюється зсув фаз $\varphi(\omega)$ між вхідними сигналами релейних датчиків, то при перевищенні певного, граничного значення зсуву фаз φ (при заданих параметрах нелінійного перетворювача) змінюються послідовності перемикань вхідних сигналів автомата, що призводить до змін форми керуючого впливу, меж інтегрування (кутів перемикання) і підінтегральної функції, тобто до зміни виразів коефіцієнтів гармонічної лінеаризації. всередині інтервалів $0 < \varphi \le \varphi_2$ і $\varphi_2 < \varphi \le 90^0$ вираження коефіцієнтів гармонічної лінеаризації не змінюються.

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DETERMINING THE TRANSIENT PROCESS TIME BY THE EXAMPLE OF BODIES HEATING USING A MODIFIED HOMOCHRONICITY NUMBER

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Annotation: The general concept of the automatic control systems constructing for increasing the efficiency of the artificial cold production process in the absorption refrigerating units is substantiated. The described automatic control systems provides necessary degree of the ammonia vapor purification from the water in all absorption refrigerating units modes and minimizes heat loss from the dephlegmator surface.

Key words: Absorption refrigerating unit, dephlegmator, energy efficiency, automatic control systems.

1. INTRODUCTION

When solving technical problems, the developing processes are studied in both space and time. It is difficult to find out the analytical solution of such problems and it is typically impossible. Experimental studies and, in a certain sense, related numerical methods (computational experiment) allows obtaining the solution of problems of varying difficulty, but only in separate both time and spatial points. The discrete nature of decisions does not allow identifying all possible links of sought quantities in the space of variations. Simplifications are used in this situation, permitting to obtain analytical solutions, allowing the most important properties of the objects under study. It mostly often occurs by replacing the objects with distributed parameters with lumped models. For example, this approach is implemented in the classical automatic control theory (ACT).

Replacement of the distributed model with the lumped one could be made in such cases:

- if a process is in equilibrium with respect to the characteristic time scale of the adjoint process. In this case, the equilibrium value off the distributed model is taken as the lumped model parameter;
- if we know the nature of changes of the studied parameter in dynamics (parameter profile) in the space of the object under study. In this case, mean integral value may be taken as the lumped model parameter. This approach is implemented in [1], where the model is recorded up to some coefficient calculated at simple forms of the space under study, or to the limited number of simple experiments obtained during the process.

2. FORMULATION OF THE PROBLEM

Parameter profile is often unknown as it is the purpose of solving the problem in a distributed formulation. However, there is a group of tasks, in the solution of which we could reasonably make an assumption on the nature of the required parameter's changes in space of the object under study. It proves sufficient for determining, with some accuracy, the time of the transition process and achieving the equilibrium state by the object under study. We illustrate the possibility of such an approach by the example of heating and cooling of simple forms bodies: an infinite plate, an infinite cylinder, and sphere. There is an exact solution for this task allowing us to estimate the error value of the approximate solution.

Body's temperature during the process of its heating is regarded as a required parameter. The stage of completion of the process can be judged by the temperature deviation value in the center of the body from the ambient temperature. Initial conditions can be recorded in a common formulation [2]:

- the origin of coordinates is at the center of the body;
- the body was in equilibrium with the environment before heating and had a temperature t_0 . At the initial moment the ambient temperature changes abruptly from t_0 to $t_{срд} = const$;
- all temperatures are considered through deviations in respect to the initial body's temperature. In this case: $\vartheta_{п} = t_{п} - t_0$; $\vartheta_{ц} = t_{ц} - t_0$; $\vartheta_{срд} = t_{срд} - t_0 = const$; $\widehat{\vartheta} = \widehat{t} - t_0$.
- the most common conditions of type III are accepted as the boundary conditions.

It is well known that the process of heating & cooling of bodies is exponential. We assume that the temperature changes profile from $\vartheta_{п}$ to $\vartheta_{ц}$ although changes during the heating process by quantitative parameters, but is stored on a qualitative level, is also exponential and can be described as

$$\vartheta_{х} = \vartheta_{ц} + (\vartheta_{п} - \vartheta_{ц}) \cdot \exp(1 - l/x). \tag{1}$$

Variables $\vartheta_{ї}$ и $\vartheta_{ö}$ are unknown and are to be determined. The mean integral value of the temperature can be determined from the ratio

$$\widehat{\vartheta} = \frac{1}{V_{Т}} \int_0^l \vartheta_{х} S_{х} dx, \tag{2}$$

and the mean integral value of distance $\widehat{l}$ from the coordinates, where the temperature is conditionally implemented

$$\widehat{l} = \frac{1}{V_{Т}} \int_0^l x \cdot \exp(1 - l/x) \cdot S_{х} dx. \tag{3}$$

For example, for the sphere $S_{х} = 4\pi x^2$, and for the plate $S_{х} = S_{бок}$ - the area of one lateral side of the plate.

Let's take the heating of a plate. By virtue of its symmetry, the heating is considered through only one lateral surface and the half thickness. In this case

$$V_{Т} = S_{бок}\delta .$$

With regard to (1), expression (2) can be written as

$$\hat{\vartheta} = \frac{1}{S_{бок}\delta}\int_0^{\delta}\left[\vartheta_ц + (\vartheta_п - \vartheta_ц)\cdot\exp(1-\delta/x)\right]S_{бок}dx$$

and after transformations

$$\hat{\vartheta} = \frac{1}{\delta}\left[\vartheta_ц\delta + (\vartheta_п - \vartheta_ц)\cdot\exp(1)\cdot\int_0^{\delta}\exp(-\delta/x)dx\right]$$

or

$$\hat{\vartheta} = \frac{1}{\delta}\left\{\vartheta_ц\delta + (\vartheta_п - \vartheta_ц)\cdot\exp(1)\cdot\left[\mathrm{Ei}(-1) + 1/\exp(1)\right]\cdot\delta\right\}. \quad (4)$$

Providing, that

$$\mathrm{Ei}(z) = C + \ln(-z) + \sum_{r=1}^{\infty}\frac{z^r}{r\cdot r!} \quad npu\,(z<0) \text{ and } C = 0.5772$$

for z=(-1), we will obtain

$$\mathrm{Ei}(-1) = C + \sum_{r=1}^{\infty}\frac{(-1)^r}{r\cdot r!}.$$

Providing, that

$$\sum_{r=1}^{\infty}\frac{(-1)^r}{r\cdot r!} = -0.7966,$$

Expression (4) after the conversion can be written as

$$\hat{\vartheta} = \vartheta_ц + (\vartheta_п - \vartheta_ц)\cdot\exp(1)\cdot\left(0.5772 - 0.7966 + \frac{1}{\exp(1)}\right)$$

or

$$\hat{\vartheta} = \vartheta_ц + (\vartheta_п - \vartheta_ц)\cdot 0.396$$

and rounding

$$\hat{\vartheta} = \vartheta_ц + (\vartheta_п - \vartheta_ц)\cdot k, \quad (5)$$

where k = 0.4.

When performing the same transformations for the expression (3), we will obtain

$$\hat{\delta} = k\cdot\delta. \quad (6)$$

In view of (5) and (6), the model that describes the heating of the body, in lumped parameter can be written in the form

$$c\cdot\rho\cdot V_T\frac{d\hat{\vartheta}}{d\tau} = S_{бок}\frac{\lambda}{\hat{\delta}}(\vartheta_п - \hat{\vartheta}); \quad (7)$$

$$\frac{\lambda}{\hat{\delta}}\cdot S_{бок}\cdot(\vartheta_п - \hat{\vartheta}) = \alpha\cdot S_{бок}\cdot(\vartheta_{срд} - \vartheta_п). \quad (8)$$

Equation (7) expresses the law of energy conservation. The right hand side determines the energy transferred inside from the border (body's surface) due to the difference (head) of the thermodynamic force potential (temperature difference). The left hand side determines the energy accumulated with respect to the capacity (thermal capacity) of the body. Equation (8) describes the boundary condition of type III and expresses the energy balance. The right-hand side describes the energy transferred from the environment to the body. The left-hand side, as in the previous equation, depicts the energy drawn from the surface inside the body.

Let's perform the transformation of equations (7) and (8). For this purpose, we plug (8) in (7)

$$\frac{d\hat{\vartheta}}{d\tau} = \frac{a}{\delta^2}\cdot\frac{S_{бок}\cdot\delta}{V_T}\cdot Bi\cdot(\vartheta_{срд} - \vartheta_п). \quad (9)$$

Next, while using (5) and (6) from (8), we will obtain

$$\vartheta_n = \frac{k\cdot\mathrm{Bi}\cdot\vartheta_{срд} + (1-k)\cdot\vartheta_ц}{(1-k) + k\cdot\mathrm{Bi}} \quad (10)$$

and plugging (10) in (5)

$$\widehat{\vartheta} = k \cdot \left[\frac{k \cdot \mathrm{Bi} \cdot \vartheta_{срд} + \dfrac{1-k}{k} \cdot \vartheta_{ц} \cdot (1 + k \cdot \mathrm{Bi})}{(1-k) + k \cdot \mathrm{Bi}} \right] \quad (11)$$

Let's replace variables $\widehat{\vartheta}$ and ϑ_n in (9) with their expressions (10) and (11). Given that $\vartheta_{срд} = const$ and $\vartheta_{ц}$ – is a variable in the heating process, we will ultimately obtain

$$\frac{d\vartheta_{ц}}{d\tau} = \frac{a}{\delta^2} \cdot \frac{S_{бок} \cdot \delta}{V_T} \cdot \frac{\mathrm{Bi}}{1 + k \cdot \mathrm{Bi}} \cdot (\vartheta_{срд} - \vartheta_{ц}) \quad (12)$$

By normalization we will bring equation (12) to nondimensionalized form. Temperatures will be normalized by value $\vartheta_{срд} = const$, ie,

$$\overline{\vartheta}_{ц} = \frac{\vartheta_{ц}}{\vartheta_{срд}} = \frac{t_{ц} - t_0}{t_{срд} - t_0}, \qquad \overline{\vartheta}_{срд} = \frac{\vartheta_{срд}}{\vartheta_{срд}} = \frac{t_{срд} - t_0}{t_{срд} - t_0} = 1,$$

and time with the complex

$$\frac{a}{\delta^2} \cdot \frac{S_{бок} \cdot \delta}{V_T} \cdot \frac{\mathrm{Bi}}{1 + k \cdot \mathrm{Bi}}.$$

As a result, the equation (12) takes the form

$$\frac{d\overline{\vartheta}_{ц}}{d\widehat{Ho}} = 1 - \overline{\vartheta}_{ц} \quad \text{or} \quad \frac{d\overline{\vartheta}_{ц}}{d\widehat{Ho}} + \overline{\vartheta}_{ц} = 1, \quad (13)$$

where

$$\widehat{\mathrm{Ho}} = \frac{a\tau}{\delta^2} \cdot \frac{S_{бок} \cdot \delta}{V_T} \cdot \frac{\mathrm{Bi}}{1 + k \cdot \mathrm{Bi}} \quad \text{или} \quad \widehat{\mathrm{Ho}} = \mathrm{Fo} \cdot \frac{S_{бок} \cdot \delta}{V_T} \cdot \frac{\mathrm{Bi}}{1 + k \cdot \mathrm{Bi}} \quad (14)$$

Usually, the similarity criterion Fo, which is also called the homochronicity number, appears in nonstationary heat transfer problems as a normalized time. By analogy, we will call the expression (14) as a modified homochronicity number. It comprises complex $\frac{S_{бок} \cdot \delta}{V_T}$ that depends on the geometry of the heated body, and also complex $\frac{\mathrm{Bi}}{1 + k \cdot \mathrm{Bi}}$ that depends on the criterion Bi and the coefficient $k = 0.4$ due to the selected profile form of a temperature variation.

Let us analyze the result obtained. Expression (13) is the equation of the inertial unit in the ACT and has a solution in the form

$$\overline{\vartheta}_{ц} = 1 - \exp(-\widehat{\mathrm{Ho}}). \quad (15)$$

It was obtained for the case of an infinite plate. However, the presuppositions are the same for the plate as for an infinite cylinder and sphere. The difference is only in complex $\frac{S_{бок} \cdot \delta}{V_T}$ from (14) that depends on the form of the body in question. We define its value bearing in mind that radius is adopted as the characteristic dimension in case of a cylinder or a sphere:

- for a plate

$$\frac{S_{бок} \cdot \delta}{V_T} = \frac{S_{бок} \cdot \delta}{S_{бок} \delta} = 1; \quad (16)$$

- for an infinite cylinder

$$\frac{S_{бок} \cdot R}{V_T} = \frac{2\pi RL \cdot R}{\pi R^2 L} = 2; \quad (17)$$

- for the sphere

$$\frac{S_{бок} \cdot R}{V_T} = \frac{4\pi R^2 \cdot R}{4/3\, \pi R^3} = 3. \quad (18)$$

Let us apply the solution (15) with regard to (14), (16), (17) and (18) to estimate the final time of the transition process for the heating of bodies. We will compare data with the known results of exact solutions [2]. In the ACT, because of (15), the transition process is considered to be completed at $\widehat{\mathrm{Ho}}=3$. This corresponds to a deviation of the sought quantity (in this case $\overline{\vartheta}_ц$) from its maximum possible value (in this case 1) by not more than 5%, i.e. $\overline{\vartheta}_ц=0.95$.

For this case, from (14)

$$\mathrm{Fo}_1=\frac{\widehat{\mathrm{Ho}}}{\frac{S_{бок}\cdot\delta}{V_T}\cdot\frac{\mathrm{Bi}}{1+\mathrm{k}\cdot\mathrm{Bi}}} \tag{19}$$

In [2] the cooling of the body is under consideration. The heating and cooling processes are symmetrical. We shall determine Fo_2 for the case $\overline{\vartheta}_ц=0.05$. Fo_1 and Fo_2 comparison results, and consequently the final time for the heating process, based on the relative error, are given in Table 1.

Table 1 - Comparison of exact and approximate computation of the final time for the heating process

Bi	Plate			Cylinder			Sphere		
	Fo_2, [2]	Fo_1, calculation (14)	ε , %	Fo_2, [2]	Fo_1, calculation (14)	ε , %	Fo_2, [2]	Fo_1, calculation (14)	ε , %
0,005	600,34	601,2	**0,14**	300,06	300,6	**0,18**	200,1	200,4	**0,17**
0,01	300,9	301,2	**0,09**	150,4	150,6	**0,15**	100,20	100,4	**0,20**
0,1	31,12	31,2	**0,26**	15,48	15,6	**0,78**	10,29	10,4	**1,1**
1,0	4,200	4,2	**~0**	2,02	2,1	**4,0**	1,31	1,4	**6,7**
10	1,58	1,5	**5,1**	0,725	0,75	**3,4**	0,45	0,5	**10,2**
100	1,34	1,23	**8,1**	0,612	0,615	**0,56**	0,38	0,41	**7,5**
1000	1,32	1,2	**8,5**	0,601	0,602	**0,13**	0,37	0,400	**7,3**

Coefficient $k=0.4$ in (14) is designed for the temperature changes profile (1) in the plate, but the best result (the relative deviation value), as compared with the exact solution, has been obtained for the cylinder. This could express of the fact that the temperature changes profiles in the bodies of various forms are of common nature, but at the same time possess some features, which are difficult to consider in calculations. In [1] it has been noted that in such case few in number experiments can be applied to determine (verify) integral coefficients while maintaining the overall form of the analytic expressions. Results of the exact solutions can be taken as the above-mentioned experiments in the case under question. Thus, instead of the common value $k=0.4$, the use of its minor variations ($k=0.42$ - for plate, $k=0.39$ - for cylinder, $k=0.36$ - for sphere) gives the results shown in Table. 2.

Table 2 - Comparison of exact and approximate final time for the heating process after factor k modification

Bi	Plate $k=0.42$			Cylinder $k=0.39$			Sphere $k=0.36$		
	Fo_2, [2]	Fo_1, calculation (14)	ε , %	Fo_2, [2]	Fo_1, calculation (14)	ε , %	Fo_2, [2]	Fo_1, calculation (14)	ε , %
0,005	600,34	601,26	**0,15**	300,06	300,6	**0,18**	200,1	200,4	**0,15**
0,01	300,9	301,3	**0,1**	150,4	150,6	**0,15**	100,20	100,36	**0,17**
0,1	31,12	31,26	**0,5**	15,48	15,59	**0,7**	10,29	10,36	**0,7**
1,0	4,200	4,26	**1,4**	2,02	2,085	**3,3**	1,31	1,36	**3,7**
10	1,58	1,56	**1,3**	0,725	0,735	**1,3**	0,45	0,46	**1,4**
100	1,34	1,29	**3,6**	0,612	0,6	**1,9**	0,38	0,37	**3,0**
1000	1,32	1,26	**3,9**	0,601	0,587	**2,36**	0,37	0,36	**3,4**

Within the entire range of Bi alteration for all the reviewed bodies, the final time for the heating process that calculated by using the proposed model in a lumped formulation differs from the results of exact solution of the model in a distributed formulation by less than 4%, i.e. it corresponds to the permissible accuracy of engineering evaluations. Additionally, the end of transition period is defined by a single value $\widehat{\mathrm{Ho}}=3$, while in [2] in this case each body and each value Bi corresponds to their own value Fo.

Thus, one expression (15) and two coefficients (Table. 3) can determine the final time for the heating of bodies of the forms under consideration.

Table 3 - Form coefficient

	$\frac{S_{бок} \cdot l}{V_T}$	k
Plate	1	0,42
Cylinder	2	0,39
Sphere	3	0,36

In addition to solving the basic task of definition of the transition process end-point at heating the body, the proposed model allows evaluating:

- temperature value $\overline{\vartheta}_ц$ in the center of the body (15) at any given time;
- temperature value on the surface of the body $\overline{\vartheta}_п$. Do this requires normalizing the expression (10) with the help of $\vartheta_{срд}$. In this issue, with provision for (15), we obtain

$$\overline{\vartheta}_п = \frac{k \cdot \mathrm{Bi} + (1-k) \cdot \overline{\vartheta}_ц}{(1-k) + k \cdot \mathrm{Bi}} = 1 - \frac{\exp(-\widehat{\mathrm{Ho}})}{1 + \frac{k}{1-k}\mathrm{Bi}}; \quad (20)$$

- temperature value at any point of the body. Do this requires normalizing the expression (10) with the help of $\vartheta_{срд}$. In this issue, with provision for (15) and (20), we obtain

$$\overline{\vartheta}_x = 1 - \left[1 - \frac{\mathrm{Bi}}{\left(\frac{1}{k} - 1 + \mathrm{Bi}\right)} \cdot \exp(1 - \frac{1}{x})\right] \cdot \exp(-\widehat{\mathrm{Ho}}); \quad (21)$$

- value Bi at different time or the time point at different Bi, at starting with which the heating process can be described by lumped model, i.e. in this case, temperature difference on the surface and in the center of the body will be less than a prescribed value that has been written, for example, in the relative form

$$\frac{t_п - t_ц}{t_{срд} - t_0} = \frac{(t_п - t_0) - (t_ц - t_0)}{t_{срд} - t_0} = \frac{\vartheta_п - \vartheta_ц}{\vartheta_{срд}} = \overline{\vartheta}_п - \overline{\vartheta}_ц < f$$

Providing for (15) and (21), we obtain

$$\overline{\vartheta}_п - \overline{\vartheta}_ц = \frac{\mathrm{Bi}}{\left(\frac{1}{k} - 1 + \mathrm{Bi}\right)} \cdot \exp(-\widehat{\mathrm{Ho}}) < f$$

For instance, the value $f = 0.1$ indicates the following: temperature difference on the surface and in the center of the heated body does not exceed 10% of the value $t_{срд} - t_0$ at the given body's thermophysical properties and conditions of heat exchange with the surrounding environment at a given moment of time.

3. CONCLUSION

A unified solution in the form (15) for bodies of different forms has been obtained because of:

- transition to a model in a lumped formulation;
- transition from the similarity criteria to similarity numbers at recording the model in nondimensionalized form. Such transition allows reducing the number of variables defined by

π-theorem (Buckingham π theorem) by the number of similarity criteria.

Thus, solution of the considered problem in [2] depends on the form of nondimensionalized time in form of a similarity number Fo and similarity criterion Bi, i.e. on 2 variables. Therefore, solution is represented as a set of curves in graphic form for each form of the body and the point under consideration in its space. In the proposed solution (15), the sought value depends only on nondimensionalized time in form of a modified homochronicity number $\widehat{\mathrm{Ho}}$, and can be mapped as one curve in graphic form.

Expression (15) is valid for different forms of the bodies examined. This gives grounds for assumptions about its validity equal for arbitrary body form. At that, the values of coefficient k and complex $\frac{S_{бок} \cdot R}{V_T}$ can be obtained, as already has been noted above, from few in number experiments. Confirmation of the latter thesis can serve as a basis for the continued work and study.

4. NOTATIONS

$a=\lambda/(c\cdot\rho)$ - temperature conductivity coefficient; $\mathrm{Bi}=(\alpha\cdot\delta)/\lambda$ -Biot similarity criterion; C - Euler constant; c - the heated body's material heat capacity; $\mathrm{Ei}(z)$ - integral exponential function; $\mathrm{Fo}=(a\cdot\tau)/\delta$ - Fourier similarity number; l - the typical size of the body; R - radius of the cylinder and sphere; S_x - area of the layer parallel to the surface of the body at a distance x from the origin of coordinates; t_0 - ambient and body temperature before heating ($_0$- zero); $t_{срд}$ - ambient temperature after the heating starts ($_{срд}$ - environment); t_n - surface temperature of the body during heating ($_n$ - surface); $t_ц$ - temperature in the center of the body during heating ($_ц$ - center); t_x - temperature at an arbitrary point of the body in the direction of x co-ordinate; $\hat{t}$ - Mean integral body temperature during heating; V_T - volume of the heated body; α - heat transfer coefficient from the surrounding media to the body; δ - ½ of the plate's thickness; λ - thermal conductivity of the body material; ρ - density; ϑ - current temperature deviation at the selected point from the temperature before heating; τ - heating process time.

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THE AUTOMATION SYSTEM OF ACCOUNTING SPORTING ACTIVITIES

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Анотація: Останнім часом стає популярним здоровий спосіб життя. Спорт є діяльність, яка служить інтересам суспільства, реалізуючи виховну, підготовчу і комунікативну функції, але не є постійною спеціальністю (професією) людини. Розвиток актуальних видів спорту, вимагає ресурсів, які будуть не тільки автоматизувати роботу організаторів змагань з інформацією, а й підвищать її ефективність. Одним з прогресуючих видів спорту на даний момент є пауерліфтинг (силове триборство). Пропонується інформаційна система автоматизованого робочого місця організатора змагань. В ході реалізації інформаційної системи супроводу спортивних змагання було виконано проектування системи за допомогою UML діаграм. Це дозволило зрозуміти завдання, які необхідно виконати при реалізації програми. Програму організована таким чином, щоб можна було швидко і просто внести всі дані про майбутні змагання: назва, місце проведення, дати, склад рефері. Після отримання інформації про спортсменів, тренерів, спортклубах, внести заявку на участь в змаганні. Також організатор має можливість переглядати статистичні дані про тренерів, рефері, учасників на основі введеної раніше інформації в базу