Definition 6. We will define the search efficiency loss record coefficient in CFPs as $p = \frac{\sum |S_i|}{|S^*|} = \frac{\sum |S_i|}{|S^*|} \cdot \frac{|S|}{|S|} = r \cdot \sum \frac{1}{r_i}$. It equals the average number of "malfunctioning" heuristics at any given moment of calculations.

We will introduce time cost estimation as $t = p \cdot \frac{|S|}{r}$ i.e. we suppose that the bigger the reduced space is and the bigger the losses because of inefficient calculations in CFPs, the longer the calculations will take. This estimation characterizes the time cost expressed through conventional units. However, it neglects both time complexity of the heuristics and their work character.

Thus it is easy to see that the main merits of the local evolutional approach is a relatively short time for the search for a quasi-optimal solution, it depends directly on the losses due to the inefficient work of the heuristics in CFPs. That is why with regard to the heuristic work character it is usually possible to suggest heuristic management strategy for the time of calculations. The aim of such strategy is to minimize the presence in CFPs thus reducing time loss due to inefficient calculations.

REFERENCES

1. Зайцев, И.Д. Моделирование процессов автоматизированного химико-технологического проектирования / И.Д. Зайцев. – М. : Издательство: Химия, 1976. – 184 с.
2. Эвристические методы календарного планирования / Т.П. Подчасова [и др.] – Киев : Техника, 1980. – 140 с.
3. Глухов, А.О. Использование рекурсивных эвристик при решении задач дискретной оптимизации большой размерности / А.О. Глухов, В.В. Трофимов // Современные проблемы менеджмента: межвуз. сб. Выпуск 6. – СПб. : Изд-во СПбГУЭФ, 2003. – С. 99–105.
4. Математические основы цифровой техники / В.М. Муттер [и др.]. – СПб. : Литера плюс, 1999. – 351 с.
5. Норенков, И.П. Использование метода комбинирования эвристик для решения транспортной задачи с временными окнами / И.П. Норенков, О.Т. Косачевчкий // Сборник докладов. Международная конференция по мягким вычислениям и измерениям. – СПб., 1998. – Т. 1.

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CONTRIBUTION OF THE AMENDMENT OF THE FIFTH ORDER IN THE ASYMPTOTICS OF FUNCTION OF DISTRIBUTION COORDINATE OF THE ELEMENTARY ACT OF SORPTION

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The problem of dynamics of sorption is the cornerstone of many chemical and nature protection technologies connected with the cleaning of harmful emissions. To model this process we use the equations of mathematical physics. Thus let's solve the system of the differential equations in the private derivatives describing kinetics of sorption and balance of absorbed impurity. For linear isotherms and standard regional conditions such a system (see [1]) is reduced to the equation

$$-\omega'_{\xi} = e^{-\tau}\left(e^{-\xi} + \int_0^{\tau} e^{\tau} d_{\tau}\omega\right), \tag{1}$$

where ω – the given concentration of absorbed substance, ξ and τ – the respectively dimensionless coordinate and time [2].

It is obvious that the elementary act of sorption – a casual event. The respectively dimensionless concentration $\omega(\xi,\tau)$ can be interpreted as statistical probability of penetration of particles of impurity in absorbing layer on depth ξ. Respectively $1-\omega(\xi,\tau)$ – probability of absorption of a molecule such layer of a sorbent, and

$$f(\xi,\tau) = \frac{\partial(1-\omega(\xi,\tau))}{\partial\xi} = -\omega'_{\xi}(\xi,\tau) \tag{2}$$

– density of probability of the elementary act of sorption.

Using (1), it is possible to find the initial moments of a random variable without solving the equation (see [3])

$$\nu_n(\tau) = n!\sum_{k=0}^{n}(-1)^k \frac{\tau^k}{k!}\sum_{l=0}^{k} C_{n+1}^{l}(-1)^l \ , \quad (n = 0,1,2,...) \tag{3}$$

where C_{n+1}^{l} – the numbers of combinations. Knowing the initial moments $\nu_n(\tau)$, it is easy to find the corresponding central moments

$$\mu_n(\tau) = \sum_{i=0}^{n}(-1)^i C_n^{n-i}\cdot \nu_{n-i}(\tau)\cdot \nu_1^i(\tau) \ . \tag{4}$$

The knowledge of all moments of a random variable is equivalent to the knowledge of its function of distribution. On the basis of this fact in [3] we receive that under $\tau \geq 18$ the random variable is distributed under the law close to the normal

$$f(\xi,\tau) \xrightarrow[\tau\to\infty]{} f_N(\xi,\tau) = \frac{1}{\sqrt{2\pi}\sigma(\tau)} e^{-\frac{(\xi - m(\tau))^2}{2\sigma(\tau)^2}} \ , \tag{5}$$

dependence on time of its parameters

$$m(\tau) = \tau + 1 \ , \qquad \sigma(\tau) = \sqrt{2\tau + 1} \ . \tag{6}$$

We will define a deviation of asymptotic expression (5) from differential function of distribution at final times

$$f(\xi,\tau) = f_N(\xi,\tau)\cdot\left(1+\varphi(\xi,\tau)\right) , \tag{7}$$

where $\varphi(\xi,\tau)$ – the relative error arising at replacement $f(\xi,\tau)$ with the normal law.

The amendments $\varphi(\xi,\tau)$ caused by asymmetry and an excess are in [3]

$$\varphi(\xi,\tau) = \sum_{n=1}^{\infty}\frac{\varphi_n(x(\xi,\tau))}{\sigma^n(\tau)} \ , \tag{8}$$

where $\varphi_n(x)$ – some functions which are subject to definition.

Functions $\varphi_n(x)$ are the polynoms which senior degree is multipled to three [3]

$$\varphi_n(x) = \sum_{k=0}^{3n} c_{nk}x^k \ , \tag{9}$$

where c_{nk} – unknown numerical coefficients. Polynoms $\varphi_{2n-1}(x)$ contain only odd degrees x and give a contribution to asymmetry $f(\xi,\tau)$. Similar to $\varphi_{2n}(x)$ – are even functions x and provide an excess $f(\xi,\tau)$

$$\varphi_{2n-1}(x) = \sum_{k=0}^{3n-2} c_{2n-1\,2k+1}x^{2k+1} \ ; \qquad \varphi_{2n}(x) = \sum_{k=0}^{3n} c_{2n\,2k}x^{2k} \ . \tag{10}$$

Developing probability-theoretic approach to modeling of dynamic sorption activity, we will show that $\varphi_n(x)$ with any number decide on the help of the central moments of a random variable of coordinate of the elementary act of sorption ξ (see 4). It is convenient to pass into the system of coordinates connected with working layer of a sorbent and as the characteristic size to use a mean square deviation

$$x(\xi,\tau) = (\xi - m(\tau))/\sigma(\tau) \ . \tag{11}$$

From (9) we will pick up coefficients c_{nk} so that identities were carried out

$$\frac{\mu_i(\tau)}{\sigma(\tau)^i} \equiv \int_0^{\infty}\left(\frac{\xi - m(\tau)}{\sigma(\tau)}\right)^i f(\xi,\tau)d\xi, \ (i = 0,1,2,3,...) \ . \tag{12}$$

Having substituted (5), (7), (8) in (12) and having executed variable replacement, we will receive

$$\frac{\mu_i(\tau)}{\sigma(\tau)^i} \equiv \int\limits_{-\frac{m(\tau)}{\sigma(\tau)}}^{\infty} x^i \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}} \left(1+\sum_{n=1}^{\infty}\frac{\varphi_n(x)}{\sigma^n(\tau)}\right) dx \,. \tag{13}$$

On the bottom limit of identity (13) arises -∞, as the population mean $m(\tau)$ grows over time quicker than a mean square deviation $\sigma(\tau)$ (see(6)). Taking into account this circumstance (13) we will receive

$$\frac{\mu_i(\tau)}{\sigma(\tau)^i} \equiv \int\limits_{-\infty}^{\infty} x^i \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}} \left(1+\sum_{n=1}^{\infty}\frac{\varphi_n(x)}{\sigma^n(\tau)}\right) dx \,. \tag{14}$$

Equating coefficients at identical degrees $\sigma(\tau)$ in the left and right parts (14) for even i we will receive on one equation concerning all $\varphi_n(x)$ with even numbers, and at odd i – on one equation concerning all $\varphi_n(x)$ with odd numbers. The ratio (14) allows us to calculate $\varphi_n(x)$ with any number. For example, passing $\varphi_1(x), \varphi_2(x), \varphi_3(x)$ evaluation and $\varphi_4(x)$, we will find at once $\varphi_5(x)$ (see (10))

$$\varphi_5(x) = c_{51}x + c_{53}x^3 + c_{55}x^5 + c_{57}x^7 + c_{59}x^9 + c_{5,11}x^{11} + c_{5,13}x^{13} + c_{5,15}x^{15} \,. \tag{15}$$

Integrals in the right part (14) at coefficients of c_{5k} will be other than zero for odd i. Taking into account a type of the right part (15), we will need eight linearly independent equations (14) with odd numbers (i=1,3,5,7,9,11,13,15). Thus in the left part (14) it is convenient to mark out obvious dependence of the central moments from $\sigma(\tau)$.

$$\begin{gathered}
\frac{\mu_1(\tau)}{\sigma(\tau)^1}=0,\quad \frac{\mu_3(\tau)}{\sigma(\tau)^3}=\frac{3}{\sigma(\tau)}-\frac{1}{\sigma(\tau)^3},\quad \frac{\mu_5(\tau)}{\sigma(\tau)^5}=\frac{30}{\sigma(\tau)}+\frac{50}{\sigma(\tau)^3}-\frac{36}{\sigma(\tau)^5},\\
\frac{\mu_7(\tau)}{\sigma(\tau)^7}=\frac{315}{\sigma(\tau)}+\frac{2415}{\sigma(\tau)^3}+\frac{714}{\sigma(\tau)^5}-\frac{1590}{\sigma(\tau)^7},\quad \frac{\mu_9(\tau)}{\sigma(\tau)^9}=\frac{3780}{\sigma(\tau)}+\frac{74340}{\sigma(\tau)^3}+\frac{213192}{\sigma(\tau)^5}-\frac{63792}{\sigma(\tau)^7}-\frac{94024}{\sigma(\tau)^9},\\
\frac{\mu_{11}(\tau)}{\sigma(\tau)^{11}}=\frac{51975}{\sigma(\tau)}+\frac{2061675}{\sigma(\tau)^3}+\frac{15758820}{\sigma(\tau)^5}+\frac{21516660}{\sigma(\tau)^7}-\frac{18051220}{\sigma(\tau)^9}-\frac{6653340}{\sigma(\tau)^{11}},\\
\frac{\mu_{13}(\tau)}{\sigma(\tau)^{13}}=\frac{810810}{\sigma(\tau)}+\frac{56486430}{\sigma(\tau)^3}+\frac{859999140}{\sigma(\tau)^5}+\frac{3622853520}{\sigma(\tau)^7}+\frac{2150285280}{\sigma(\tau)^9}-\frac{4006270632}{\sigma(\tau)^{11}}-\frac{393371616}{\sigma(\tau)^{13}},\\
\frac{\mu_{15}(\tau)}{\sigma(\tau)^{15}}=\frac{14189175}{\sigma(\tau)}+\frac{1584457875}{\sigma(\tau)^3}+\frac{41528877390}{\sigma(\tau)^5}+\frac{356114508750}{\sigma(\tau)^7}+\frac{935959124100}{\sigma(\tau)^9}+\frac{58146919740}{\sigma(\tau)^{11}}-\\
-\frac{957880837200}{\sigma(\tau)^{13}}+\frac{45599275904}{\sigma(\tau)^{15}}.
\end{gathered} \tag{16}$$

We will equate in these eight equations coefficients at $\sigma(\tau)^{-5}$ on the left and on the right, we will receive

$$\left.\begin{aligned}
&\frac{1}{\sqrt{2\pi}}\int\limits_{-\infty}^{\infty} x^1 e^{-\frac{x^2}{2}}\varphi_5(x)dx=0, && \frac{1}{\sqrt{2\pi}}\int\limits_{-\infty}^{\infty} x^9 e^{-\frac{x^2}{2}}\varphi_5(x)dx=213192,\\
&\frac{1}{\sqrt{2\pi}}\int\limits_{-\infty}^{\infty} x^3 e^{-\frac{x^2}{2}}\varphi_5(x)dx=0, && \frac{1}{\sqrt{2\pi}}\int\limits_{-\infty}^{\infty} x^{11} e^{-\frac{x^2}{2}}\varphi_5(x)dx=15758820,\\
&\frac{1}{\sqrt{2\pi}}\int\limits_{-\infty}^{\infty} x^5 e^{-\frac{x^2}{2}}\varphi_5(x)dx=-36, && \frac{1}{\sqrt{2\pi}}\int\limits_{-\infty}^{\infty} x^{13} e^{-\frac{x^2}{2}}\varphi_5(x)dx=859999140,\\
&\frac{1}{\sqrt{2\pi}}\int\limits_{-\infty}^{\infty} x^7 e^{-\frac{x^2}{2}}\varphi_5(x)dx=714, && \frac{1}{\sqrt{2\pi}}\int\limits_{-\infty}^{\infty} x^{15} e^{-\frac{x^2}{2}}\varphi_5(x)dx=41528877390.
\end{aligned}\right\} \tag{17}$$

Having substituted in (17) decomposition (15) and having executed integration on x, we will receive the system of the linear algebraic equations of rather unknown coefficients written down in a matrix form $c_{5\ 2k+1}$, k=0,1,…,7

$$\hat{A}^{(8)} \cdot \begin{pmatrix} c_{51} \\ c_{53} \\ c_{55} \\ c_{57} \\ c_{59} \\ c_{5,11} \\ c_{5,13} \\ c_{5,15} \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ -36 \\ 714 \\ 213192 \\ 15758820 \\ 859999140 \\ 41528877390 \end{pmatrix}, \tag{18}$$

where $\hat{A}^{(n)} = \begin{pmatrix} I_1 & . & . & I_n \\ I_2 & . & . & I_{n+1} \\ . & . & . & . \\ I_n & . & . & I_{2n-1} \end{pmatrix}$, a $I_m = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} x^{2m} e^{-\frac{x^2}{2}} dx = 1 \cdot 3 \cdot 5 \cdot \ldots \cdot (2m-1),\ m = 1, 2, 3, \ldots$.

The only decision (18) is the set of numbers

$$c_{51} = -\frac{487}{256}, \quad c_{53} = \frac{630}{53}, \quad c_{55} = -\frac{3964}{173}, \quad c_{57} = \frac{1360}{93},$$
$$c_{59} = -\frac{508}{141}, \quad c_{5,11} = \frac{97}{256}, \quad c_{5,13} = -\frac{13}{768}, \quad c_{5,15} = \frac{1}{3840}. \tag{19}$$

We will emphasize that the system for their receiving was certain and thus we in any way didn't use information about $\varphi_1(x), \varphi_2(x), \varphi_3(x)$, $\varphi_4(x)$.

The fifth amendment defined by formulas (15), (19) adequately approaches a deviation of the $\Delta_5 = f - f_N(1 + \varphi_1 + \varphi_2 + \varphi_3 + \varphi_4)$ fourth approach from distribution function $f(\xi, \tau)$ (fig. 1).

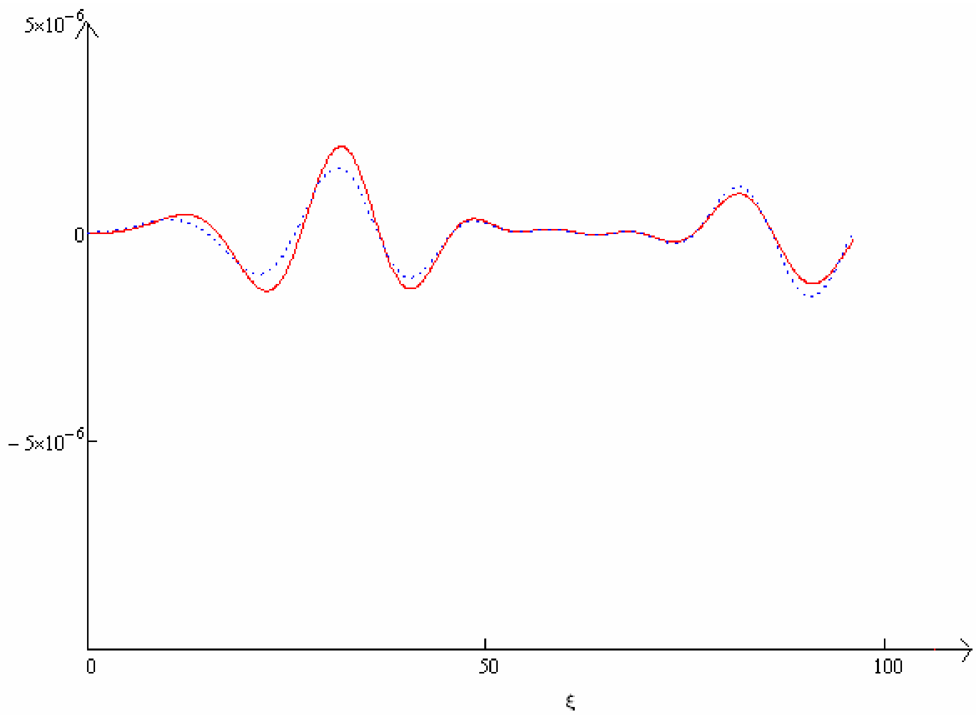

Fig. 1 –Function deviation $f(\xi,60)$ from the fourth approach (a continuous curve) and a contribution of the amendment to its fifth order on σ^{-5} (a dotted line)

REFERENCES

1. Ехилевский, С.Г. О формировании квазистационарного профиля концентрации CO_2 при фильтрации выдыхаемого воздуха через кислородсодержащий продукт регенеративного патрона / С.Г. Ехилевский, С.М. Ткачев // Вестн. Полоц. гос. ун-та. Серия В. Промышленность. Прикладные науки. – 2008.– №8. – С. 115 – 120.
2. Пак, В.В. Об использовании ресурса шахтных респираторов с химически связанным кислородом / В.В. Пак, С.Г. Ехилевский // Изв. вузов. Горный журнал. – 1996. – №1.– С. 66 – 71.
3. Ехилевский, С.Г. Вклад высших моментов случайной величины в асимптотику функции распределения / С.Г. Ехилевский, Д.В. Пяткин // Вестн. Полоц. гос. ун-та. – 2009. – №3. – С. 100 – 108.

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MATHEMATICAL MODEL OF THE FIXED OXYGEN BREATHING APPARATUS WITH A CIRCULAR AIRWAY SCHEME

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The research deals with the influence of the CO_2 *breakthrough on the dynamic sorption activity of the regenerative cartridge of fixed oxygen breathing apparatus with a circular airway scheme. It is illustrated that the breakthrough return during breath at the later stages of the apparatus operation is essential and depending on the apparatus model or its operating regime noticeably (up to 10%) reduces its protection term.*

The atmosphere in the fixed oxygen breathing apparatus regenerates in the process of the exhaled air filtration through the regenerative cartridge with porous granules of potassium superoxide-based oxygen-containing product. As a result of the CO_2 chemisorption in the proportion close to ideal the oxygen necessary for breathing is produced

$$4KO_2 + 2CO_2 = 2K_2CO_3 + 3O_2 + 360\text{ kJ}, \tag{1}$$

Regenerating process modeling is a classical task of sorption dynamics (see [1-3]) that traces the evolution of admixture break through the absorber layer. It is usually solved by using mathematical physics methods if there are stationary boundary conditions upon entering the filter [4]. However, the apparatus with a circular airway scheme, besides the invariable component set by the apparatus operation regime, adds the CO_2 breakthrough that steadily increases as the regenerative cartridge resources exhausts. In other words, a variable absorber concentration upon entering the absorber layer takes place. The research [5] suggests an appropriate formalism that analytically describes the dynamic sorption activity with a variable absorber concentration upon entering the filter and comes to the following equation system:

$$-\omega_{\xi}'(\xi,\tau) = e^{-\tau}\left[e^{-\xi}\omega_0(0) + \int_0^{\tau} e^{\tau} d_{\tau}\,\omega(\xi,\tau)\right], \qquad \tau > 0, \tag{2}$$

$$u(\xi,\tau) = e^{-\tau}\int_0^{\tau} e^{\tau}\omega(\xi,\tau)\,d\tau, \qquad \tau > 0, \tag{3}$$

where τ and ξ are dimensionless time and coordinate (the penetration depth in the absorber layer) respectively, $\omega(\xi,\tau)$ – reduced concentration CO_2, $\omega_0(0)$ – its initial value upon entering the filter, $u(\xi,\tau)$ – waste product ratio;

The solution (2) can be presented as a series

$$\omega(\xi,\tau) = e^{-\xi-\tau}\sum_{n=0}^{\infty}\frac{f_n(\tau)}{n!}\xi^n, \tag{4}$$

with its coefficients connected by the recurrent correlation

$$f_{n+1}(\tau) = \int_0^{\tau} f_n(\tau)\,d\tau, \tag{5}$$

and knowing that

$$f_0(\tau) = e^{\tau}\omega_0(\tau) \tag{6}$$