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THE CAUSAL RELATIONSHIPS IN THE MANAGEMENT PROCESS OF CEMENT PRODUCTION

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Ushbu maqolada, to'g'ridan-to'g'ri va teskari xarakterga ega bo'lgan sementdagi sabab-ta’sir munosabatlarga asoslangan holda, betonning siqilish kuchi asosan suvsiz birikmalarni yoqish paytida olingan reaktivlikka, silliqlash nozikligiga, ohak miqdori va boshqa oksidlarga bog'liq bo'lib, tsement sifatiga katta ta'sir ko'rsatadi xom ashyoni maydalashning nozikligi. Modellar kimyoviy tahlil natijalariga va fizik-mexanik tabiatning individual ravishda aniqlangan ma'lumotlariga, diffraktogrammalarga va fizik-kimyoviy xarakterdagi ma'lumotlarga asoslangan holda ko'rib chiqiladi.

Kalit so'zlar: boshqaruv, texnologiya, jarayon, ishlab chiqarish, tsement, sifat, algoritm, avtomatlashtirish, tegirmon, tashxis, avtomatlashtirilgan jarayonni boshqarish tizimi, qovurish, klinker.

В статье на основепричинно-следственных связей, носящих, как прямой, так и обратный характер, выявлено, что прочность бетона на сжатие в значительной степени зависит от реакционной способности полученных при обжиге безводных соединений, тонкости помола, количества свободной извести и прочих окислов, а также большое влияние на качество цемента оказывает тонкость помола сырьевых материалов.

Разработаны соответствующие модели, базирующиеся на основе результатов химического анализа и отдельных экспрессивно полученных данных физико-механического характера, на основании дифрактограмм и тех же данных физико-химического характера.

Ключевая слова: управление, технология, процесс, производство, цемент, качество, алгоритм, автоматизация, мельница, прогноз, АСУТП, обжиг, клинкер.

In the article on the basis of cause-effect relationships in cement, which are both direct and reverse in nature, it is revealed that the compressive strength of concrete largely depends on the reactivity of the anhydrous compounds obtained during firing, the fineness of grinding, the amount of free lime and other oxides, as well as a great influence on the quality of cement has a fine grinding of raw materials. Results of calculation of standard deviations. The models are obtained on the basis of the results of chemical analysis and individual expressive data of physical and mechanical character, on the basis of diffractograms and the same data of physical and chemical character.

Keywords: control, technology, process, production, cement, quality, algorithm, automation, mill, forecast, process control system, firing, clinker.

The development and implementation of automated process control systems, which give the maximum economic effect, are possible only with a systematic approach to solving automation problems, when the technological process, equipment, raw materials and automation tools are considered simultaneously and interrelated. In this case, much more information about the automated object is required than when creating local management systems. The system is understood as a complete Autonomous entity consisting of a set of interacting elements and performing a certain function [1,2]. A characteristic feature of APCS is the use of a PC. Since the APCS are multifunctional, a certain number of programs are put into the "memory" of the machine, each of which provides the implementation of a particular function of the control system [2,4]. Construction of systems of automated (automatic) control of complex objects is associated with the study of complex problems. One of them is obtaining information about the controlled object, evaluation of its parameters and characteristics, i.e. its identification [1,3,5].

The quality of cement depends on the work of three processes: raw materials, firing and grinding. In the raw material shop is determined by the quality of raw flour or sludge, ie chemistry and. Mineralogy of raw materials. The firing and cooling regime of clinker has a decisive influence on the Mineralogy of cement. During grinding, additives are used that greatly affect the quality of cement. Characteristics of the future cement largely depend on the fineness of the grinding, the presence of harmful impurities in it. Generally speaking, any process within even one redistribution affects the final characteristics of the cement. Since the previous algorithmic blocks quickly identify chemistry and Mineralogy, and the process itself provides information about the state of the governing bodies (the firing and cooling temperature, the fineness of the grinding of raw materials and clinker, the cost of materials and charge, etc.), it suggests the conclusion about the need for automatic development of the direction and ways of regulating production technology.

Currently, there is a lot of material about the type and nature of cause-effect relationships in cement, which are both direct and reverse. Here are the most important of them, in particular those that directly or indirectly affect the quality of cement and concrete prepared from it [3,4].

The compressive strength of concrete (the main characteristic) largely depends on the reactivity of the anhydrous compounds obtained during firing, the fineness of the grinding, the amount of free lime and other oxides. The compounds C_3S (alit $-3CaO \cdot SiO_2$), CA (aluminate $-CaO \cdot Al_2O_3$), $\beta - C_2S$ (Belit - $2CaO \cdot SiO_2$) have the greatest reactivity or hydraulic activity. These minerals are quickly entering into the compound with water, give the high strength of hydrate compounds. The high content of clinker $\gamma - C_2S$ and C_3A (tricalcium aluminate - $3CaO \cdot Al_2O_3$) due to their inertia leads to a decrease in its strength. Thus, it is necessary to achieve a situation in which the clinker would be dominated by C_2S, CA and reduced content C_3A and $\gamma - C_2S$. In this case, the chemical composition of the raw material is very important. If it is carefully selected, the mode of firing and cooling of the clinker becomes very important. With rapid cooling of the clinker, small crystals C_3A are formed, and with slow cooling - large and large grains, which further disintegrate into C_2S and CaO, and in the composition C_2S modification $\gamma - C_2S$ can prevail, i.e. the quality of the cement begins to deteriorate.

With stable chemical raw materials and the refrigerator mode, the firing mode is of great importance. Low temperatures cause poor passage of chemical reactions and displacement of Mineralogy aside . Too high temperatures lead to the formation of clinker rings and the destruction of the furnace. The permissible temperature range should not exceed 100-150°C.

Great influence on the quality of cement has a fine grinding of raw materials. Poor grinding and mixing lead to heterogeneity of cement grains, as a result, the content of C_3S in the clinker decreases, and C_2S increases, and the percentage of $\gamma - C_2S$ increases. With too fine grinding, clinker rings are formed and the furnace is destroyed.

The lack of air in the nozzle is the reason for the formation of a reducing atmosphere in the furnace, which in turn contributes to the formation of chemically pure iron in the clinker, leads to irregularities in the hydration process and, as a consequence, to a decrease in strength.

A small amount (up to 2%) of phosphates in the charge or fuel composition increases the hydraulic activity C_2S by reducing the content $\gamma - C_2S$ and thereby increases the strength of the concrete. At the same time, an increase P_2O_5 of more than 2% leads to a decrease in its strength.

Very harmful to the cement inclusion in its composition of periclase MgO, which in the creations leads to an uneven change in the volume of concrete, to the formation of cracks in it.

As already mentioned, the quality of cement depends on the fineness of its grinding: the thinner the grinding, the greater the specific surface area of the cement particles, higher its ability to hydrate, greater strength and better quality (with rapid cooling of the clinker).

The heat of hydration is usually associated with the possibility of laying concrete in the cold. The greatest heat of hydration (three. times more than C_2S) possess C_3S and C_3A. Concrete made of clinkers with a high content of C_3S and C_3A is more appropriate for use in the Northern regions. The increased content of concrete C_3A increases its chemical resistance.

Ensuring the necessary dosage of components (calcium, silicon, aluminum and iron oxides) in the raw mixture entering the furnace is the main task of regulating the composition of cement. The main function of APCS dosing and preparation of the mixture is to ensure the homogeneity of the raw material and its compliance with the specifications. In this case, the efficiency of the system depends on the quality of the feedstock, i.e. the possibility without automated control to obtain the desired composition of the mixture, which after mixing is practically impossible to adjust.

The most famous of the ACS operation of the dosages provides for periodic laboratory tests and manually enter in the PC data on the composition of the raw mix. In this case, the main task is to achieve a given composition in each load. Fluctuations in the composition in one load are eliminated by homogenization using a mobile Elevator, air flow (dry method) or mixing in the sludge (wet method).

The prepared raw material is usually fired in rotary kilns, where efficient and timely heat transfer to the material and its removal are carried out. The need for automated control of the rotary kiln is explained by the fact that the characteristics of raw materials, fuel and equipment change over time, and this requires appropriate changes in the operating parameters of the kiln.

Disturbances are often short-lived and

difficult to control. The operator waits for the moment when the total effect of disturbances will cause a stable deviation of the process mode from the normal, and then begins to affect the process. However, since the process is multifactorial and insufficiently studied, the parameters must be adjusted continuously, which the operator is not able to do without a PC.

Adjustable parameters of the furnace are: the rotation speed of the kiln (the time of passage of materials through the furnace); the feed rate into the furnace (furnace performance); fuel consumption; exhaust gas flow rate; the flow rate of primary combustion air; a dust return of the collectors of the furnace.

The operation of the clinker cooler is a part of the furnace operation as the recycled heat is used to heat the secondary air (fuel utilization rate increases). To control the operation of the refrigerator, it is necessary to regulate the air supply, separate the hot air entering the furnace from the outgoing and change the speed of one or more grate.

The refrigerator oven system is the most complex multi-factor control object. As experience shows, the development of a correct mathematical model and control algorithm requires serious research of process control systems in real industrial conditions.

Grinding is performed by three units: a mill, an Elevator delivering mill products to the separator, and a separator sorting the material by size. The main control parameters of the grinding are the feed rate of the material into the mill and the productivity of the separator. With automated grinding control based on the control of power consumption - mill, Elevator and separator, as well as temperature, the feed rate is adjusted to ensure maximum product yield at a given granulometric composition or a given specific surface area.

Thus, the tasks of enterprise management can be formulated as tasks of optimization of the corresponding technological processes. Process optimization criteria are interrelated and must comply with the technical and economic criteria of the enterprise. It is this generalized criterion that we have defined. This is the minimum permissible activity of clinker or cement (output parameter of cement production). The output values of all the repartitions are assumed to be stable, except for one, which can be adjusted according to the proposed models and ratios. Having thus obtained the value of the output value, we can begin to consider the control algorithms directly by the Department.

We show the principles of construction of control algorithms and connection of the developed system with the schemes of local controls on the example of cement grinding.

The grinding process can be represented in the form of Autonomous technological system including a management apparatus, a classifier, a transport device nodes loading

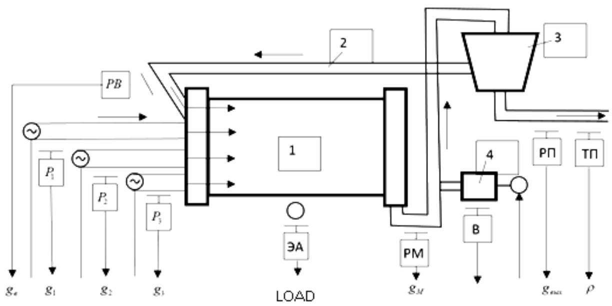

Figure.-1. Technological scheme of the mill.
1-mill; 2-trakt return grit; 3-separator; 4-blowing device; g_b -return batch; $g_1 - g_3$ - download mill components; g_M -exit mill; $g_{вых}$ -output of aggregate; ρ -fineness; $PB, P_1 - P_3$, PM, РП -flow meters; ТП -the gauge of the fineness of grinding; ЭА -electro-acoustic transducer, which characterizes the loading of the mill; B -a pressure sensor (dilution).

In all cases, the control is transferred to the inlet, to the feedstock feeders to the mill and to the devices regulating the head in the separator.

Structural-dynamic scheme of the mill is shown in Fig. 2, where $W_1(p), W_2(p), W_3(p)$ - transfer functions, respectively, of the mill, its separator and the inlet to the separator.

The transfer function of the object is determined by the formula [4]

$$W_{02}(p) = W_{01}(p)W_{12}(p) = W_{01}(p)W_3(p).$$

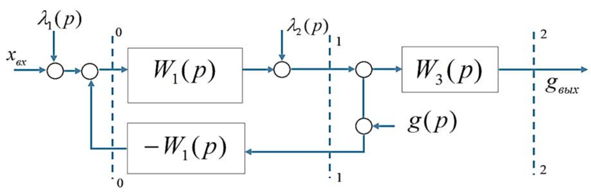

Figure 2. Structural-dynamic scheme of the mill.

The first link in the diagram represents the anti-parallel connection, so

$$W_{01}(p) = \frac{W_1(p)}{1 - W_1(p)W_2(p)};$$

$$W_{02}(p) = W(p) = \frac{W_1(p)W_3(p)}{1 - W_1(p)W_2(p)}.$$

Thus, to create a control algorithm, it is necessary to find expressions for operators:

$$W_i(p) = N_i(p)e^{-p\tau},$$

$$N_i(p) = \frac{K}{Tp+1},$$

where K is the transfer coefficient; T is the time constant of delay; i is the site of the object.

The control operator can be found analytically if one output parameter is expressed as a function of the others. This makes it possible to use the proposed algorithms for finding analytical expressions of communication in determining the quality of products.

It is shown that at (stabilized fineness output) control can be found analytically [3,5]:

$$Y(p) = g(p)\frac{W(p)N_{01}(p)e^{-p\tau 01}}{1+W_1(p)N_{01}(p)e^{-p\tau 01}} \times$$

$$\times N_{12}(p)e^{-p\tau 12} + \lambda_1(p) \times$$

$$\times\left[1-\frac{W(p)N_{01}(p)e^{-p\tau 01}}{1+W_1(p)N_{01}(p)e^{-p\tau 01}}N_{12}(p)e^{-p\tau 12}+\lambda_2(p)\right],$$

where $\lambda_1(p), \lambda_2(p)$-independent random control values; $Y(p)$-output variable (performance); $g(p)$-noise value, (internal perturbation).

The values of $N_i(p)$ and τ can be found from experimental data on the readings of instrumentation, and the dependence of $Y(p)$ on $\lambda_1(p)$ and $\lambda_2(p)$ is determined by the Kolmogorov-Gabor polynomials using the mgua algorithms [5,6].

To do this, we define the range of tasks that need to be solved during the experiment. First, it is necessary to find a working model for predicting the 28-day activity of cement (an indicator that determines the brand of cement), and secondly, to choose the parameters that allow to build an adequate mathematical model and meet the requirements of minimizing the number of devices and measurement techniques, minimizing the complexity of measurement, expressiveness, automation of measurement process technology, and thirdly, to check the mechanism of adaptation of the model to the conditions of this production.

The experiment was conducted at the Jizzakh cement plant, the material was Portland cement. 25 cement samples were taken. Samples; were studied in parallel to the factory staff; when the divergence of the results was performed by the arbitration study, which corrected the data. In addition, each sample was subjected to URS-50I diffractometry ($v = 35, j = 10$ mA Siα -radiation, $v_s = 1$ deg/min, survey interval 41,5± 1,5°).

Chemical analysis data were used to determine the design characteristics and design mineralogical composition. At the same time, the relations were used

$$C_8\ S = 4{,}07CaO\text{-}\ 7{,}6\ SiO_2\text{-}6{,}72Al_2O_3\text{-}1{,}42Fe_2O_3,$$

$$C_2S = 8{,}6\ SiO_2 + 5{,}07\ Al_2O_3\text{-}\ 3{,}7\ CaO,$$

$$C_3A=2{,}65(Al_2O_3\text{-}0{,}64Fe_2O_3)$$

$$C_4AF=3{,}04Fe_2O_3$$

$$CaSO_4=1{,}7SO_3,$$

$$KH=\frac{CaO(1{,}65Al_2O_3+0{,}35Fe_2O_3+0{,}7SO_3)}{2{,}8SiO_2},$$

$$n=\frac{SiO_2}{Al_2O_3+0{,}35Fe_2O_3}\quad p=\frac{Al_2O_3}{Fe_2O_3}.$$

We present the parameters of chemical (I) and x-ray diffraction analysis and physical and chemical tests (II) for the construction of mathematical models for predicting cement quality management:

I	II
x_1-SiO_2	$x_1^p - 301(C_3S)$
x_2-Al_2O_3	$x_2^p - 277$ (basic materials)
x_3-Fe_2O_3	$x_3^p - 274(C_3S, C_2S)$
x_4-MgO	$x_4^p - 270(C_3A)$
x_5-CaO	$x_5^p - 268(C_4AF)$
x_6-SO_3	$x_6^p - 260(C_3S, C_2S)$
x_7 - specific surface	$x_7^p - 241(CaO_{CB})$
x_8 – residue on the sieve 008	$x_8^p - 218(C_3S, C_2S)$
x_9 – beginning of setting	$x_9^p - 210(MgO)$
x_{10} – duration of setting	$x_{10}^p - 191(\gamma - C_2A, C_3A)$
x_{11} – the spreadability of the cone	$x_{11}^p - 176(C_3A)$
x_{12} – normal density	$x_{12}^p - 161(C_2A)$
x_{13} – specific gravity	$x_{13}^p - 147(MgO)$
x_{14} – V-28-day activity	

Numbers from 301 to 147 mean the interplanar distances corresponding to the given phases, A. the Main cement minerals give a set of reflections superimposed on each other. Lines free of overlapping, small and intensity is low.

When x-ray quantitative phase analysis it is recommended to use these weak lines [3,5}; for $\beta - C_2S$ -line of 2.88 (121) having a diffraction pattern for the pure mineral is 5-6 times lower intensity than the peak 2,77— 2,78 (122) (it can be characterised as medium or weak); for C_3S-line 3,03 (401), 2,96 (402), 1,78 (620), of which none reaches 50-60% of the height of the lines 2,60 (405), 2,75 (404), 2,77 (009); for C_3A and C_4AF-the strongest line of 2.70 (440) and 2.66 (141), but it should be noted that the total content of these minerals in the clinker does not exceed 25%.

Thus, to determine the phase composition, only weak lines are used, the reflections of which give the most information about the cement.

Since the aim of the experiment was to find a model for predicting 28-day activity, it was decided to move away from the conventional method of selecting lines and use the most characteristic and dispersed reflections, because they provide more information about the activity; in addition, the adopted algorithm: finding connections itself is able to select the most significant for predicting the line.

On diffractogramme cement mineral is easily detected 13 lines that can be decrypted using the card file data x-ray diffraction (ASTM card) or crystallographic tables [7] cement $C_3S, \beta-C_2S, \gamma-C_2S, C_3A, C_4AF, CaO, MgO$.

For the solution of our problem is rather the information contained in difractometric tables, i.e. the intensity of the charactertion lines.

Of all the types of measurements taken for cement, diffractometric determination of process parameters without decoding is the most expressive, and the expressiveness increases significantly when choosing lines in a narrow range of angles (10-15°) and can be reduced to 20-30 minutes.

All researchers seek to obtain dependencies between a function and independent variables. Many well-known models constructed to control cement production are multidimensional and have numerous polynomials simplified by discarding terms with high degrees at their small effect on the function. Their use is complicated by the complexity of the computational process.

Any complex dependence can be approximated using the Kolmogorov-Gabor power polynomial [5,6] using mgua using the method of group consideration of arguments. The block diagram of the simulation algorithm is shown in Fig. 3.

However, the Method of group accounting of arguments is not sufficient — the model is built in an implicit form, its recovery is significant difficulties, and with a slow increase in the accuracy of approximation and an indefinite number of steps is impossible at all. That is why in the literature the question of model reconstruction is either silent or stipulated in extremely uncertain terms.

Number	Number of selection steps	Support function		Number	Number of selection steps	Support function	
		Linear	Nonlinear			Linear	nonlinear
Physical,mechanical and chemical data				X-ray diffraction data			
22	1 2 3 4	11,75 9,51 9,14 8,84	12,60 10,19 9,26 8,89	22	1 2 3 4	11,63 11,46 11,02 10,81	12,50 9,55 9,17 9,01
21	1 2 3 4	11,60 9,76 9,41 9,13	12,73 10,35 9,52 9,24	21	1 2 3 4	11,51 11,31 11,08 10,25	12,65 9,45 9,04 9,01
20	1 2 3 4	11,67 9,88 9,62 9,56	12,69 10,20 9,10 9,09	20	1 2 3 4	11,64 11,11 11,07 11,05	12,67 9,78 9,54 9,42

Results of calculation of standard deviationsMeanwhile, the method of group accounting of arguments quickly converges already in the first two orthree steps, the next steps give little to increase the accuracy of the model (table). This circumstance was used to automate the process of building a model, which resulted in the creation of an additional program that takes into account the data obtained during the operation of the main algorithm. With the help of the developed program the model is built and the predicted function is calculated.

The dependence search could be performed on the basis of linear, nonlinear and mixed support functions. The model drift was studied at different ratios of processed and predicted samples (25 in total). The approach organized in this way made it possible to obtain up to 100 models, the number of which was determined by the formula $\Pi = \mathrm{fgck}$, where f is the number of support functions; g is the number of data types; c is the number of combinations of statistics; k is the number of models selected for data f,g,c. From 100 models were selected those that most correspond to the solution of the tasks.

Was first obtained by the model based on the results of the Chi-nomic analysis and individual expressive data obtained physico-mechanical nature, then — on the basis of diffraction patterns and the data of the physico-chemical nature. An attempt was made simulations based on fineness of grinding and diffractogramme that have not been decoded.

When drift was detected, each model had a different number of statistics, other statistics were used to test the constructed models.

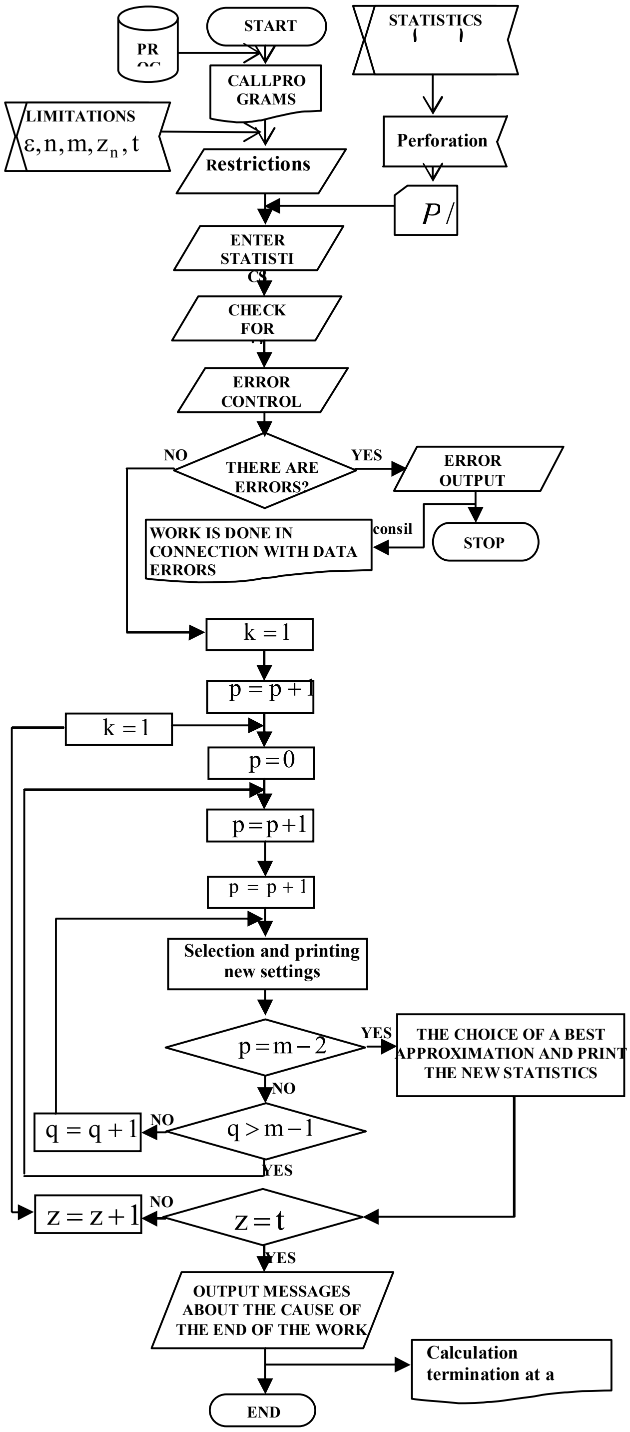

Figure. 3. Block diagram of simulation algorithm:

Blocks 1-3-input of statistics $x_{i,j}, i=1,2,3,...,n,$ $3 \le n \le 40,\ j=1,2,3,...,m,\ 3 \le m \le 16$ and constraints (specified accuracy ε , m,n -matrix size, z_n -diagram modeling; $z_n = 1$ -linear form, $z_n = 2$ - the quadratic form, z -number of steps selection) 4-sorting statistics on the numbers of cards and their value; 5-7-analysis of the input data for correctness, a selection of error messages; $8-8\alpha$ -collection of information and its translation into machine language; 9-13, 18-20 of the coecients (k is the number of new statistics in the same row of the selection, p,q -coefficients busting); 14-choice of calculation scheme, calculation of Gauss coefficients, solution of equation systems, calculation of accuracy, decision-making on continuation of work; 15, 17 - check of search coefficients; 16-choice of the best approximations and their transfer to the next step of selection; 21-choice of model structure; 22-results.

The choice of statistics for these purposes was random, the only requirement being that the test statistics should not be part of the set used to build the model.

$$V=536{,}372674+2{,}455766x_1-0{,}012841x_7-$$
$$-4{,}135759x_8+40{,}054059x_9;$$
$$V=0{,}540716(0{,}493184T+0{,}344099R+$$
$$+0{,}000336TR)+0{,}393335(0{,}314187M+$$
$$+0{,}356612N+0{,}000687MN),$$

where

$$T=0{,}201663x_7+67{,}890822x_8-0{,}027423x_7x_8;$$
$$R=491{,}8\ 44545x_9+16{,}406477x_{12}-17{,}505418x_9x_{12};$$

$$M=255{,}797039x_6+0{,}150259x_7-0{,}082779x_6x_7;$$
$$N=74{,}029995x_9+131{,}769335x_{13}-3{,}209073x_9x_{13};$$
$$V=544{,}653558+2{,}110936x_1-0{,}043084x_7-$$
$$-4{,}139910x_8+39{,}645586x_9;$$
$$V=0{,}553994(506146T+0{,}353467R+$$
$$+0{,}000269TR)+0{,}383055(0{,}394798M+$$
$$+0{,}339939N+0{,}000548MN)+0{,}000130\times$$
$$\times(0{,}506146\ T+0{,}363467\ R+0{,}000269\ TR),$$

where

$$T=0{,}202784x_7+68{,}301597x_8-0{,}027672x_7\ x_8;$$
$$R=484{,}676485x_9+16{,}169394x_{12}-17{,}064293x_9x_{12};$$

$$M=6{,}495295x_9+130{,}274540x_{13}+24{,}337518x_9x_{13};$$

$$N=259{,}329812x_6+0{,}149464x_7-0{,}083658x_6x_7;$$
$$V=542{,}862303+2{,}470396x_1-0{,}044345x_7-$$
$$-4{,}234846x_8++38{,}822507x_9;$$

$V=0,446384(0,453147T+0,456609R+$
$+0,000187\,TR)+0,454929(0,473628M+$
$+0,346848N+0,000372MN)+0,000163\times$
$\times(0,453147T+0,456609R+0,000187TR),$
where
$T=0,200438x_7+67,180583x_8-0,027046x_7x_8;$
$R=75,129236x_8+335,565111x_9-50,911671x_3x_9;$

$M=272,960375x_6+0,145719x_7-0,086970x_6x_7;$
$N=201,97265x_4+357,39783x_9+148,0377x_4x_9;$
$V=676,634084-0,066925x_5^p+1,316360x_7^p+$
$+0,622049x_8^p-6,039242x_7-3,917259x_8;$
$V=0,426732(0,935512T+0,116430R-$
$-0,000106TR)+0,304926(1,173498M+$
$+0,040470N-0,000442MN)+0,000554\times$
$\times(0,935512T+0,116430R-0,000106TR),$
where
$T=20,125318x_7+67,850028x_7-2,736966x_7x_8;$
$R=197,322037x_7^p+18,071731x_7-7,562951x_7^px_7;$

$M=96,135274x_5^p+17,408456x_7-3,476775x_7^px_7;$

$N=81,236135x_{12}^p+17,159561x_7-2,867514x_{12}^px_7;$
$V=696,847187-0,0022748x_{33}^p-0,087957x_4^p+$
$+1,724957x_7^p-6,267192x_7-4,660565x_8;$
$V=0,422879(0,939960T+0,118570R-$
$-0,000120TR)+0,306207\ (1,180601\ M+$
$+0,034882N-0,000445MN)+0,000560\times$
$\times(0,939960T+0,118570R-0,000120TR),$
where
$T=20,237243x_7+68,249645x_8-2,761452x_7\ x_8,$
$R=195,943931x_7^p+18,048717x_7-7,513868x_7^px_7,$
$M=96,802388x_7^p+17,397182x_7\text{-}\ 3,496918x_5^px_7,$
$N=81,078208x_{12}^p+17,158857x_7\text{-}\ 2,862506x_{12}^px_7;$
$V=705,304816+1,713262x_7^p+0,090845x_8^p-$
$-0,812745x_{12}^p-6,470074x_7-4,719808x_8;$
$V=0,423026(0,944871T+0,103398R-$
$0,000100TR)+0,304762(1,102419M+$
$+0,118780N-0,000459MN)+0,000564\times$
$\times(0,944871T+0,103398R-0.000100TR),$
where
$T=20,041492x_7+67,198307x_8-2,705218x_7x_8;$
$R=67.812647x_{11}^p+16,713122x_7-2,381683x_{11}^px_7;$

$M=100.4590C8x_5^p+17,29461x_7-3,60814x_5^px_7;$

$N=314,333596x_9^p+18,654102x_7-12,122100x_9^px_7.$

When building models we used the values $x_7/100$.

As selection criteria the average accuracy of forecasting and run-up of deviations of the forecast of 28-day activity were chosen (the run-up was the difference between the minimum negative and maximum positive values of the calculated function). Accuracy criteria were 10-12 units, run - up - ±20 units of activity. This numeric value corresponds to the practice adopted in cement production 5% probability the accuracy guarantee of the brand.

It was found that the prediction of 28-day activity of cement or clinker is possible for almost all models obtained. With the exception of model 8, 9, 11, having a somewhat increased running compared with accepted. So, for forecasting it is possible to use several standard data, and from them to select that type which in the best way satisfies applied expressive means of measurement. This conclusion is supported by the adequacy of the models for forecasting accuracy (the deviation in accuracy does not exceed 2 units of activity, which is less than 0,5%), run-up (most models have a run-up within ±20 units and less) and appearance (for example, models 1, 3, 5 have the same parameters, and their coefficients differ little from each other).

Linear models are the most complete, since the increase in accuracy is practically stopped at the second step of selection and the inclusion of new members in the model is not required, i.e. three or four parameters are enough to predict 28-day activity. This suggests that the list of measurements required for modeling can be reduced by 5-6 times, which is very important in the development of the Express method.

When predicting the brand, all models give very satisfactory results. Therefore, in such cases it is possible to use unencrypted diffractograms.

The best models providing accuracy of the order of 9-10 units at run-up ±19 units-the first and the sixth.

The nature of the models varies slightly with the number of observations exceeding 20. This is clearly seen in models 1, 3, 5, which contain a different number of statistics. All their coefficients and the free term differ little from each other, and the set of parameters is exactly the same; similar similarity in other models. This gives reason to believe that 20-25 statistics are enough for the formation of models.

Analysis of the type and condition of the model allows the development of technical recommendations and thus provides the basis for operational management.

All components that make up the model can be divided into main and additional components; the contribution of additional components to the projected value is insignificant. In all models, the main components are formed in the first step of selection, additional — in the following. The main components have a high correlation coefficient with the predicted value and allow us to determine how to influence the activity. By the type of model, you can determine the direction of influence (the sign of the coefficient of the parameter in question).

The main component of the obtained models is the fineness of the grinding, characterized by the residue on the sieve 008 and the specific surface. The smaller the balance on the sieve 008, the higher the activity. The coefficients of the remainder on the sieve 008 in the model are -3,9 and -4,1.

The specific surface area coefficient is also included in the model with a negative sign. Here it is necessary to find out the nature of the grinding and determine what it is associated with. Grinding of clinker is relatively well up until not achieved the factionalism comparable to the grain Alita (single crystals). Further increase in the fineness of the grinding is achieved by crushing the crystal, which is undesirable, since this leads to heterogeneity of the fractional composition and to a decrease in strength, which is associated with high energy costs and an increase in grinding time.

According to the results of the analysis, the average value of the specific surface area is $2850 cm^2/g$, which corresponds to a very large grain (70 microns or more). Apparently, the grinding of clinker to a single crystal size is achieved already at a specific surface area of $2700-2800 cm^2/g$. This indicates an extremely poor cooling mode of clinker and that the cooling is slow. Models based on x-ray diffraction data have a high correlation of activity with Belite (C_2S) and low correlation with alite (C_3S), although both, as it follows from cause-effect relationships, are included in the model with a positive sign (in large grains alite decomposes into Belite and its activity decreases).

The result of this analysis is the development of two ways to influence the quality of cement. The first is some coarsening of the grinding; it must act during the time of clinker production. The second is aimed at changing the operating mode of the refrigerator; the method should be implemented simultaneously with the first; the result of its application is an increase in the contribution of alite and a decrease in its specific surface area.

Thus, the obtained models can be used for operational management.

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