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RESEARCH OF SETTINGS OF FORCED ACTION MIXER WITH CHANGING ANGLE BLADES

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Abstract. Analysis and evaluation of structural and technological parameters of forced action mixer was carried out on the basis twin-shaft forced action mixer. Theoretical methods of moving material into the twin-shaft mixer chamber, using a stochastic approach were proposed in this article. The process of moving material was researched by the theory of Markov chains. Based on the proposed method of improving system of quality assessment in terms the variation coefficient of mixture. And was predicted that the main parameter that affects the direction of movement particles of material and quality of mixing - is the rotation angle of the blade. It was the main option of the research. To test the theoretical foundations of the movement of substances and improve the quality of the mixture, experimental stand was developed – Laboratory twin-shaft forced action mixer with changing angle blades. The conducted experiments have confirmed the validity of theoretical research. The Algorithm of design of new constructions of twins-shaft concrete mixers was proposed, based on conducted researches. The working hypothesis that the movement of material between the mixing zones depends on the "transition probabilities", which is defined by angle blade was confirmed as a result of mathematical modeling of moving material and performed experimental studies. On the basis of theoretical research the method of calculation of basic parameters of advanced laboratory twin-shaft concrete mixers was crated. The laboratory twin-shaft concrete mixers with rotary blades was created.

The investigations can improve the efficiency of the mixer by reducing cycle time and energy consumption.

Key words: mixer, twin-shaft concrete mixer, twins-shaft forced action concrete mixer, coefficient of variation, concrete, mixing stochastic model, Markov chains.

Introduction

Quite often the twin-shaft forced action mixers are used for the production of mixed concrete and for reinforced concrete structures.

Formulation of problem

Therefore, improving the means of preparing concrete mixes and solutions that will have simpler design, lower energy loss and metal consumption is relevant and promising researching task for the development of engineering and construction industry in Ukraine. The analysis and estimation of existing researches of mixers were carried out, that identified the main task of this work.

Analysis of recent research results

The scope of their optimal use is virtually unlimited, according to modern recommendations [1, 5, 6, 12, 15]. For example, mixture prepared in such mixer has the highest structural strength by water-cement ratio coefficient [10, 16, 19]. These mixtures are ideal for making hard and harder mixtures [19]. Their distinctive feature is the lowest duration of the mixing cycle – 45-90 sec, compared to other types of mixers. However, despite their many advantages, they have some disadvantages, namely the high cost of mixing, and consequently – high cost of driving mechanism, rapid wear armor mixer. Overall, the construction of this type of mixer is not well studied, so we should carry out research of processes and phenomena occurring in the middle of mixing chamber. An important trend in the development of this equipment is the desire to generalize the theoretical foundations of design and calculations of this type of construction equipment [1, 5, 12].

Purpose of research

The primary goal of research is increase efficiency of process preparation of mixture on twin-shaft forced action mixer by optimal blade angles of rotation and determination of mixing time, depending on the coefficient of variation, through mathematical modeling of moving particles mixture.

Results of research

During the mixing process in its working volume occurs relative movement of particles of different components, which were "separated" or were implemented unevenly. As a result of mixing process, the particles location in the working volume of the mixer may be infinitely different. Under such conditions, the ratio of components in the mixture micro-volumes – the value is too random, because most of the known methods for assessing uniformity of mixture (quality) based on the methods of statistical analysis.

For simplicity, all mixture conditionally consists of two components: main component and secondary component that includes other components. This method helps to evaluate the homogeneity of mixture by using distribution parameter of a random variable – content of main component in the mixture samples. The component is easy to analyze or its distribution in the mix is very important for the technical requirements, is often choose as main component. This criterion of mixture quality is the coefficient of variation, %:

$$V_c = \frac{100}{\bar{c}} \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (c_i - \bar{c})^2}\ , \qquad (1)$$

where: $\bar{c}$ – arithmetic mean of concentration a main component in all n samples mixture %, c – concentration of a key component in the i-th sample mixture, % [14].

As for the mixing of building materials, this criterion is called the coefficient of heterogeneity, because of coefficient the heterogeneity of the mixture is increasing.

The analysis of experimental dependence $V_c = f(t)$ (t – mixing time), shows that the kinetic curve of mixing process has three characteristic areas (Fig. 1), where each of them reflects a certain period of time mixing.

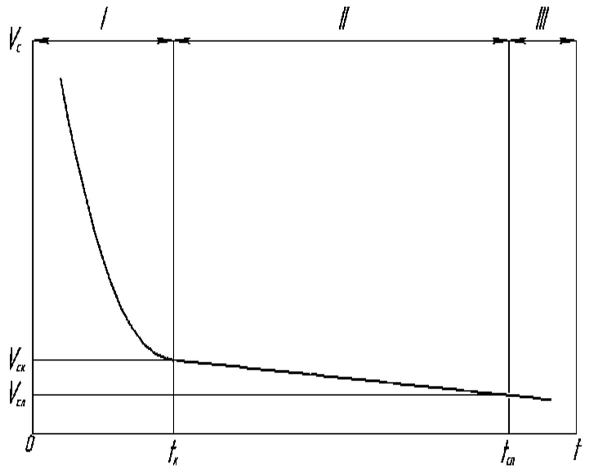

Fig. 1. Dependence of heterogeneity mixture from mixing time.

At 1-st period in mixer volume convection hyphenation of components is dominated. The process of segregation has low speed, compared with the process of moving. Therefore, in 1-st period V_c decreases sharply to some value V_{ck}. At the end of this period (t_{cp}) in the working volume of mixer virtually no aggregates (macro-volumes) consisting of particles of one component.

In 2-nd period, the mixing speed became equal to the speed of segregation, that is the value V_c varies slightly over time (compared with 1-st period). It self the mixing process is implemented mainly through the movement of individual particles relative to each other. Because of resemblance to the diffusion process of molecules it`s called diffusion.

In 3-d period the mixing speed equal to the speed of segregation, that is V_c does not change with time. The lowest value of coefficient of heterogeneity called marginal heterogeneity $V_{сп.}$ The time $t_{сп}$, at which the mixture becomes homogeneous (estimated value $V_{сп}$), is optimal mixing times because of further stirring V_c it doesn`t change.

In the 1st period the physical and mechanical properties of the mixture do not affect significantly the kinetics of mixing process, and in the 2nd and 3rd periods, their influence is noticeable. Therefore, different mixes in a mixer with different physical and mechanical properties will have different values of V_c. [10, 11, 14]

The physics of mixing process in a continuous mixer differs from cyclic mixer fact that the quality of mixing depends not only on the speed of mixing in the working volume of the mixer, but the nature of the power components.

Considering the mode of twin-shaft mixer to determine its nature effectiveness within a stochastic model in which the movement of matter is random and is described by probabilistic methods. [3]

To do this, all volume of the mixer is divided into the equal number of elementary volumes – mixing zones. At first step, define the volume one shaft of mixer – the cylinder without adjacent cylindrical segment that mixed by blades of nearby shaft (Fig. 2, shaded area).

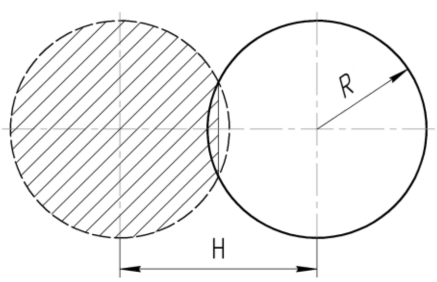

Fig. 2. The scheme of elementary volume: R – radius of the mixing zone, H – distance between the axis of the shafts.

Further, the cylinders are divided into mixing zones whose number equal to the number of blade arrangements mounted on the shaft (Fig. 3).

Based on the definition of mixing process in the theory of dynamical systems [20, 21], as the properties of the system "forget" about the initial condition (state) over time, we will determine this time. To describe the movement of heterogeneous systems we will use Markov chains theory [7, 13, 17, 18, 22, 23] so the transition probability $p_{ij}(t)$ depends on time and there is a time t, which corresponds to a transition in which n matrix of transitional probabilities are unchanged. This state of the system, "a state of oblivion" equal $t_{сп}$, time that determines the beginning of 3-d period of kinetic curve mixing process (see. Fig. 1), in which the mixing speed equal to the speed segregation V_c that doesn’t change with time.

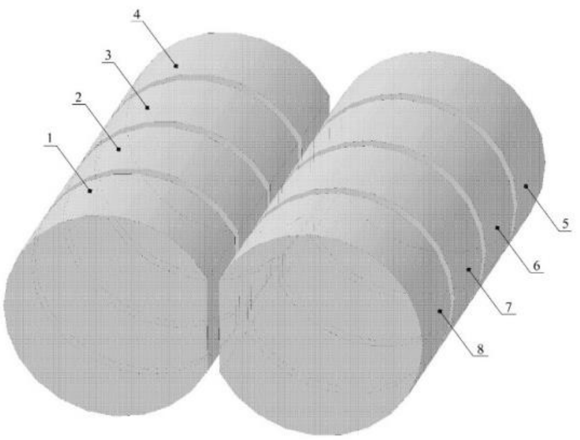

Fig. 3. The three-dimensional model of 8 mixing zones.

So, the analysis of workflow process forced action mixer is aimed at determination of the limiting factor of heterogeneity $V_{сп.}$ – the lowest value of coefficient in time $t_{сп}$, at which the mixture becomes homogeneous.

This indicator characterizes mixer, it effectiveness and mixing quality.

Based on the general theory of Markov chains, the initial state of system can be characterized by the vector $G(0)$, where each component $g_i(0)$ is the probability of finding of one of the components of the mixture in the i-th mixing zone:

$$G(0) = [\, g_1(0), g_2(0), \dots, g_k(0)], \qquad (3)$$

where: k – the number of mixing zones.

Then specified the value of transitions probability of particle from i-th mixing zone in a j-th, it is the probability matrix (connections). According to the theory of Markov after n transitions (rotating shaft) distribution of matter in the mixing zones can be written as matrix multiplication:

$$G(n) = G(0)p^n, \qquad (4)$$

where: n – the matrix of transition probability with dimension $k \times k$, $G(n) = [\, g_1(n),\, g_2(n)\, , \dots,\, g_k(n)]$ – the state vector system after n transitions.

To assess the heterogeneity V_n, %, distribution of material after transitions determined:

$$V_n = 100k\sqrt{\frac{1}{k-1}\sum_{i=1}^{k}\left[g_i(n) - \frac{1}{k}\right]^2}. \qquad (5)$$

The mixer, which reaches value V_3 in the less number of rotation shaft (less time mixing) is the best.

The scientifically-research idea took the position that the mixing efficiency is determined by the speed of the transition material from state of inhomogeneous embedded to the state of "forgetfulness".

The main performance indicators of twin-shaft forced action mixer include:

– the number of shaft rotations at which mixture becomes the homogeneity (the time of "forgetfulness" t_{cp}),
– the angle of blade rotation,
– the power drive on mixing,
– the productivity.

Thus, on the basis of the above, the following hypotheses were formulated, the implementation of which would achieve the desired result in the creation of new or would improve existing structures of twin-shaft forced action mixers.

1. The moving of material between the mixing zones in a particular direction depends on "transition probabilities", which physical meaning is defining as difference of entropy before and after the transition, which differently interprets the way of determination the power of mixing.

2. The moving of material is made within each transition (shaft rotating), that is a discrete model.

This approach will allow to get mathematical model for the researched environments, more intelligently and with fewer bugs or as necessary to improve the methodology of research results.

To determine the probability of transition material in one direction or another, consider the most common scheme of movement, which is shown in Fig. 4. It is believed that during one shaft rotation the material will be transiting with probability p to a nearby zone, with probability q to opposite zone and with probability r will remain in it:

$$p + q + r = 1. \qquad (6)$$

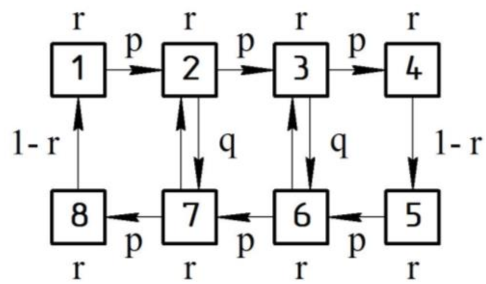

Fig. 4. The transition scheme of material for twin-shaft mixer.

The determination of probability of transition of material will be entirely experimental by the example of one of the mixing zones (Fig. 5).

With help of software MathCAD one transition of material in appropriate ways, depending on the blades angle is simulated.

The probability of transition is determined as numerous simulations of the transition by the randomly algorithm «white noise." The results are processed by statistical methods, resulting in transition probability becomes dimensional value that reflects the difference in entropy before and after the transition.

For adequacy of the experiment the rheological properties of the material (concrete mix) should be created, replacing it by some number of balls with some diameter and density of the material.

More accurate description of the mixing process can be provided by three-dimensional probabilistic model

(Fig. 6). In this scheme the probability of leaving the material in the same mixing zone and description of the movement of particles of material in it is more widely understanding. As shown in Fig. 6, the movement of material into the mixing zone is made in the radial and circumferential directions, but on two-dimensional scheme it is described as remaining the matter in the same mixing zone, and consistent with probability.

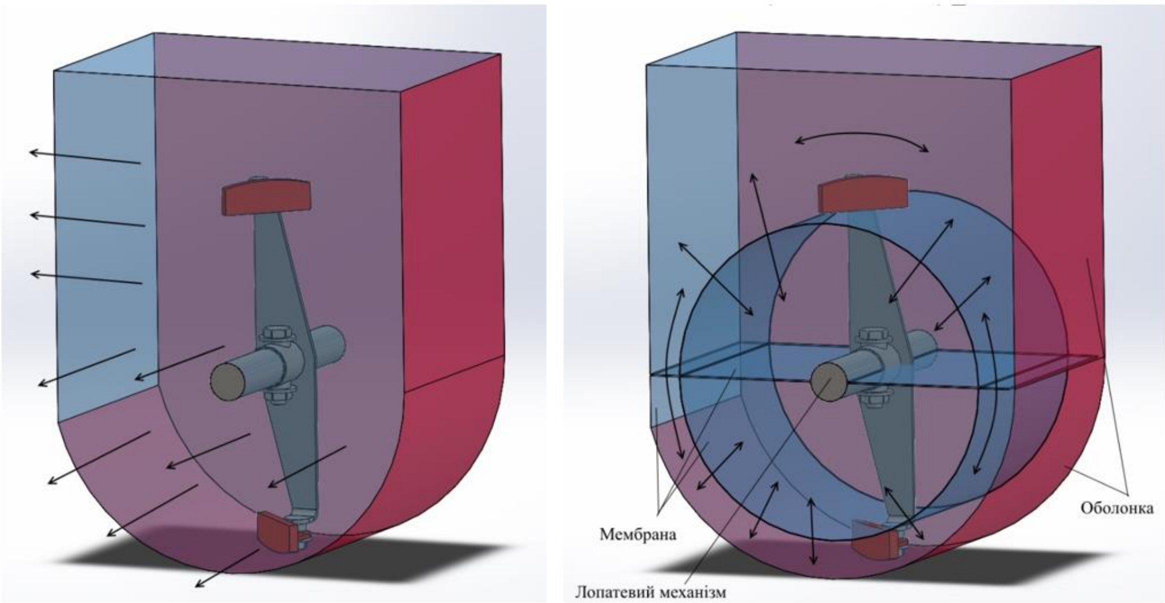

Fig. 5. The scheme to determinate the probability of movement material.

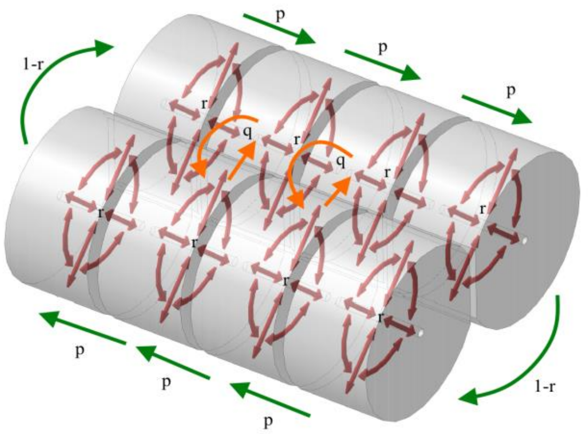

Fig. 6. The scheme of moving material in the mixer.

Considering the three-dimensional scheme of movement material and particles in the mixer, let`s introduce the probability of remaining of material in the same mixing zone as the total probability of moving material in the radial S and circumferential C direction.

Also, the movement of material along the axis of the mixing shaft determined as probability of axial movement A, and the probability of movement into opposite mixing zone E (Fig. 7).

- *Radial direction* – s the movement of material within the ranks of the blade arrangements of the mixer in the direction from the axis to the largest radius (hull mixer) and in the opposite direction. Each of the mixing zones, is going to be divided in the radial direction on N_S equal rings,
- *Circumferential direction* – s the movement of material within the ranks of the blade arrangements of the mixer in a closed circulation circuit. Each of the mixing zones, is going to be divided in the circumferential direction on C_R sector level (α – angle sector, hail):

$$N_C = \frac{360°}{\alpha}. \quad (7)$$

For further calculation is necessary to know the values of the following parameters:

- Number of cells in each of the received parts (zones):

$$N_j = N_C \cdot N_S, \quad (8)$$

- Numbering mixing zones in each of the pieces obtained from the index growth:

$$J_C = (n_S - 1) \cdot N_C, \quad (9)$$

- Number of rings:

$$n_S = \overline{1, N_S}, \quad (10)$$

- The radius of the ring, provided the same amount of cells:

$$R_i = \sqrt{R_{i-1}^2 - \frac{R_0^2}{N_S}}, \quad i = \overline{1, N_S - 1}. \quad (11)$$

System status at time $\tau = k \cdot \Delta T$, were k – number of transition, ΔT – the duration of the transition, expressed as a column vector of size $(N_I \times N_j) \times 1$:

$$S^k = \left[S_1^k \;\; S_2^k \; ... \; S_{N_j}^k \;\; S_{N_{j+1}}^k \; ... \; S_{N_j \cdot (N_j - 1)}^k \;\; S_{N_j \cdot N_I}^k \right]^T,$$

The next state of the S^{k+1} depends on the current and can be presented in:

$$S^{k+1} = S^k \cdot P, \quad (12)$$

where: P – matrix of transition probabilities. In turn, the matrix of transition probabilities with regard the three direction of movement material particles is given by:

$$P = P_C \cdot P_S \cdot P_A, \quad (13)$$

where: P_C – matrix of transition probabilities when moving particles in the circumferential direction, P_S – matrix of transition probabilities when moving particles in the radial direction, P_A – matrix of transition probabilities when moving particles in the axial direction.

$$P_S=\begin{pmatrix} P_{S_{1.1}} & 0 & \cdots & 0 \\ 0 & P_{S_{2.2}} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & P_{S_{N_I-N_J}} \end{pmatrix},\quad P_C=\begin{pmatrix} P_{C_{1.1}} & 0 & \cdots & 0 \\ 0 & P_{C_{2.2}} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & P_{C_{N_I-N_J}} \end{pmatrix}, \tag{14}$$

$$P_A=\begin{pmatrix} P_{A_{1.1}} & P_{A_{1.2}} & 0 & 0 & & 0 & 0 & 0 \\ P_{A_{2.1}} & P_{A_{2.2}} & P_{A_{2.3}} & 0 & \cdots & 0 & 0 & 0 \\ 0 & P_{A_{3.2}} & P_{A_{3.3}} & P_{A_{3.4}} & & 0 & 0 & 0 \\ & & \vdots & & \ddots & & \vdots & \\ 0 & 0 & 0 & 0 & \cdots & P_{S_{N_{I-1}-N_{J-2}}} & P_{S_{N_{I-1}-N_{J-1}}} & P_{S_{N_{I-1}-N_J}} \\ 0 & 0 & 0 & 0 & & 0 & P_{S_{N_I-N_{J-2}}} & P_{S_{N_I-N_J}} \end{pmatrix}$$

where: 0 – zero matrix of size $N_I \times N_I$ and $N_C \times N_C$ for matrices of transition probabilities when moving particles in the circumferential and radial and axial direction, respectively, $P_{C_{ij}}, P_{S_{ij}}, P_{A_{ij}}$ – block matrix of transition probabilities when moving particles in the circular (matrix size $N_j \times N_j, i=\overline{1,\ N_J}$), radial (size matrix $N_C \times N_C, i=\overline{1,\ N_J}$) and the axial direction, respectively, for each i-th particle mixing chamber (formula 15).

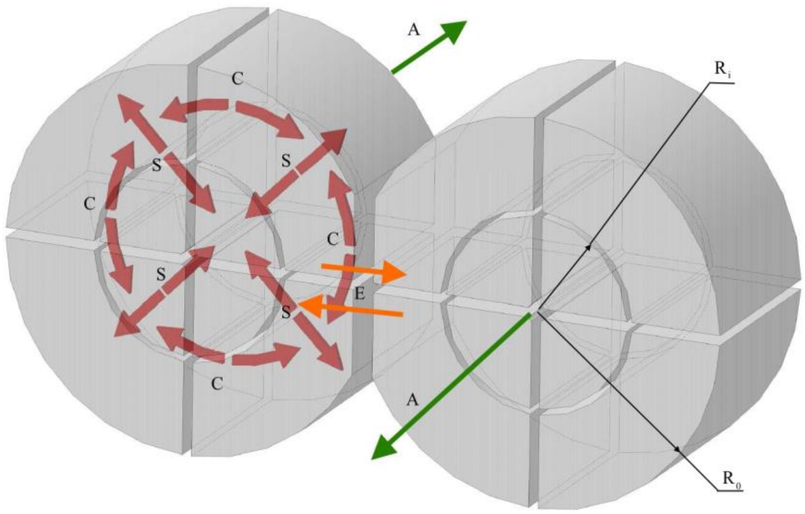

Fig. 7. The calculated scheme to describe all movement of material in the mixer.

$$P_{C_{ij}}=\begin{pmatrix} M_{C_{1.1}} & 0 & \cdots & 0 \\ 0 & M_{C_{2.2}} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & M_{C_{N_J\ N_J}} \end{pmatrix}$$

$$P_{S_{ij}}=\begin{pmatrix} M_{S_{1.1}} & M_{S_{1.2}} & \cdots & M_{S_{1,N_J}} \\ M_{S_{2.1}} & M_{S_{2.2}} & \cdots & M_{S_{2,N_J}} \\ \vdots & \vdots & \ddots & \vdots \\ M_{S_{N_J,1}} & M_{S_{N_J,2}} & \cdots & M_{S_{N_J N_J}} \end{pmatrix} \tag{15}$$

where: 0 – the zero matrix of size $N_J \times N_J$ and $N_C \times N_C$ or matrices of transition probabilities when moving particles in the circumferential and radial and axial direction, $M_{C_{i,j}}, M_{S_{i,j}}$ – block matrix of transition concentrations of the material from l cell to m cell at moving particles in the circumferential direction of the size $N_C \times N_C, i=\overline{1,\ N_J}$, radially direction of the size $N_C \times N_C, i=\overline{1,\ N_J}$, $j=\overline{1,\ N_J}$, respectively. For axially moving particles the block matrix of transition probabilities ($i=\overline{1,\ N_I},\ j=\overline{1,\ N_I}$), will look like:

$$P_{A_{ij}}=\begin{pmatrix} p^a_{1+I_a,\ 1+I_a} & 0 & \cdots & 0 \\ 0 & p^a_{2+I_a,\ 2+I_a} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & p^a_{N_J+I_a,\ N_J+I_a} \end{pmatrix},$$

were $p^a_{l,m}$ – probability of transition concentration of the material while moving particles in the axial direction $l=\overline{1, N_I \cdot N_J}$, $m=\overline{1, N_I \cdot N_J}$, $I_a=(i-1)\cdot N_J$, and $J_a=(i-1)\cdot N_J$ indices of growth.

The block matrices of transitions of material concentration from l cell to m cell is the same for transition in the circumferential and radial directions (Formula 16):

$$M_{C_{i,j}}\begin{pmatrix} p^c_{1+I_c,1+I_c} & p^c_{1+I_c,2+I_c} & 0 & 0 & & 0 & p^c_{1+I_c,N_C+I_c} \\ p^c_{2+I_c,1+I_c} & p^c_{2+I_c,2+I_c} & p^c_{2+I_c,3+I_c} & 0 & \cdots & 0 & 0 \\ 0 & p^c_{3+I_c,2+I_c} & p^t_{3+I_c,3+I_c} & p^c_{3+I_c,4+I_c} & & 0 & 0 \\ & & \vdots & & \ddots & & \vdots \\ p^c_{N_C+I_c,1+I_c} & 0 & 0 & 0 & \cdots & p^c_{N_C+I_c,N_C+I_c} & p^c_{N_C+I_c,N_C+I_c} \end{pmatrix} \tag{16}$$

where: $p^{c}_{l,m}$ – the probability of transition concentration of material while moving particles in the circumferential direction $l = \overline{1, N_C}$, $m = \overline{1, N_C}$, $I_c = (i-1) \cdot N_C$ – indices of growth.

$$M_{S_{i,j}} = \begin{pmatrix} p^{s}_{1+I_s,1+I_s} & 0 & \cdots & 0 \\ 0 & p^{s}_{2+I_s,2+I_s} & & 0 \\ \vdots & & \ddots & \vdots \\ 0 & 0 & \cdots & p^{s}_{1+I_s,1+I_s} \end{pmatrix} \quad (17)$$

where: $p^{s}_{l,m}$ – the probability of transition concentration of material particles while moving radially $l = \overline{1, N_C}$, $m = \overline{1, N_C}$, $I_s = (i-1) \cdot N_C$ – indices of growth.

The system state can be represented as a column vector, for twin-shaft mixer:

$$S^{k}_{D} = \left[S^{k}_{a} \quad S^{k}_{b}\right]^{T} \quad (18)$$

where: S^{k}_{a} and S^{k}_{b} – the state of system during rotation of the first and second shafts, respectively (Fig. 2.).

The state of system S^{k+1}_{D} can be represented in matrix form:

$$S^{k+1}_{D} = S^{k}_{D} \cdot P_D \cdot P_U\,, \quad (19)$$

where: P_D – mixing matrix that looks like:

$$P_D = \begin{pmatrix} P & 0 \\ 0 & P \end{pmatrix}, \quad (20)$$

where: 0 – zero matrix size $N_I \times N_J$.

P_E – exchanging matrix of material particles during rotation 1-st and 2-nd shafts. Matrix elements except the elements $p^{e}_{N_{j} \cdot i_{I} - N_C + i, N_{j} \cdot J_{I} - N_C + j}$, were $i = \overline{1, \frac{N_C}{2}}$, $i_I = \overline{1, N_I}$, $j = \overline{\frac{N_C}{2} + 1, N_C}$, $J_I = \overline{N_I + 1\,, 2 \cdot N_I}$, is zero.

The mathematical model allows us to calculate the number of transition (shaft rotation) after which the matrix of transition probabilities cease to vary over time, indicating that the system achieve steady state ("forgot" their original position), and therefore the maximum degree of homogeneity of the mixture.

To verify the obtained data the scheme of laboratory stand was developed and described.

It consists of a laboratory mixer, inductive sensor, frequency converter, analog-digital signal converter, a computer with specially developed software and photo camera.

The lab mixer equipped with a contactless inductive sensor and bracket on one of the shafts with which the number of rotations of the shaft can be read. The signal reaches the signal converter, and displayed on the monitor of computer. Also, through the signal converter the frequency converter is connected to the computer that controls electric laboratory setting. It maintains continuous operation at a given engine speed and stops it after a given number of rotations of lab twin-shaft mixer.

The value of the "forgetting time" that an equals the number of mixer shaft rotations at given blades angle, is entered into the computer, after it determining. And blades are set in the required position using a specially designed protractor. Then all previously designing components of the mixture in the mixer, are downloaded and the experiment begins.

On the basis of the experimental scheme was designed construction of the experimental setup [2, 4, 8, 9] - Laboratory twin-shaft concrete mixers (Fig. 8).

The lab mixer on the cart is situated in the correct place for experimentation and wheels fixed by stops (16).

Then, through the open side door (12), located in the cover (11), installing the position of blades (3) - rotation angle with a special protractor. Further downloaded all previously dosaging components of future mixture: scree, cement and sand. Then the side door (12) closed and connected to the control panel (17). By setting a mode of drive motor (9) with frequency converter (21).

Then, the initial process of mixing the dry components in which, depending on the selected initial provisions blades (3) material will be distributed over the mixing chamber (20 sec.).

Then, by CIP head system (13) uniformly sprayed water, and mixing ingredients of mixture are already in final form. This stage lasts 20-25 sec. and it is the most difficult mixing period, as there is a significant increase of dynamic and kinetic viscosity of the mixture and increase the resistance of the environment on the machine.

Another 20-25 sec. mixer working after stopping the water supply. Then drive motor (9) stopped and through the open side door (12) take the samples from different areas of the mixing chamber.

The residue is discharged through the unloading opening (6), driven by lever (8) which fixed with screws (7), is discharged from the mixing chamber.

After sampling and discharge residual mixture through unloading opening (6) the side door (12) and unloading opening (6) is closing, and mixing chamber is washed by water through the pipe system CIP (13) and then unloading hole open and poured all dirt.

Also laboratory mixer equipped with an emergency stop button, flashlight, two limit switches on the side door and appropriate warning label (Fig. 9), making it safe for use in the classroom.

The results of experimental researches are shown in Fig. 10. In a graph curves "oblivion" for different blades angles, which are obtained during the processing of data results by "slick average method".

As you can see from the graphs, for different blades angles α charts differ, since the probability of transition in certain direction is dependent on this parameter.

Among the researched values of blades angle the most efficient $\alpha = 34°$.

Comparing the experimental results and theoretical research (Fig. 10).

As follows from these graphs, the state of "forgetting" in an experimental and theoretical way doesn`t have big difference, and fit into the allowable error of 15%.

The evaluation and analysis of the test samples show that the quality of the prepared mixture meets the calculated time (number of rotations). The quality of the mixture was assessed visually and in terms of strength (Fig. 11).

Fig. 8. The design of the experimental setup: 1 – the case, 2 – shafts, 3 – blades, 4 – bearing assembly, 5 – shaft seal, 6 – unloading opening, 7 – lock, 8 – the lever, 9 – drive motor, 10 – synchronizer, 11 – cover, 12 – side door, 13 – CIP pipe system, 14 – pin sensor, 15 – cart, 16 – wheel with stops, 17 – control panel, 18 – electrical cabinet, 19 – relay, 20 – fuse, 21 frequency converter

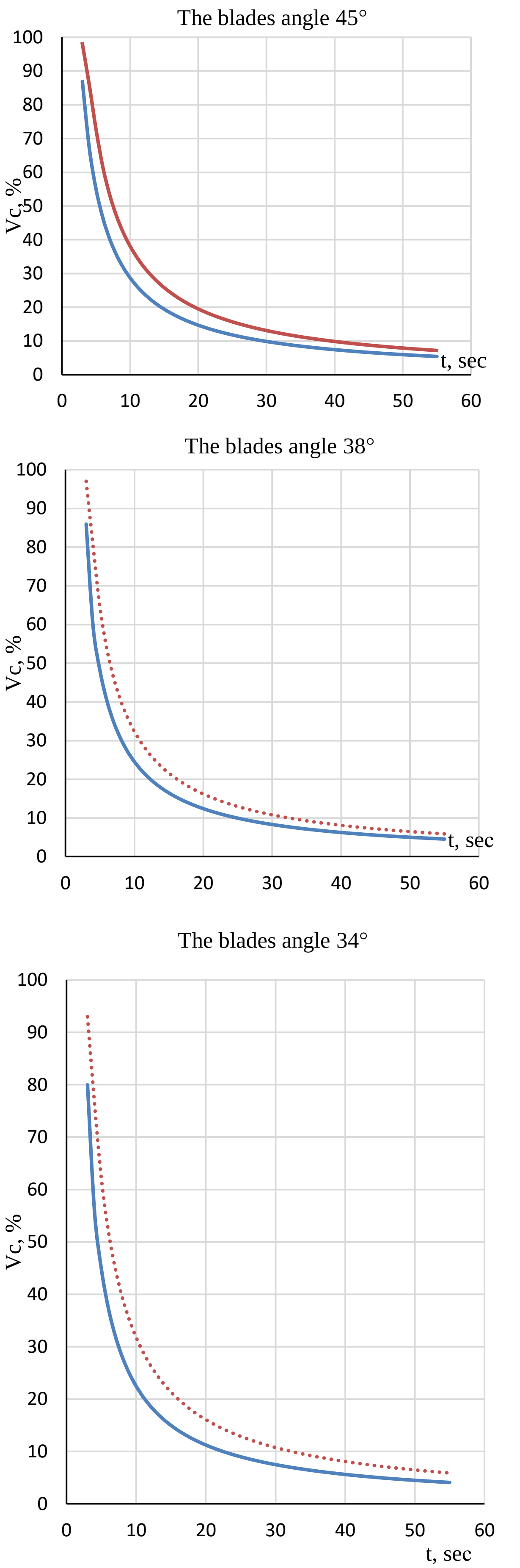

Fig. 9. The comparison of theoretical (solid line) and experimental (broken line) "Oblivion curves"

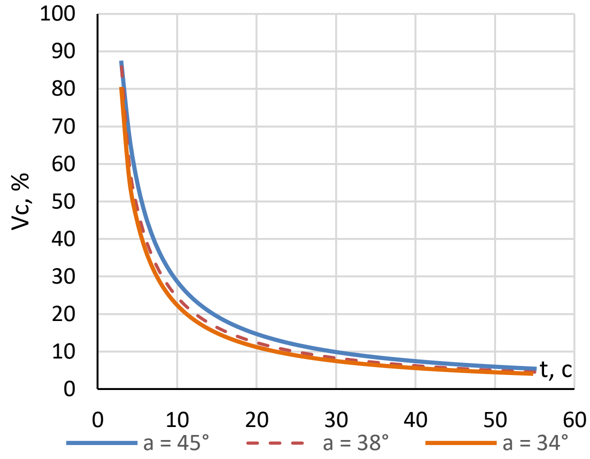

Fig. 10. The graphs of "Oblivion curves"

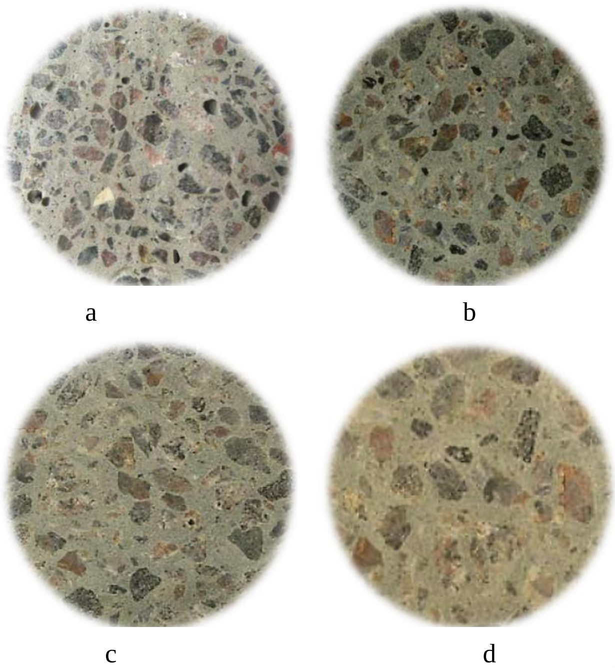

Fig. 11. The comparing of sections of prototypes: *a)* $t = 20s$, b) $t = 30s$, c) $t = 40s$, *d)* $t = 50s$

The data collected during the research probability of transition material processed by statistical methods, and based on their results define conversions (rotating shaft) and the mixing.

These parameters are essential for experimental studies of concrete mixture in a laboratory mixer, to confirm or refute the prevailing theoretical positions.

Conclusions

1. The working hypothesis that the movement of material between the mixing zones depends on the "transition probabilities", which is defined by angle blade was confirmed as a result of mathematical modeling of moving material and performed experimental studies.
2. On the basis of theoretical research the method of calculation of basic parameters of advanced laboratory twin-shaft concrete mixers was created.

3. The laboratory twin-shaft concrete mixers with rotary blades was created.

4. The investigations can improve the efficiency of the mixer by reducing cycle time and energy consumption.

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ДОСЛІДЖЕННЯ НАЛАШТУВАНЬ ЗМІШУВАЧА ПРИМУСОВОЇ ДІЇ ЗІ ЗМІННИМИ ЛОПАТКАМИ

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Анотація. Аналіз та оцінка структурних та технологічних параметрів змішувача з примусовою дією проводився на основі змішувача з примусовою дією з двома шахтами. У цій статті запропоновані теоретичні методи переміщення матеріалу в камеру змішувача з двома шахтами з використанням стохастичного підходу. Процес переміщення матеріалу досліджувався теорією ланцюгів Маркова. На основі запропонованого способу вдосконалення системи оцінки якості з точки зору коефіцієнта варіації суміші. І було передбачено, що основний параметр, який впливає на напрямок руху частинок матеріалу та якість перемішування - це кут повороту леза. Це був головний варіант дослідження. Для перевірки теоретичних основ руху речовин та покращення якості суміші було розроблено експериментальний стенд - лабораторний змішувач з примусовою дією з двостороннім валом із змінними кутами лопатей. Проведені експерименти підтвердили обгрунтованість теоретичних досліджень. На основі проведених досліджень запропоновано алгоритм проектування нових конструкцій двошарових бетонних змішувачів. Робоча гіпотеза про те, що рух матеріалу між зонами перемішування залежить від «ймовірностей переходу», що визначається кутовим лезом, було підтверджено в результаті математичного моделювання рухомого матеріалу та проведених експериментальних досліджень. На основі теоретичних досліджень було розроблено метод розрахунку основних параметрів передових лабораторних двошарових бетонних змішувачів. Створено лабораторні бетонні змішувачі з поворотними лопатями. Дослідження можуть підвищити ефективність змішувача за рахунок скорочення часу циклу та споживання енергії.

Ключові слова: змішувач, бетонозмішувач з двома шахтами, бетономішалка з примусовою дією з двома шахтами, коефіцієнт варіації, бетон, стохастична модель змішування, ланцюги Маркова.

ИССЛЕДОВАНИЕ НАСТРОЕК СМЕШИВАТЕЛЯ ПРИНУДИТЕЛЬНОГО ДЕЙСТВИЯ С ИЗМЕНЯЮЩИМИСЯ ЛОПАТКАМИ

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Аннотация. Анализ и оценка структурных и технологических параметров смесителя с принудительным действием проводился на основе смесителя с принудительным действием с двумя шахтами. В этой статье предложены теоретические методы перемещения материала в камеру смесителя с двумя шахтами с использованием стохастического подхода. Процесс перемещения материала исследовалось теорией цепей Маркова. На основе предложенного способа совершенствования системы оценки качества с точки зрения коэффициента вариации смеси. И было предусмотрено, что основной параметр, который влияет на направление движения частиц материала и качество перемешивания это угол поворота лезвия. Это был главный вариант исследования. Для проверки теоретических основ движения веществ и улучшения качества смеси был разработан экспериментальный стенд лабораторный смеситель с принудительным действием с двусторонним валом с изменяемыми углами лопастей. Проведенные эксперименты подтвердили обоснованность теоретических исследований. На основе проведенных исследований предложен алгоритм проектирования новых конструкций двухслойных бетонных смесителей. Рабочая гипотеза о том, что движение материала между зонами перемешивания зависит от «вероятности перехода», что определяется угловым лезвием, было подтверждено в результате математического моделирования подвижного материала и проведенных экспериментальных исследований. На основе теоретических исследований был разработан метод расчета основных параметров передовых лабораторных двухслойных бетонных смесителей. Созданы лабораторные бетонные смесители с поворотными лопастями. Исследования могут повысить эффективность смесителя за счет сокращения времени цикла и потребления энергии.

Ключевые слова: смеситель, бетоносмеситель с двумя шахтами, бетономешалка с принудительным действием с двумя шахтами, коэффициент вариации, бетон, стохастическая модель смешивания, цепи Маркова.

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