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A Quantitative Criterion for Quality Mixing Assessment for the Effective Unit of Mixed Products

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Abstract. The paper proposes the new quality assessment criteria of resulting mixture for effectively used unit of mixed products enabling to consider the deviation of all the mix components taking into account the share of each component in the mixture. Quantitative requirements for stability of the dosing devices of mixing apparatus are determined for the specified allowable value of dispersion.

Key words. mixture production, determined formation of homogeneity, mixture quality assessment criteria, mixing devices, the quality of mixed products.

1. Introduction

The general technology approaches to homogeneity formation of loose materials mixtures, which have exclusively probabilistic character [1-8], are known. Such scientific approach was reasonable in the middle of the last century and was not undergone any basic changes up to our time. The most complete generalization of these methods and their characteristics was formulated in the work [1], and as for the last materials in the works [9-11]. All these authors pointed out the complexity of the description and data modeling of mixing processes, and there was not always the predictable use of ready mixas a result.

Currently the production of homogeneous common lots of high-volume mixture products (15 ... 20 tons and more) is often achieved by means of small lots mixing which differ significantly in their characteristics. In this case, the homogeneity of the total lot (the mixing quality) is controlled by the radius of dispersion obtained r_v from the full-scale tests according to formula:

$$r_v = 0,6745\sqrt{\frac{\sum_{i=1}^{n}(V_i - V_{cp})^2}{n-1}}, \tag{1}$$

where V_i – is the main characteristic of the trial test; V_{cp} – is the average value of the main characteristic for a series of tests.

If the dispersion of the basic characteristic exceeds the allowable value r_v , the total lot is subjected to re-mixing.

This quality control of the mixing process is, firstly, expensive, and secondly biased, since the deviation of the main characteristic is caused not only by poor-quality mixing, but also by the dispersion characteristics of small lots.

The quality of various components mixing in the chemical, medical, construction and other industries, as the analysis shows [1-8], is evaluated by various criteria, however, in the post-Soviet space, the homogeneity coefficient got the most distribution:

$$V = \frac{100}{C_0}\sqrt{\frac{\sum_{i=1}^{n}(C_i - C_0)^2 \cdot n_i}{n-1}}, \% \tag{2}$$

$$V = \frac{100}{x}\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - x)^2}, \% \tag{3}$$

where $C_i -$ is the concentration value of one of the components in the samples; $C_0 -$ is the concentration of the same component with an ideal distribution; $n_i -$ is the number of samples with concentration C_i; $n -$ is the total number of samples; $x_i -$ is the number of particles of a component with an ideal concentration C_0; $x = \frac{\sum_{i=1}^{n} x_i}{n} -$ is the selective average number of particles (tubes, granules, etc.).

In this case, these values were determined only for one of the mixture components, most often for the component of the smallest volume. It is the key component as it is more sensitive in ratio rating violation. Such an assessment is characterized by simplicity, but assesses the process objectively only when two components are mixed. When mixing three components, for example, the diffusion of the smallest component may prove to be insignificant and the coefficient of variation will be close to none, and the actual and required number of particles of the other two components will differ substantially from each other. This will result in considerable heterogeneity of the mixture. It is also difficult to evaluate the mixing quality of several components which have the same volume.

2. Problem formulation

The first scientific justification of refusal of probable homogeneity formation and its technological implementation was proposed in the work [12-14]. The innovative component mixing technique with an ordered component arrange mentrelative to each other was proposed. This provided higher quality of the mixture obtained and the determined formation of their homogeneity taking into account technical parameters of mixing and portioning devices [15, 16]. The scientific novelty of the work is defined by the new approach to the quality forming of future products, and the deductive design of mixing and packing complexes when accounting the ready mixparameters and the equipment parameters .

To solve the technological problem this work proposes to introduce the concept of the effective unit of mixture use which is formed from small lots of homogeneous components with different physical and chemical properties, but providing the uniform, equal effect of its use.

It is expedient to establish the criterion that would allow, firstly, to assess the quality of the mixing process, and secondly, to perform non-destructive testing during the mixing and, thirdly, to correct the process in order to increase product homogeneity.

When developing the criterion for quality mixing assessment of small lots, the number of which is from two to six, often with ratios close to unity, firstly, it is necessary to strive for the criterion to take into account the deviations of all components in the mixture, and secondly, when establishing such an integral indicator it is necessary to take into account that the same absolute ratio deviation of the j-th small lot causes a different mixing quality, depending on the share of this lot in the mixture. Therefore, obviously, it is necessary to take not absolute, but relative deviations of the ratio. Thirdly, such a generalized criterion should take into account not only the mixing quality, but also reflect the quality of the mixed product as a whole, i.e. to take into account the degree of influence of the ratio deviation of small lots to the deviations of the output characteristics of the mixture.

3. Theoretical part

When mixing products with a total weight G, the weight ratio $G_1;G_2;...;G_J$ of J small lots is usually given. Then the weight fraction j-th of the small lot is:

$$P_{jb} = \frac{G_j}{G}. \tag{4}$$

For the effective mixture unit, the weight W of the weight j-th of the small lot w_j can be represented as:

$$w_j = w \cdot P_{jb} = w_{0j} \cdot m_j, \tag{5}$$

where w_{0j} – is the arithmetic mean of the mass of one mixture element j-th of the smallest lot; m_j – is the expected number of mixture elements j-th of the smallest lot in the effective unit of the mixture.

Total number of elements in the effective unit of the mixture:

$$m = \sum_{j=1}^{J} m_j. \tag{6}$$

Due to value smallness of the one element mass dispersion of j-th of the smallest lot Δw_j (it is estimated that the product of numbers $\Delta w_j \cdot m_j < 1$) next will be assumed to be w_{0j} constant.

Then in the i-th sample of weight w which has m unit mixed elements, the absolute difference between the actual and the required fraction of the j-th small lot is represented as:

$$\Delta P_{a\delta ci} = \left| \left(\frac{w_{0j} \cdot m_{j\partial i}}{w} - \frac{w_{0j} \cdot m_j}{w} \right) \right| = \left| \left(P_{j\partial i} - P_j \right) \right|. \tag{7}$$

Graphically, for example, when mixing three lots, this can be represented as a dynamic equilibrium triangle (Fig. 1).

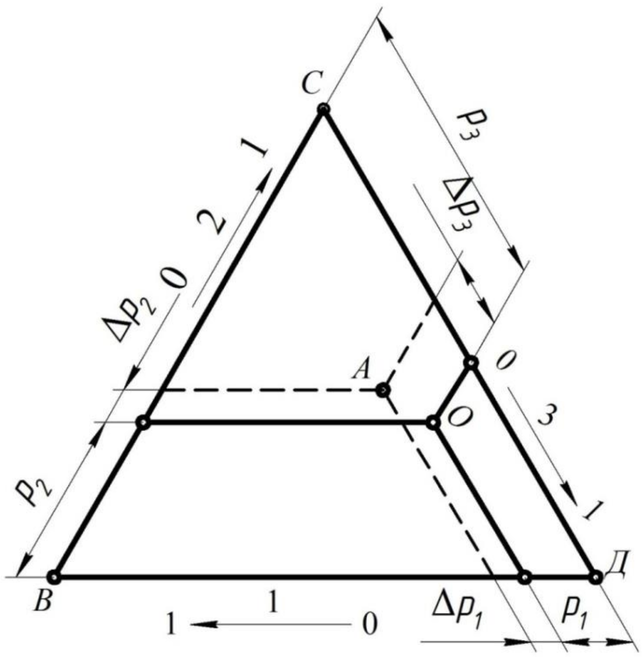

Figure 1. Dynamic equilibrium triangle of three constituent lots.

When dividing this value by the required fraction of the j-th small lot, we obtain the measure of the deviation of the ratio of the j-th smallest lot in the i-th sample:

$$\Delta P_{ji} = \frac{\Delta P_{абсji}}{P_j} = \left| \left(\frac{m_{j\partial i} - m_j}{m_j} \right) \right| \tag{8}$$

Then, obviously, for i-th sample, the most general indicator of the mixing quality is the measure of the deviation of the total lot, which is the sum of the deviation measures of the constituent lots:

$$\Delta P_i = \sum_{j=1}^{J} \left| \left(\frac{m_{j\partial i} - m_j}{m_j} \right) \right| \tag{9}$$

The average measure of the deviation between the total lot according to the data of the samples is determined from the formula:

$$\Delta\bar{P} = \frac{\sum_{i=1}^{n} \Delta P_i}{n} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{J} \left| \left(\frac{m_{j\partial i} - m_j}{m_j} \right) \right|}{n}, \tag{10}$$

where n - is the number of samples.
Selective variance of the discrepancy measure of the common batch:

$$D(\Delta P) = \frac{1}{n-1}\sum_{i=1}^{n}\left(\Delta P_i - \Delta\bar{P}\right)^2 \tag{11}$$

Selective standard deviation:

$$\sigma\left(\Delta P\right) = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(\Delta P - \Delta\bar{P}\right)^2} \tag{12}$$

With continuous mixing of small lots [1,5,12,14], consisting in the single-piece feeding of tubes with metering devices, it is possible to continuously monitor the mixing quality during the operation by determining the actual value of the divergence measure of the common lot ΔP_∂ and to control the process, for example, small computing modules and power supplies, ensuring the following:

$$\Delta P_\partial \le \left[\Delta P\right] \tag{13}$$

We can determine the allowable value of the discrepancy measure of the total lot $\left[\Delta P\right]$ and establish quantitative requirements for the stability of the metering mixing device for a given permissible value $\left[r_V\right]$. It is possible because the main characteristic spread is influenced not only by mixing quality but also the characteristic dispersion of small lots.
We determine the maximum possible relative amplitude of the metering device's output and the relative amplitude δ_{m_0} of the supply of the components δ_{m_j} of the mixture for the given allowable value of the divergence measure of the total lot $\left[\Delta P\right]$.
When mixing J small lots on a mixing machine having W_j metering devices for feeding a j-th small lot,

$$\Delta P = \frac{\Delta m_1}{m_1} + \frac{\Delta m_2}{m_2} + \ldots + \frac{\Delta m_J}{m_J} \le \left[\Delta P\right], \tag{14}$$

where Δm_j – is the unit amplitude of the supply of the smallest lot.

In the case of the same productivity m_0 of all the metering devices of the mixing machine:

$$m_1 = m_0 \cdot W_1;\; m_2 = m_0 \cdot W_2;\; \ldots\; m_J = m_0 \cdot W_J \tag{15}$$

The experiments proved that [12]

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$$\Delta m_j = \Delta m_0 \cdot \sqrt{W_j}, \tag{16}$$

where Δm_0 – is the amplitude of the performance of a single metering device.
Then:

$$\Delta P = \frac{\Delta m_0}{m_0}\left(\frac{\sqrt{W_1}}{W_1} + \frac{\sqrt{W_2}}{W_2} + \ldots + \frac{\sqrt{W_J}}{W_J}\right) = \delta_{m0} \cdot \sum_{j=1}^{J} \frac{1}{\sqrt{W_j}} \le [\Delta P] \tag{17}$$

Location:

$$\delta_{m_0} \le \frac{[\Delta P]}{\sum_{j=1}^{J} \frac{1}{\sqrt{W_j}}} \tag{18}$$

Respectively:

$$\delta_{m_j} = \sqrt{W_j} \cdot \delta_{m_0} \le \frac{[\Delta P] \cdot \sqrt{W_j}}{\sum_{j=1}^{J} \frac{1}{\sqrt{W_j}}} \tag{19}$$

It is convenient to carry out the relative amplitudes determination δ_{m_0} and δ_{m_j} using the nomogram (Fig. 2) or on the computational module.

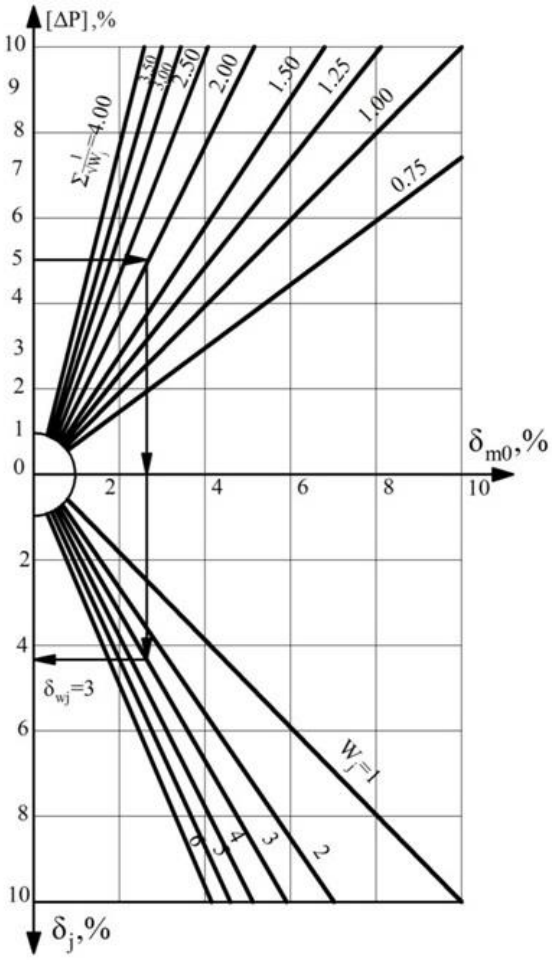

Figure 2. Nomogram of the relative amplitudes determination of the metering device performance δ_{m_0} and the feed unit δ_{m_j}

4. Conclusion

The adapted quantitative criterion for quality mixing assessment is developed. This criterion allows to control the mixing quality without appeal to expensive destructive tests. It can provide high uniformity of composite products due to assignment of admissions on operation stability of metering devices of mixing device. High performance of process was determined using theoretical and pilot studies. In particular, the degree of mixture uniformity was raised in 2-2,5 times, the power expenses due to the exception of long operation of components was decreased in 2,5 -3 times, the working area was decreased in 3-5 times, and labor productivity was increased in 2-2,5 times because of the technology chain reduction [13,17,18].

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