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THE ANALYSIS OF MIXING DEGREE OF GRANULAR PRODUCTS WITH THE USE OF MICROTRACERS

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Summary. Paper presents the results of investigations on the mixing process of six mineral blends of similar physical properties. Mixing process was realized in the mixers of various construction and capacity. Different mixing duration and filling degree of the mixers were used. The uniformity of mixtures was determined indirectly, by means of microtracers introduced into mixture: the uniformity of their distribution in mixed material was determined after each mixing cycle.

Keywords: mixing, homogeneity, microtracers.

INTRODUCTION

Mixing of loose, granular materials is a very complex process, where the mixed compounds are distributed by random, chaotic motion of the particles. Mixing process is realized in various mixers, different in the type, shape of agitator, technological parameters etc. [Boss 1987, Dreszer et al. 2007].

Mixing process is strongly affected by the physical properties (such as the density, moisture content, average particle size, the angle of repose, slip angle and shape of the particles) of the components. Moreover, the kinetics of mixing process depends on its realization conditions as well as on the construction of mixing assembly [Rachowiecki A. 1991, Grochowicz, Walczyński 2004, Kulig, Laskowski 2008, Dziki, Laskowski 2006].

The objective of mixing process consists in achieving such a state of mixture where its particles are situated in random positions. After achieving the maximum mixing degree, obtained system often stratifies tending to stable equilibrium state, where the particles of the same physical properties take up a definite location in the bed. Such a phenomenon is defined as segregation [Wiliams 1976]. Basic parameter to evaluating the quality of this process is the mixing degree that may be described [Rose 1959], by the relationship:

$$M = 1 - \frac{s}{\sigma_0}, \tag{1}$$

where:

M – mixing degree,
s – standard deviation after mixing,
σ_0 – standard deviation in state of primary segregation.

The numerical value of mixing degree ranges within the interval from 0 to 1, where value 0 denotes the mixture non-mixed, while value 1 – the system perfectly mixed. Adequate definition of the quality scale may by expressed by evaluation of the mixing state [Boss 1987].

The kinetic model of mixing process for heterogonous grainy materials was also proposed [Rose 1959]:

$$\frac{dM}{dt} = A(1 - M) - B\phi , \qquad (2)$$

where:
M – mixing degree,
A i B – constants depended on the mixed compounds,
Φ – potential of segregation.

According to Rose, the potential of segregation may range within –1 and +1; depending on the initial compound distribution in the mixer and its relation with mixing degree, the M may be expressed as follows:

$$M = 1 - \Phi^2. \qquad (3)$$

In investigations on evaluating the mixing degree, the proper material sampling and sample analysis are an important factor. Sampling should be representative, what is attainable only at an assumption that the samples were taken from measuring points uniformly distributed in whole volume of the mixture. The problems of sampling and sample analysis were considered by a number of scientists [Ciftici et al. 2002, Eisenberg et al. 1992, Heidenreich et al. 2000, Laurent et al. 2002, Lindley 1991].

The accuracy of mixing process analysis depends also on the size of tested sample. In feed processing industry the size of material sample is specified by adequate standard regulations [Kwiatek et al. 2004, Matuszek, Tukiendorf 2008]. Boss determined the condition of minimum sample dimension i.e. it must contain at least as many particles that, in case of ideal mixing, the component occurring in lowest concentration is represented in the sample by at least one particle. Therefore, the small samples provide a strong dispersion, whereas too much ones may suggest better homogenization of the mixture than it really is [Boss 1987, Wiliams 1976, Putier 2001].

Usually the mixtures used in feed processing industry are multicomponent, where each component represents different physical properties; thus, achieving their satisfactory blend may be often very difficult. Determination of basic mixing parameters, such as mixing duration for given type of the mixer, is an important element deciding on the quality of final product [Fan 1970, Rollins et. al. 1995, Królczyk, Tukiendorf 2008].

OBJECTIVE OF RESEARCH

The studies aimed at checking the possibilities of evaluating feed mixture homogeneity with the use of Mocrotracer ^{TM} F – Blue.

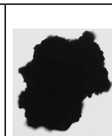
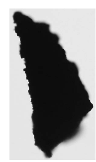
MATERIALS AND METHODS

Investigations were carried out in four horizontal band mixers and one vertical conical of planetary type. According to technical specification mixing effectiveness of the machines was 1:10000.

Tests were conducted in accordance with the ASAE Standard (No.S303) describing the testing procedures of mixing effects. According to this procedure from each batch of mixed material 10 samples of 80 g weight were taken.

The Microtracer ™ F-Blue at a rate of 50g per 1 ton of mixture was used for tracing. 1 g of microtracer contains 25000 particles. At such a number of particles and 100% mixture homogeneity, a 80g mixture sample should contain 100 microtracer particles. Specific characteristics are showed in the table 1.

Table 1. Amount and mass of microtracers

Kind of microtracer	Mass of 100 units [g]	The biggest size [mm]	Photo
Blue	0,0029 0,0029 0,0029 0,0031	505,30 288,22 416,16 246,09 543,25 259,67 288,02 239,13	   
Average	**0,00295**	**348,23**	
Standard deviation	0,0000086	*114,4132*	
Red	0,0034 0,0032 0,0034 0,0029	296,35 301,61 281,02 264,00 343,02 182,04 156,74	  
Average	**0,003225**	**260,6829**	
Standard deviation	*0,000204634*	*62,26671*	

The microtracer, after initial mixing with soyabean meal was supplied directly to the mixer just after its filling. Samples of 80g weight taken for determination of the mixing degree were separated in the Rotary Detector (model BL-89, series XO-7) for snatching the microtracers. The tracer test involves pouring a feed sample throught a “Rotary Detector” laboratory magnetic separator isolating the tracer on a small filter paper. For a quantitative estimate of the tracer and by inference the medication, one demagnetizes the magnetic material and sprinkles it onto a larger filter paper wetted with the appropriate developer (50% ethanol) to yield a paper with countable spots.

Material for tests included the mixtures marked by letters: A, B, F.

Scope of the tests:

– mineral mixtures A and B, mixing duration – 3, 5 and 7 minutes, mixer capacity 400 liters, horizontal mixer, filling 100%,
– mineral mixture F, mixing duration 5, 6, 7, 8, 10 min., mixer capacity 1500 liters, horizontal mixture, filling 100%.

Following physical parameters were determined for all the mixtures: angle of repose, slip angle, bulk density, shaken density, moisture content, mean geometric size of the particle.

Obtained measurement results were statistically analyzed and variation coefficient was determined as a criterial value evaluating the quality of mixing process.

Time of emptying was checked for all the mixers, next the frequency of sampling was assigned.

Exceptionally, the samples for determination of the mixing degree from mixture marked by letter A were received at constant capacity. It allows to determine the whole received sample.

RESULTS AND DISCUSSION

Selected physical parameters of the mixtures tested, significant for the process of mixing are presented in table 2. The test were carried out in accordance with obligatory standards.

Table 2. Physical characteristics of investigated mixtures

Mixture	Angle of repose [°]	Slip angle [°]	Bulk density [kg·m^{-3}]	Shaken density [kg·m^{-3}]	Moisture content [%]	Mean geometric size of particle d_g [mm]
A	38	24,50	1448	1468	2,10	0,42
B	37	23,75	1235	1270	1,95	0,47
F	30	33	1188	1237	2,3	0,49

Mean geometric size of the particle tested mixtures ranged from 0,42 to 0,49 mm, whereas the bulk density was within the range of 1188 – 1448 kg·m^{-3}. Above results enabled to count the tested mixtures among powdery products.

Measuring results of mixing efficiency – mixture A Table 3 presents the investigation results concerning the occurrence of microtracer particles in the samples and calculated on this basis variation coefficients for the tested mixture.

Obtained results showed that the optimum mixing duration enabling to get homogenous product for the mixture of given raw material composition, amounts to 5 min. Either, the shortening of mixing time or its elongation cause a disadvantageous changes in mixture homogeneity.

Table 3. Number of microtracer particles in particular samples – the mixture A

Sample	Number of microtracer particles in the sample		
	4min.	5min.	7min.
1	153	157	153
2	156	140	152
3	165	134	157
4	157	158	175
5	137	152	137
6	129	134	142
7	157	130	161
8	168	159	138
9	177	139	134
10	130	147	146
Mean	*152,9*	*145*	*149,5*
SD	16,148	11,005	12,713
CV	**10,561**	**7,5897**	**8,5034**

Test results for the mixture B

The results of testing the homogeneity of mixture B are given in tables 4 and 5.

Table 4. Number of microtracer particles in particular samples after mixing over 4 min – the mixture B

Sample	Number of microtracer particles in the sample		
	4 min.	5 min.	7 min.
1	103	108	117
2	123	110	105
3	93	121	100

4	121	125	108
5	91	123	99
6	92	91	115
7	79	100	106
8	114	110	123
9	132	117	125
10	114	107	125
Mean	*106,2*	*111,2*	*112,3*
SD	17,145	10,665	10,034
CV	**16,144**	**9,5905**	**8,9348**

Testing results for mixture F

Investigations included several mixing durations, i.e. 5, 6, 7, 8, 10 min. in order to assign the time necessary to getting the homogeneity consistent with the standard requirements for premixes. The results are presented in table 5.

Table 5. Values of CV coefficient for particular mixing duration of the mixture F

Sample/mixing duration	5	6	7	8	10
	Number of microtracer particles				
1	73	101	86	126	86
2	85	81	92	112	107
3	85	103	129	113	89
4	93	108	97	115	99
5	128	106	92	98	83
6	94	106	99	107	101
7	133	112	91	106	118
8	109	89	91	99	101
9	105	85	87	96	77
10	81	90	78	105	103
Mean	*98,6*	*98,1*	*94,2*	*107,7*	*96,4*
SD	19,957	10,857	13,555	9,1415	12,429
CV	**20,24**	**11,067**	**14,389**	**8,4879**	**12,894**

The test results showed that the adequate homogeneity characterized by CV below 10% was achieved after 8 min. mixing duration (table 5). Thus, it is suggested – at production of premixes in tested mixer type – to emplay the mixing duration of 8 min.

CONCLUSIONS

The investigations concerning determination of homogeneity for 6 mixtures from mixtures from various mixers by means of the microtracers showed that this method is useful to analysis of mixing process in production plants. The method enables fast reaction during technological process running, thus it eliminates the risk of producing mixtures of non-standard parameters.

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ANALIZA STOPNIA WYMIESZANIA PRODUKTÓW SYPKICH Z ZASTOSOWANIEM MIKROWSKAŹNIKÓW

Streszczenie. W pracy przedstawiono wyniki badań procesu mieszania sześciu mieszanek mineralnych o zbliżonych właściwościach fizycznych. Proces mieszania prowadzono w mieszarkach o różnej pojemności i konstrukcji. Stosowano różne czasy mieszania i stopnie wypełnienia mieszarki. Jednorodność mieszanek określano pośrednio przez wprowadzenie do mieszanki mikrowskaźników (microtracers) i oznaczenie równomierności ich rozmieszczenia po cyklu zmieszania.

Słowa kluczowe: mieszanie, homogenność, mikrowskaźniki.