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THE APPLICATION OF IMAGE ANALYSIS AS A METHOD OF EVALUATION OF GRANULAR BLEND'S QUALITY

Marek Tukiendorf[1], Marek Krótkiewicz[1], Janusz Boss[2]

[1]Technical University of Opole, [2]University of Opole; Opole

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Due to difficulties in determination of a blend quality in industrial conditions using conventional methods there are needs of finding out brand-new solutions providing quick and precise estimation of a mixing degree *M* at certain stage of mixing. One of these methods can be a computer picture analysis of the crosswise profile of bin fulfilled by the two-component granular blend. Based on the laboratory mixing device, containing two or more the same bins, the usefulnees and effectiveness of this method was presented to evaluate the mixed bed quality. The snapshots of the crosswise profiles provide estimation of the mixing degree at certain stage of mixing. The achieved parameters were compared statistically with the parameter obtained using classical sieve analysis. The obtained mixing parameters expressed in the *M* degrees versus the proces steps were presented graphically in the scatterplots. Next, the photographic result with those achieved using the classical sieve method were compared statistically. The results were satisfying.

INTRODUCTION

Mixing using the funnel-flow method consists in discharging granular material from bin to bin. Its basic component is observed in assumedly determined bin transverse profiles. An estimation of the component fraction in particular profiles is possible following its separation. The separation process is not always easy to conduct. In the case of mixing materials with similar diameters, this trial is very labour-consuming. For large quantities and small diameter dimensions, this process may be even impossible to carry out [Roberts, 1998]. Thus, the evaluation of the quality of such blends may be difficult, and consequently does not allow estimating a real value of a mixing degree *M* [Boss, 1987, 1991; Boss *et al.*, 1997 a, b].

An evaluation of mixing effects is performed based on the estimation of quantity fractions of the key component – tracer. Depending on the type of mixed components and the trials of mixing as well as the time of the process duration, the σ value changes and influences the degree of mixing according to the relation proposed by Rose (1) [1959]:

$$M=1-\sigma_i/\sigma_0 \quad (1)$$

where: σ_i – is the standard deviation of a system following consecutive steps of mixing, and σ_0 – is the standard deviation of a system in the stage of prime segregation.

Due to a number of difficulties appearing during the application of conventional methods for the evaluation of the blend quality in industrial conditions, brand-new solutions allowing fast and precise determination of the mixing degree *M* are required in every stage of the process. One of these can be method of analysis of photographic image of the bin transverse profile for two-componential granular blend; being the subject of the presented paper.

METHODS

In the experiment, a simple device was used that allows estimation of the components' concentrations on the laboratory scale. This evaluation can be performed *via* dismantling of the successive rings of the bin, releasing the granular substance and subjecting it to sieve analysis or other separation method (Figures 1, 2).

The mixing was conducted through the consecutive steps of discharge and bin replacement [Boss, 1991].

The two-component granular systems differing considerably in densities were mixed (with density ratio of

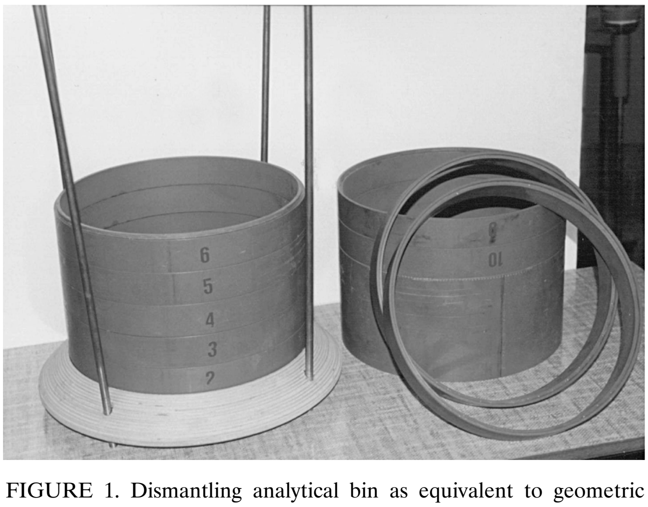

FIGURE 1. Dismantling analytical bin as equivalent to geometric dimensions of laboratory bins employed in the mixing process using a funnel-flow method.

Author's address for correspondence: Marek Tukiendorf, Politechnika Opolska, ul. Mikołajczyka 5, 45-233 Opole, tel.: (48 77) 400 63 09, fax: (48 77) 455 60 80, e-mail: mtuk@po.opole.pl

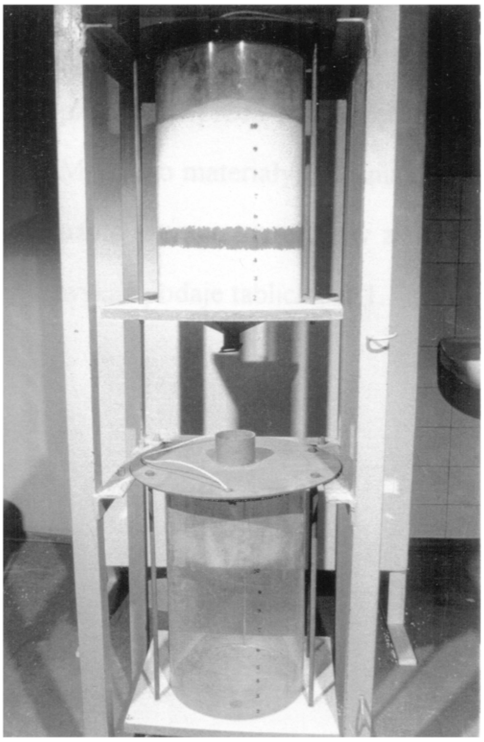

FIGURE 2. Laboratory mixing system using a funnel-flow method; a supplying bin over a receiving bin with the prepared tracer load and dispersing phase.

ρ_1/ρ_2= 8.25 and diameter ratio of d_1/d_2=1.50). The tracer in the quantity ratio of 1:10 was placed in the fifth medium mixer section. Next, following the succeeding steps was led of discharge, the system to the dynamically stable stage. It was proved in earlier research that the number of 10 steps is sufficient and further mixing does not affect any quality changes in the system [Boss *et al.*, 1997 a, b]. To enhance the mixing effect at the material with so considerable difference in density, a roof shape insert system (RSI) was used with divergence angle of 120 degrees [Schlick *et al.*, 1996]. The cone was situated in axes of bins (Figure 3) The study

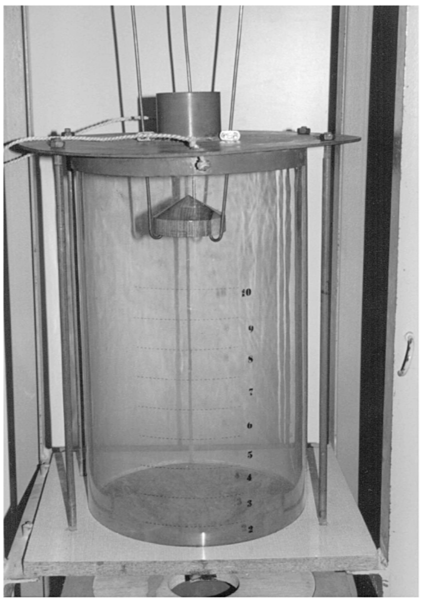

FIGURE 3. The cone situated in axes of bins – Roof Shaped Insert System.

was performed in two stages: with and without application of RSI system.

In the experiment the area of observation was divided into 10 equal profiles of the same height. Next, the distribution of the tracer's concentration was assessed.

Two methods of evaluation of the tracer's fraction were used:

(*i*) Assessment of the degree of homogeneity of grains' superficial distribution based on the computer determination of two classes of objects (background and mixed material).

The quantity of superficial fraction of objects affiliated to different classes is a result of the algorithms used. These algorithms are a classical element of acquisition and image transformation.

Two classes of objects were determined in the research conducted. The one-elemental vector of characteristics was applied to describe objects based on the intensity value of the reflected light. A recognition function (A) must be treated as a product of three representations corresponding to three phases of data transformation:

$$A=F\cdot C\cdot B \qquad (2)$$

$B:D\rightarrow X$ is a reception after which a value of an intensity of the reflected light is attributed to the objects. It is a phase related to physical acquisition of the characteristic describing the ability to reflect the light and to transform it to normalized numeric value.

$C:X\rightarrow R^L$ stands for a determination of affiliation function depicting the similarity degree of objects to a certain class. This representation aims at defining a function, which basing on the values of characteristic of objects, will be counting the similarity degree of objects.

$F:R^L\rightarrow I$ the last element of the process is representation of values of the affiliation function and denotes the moment of decision making of objects' affiliation to a selected class. This procedure consists in assessing the border brightness of objects that will be used to select them to separated sets. Consequently, each object will be provided with a number of class it is affiliated into [Krótkiewicz & Ulbrich, 1994; Krótkiewicz, 1994, 1998].

X– space of characteristics; D – set of objects; R – set of real values determining similarity degree; I – set of class' numbers.

(*ii*) The method of classic sieve analysis allowing determination of the tracer's share in each of the bin profiles. It consists in separation of the two-component granular system differing in diameter size.

The results obtained by the two above-mentioned methods were compared.

RESULTS

The use of the RSI system caused a considerable increase in equilibrium mixing degree from Me_1=0.65 to Me_2=0.77 in the case of the sieve analysis and from Me_1'=0.69 to Me_1'=0.73 in the case of the computer picture analysis, respectively (Me – degree of mixing in the equilibrium state).

The observed values of concentration distribution of the tracer were changed according to the formula (4) and presented in Table 1 and Figures 4 and 5.

TABLE 1. Mixing degrees for succeeding steps and systems for methods used.

Degree of Mixing /Number of Step	1	2	3	4	5	7	10	Method of analysis/System of mixing
M	0.75	0.62	0.59	0.62	0.58	0.64	0.65	Sieve analysis without the RSI system
M	0.81	0.60	0.54	0.67	0.72	0.69	0.69	Computer analysis without the RSI system
M	0.65	0.71	0.81	0.78	0.79	0.78	0.77	Sieve analysis with the RSI system
M	0.72	0.77	0.76	0.74	0.74	0.72	0.73	Computer analysis with the RSI system

RSI System = Roof Shaped Insert System; *M* – Degree of Mixing

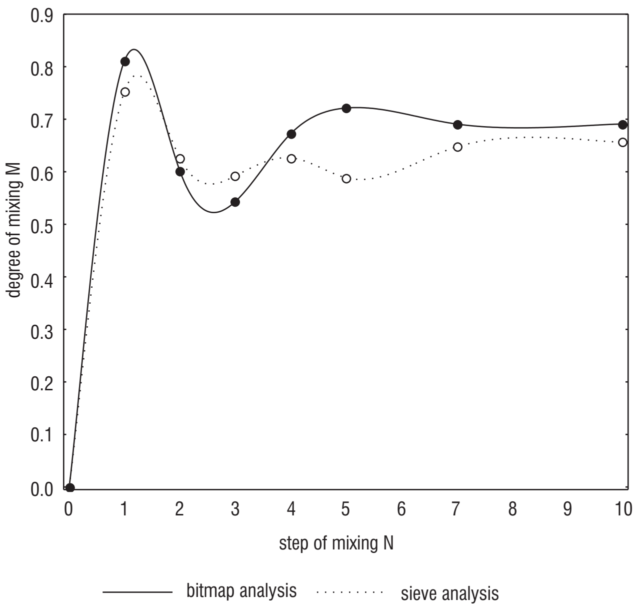

FIGURE 4. Changeability of the degrees of mixing vs. the number of steps without the RSI System.

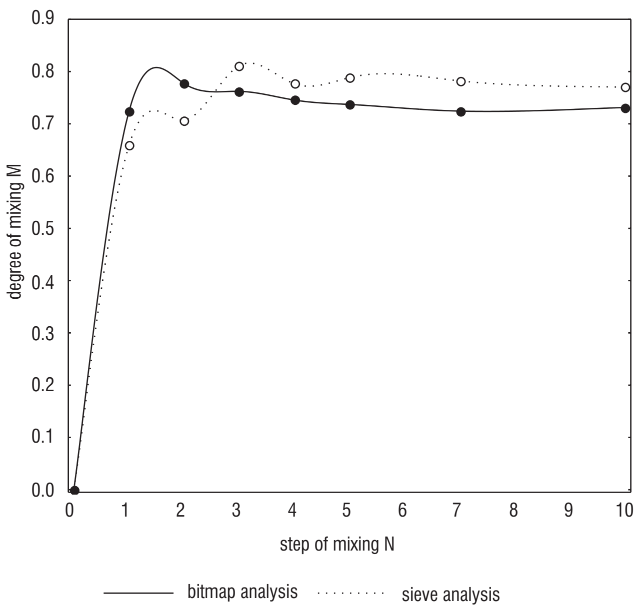

FIGURE 5. Changeability of the degrees of mixing vs. the number of steps with the RSI System.

A rough visual analysis suggests that changes in the mixing degrees from the total segregation up to the equilibrium state (step N=10) are similar for both methods (see scatterplots in Figures 4 and 5). The two sets of values from sieve and computer analyses were set together. The changes in the mixing degrees for the system without inserts were presented in Figure 4, while these for the system with the RSI in Figure 5.

The results of statistical analysis of similarity between these changes based on the Bartlett's test are presented in Table 2.

TABLE 2. Bartlett's analysis.

Comparison of sieve and computer analyses	Without RSI System	With Roof Shaped Insert System
statistic λ^2	0.0554	0.01361

Both achieved statistics λ^2 are much lower than the critical value $\chi^2=3.84$ and prove the observed similarities.

CONCLUSIONS

The results provide evidence that the computer bitmap analysis may be successfully applied in such a measurement process wherein other types of analysis of the investigated material system cannot be used or are difficult to use.

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ZASTOSOWANIE ANALIZY OBRAZU JAKO METODY OCENY JAKOŚCI MIESZANINY ZIARNISTEJ PODCZAS MIESZANIA SYSTEMEM FUNNEL-FLOW

Marek Tukiendorf[1], Marek Krótkiewicz[1], Janusz Boss[2]

[1]Politechnika Opolska, [2]Uniwersytet Opolski; Opole

Z uwagi na wiele trudności wynikających ze stosowania konwencjonalnych metod określania stanu jakości mieszaniny w warunkach przemysłowych potrzebne są nowe rozwiązania pozwalające na szybkie i precyzyjne określanie stopnia zmieszania *M* w danym momencie procesu. Jednym z takich rozwiązań może być zaproponowana tu metoda analizy obrazu fotograficznego przekroju poprzecznego zbiornika wypełnionego dwuskładnikową mieszaniną ziarnistą. Na przykładzie laboratoryjnego urządzenia mieszającego składającego się z dwóch jednakowych zbiorników pokazano przydatność i skuteczność tej metody jako dobrego sposobu oceny jakości mieszanego złoża. Zatrzymane fotograficznie obrazy wybranych przekrojów pozwalają na oszacowanie stopnia zmieszania całego układu w dowolnym momencie prowadzenia procesu. Uzyskane tą drogą parametry zmieszania układu w postaci wartości stopni zmieszania *M* przedstawiono graficznie ilustrując ich przebieg zmienności wraz z kolejnymi krokami procesu (rys. 4 i 5). Następnie porównano w sensie statystycznym podobieństwo wyników uzyskanych na drodze analizy fotograficznej z wynikami otrzymanymi na drodze klasycznej analizy sitowej. Efekty tego porównania były zadawalające (tab. 2).