Continuous Measurement of Degree of Mixing in Power Mixer by Optical Method

Continuous Measurement of Degree of Mixing in Powder Mixer by an Optical Method

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A new system has been developed to measure continuously the flow characteristics of solid particles and the degree of mixing in powder mixers. Modulated light from a light-emitting-diode is conducted onto a mixture of colored particles through a probe consisting of a pair of optical fibers, and the intensity of the reflected light from the surface of the mixture is measured continuously by a high-sensitive photometer. Five sets of the probes are installed in separate positions of a mixer vessel. The signal from the five photometers are processed by an analog-to-digital converter and a microcomputer system. The concentration of the key component in the mixture and the degree of mixing at every moment are calculated and displayed on the video screen of the computer system.

1. Introduction

Most of the conventional methods of evaluating the performances of powder mixers are based on a kind of off-line measurements. After starting the operation of a powder mixer, in which two or more components of particulate matrials to be mixed are charged at a known ratio, a number of spot samples are randomly taken out of the mixture in the mixer by stopping its operation at a given time interval, and all the samples are analyzed to know the concentrations of the key component and then to calculate the variance or standard deviation of the key component concentrations, which represents the degree of mixing of the mixture in the powder mixer.

This procedure, however, is so tedious and time-consuming that one cannot obtain enough data for the performance evaluation of a powder mixer within a short or limited period of time. Recent development of high-performance functional materials such as fine ceramics, synthetic engineering plastics and other many composite materials, urges more efficient powder mixers to be selected or devised, and more efficient methods of assessing the performances of many potential mixers of different types, have to be employed or devised. Recent great progress in optical fiber technology and microelectronics has made this possible.

Yano, Satoh and Mineshita[1] and Yano. Satoh, Mineshita and Yamamoto[2] utilized plastic optical fibers (Du'Pont's CROFON(R)) to measure intermittently the degree of mixing in various continuous powder mixers. Ishida and Shirai[3]. Morooka, Kawaguchi and Kato[4], Rogers, Bell and Hukki[5] and Baba, Nakajima, Morooka and Mitsuyama[6], used optical fiber probes to study the dynamic behaviors of solid particles in fluidized and moving beds through the reflected or fluorescent light from the particles subject to visible or ultra-violet light beam. Image sensors were also utilized by Kamiwano *et*

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al.[7),8)], to analyze the fluid motion in mixing vessels.

In this paper, a new method for on-line and real-time measurement of the degree of mixing will be described.

2. Experimental

2.1 Photometer

The concentration of, for example, a black-colored powder in a mixture of black and white powders, can be known by measuring the intensity of the reflected light from the surface of the mixture, on which a light of certain wave length and constant intensity from a light source is projected. To avoid the effects of other lights except the one from the source on the measured intensity of the reflected light, and also to obtain a high sensitivity, however, some considerations and devices are necessary.

Fig. 1 shows the block diagram of the photometer developed for those purposes, though the basic circuit design is well-known. The light from a light-emitting-diode (GaAsP type, hig brightness, wave length = 580 nm), modulated by a square wave of the fundamental frequency of 460 to 725 Hz, is conducted onto the surface of a mixture of colored powders through a probe consisting of a pair of plastic fibers (the core diameter 1 mm, clad thickness 0.05 mm, totally 1.1 mm diameter, MMA made, peek transmittancy at 580 nm, produced by Mitsubishi Rayon Co. ESKA SH4001).

The reflected light from the surface of the mixture is then conducted through the probe to a phot sensor (a monolithic combination of a photosensitive diode (PIN) and a high performance operational amplifier). The electric signal proportional to the intensity of reflected light is fed to the band pass filter of active type (tuned to the modulating frequency) and then is rectified synchronously with the modulating square wave to obtain the dc potential proportional to the intensity of reflected light.

Fig. 2 shows the calibration curves of the photometer for the binary powder mixtures, the properties of which are listed in Table 1.

2.2 Computer system

Five sets of the photometers are prepared and each of the probes of the photo-

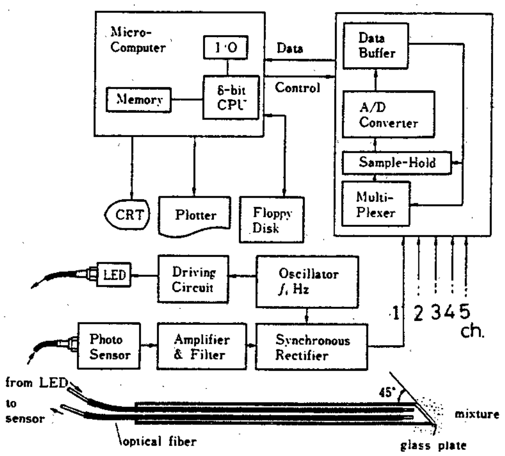

Fig. 1 Photometer and Computer System

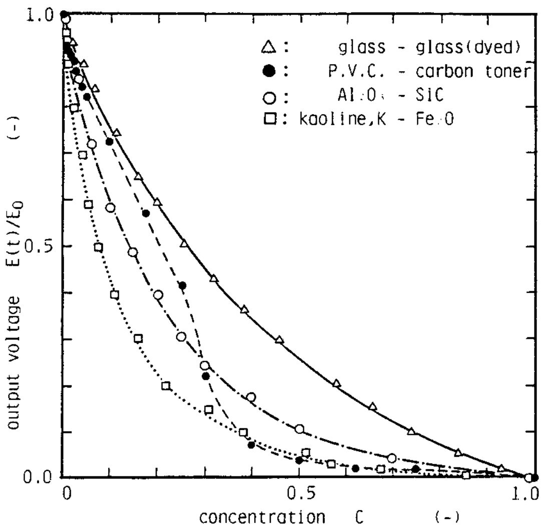

Fig. 2 Calibration Curves of Photometer for Binary Powder Mixtures

Table 1 Properties of the binary powders used in the experiments

material	diameter [μm]		density [kg/m^3]		
	range	average	true	bulk$_{1)}$	bulk$_{2)}$
glass	150 – 350	250	2500	1420	1460
glass (dyed)	150 – 350	250	2500	1420	1460
Kaoline	4 – 16	8	2860	520	840
Fe_2O_3	– 10	3	5770	530	810
Al_2O_3	175 – 320	275	3970	1684	1943
SiC	160 – 320	259	3240	1570	1770
P.V.C.	40 – 200	122	1540	494	604
Carbon	4 – 24	11.5	1174	445	592

1) loose packing 2) dense packing

meters is mounted on a separate position in a powder mixer vessel. The signals from the photometers are fed to the 8-channel multiplexer, the A/D comverter (12 bits, 25 microseconds) and then the microcomputer (8 bits, 64 KB), as shown in Fig. 1. This computer system can be anything, of course, if it has proper performances.

2.3 Powder mixer

The powder mixer we used for demonstration is shown in Fig. 3. The vessel is vibrated in three dimensional directions by an unbalanced electric motor drive. The main direction of vibration is vertical to overcome the gravity effect, while the mixture in the vessel is agitated by an impeller at rather high speeds. The frequency of vibration is the key to good mixing. Fig. 3 also shows the positions of the probes of the photometers.

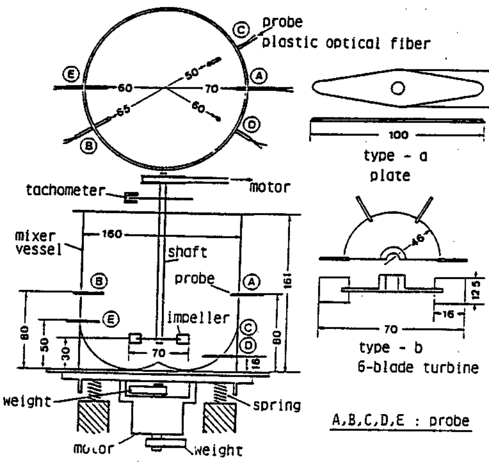

Fig. 3 Powder Mixer

3. Results and Discussion

To avoid the effects of various noises on the measured values of the concentration of colored powders, the output signal of the each photometer has been averaged for a short period of time by Eq. (1):

$$E(t) = \sum_{i=0}^{m-1} E(t + i\tau)/m \tag{1}$$

The concentration of colored powder is calculated by the polynomial approximation of the calibration curve in Fig. 2:

$$C(t) = \sum_{i=0}^{n} a_i E^i(t) \tag{2}$$

The degree of mixing of the mixture in the powder mixer has been calculated by Eq. (3):

$$M(t) = [\sum_{j=1}^{N} \{C_j(t)/C_0 - 1\}^2/N]^{0.5} \tag{3}$$

where $C_j(t)$ is the concentration at the j-th position of the probe and C_0 the charged concentration of colored powders.

Fig. 4 shows the flow chart of the programming for the computer system in Fig. 1. After PVC powder (white) is charged into the mixer vessel, the vessel is vibrated at a certain frequency and the agitating impeller is rotated at a certain speed. Then, a small amount of carbon toner (black) is added instantaneously to the PVC powder in the vessel, and the measuring system in Fig. 1 is started into operation.

The variation with time of the carbon toner concentrations at the five points in the vessel is shown in Fig. 5 for the operating conditions indicated on the same figure. As can be seen from the figure, a circulation of the toner powder in the vessel is clearly observed.

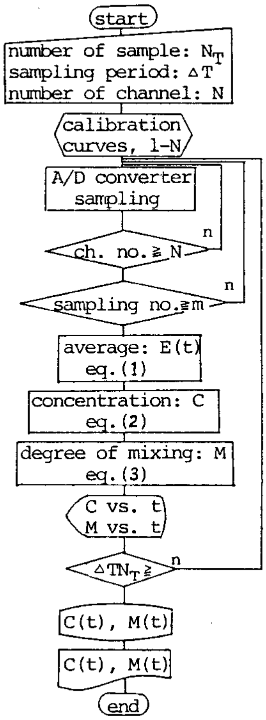

Fig. 4 Flow Chart of Computer Programming

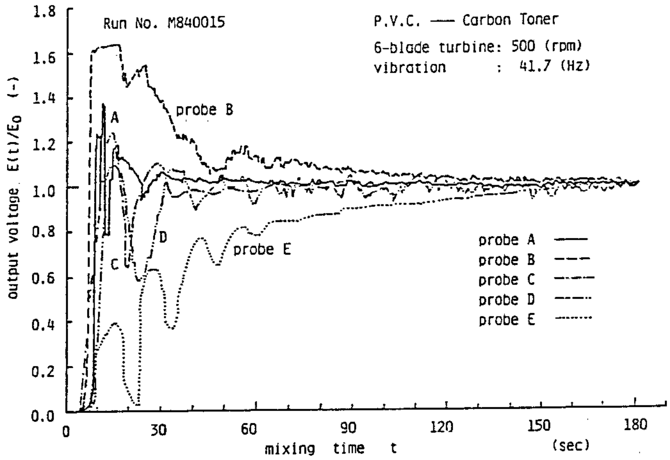

Fig. 5 Variation with Time of Carbon Toner Concentration in Powder Mixer

The variation of the degree of mixing, M, with time for the case of Fig. 5 is illustrated in Fig. 6. Since the degree of mixing is defined as the standard deviation of the toner concentrations at the five points, the smaller the value of M, the better the state of mixedness. The case shown in Figs. 5 and 6 is that of good mixing. These results have been compared with those obtained by the conventional method of fifteen spots samples and the agreement between them has been quite excellent. Therefore, if one can

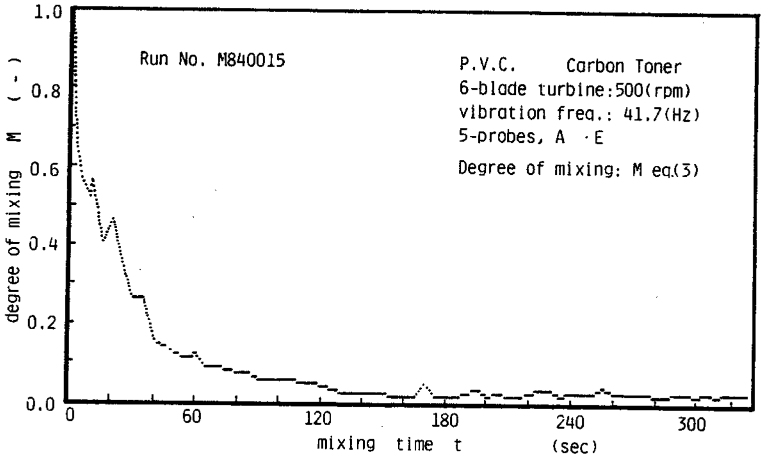

Fig. 6 Variation of the Degree of Mixing with Time (corresponding to Fig. 5)

measure the concentration of the key component continuously, only five points measurement will give satisfactory results.

Figs. 7 and 8 show another results for different operating conditions. This case is that of poor mixing. Specifically, the vibrating frequency is lowered. It can be seen that the effect of the frequency is critical on the degree of mixing.

The range of operating conditions for good mixing is shown in Fig. 9. The important thing to note is that the assessment of the performances of powder mixers, such as the shown above, can be done on-line and in real time. A combination of the powders having much different densities have also been tested, and the phenomena of mixing and segregation depending on the vibrating frequency have been clearly and quantitatively observed while the mixer is always under operation.

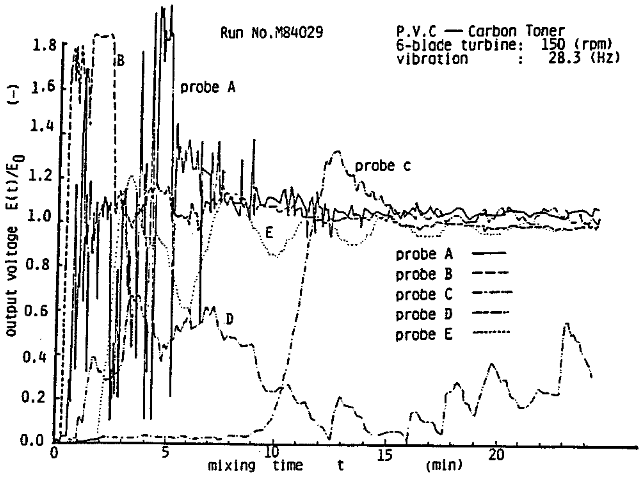

Fig. 7 Variation with Time of Carbon Toner Concentration in Powder Mixer

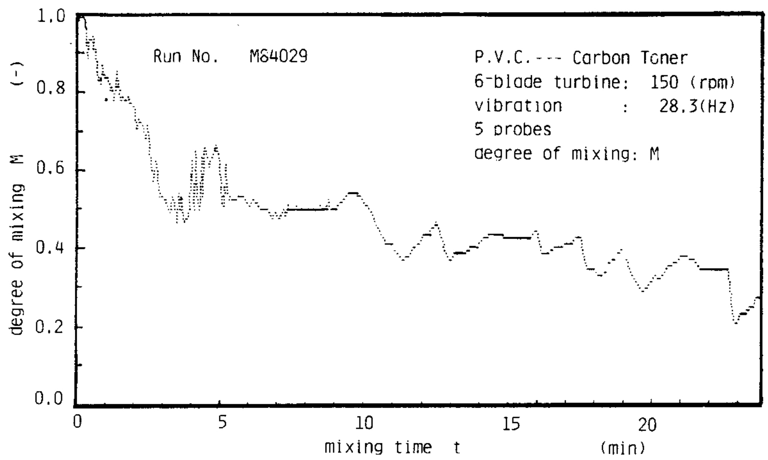

Fig. 8 Variation of the Degree of Mixing with Time (corresponding to Fig. 7)

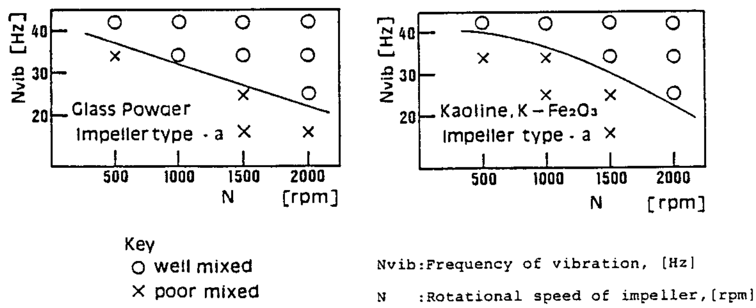

Fig. 9 Range of Operating Conditions for Powder Mixer with Vibration

4. Conclusion

Continuous measurements of the degree of mixing will facilitate a quick and efficient assessment of the performances of powder mixers and the effects of the operating conditions on their performances, thus stimulating the developments of the solid mixing technology for the rational design of efficient powder mixers.

Another possible applications of the measuring system presented here are in the field of mixing of multiphase systems such as gal-liquid, gas-solid and gas-solid-liquid systems if the structure of the light probe is properly designed.

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