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SCREENING AND CLASSIFICATION OF CERAMIC POWDERS

Shigeo Miwa

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16. Abstract

A summary is given of the classification technology of ceramic powders. Advantages and disadvantages of the wet and dry screening and classification methods are discussed. Improvements of wind force screening devices are described.

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SCREENING AND CLASSIFICATION OF CERAMIC POWDERS

Shigeo Miwa

1. Introduction

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There has recently been a demand for improvement in screening and classification technology. Moreover, most of these demands are for precise screening and classification of fine powders. In particular, the strong demand in the field of crude ceramic materials expresses the trend toward mass production and changes to commercial quality. Moreover, this trend is particularly strong in small scale production where there are hopes of one day being successful in mass production by large industries. However, it is not yet clear whether this trend will lead to high quality production in small industries.

Although the details of this classification technology have not been published, we would like to introduce a summary of classification technology and future trends in this text. Furthermore, the Japanese Powder Industrial Society is proceeding wi "A Manual for Classification and Screening Technology". The preliminary points of this handbook will also be mentioned in this text.

2. Advantages and Disadvantages of the Wet and Dry Screening and Classification Methods

The screening and classification methods currently being used are first classified in the two areas of wet and dry methods with regard to the particle diameter of powders, which is from about 1 micron to 100 microns.

* Numbers in margin indicate foreign pagination

(1) Wet Classification Method

This is the method whereby powders are classified when they are dispersed in water, organic liquids, etc. This method can be used with the majority of crude ceramic powders. This method can also theoretically be used with fine powders that easily disperse in a liquid when the proper medium is selected. However, when a dry powder is preferred, operations such as filtration, centrifugation, and drying are also carried out. In particular, fine powders usually adhere to one another when they are dried and therefore there are often problems with the wet method. Moreover, waste treatment is another important problem.

(2) Dry Method

This is the method whereby a powder is dispersed throughout an inert gas. The process whereby powders are manufactured in a dry state is usually simple and the equipment that is employed is often simple. In particular, there are no problems with waste treatment and therefore the dry method is often preferred.

However, dispersion of fine powders in a gas is difficult and complete dispersion of fine particles in a gas current is theoretically almost impossible. This is due to the fact that the particles adhere together because of static electricity and the water component in the gas. Consequently, there is a deterioration in classification precision in comparison to the wet method. Furthermore, instead of waste treatment, a dust collector must be considered.

3. Types of Wet Classification

Screening and classification by the overflow method has been carried out for many years using a precipitation vat. In this case it is necessary to remove the precipitate by hand. A rake, etc. may also be used. However, there are many times when the equipment is too large and the precipitates cannot be completely removed. Thereupon, precipitated particles can be removed in slurry form from the precipitation vat using the decantation method. Complete automation is carried out with a timer. This is the most practical method and is particularly superior in that there are few mixtures of coarse particles in the fine powders.

However, there are disadvantages in that batch drying is carried out and mass quantities of powder cannot be treated. Thereupon, the method whereby a slender precipitation tube is stood vertically and the powder is screened continuously with a rising current has been used. However, in comparison to the aforementioned batch method, the screening and classification precision is low.

With the water fan method, sodium hexametaphosphate, sodium pyrophosphate, etc. can be used as dispersants to facilitate dispersion. Alcohol and water mixtures are also effective. Preliminary tests are being carried out on these dispersants. The simplest testing method is to line up several test tubes and fill each with a specific amount of fine powder. After various liquids are added, the test tubes are shaken and observed after a specified period of time. The apparent volume of the precipitates (precipitate volume) is compared. The precipitate volume increases with increased dispersability.

In contrast to this water fan method, attention has recently been focused on the sieve method. Particular attention has been paid to the microsieve method. This method employs a sieve with openings of several microns in size. However, the microsieves are small sieves that are reinforced with an aluminum frame having a diameter of 75 mm ϕ. They also cost about 100,000 yen. They are not desirable from the point of mass treatment. A larger sieve with pores that are about 20 microns in diameter has recently been developed and therefore practical use of these sieves is anticipated.

With regard to the wet sieve method by microsieves, etc., a sieving device that employs a circulating water current in an ultrasonic wave vat has been developed. Practical use of these methods with the aforementioned sieve method may also be possible one day. The sieve method has an advantage in that mixtures with large particles are not often seen. Moreover, since screening of a narrow particle size range is also theoretically possible, progress in the future is anticipated.

4. Two Types of Dry Screening And Classification Methods

As with the wet method, when powders are classified by the dry method, the sieve method and the wind force method can be employed.

In comparison to the sieve method, there are few mechanical operating sections with the wind force method. Therefore, there are few restrictions of the facilities that are employed and the equipment is simple. Moreover, a closed system can also be employed. Therefore, that is an advantage in that this method is useful in processing. However, when the amount of powder treated is large, a large amount of air must be employed as the medium. Consequently, even though the cost of the equipment is low and little space is needed for the operation, dust collectors and other accessories are necessary. In particular, when there is a large amount of fine powders that are to be treated, the back filters must be given sufficient consideration.

In order to improve screening efficiency with the wind force method (accurate differentiation), it is necessary that the mixture ratio of powder and air (kg of powder to be treated/kg of air) be as low as possible. A mixture ratio of 1 or less is often used. That is, it is necessary to make sure that the concentration of powder is as weak as possible, that the powder is well dispersed, and that little adhesion between powder particles occurs. Consequently, when considering the wind force screening method alone, it seems that a large air current and many extra pieces of equipment are necessary. In this case, the sieve equipment should be compact and the facility cost should be low. The wind force screening method will be effective when it is rationalized as a process itself and furnished with devices for dust removal, dust collection, and air circulation.

Next, the wind force classification method assumes that the powder is sufficiently dispersed in an air current. This air current contains a water component and the particles themselves will adhere to one another. Therefore, there is a reduction in classification efficiency. Adhesion of particles also occurs due to static electricity in the air current. Moreover, screening is sometimes impossible when the particles adhere to the walls. It is necessary to carry out preliminary studies on the properties of the powders. A predrying treatment should be considered for those powders that contain a water component and there are also cases where powders that adhere to one another can be pulverized with some type of mechanical method immediately before they are placed in the screening device. The mechanical dispersion method is also important with various wind force screening devices.

5. Screening Theory

Devices that are used for classification of particles with /393 both the dry and wet methods vary in accordance with the particle diameter because of the effects of the resistance of the fluids or air current. This resistance moves in the opposite direction to the screening force. The screening force is gravity, inertia (during a change in direction) and centrifugal force. There are many cases where the two aforementioned forces are simultaneously found with the wind force method.

The theoretical explanation of screening devices varies with the type of screening equipment. In general, the flow of the fluid should be standardized and scattering of particles should be kept at a minimum.

6. Screening and Basic Testing Methods

Basic screening tests should first be carried out on the powders to be treated when a screening device is being selected.

The wind sieve device developed by the Japan Cement Technology Association is effective as a simple screening device for wind force screening and classification. Table 1 shows an example of the screening points. The results of screening will be evaluated using these results. Judging from the fly ash and silicon carbide examples, it seems that the particle size of the screened products has a wider range with the latter than the former. When these results are illustrated, Figure 1 is obtained. For instance, large powders of -6 microns are made. However, the size of the particles differs with the sample that is employed, even though the same device is used. Therefore, there are often errors in classification. Although it is not shown here, when calcium hydroxide is classified with the same device, it is difficult to get the sample up to the wind sieve without dispersing the sample. Moreover, even when it does reach the wind sieve, the particles adhere to one another. In this case, it is necessary to select the strongest wind current possible.

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TABLE 1. Results of Wind Force Classification with the Japan Cement Technology Association Wind Sieve Device (Medium Size)

(About 5 g of sample was screened for 60 minutes and passed through a sieve for 10 minutes. This was repeated until the loss was less than 1%).

(1) Values of Particle Size Measurement with Screened Product (Integration %)

Sample: fly ash

Particle size measurements: light diffusion method (device made by Seishin)

Particle diameter (μm)	Feed	30 μm cut		25 μm cut		20 μm cut		15 μm cut		10 μm cut	
		o	u	o	u	o	u	o	u	o	u
~25	24.0	64.5	1.9	50.5	0.4	43.0	1.5	39.5		32.0	
~20	34.5	81.5	7.0	73.0	0.7	62.0	2.3	60.0		45.5	
~15	46.5	87.8	19.8	83.5	10.4	81.5	3.5	81.5	12.8	60.0	
~10	62.5	93.1	33.9	92.5	26.1	87.8	23.2	90.5	29.4	75.5	3.3
~ 8	72.5	94.9	52.1	93.8	45.8	90.2	45.4	94.0	49.8	87.0	9.3
~ 6	80.5	96.8	68.8	94.5	62.8	93.4	62.5	95.5	65.2	94.0	22.4
− 6	19.5	3.2	31.2	5.5	37.2	6.6	37.5	4.5	34.8	6.0	77.6

ρ_p: 3.1 g/cm³

Note 1) The values in the table are the integration %. The -6 (μm) column is the total of 6 μm or less.

Note 2) o are the coarse particles, u are the fine particles.

Note 3) The 30 μm cut values were values from a set screening point and were obtained with the Stokes equation.

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(2) Particle Size Measurements of Screened Product (Integration %)

Sample: Silicon carbide
Measurement method: light diffusion method (equipment made by Seishin)

Particle diameter (μm)	Feed	30 μm Cut		25 μm Cut		20 μm Cut		15 μm Cut		10 μm Cut	
		o	u	o	u	o	u	o	u	o	u
~25	8.3	40.0	0.8	30.6	0.1	19.5	0.3	10.3	4.7	7.9	1.2
~20	22.3	94.6	5.2	71.9	3.9	53.0	0.4	30.6	7.5	20.4	1.7
~15	40.3	97.6	26.7	97.5	19.1	92.2	3.2	57.9	8.9	37.1	2.6
~10	61.3	98.1	52.6	98.1	47.7	96.7	36.0	90.6	9.1	60.6	3.7
~ 8	71.5	98.3	65.2	98.6	61.5	96.2	53.4	97.0	26.1	74.5	4.9
~ 6	77.5	98.4	72.6	98.9	69.6	97.2	63.4	97.5	41.9	82.2	7.3
− 6	22.5	1.6	27.4	1.1	30.4	2.8	36.6	2.5	58.1	17.8	92.7

ρ_p : 3.20 g/cm³

Notes 1), 2) and 3): Same as in Table(1).

Next we will consider problems with the screening conditions. /394
Table 2 shows the results of studying changes in the atmospheric humidity. It is clear that there is a remarkable change in screening results with a change in the air. Moreover, since this study was carried out on substances that screened relatively easily, studies should be carried out on substances that easily adhere to one another. These effects can be minimized by using a humidifier or a device that employs centrifugal force. Therefore, it will be necessary to consider this point in the future. In this case it seems that it would be relatively easy and inexpensive to employ a humidifier and high temperature air circulation. By way of comparison, Table 3 shows the particle size of powders that adhere to the tube walls. This phenomena is not limited to fine powders. The particles may adhere to the walls simply because they are close by.

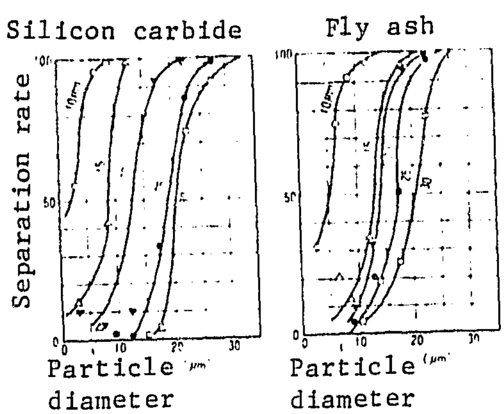

Figure 1. Screening Performance of Cement Air Sieve Device

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Table 2 Changes By Atmospheric Humidity

Sample: Fly Ash

Particle diameter (μm)	Size of particles introduced from light diffusion method	Apparent particle size by wind sieve method R.H. 64%	R.H. 75%	R.H. 85%
~25	23.5	30.1	45.^	53.0
~20	34.5	45.1	59.5	67.8
~15	46.5	51.1	75.0	80.0
~10	63.0	69.1	87.5	96.0
−10	37.0	30.9	12.5	4.0

Note 1) is as was listed in the preceding table.

Note 2): R.H. is relative humidity.

(There is an obvious increase in adhesion with an R.H. of 75% or more and large particles are obtained.)

Table 3 Powder Particle Size When Particles Adhere to Walls

sample: silicon carbide

Particle diameter (μm)	10 μm cut	15 μm cut	20 μm cut	feed
~25	12.5	8.7	19.2	8.3
~20	24.0	12.8	32.8	22.3
~15	41.2	35.4	55.0	40.3
~10	75.8	71.2	82.5	61.3
~ 8	88.0	83.9	93.0	71.5
~ 6	96.0	96.0	98.4	77.5
− 6	4.0	4.0	1.6	22.5

Note 1) measured with the light diffusion method

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In this way it is easy to carry out tests on conditions. It is usually effective to test the equipment first and then to study operating conditions. Figure 2 shows a screening device made from 100% glass. It has an advantage in that the particles can be observed during screening. Many reports have been written on this device.

Moreover, Figure 3 shows the adhesion effects with sonic waves. Frequency is added with a commercial speaker. With low frequency waves, adhesion is not very obvious. However, sonic waves can be produced from the noise of the wind blower and it seems that it may be necessary to consider this point when setting up a screening device.

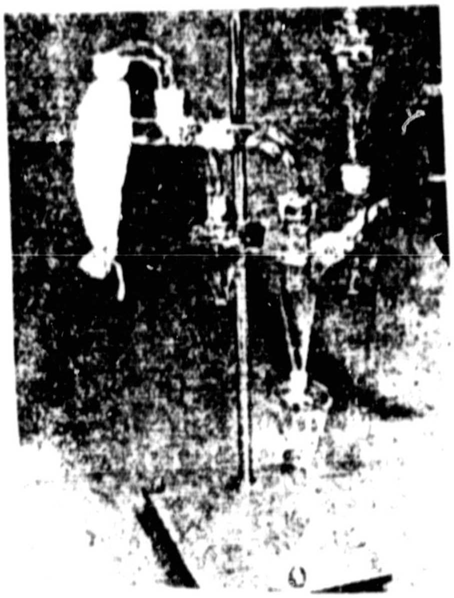

Figure 2 100% Glass Screening Device for Basic Screening Tests (made by Doi Rigaku Co., Ltd.)

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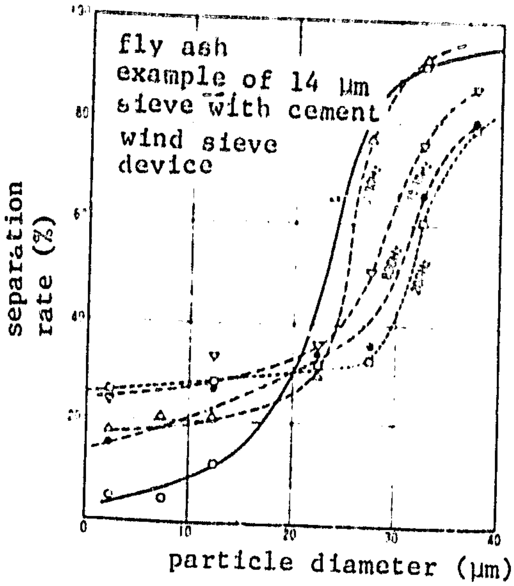

Figure 3. Adhesion Effects of Sonic Waves

7. Improvement of Wind Force Screening Device

Recently special attention has been paid to improving the screening properties of wind force screening devices. A result of this interest has been the development of a screening device by the Donaldson Co. This device is shown in Figure 4. It is characterized by the fact that there is little effect of disruption of the air current by reducing the pressure of the system. It operates by centrifugal power. Screening on the order of 1 micron can be carried out efficiently. Moreover, it is also used for dispersion of powders.

In order to prevent disruption of the air flow by the inside walls, a revolving wall screening device can be used. A typical example is the microplex made by Arupine* (Figure 5). It is characterized by the fact that centripetal force and resistance both operate at the revolving walls.

* Translator's note: term unknown; transliteration of phonetic characters.

Adhesion among particles in the dry current cannot be avoided and therefore it may help to use a repeated screening operation. A multistage current layer screening device can also be considered.

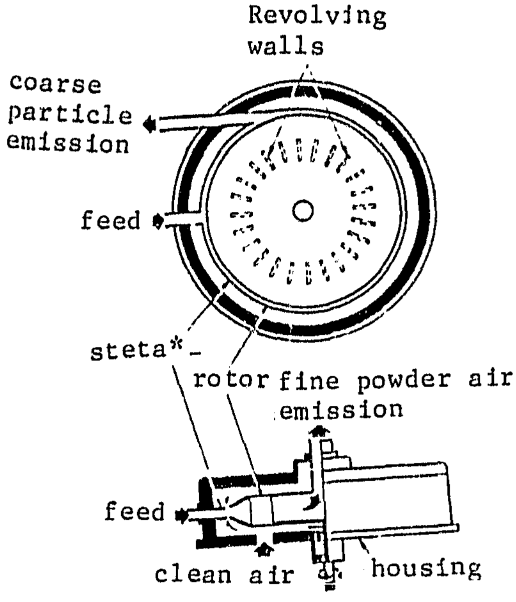

Figure 4 Donaldson Screening Device

*Translator's note: term unknown; transliteration of phonetic characters.

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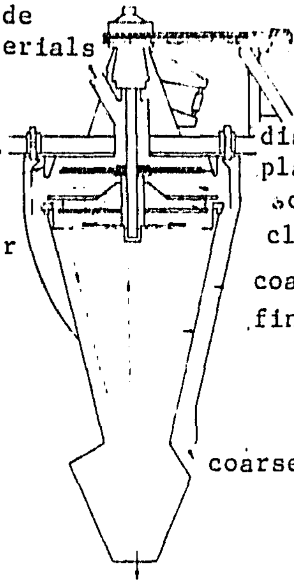

Figure 5. Microplex (vertical model)

8. Use of the Louver Method in Ceramics

Figure 6 shows the theory of the louver system. Several blades are set up in an air current to retain particles from the standard current. This can be used with a type of intersection adjustment. Figure 7 shows one of the many examples of the application of this system. This type of screening device is particularly effective for screening of particles that are about 100 microns. Extreme adhesion of particles is not seen with this device. Since the entire device does make strong mechanical vibrations, it can be covered. It has a

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dust remover and is effective in removing fine particles. It is 100% stainless steel.

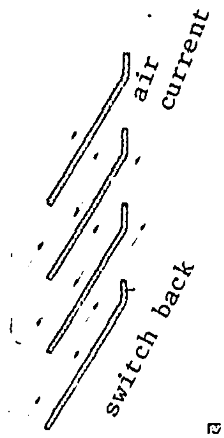

Figure 6 Louver System

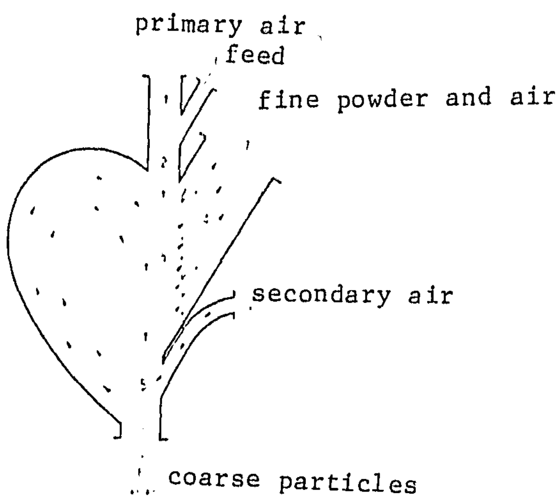

Figure 7 (a) Wind Force Screening Process

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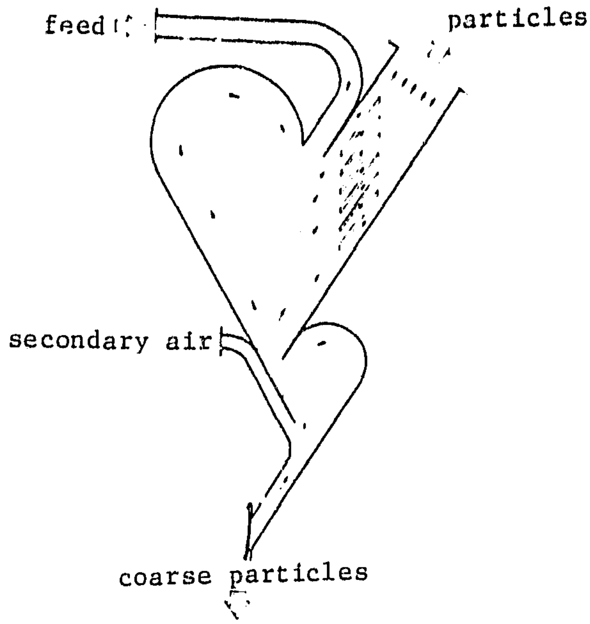

	standard			
TYPE	(mm) ht.	(mm) width	(m³/min) amt of air	(ton/h) powder
12		145	12.6	0,3
25	1420	200	24	0.5
50	2130	300	54	1.2
100	2840	400	96	2.1
200	4250	600	216	4.6

(mixture ratio of m=0.3, for silica use)

Feed 7 (b) May-O Separator (Tokuju Co., Ltd.)

Although the device shown in Figure 8 does not exist, it is a device planned by the author. It operates by a centrifugator mechanism. However, it also employs reduced pressure system and louvers, as well as revolving walls.

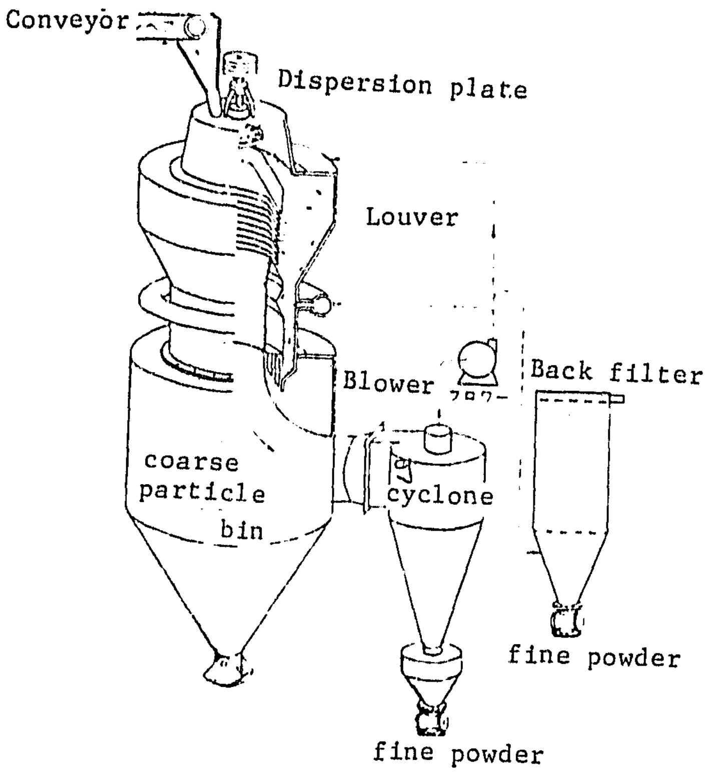

Figure 8 Louver Type Screening Device of the Author

9. Problem of Contamination

The powders obtained after screening are often used as they are, as finished products. The main problem with this is impurities that are mixed with the powder. The main cause of contamination is adhesion and fixation to container walls. This is a particularly important problem. With wind force screening devices adhesion to revolving blades cannot be prevented. The particles that adhere to one another increase in adhesive strength over time and in 24 hours a large substance is often obtained. This is