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Recovery of Diatom Skeleton from Low Grade Diatomaceous Earth by Shape Separation Method Using Fluid Field

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Shape separation method – a separation process which utilizes the fact that particles of different shape behave differently in force fields- is regarded as an useful measure for recycling, mineral processing, upgrading powdered material and so on. In this study, a trial was given to shape separation method using fluid field to recover pure diatom skeleton – which is thought to have many uses in itself and potential for various applications –from low grade diatomaceous earth of southeastern part of the Korean Peninsula. The striking difference of shape between diatom skeleton and other minerals like clay and quartz made it natural to choose shape separation method. Considering the size of particles to be separated, among many possible methods of shape separation, hydrodynamic field using hydrocyclone was adopted. And it resulted in recovery of pure diatom skeleton with high purity

Keywords: diatomaceous earth, diatom skeleton, shape separation, fluid field

Introduction

Shape of particles, along with size, density, composition and etc., is one of important physical property in handling particulate or bulk materials. It plays an important part to make materials show off their function. But controlling the shape of particles in production stage has many difficulties in technical and economic points of view. Therefore recovering the particles of desired shape selectively from product - what we call shape separation - is expected as a new measure for upgrading particulate materials.

Shape separation method proposed so far are mainly based on the fact that particles' sliding and rolling characteristics depend on their shape[1]. These methods have been considered as effective not only for enhancing material value but also for recycling and resources beneficiation[2,3]. These are, however, not suitable for relatively small particles of highly adhesive.

For the shape separation of small particles, the methods utilizing electrostatic force or fluid resistance have been considered[4].

In this study , in order to establish the shape separation method usnig fluid field as a reliable separation step in recycling and resources processing and to propose a means to utilize low grade diatomaceous earth buried in southeastern part of the Korean Peninsula as well, a basic investigation for shape separation of pure diatom skeleton from diatomaceous earth using fluid field was performed.

Experiment

Diatomaceous earth produced from Young-Il diatomite mine - located in southeastern part of the Korean Peninsula - was used as sample. Received sample was composed of diatom skeleton, quartz particles and clay minerals as can be seen in Fig.1. These minerals were loosely aggregated and scrubbing with a mixer was enough to liberate each mineral. There is a striking difference between the shape of diatom skeleton and other minerals. This fact suggests the possibility of shape separation of these minerals.

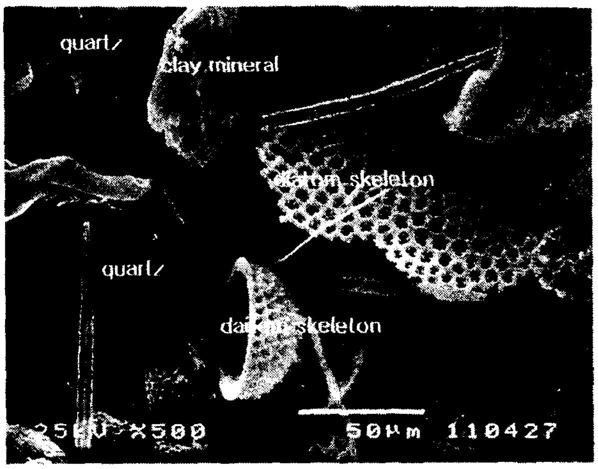

Fig. 1 SEM image of diatomaceous earth sample

The particle size of scrubbed sample was in the range of several or several ten micrometers. Fig.2 shows the size distribution of scrubbed sample and Table 1 shows the chemical composition of sample.

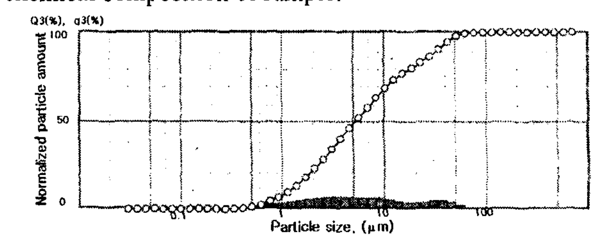

Fig. 2 Particle size distribution of scrubbed sample

Table 1. Chemical composition of diatomaceous earth sample

Component	SiO_2	Al_2O_3	Fe_2O_3	Ig. Loss
Wt%	80.6	10.0	1.54	4.82

For shape separation of these minerals, wet type cyclone composed of 5 stage (Cyclosizer, Warman Co., Australia) was used. Fig.3 shows the schematic diagram of apparatus used.

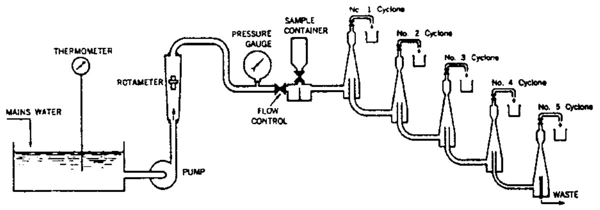

Fig. 3 Schematic diagram of apparatus (cyclosizer)

Table 2 shows the limiting particle size of each cyclone under standard condition[5] and Table 3 shows the experimental condition of this study.

Table 2. Limiting and effective particle separation size at the standard conditions

Cyclone No.	Limiting Particle Separation Size (μm)	Effective Particle Separation Size (μm)
1	44± 2	43± 2
2	33± 1	32± 1
3	23± 1	22± 1
4	15± 1	15± 1
5	11± 1	11± 1

The standard values of the variables are :
Water flow rate : 11.6ℓ /min.;
Water temperature : 20℃;
Particle density : 2.65g/cc;
Time of elutriation : infinite for limiting size
30 min. for effective size

Table 3. Experimental conditions

Conditions		
Water flow rate		11.6ℓ /min.;
Water temperature		20~26 ℃
Amount of sample		30g
Particle density	diatom skeleton	2.00g/cc
	others	2.65g.cc
Time of elutriation	preparation	5min.
	elutriating	30min.

Separated particles were observed with SEM and shape of particles were analyzed with image analyzer.

Results and Discussion

Particles settling in fluid experience drag force and the drag coefficient depends on their shape. If the particles settled in turbulent flow, the effect of shape would increase. Endoh et al. investigated the relation between the cut point of cyclone and Heywood diameters of various particulate materials having similar density[4]. They made it clear that particles of same Heywood diameter and same density might have different Stokes diameter depending on their shape. Fig. 4 shows one of their results. This result suggests the possibility of separating particles having same Heywood or Feret diameter of different shape by combining sieving and dynamic shape separation process.

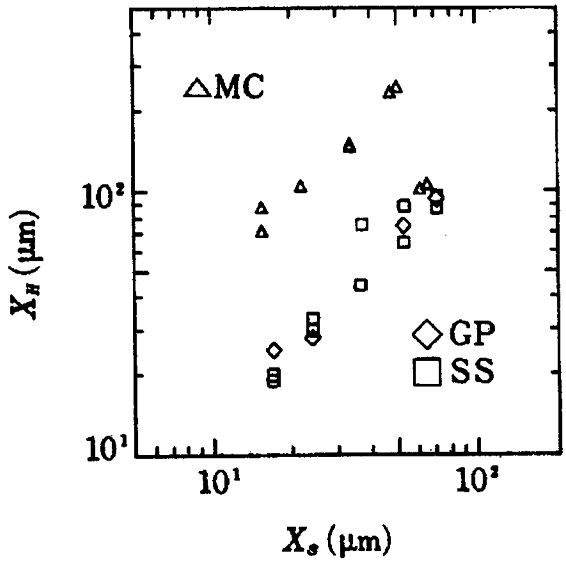

Fig. 4 Relation between Stokes diameters in the cyclones and the Heywood diameter of particles classified by the wet cyclones (after Endoh et al.[4]).

In case of diatomaceous earth composed of diatom skeleton, quartz particles and clay minerals, not being considered the shape of each minerals, the cut point of each minerals at each cyclone would be calculated as shown in Table 4[5].

Table 4. Effective particle separation size of diatom skeleton and other minerals

Cyclone No.	Effective particle separation size	
1	diatom skeleton	55± 3
	others	43± 3
2	diatom skeleton	41± 1
	others	32± 1
3	diatom skeleton	27± 1
	others	22± 1
4	diatom skeleton	19± 1
	others	15± 1
5	diatom skeleton	14± 1
	others	11± 1

As can be seen in Table 4, if shape effect did not work, it would not be easy to separate each minerals collected in apex chamber of each cyclone by a simple physical method like sieving. In real case, however, there exists striking difference in their size between diatom skeleton and other minerals collected in each apex chamber. Fig. 5 shows recovered particles from apex chamber of No.5 cyclone. The notable difference in size between diatom skeleton and other minerals made it possible to use sieve for separating them and Fig.6 shows the diatom skeleton recovered as over size product of sieving.

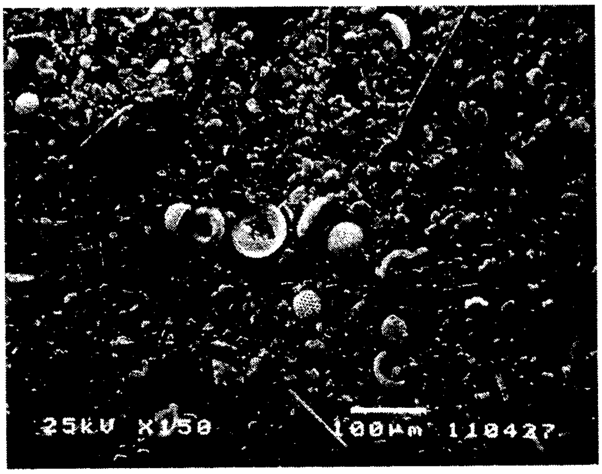

Fig. 5 Example of recovered particles in apex chamber of No.5 cyclone.

Fig. 6 Recovered diatom skeleton as over size after sieving the particles shown in Fig.5.

The chemical composition of recovered diatom skeleton is given in Table. 5. It shows that recovered diatom skeleton are very pure[6].

Table 5 Chemical composition of diatom skeleton recovered

Component	SiO_2	Al_2O_3	Fe_2O_3	Ig. Loss
Wt%	80.6	10.0	1.54	4.82

Fig.7 shows the relation between the Heywood diameter(X_H) and Stokes diameter(X_S) of particles classified by cyclones used. The Heywood diameter of particles were calculated from the SEM image of particles . Stokes diameter were calculated by multiplying cut size of cyclone by a factor that Endoh et al. proposed for silica sand [4]. As can be seen in Fig.7, the ratio of X_H to X_S of other minerals is about 1. But the ratio of diatom skeleton is much higher than that of other minerals. This fact indicates that particles of same Heywood diameter may have different settling velocity in cyclone. It also suggests that combining sizing separation and dynamic shape separation can be a good means for separation of particles having different shapes.

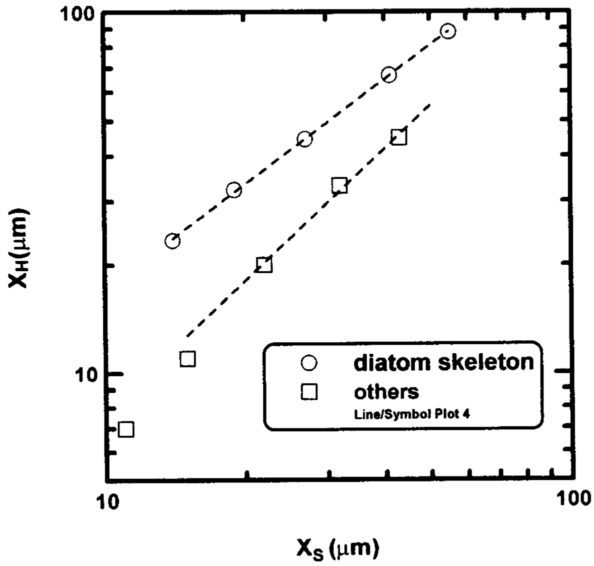

Fig. 7 Relation between Stokes diameters in the cyclones and the Heywood diameter of diatom skeleton and other minerals classified by the wet cyclones.

Conclusion

A basic study for recovery of pure diatom skeleton from low grade diatomaceous earth was conducted by shape separation method using fluid field. The result are summarized as follows.

1. Particles of same Heywood diameter may have different settling velocity in fluid field depending on their shapes.
2. It was possible to recover pure diatom skeleton from diatomaceous earth by combining dynamic shape separation using hydrocyclone and sizing separation using seive.

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