Korean J. Chem. Eng., **16**(6), 837-839 (1999)

Inorganic Microballoon Production from Shinju-Gan Using an Entrained Bed Reactor

Yoshimitsu Uemura*†, Sumio Nezu, Hidetaka Honda, Yoshihiro Ohzuno, Kazuya Ijichi and Yasuo Hatate

Department of Applied Chemistry and Chemical Engineering, Kagoshima University, 1-21-40 Kohrimoto, Kagoshima 890-0065, Japan
*Department of Bioengineering, Kagoshima University, 1-21-40 Kohrimoto, Kagoshima 890-0065, Japan
(*Received 6 May 1999 • accepted 16 October 1999*)

Abstract−Hollow inorganic microparticles were produced continuously from a volcanic glass (shinju-gan or perlite) using an entrained bed reactor. The microparticles are called expanded perlite. The raw material was a sieved fraction (104 μm in volume average diameter) of crushed perlite, which is from China. The effects of temperature and residence time on expanded perlite yield were investigated.

Key words: Inorganic Microballoon, Expanded Perlite, Perlite, Entrained Bed Reactor

INTRODUCTION

Hollow inorganic microparticles can be obtained from perlite (or shinju-gan, a volcanic glass) particles if they are heated up at high heating rates and maintained at about 1,000 K for a certain short period. The hollow inorganic microparticles are called expanded perlite. In general, the ballooning mechanism of such volcanic glasses is considered to be similar. When a volcanic glass particle is heated up at a certain temperature, around 1,000 to 1,300 K, softening of the entire particle and vaporization of crystal water within the particle occur at the same time. Expanding water vapor hollows and expands the particle.

Hollow inorganic particles, such as expanded perlite, have qualities as a building material, such as low density, non-toxicity, fire-proofness, thermal insulation and acoustic insulation. In Japan, its production has reached more than 200,000 tons annually. The current apparatuses for commercial production of expanded perlite are a rotary kiln and an ordinary fluidized bed. A rotary kiln or an ordinary fluidized bed has unfavorable features for producing expanded perlite, which are non-uniform residence time and dense solid phase especially in the case of usual fluidized bed. Both can cause agglomeration of softened perlite particles and breaking of expanded perlite once formed. Expanded perlite particles are more easily broken during the production process compared with other inorganic balloons. An entrained bed is more appropriate than the conventional processes for producing expanded perlite because of its more uniform residence time and more dilute holdup of solids, as well as its capability for dealing with any particle diameter. It is thus obvious that an entrained bed is superior to rotary kiln or ordinary fluidized bed for producing expanded perlite. Surprisingly, few reports can be found for applications of entrained beds to expanded perlite production. Tsuji et al. [Tsuji et al., 1984] reported a combination of spouted bed and pneumatic conveying (regarded as an entrained bed) for producing hollow spheres of about 500 μm from volcanic ash in the Kitami district of Hokkaido.

In this study, expanded perlite, a type of the inorganic microballoons, was produced from perlite, a type of volcanic glass, using an entrained bed reactor. Using the entrained bed reactor, the effects of residence time and riser temperature on expanded perlite yield were investigated.

EXPERIMENTAL

1. Experimental Setup and Material

The experimental setup used in this study is illustrated in Fig. 1. The reactor (SUS304) consisted of a riser (1,500 mm high and 23 mm in internal diameter), a feeder and a cyclone. In the reactor, perlite particles fed from the rotary feeder pass through the riser, then leave the reactor *via* the cyclone. Three electric jacket-heaters around the riser were used to raise the tempera-

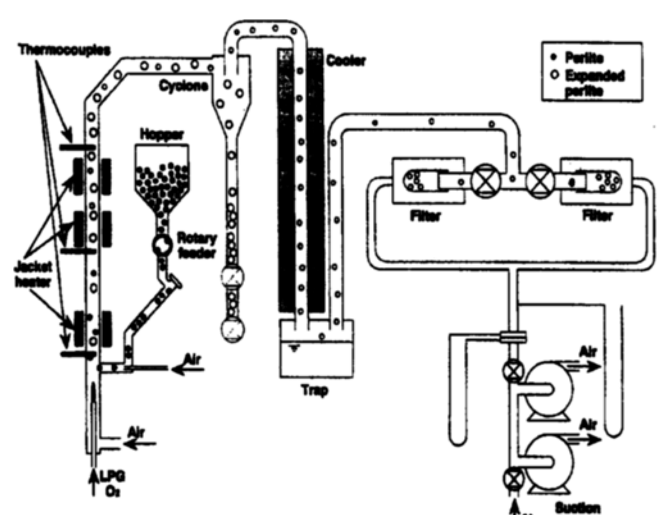

Fig. 1. Entrained bed reactor for producing expanded perlite.

†To whom correspondence should be addressed.
E-mail: yuemura@be.kagoshima-u.ac.jp

Table 1. Chemical analysis of volcanic glasses

	SiO_2	Al_2O_3	K_2O	Na_2O	CaO	Fe_2O_3	MgO	TiO_2	Ig. loss
Perlite (China)	72.70	13.56	4.25	3.38	0.66	0.83	0.11	0.08	4.42
Yoshida Shirasu	69.72	12.60	3.36	2.89	1.59	1.56	0.29	0.28	5.85

Fig. 2. SEM photographs of perlite (top) and expanded perlite of Run P-2-5 (bottom).

ture together with LPG combustion in the riser. Three thermocouples were attached to the riser to monitor the temperatures. An air-inlet at the bottom of the rotary feeder was used for sending air to blow perlite particles into the riser. The cyclone at the top of the riser was used for separating expanded perlite from the flue gas. A trap was used for catching water formed by LPG combustion. Filters were used for collecting minute particles. Ground and sieved perlite was used as the feed material. The particles were dried and stored in an air-tight bottle, and were used for the experiments. Fig. 2 shows photographs of the prepared perlite particles used as the feed material (top) and a typical sample of expanded perlite obtained in Run P-2-5 (bottom). In Tables 1 and 2, the chemical analysis and average particle sizes of perlite used are listed respectively.

2. Production of Expanded Perlite

With the apparatus shown in Fig. 1, the following experiment was conducted to obtain hollow inorganic microparticles (expanded perlite). At first, all the cooling waters started flowing. The reactor was heated by three electric heaters. LPG was fed when the apparatus reached the LPG ignition temperature. When the temperature reached the desired temperature, perlite particles were fed from the feeder. The feed rates were 15, 25 and 26 g/min for Runs 1, 2 and 3, respectively. Most of the particles from the riser were separated from the exit gas at the cyclone. Recovered particles in each run were classified into two parts: those floating in water, and those sunk in water. In this study, the former was defined as expanded perlite. The particle size distribution and the averages of the perlite and expanded perlite particles were measured by Coulter LS 130. Table 3 shows the experimental conditions and expanded perlite yield.

Table 2. Average diameters of perlite used

dp_{10} [μm]	dp_{32} [μm]	dp_{43} [μm]
2.8	15.3	104

Table 3. Experimental conditions and expanded perlite yield

Run no.	Feed rate of perlite [g/min]	Residence time in riser [s]	Temperature of riser [K]	Expanded perlite yield [%]
P-1	15	0.35	820	0
P-2-1	25	0.39	910	7
P-2-2	25	0.27	950	4
P-2-3	25	0.39	1000	3
P-2-4	25	0.41	940	19
P-2-5	25	0.26	1110	64
P-2-6	25	0.34	1110	67
P-3-1	26	0.37	1060	75
P-3-2	26	0.34	1140	70

RESULTS AND DISCUSSION

1. Particle Morphology and Size

As can be seen from Fig. 2 (bottom), expanded perlite particles were not spherical in general, and their surface showed many cracks. As can be seen from Fig. 3, an expanded perlite particle has many small chambers of a few to fifty microme-

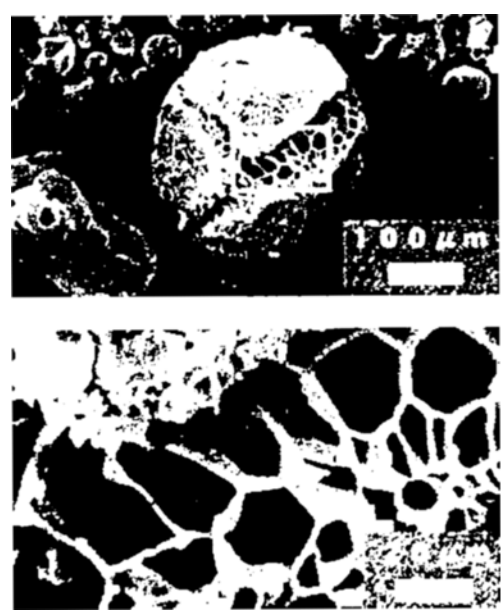

Fig. 3. SEM photographs of expanded perlite (Run P-3-2).

Table 4. Physical properties of expanded perlite produced

Run no.	Residence time in riser [s]	Temperature of riser [K]	Average diameters of expanded perlite dp_{10} [μm]	dp_{32} [μm]	dp_{43} [μm]	Bulk density of expanded perlite [g/cm^3]	Bulk density of unfloated fraction of product [g/cm^3]
P-2-1	0.39	910	-	-	-	0.21	0.86
P-2-2	0.27	950	53	116	154	0.21	0.87
P-2-3	0.39	1000	-	-	-	-	0.95
P-2-4	0.41	940	7.3	82	228	0.13	0.71
P-2-5	0.26	1110	157	236	290	0.21	0.43
P-2-6	0.34	1110	-	-	-	0.24	-
P-3-1	0.37	1060	19	120	197	0.21	-
P-3-2	0.34	1140	16	139	203	0.15	-

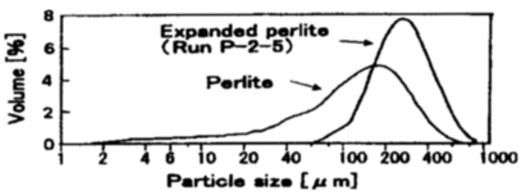

Fig. 4. Particle size distribution of perlite and expanded perlite (P-2-5).

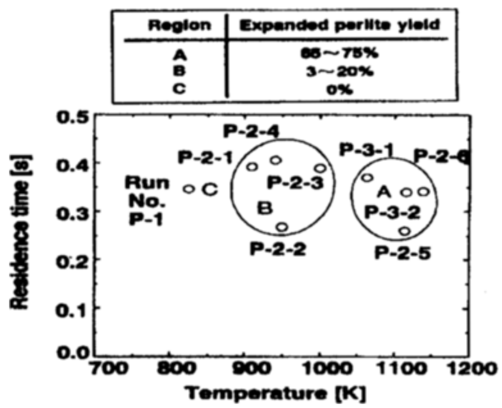

Fig. 5. Effects of temperature and residence time on expanded perlite yield.

ters. This non-spherical shape of expanded perlite is derived partly from its multi-chamber structure. Another typical inorganic microballoon, shirasu balloon [Uemura et al., 1998], is spherical and single-chambered. The size distributions of perlite and expanded perlite are illustrated in Fig. 4. In Table 4, the average diameters and bulk density of expanded perlite obtained are listed. As shown in Fig. 4, the particle size distribution increased by ballooning, which shows net expansion. The net expansion is also obvious from average diameters (Tables 2 and 4) and SEM photographs (Fig. 2). The tailing on the left of perlite size distribution in Fig. 4 was eliminated by ballooning. Those minute particles of 2 to 20 micrometers might have stuck to the reactor internal walls, or they might have been entrained with flue gas to the trap or filter. The bulk density of expanded perlite was from 0.13 to 0.24 g/cm^3. There is no explicit tendencies between temperature and bulk density or between residence time and bulk density. Bulk density is not only a function of expansion ratio but also a function of particle size distribution. That may make a simple interpretation for the bulk density results difficult.

2. Expanded Perlite Yield

The effects of riser temperature and residence time on expanded perlite yield are shown in Fig. 4. Expanded perlite was substantially yielded at the temperatures higher than 1,000 K. The boundary temperature was 1,350 K for producing shirasu balloons using a similar experimental setup [Honda et al., 1997].

CONCLUSIONS

The following conclusions were reached in this study.

(1) Expanded perlite obtained was multi-chambered and its expansion ratio was from 1.5 to 3.

(2) The bulk density of expanded perlite was from 0.13 to 0.24 g/cm^3, which is classified into the JIS class S, which stands for standard.

(3) Expanded perlite was substantially yielded at temperatures higher than 1,000 K.

REFERENCES

Honda, H., Nezu, S., Ijichi, K., Ohzuno, Y., Uemura, Y. and Hatate, Y., "Mechanical Strength of Shirasu Microballoons Produced by a Circulating Fluidized Bed Reactor," Proceedings for The 10th Symposium on Chemical Engineering, Kyushu-Taejon/Chungnam, OC-14 (1997).

Sodeyama, K., Sakka, Y., Kamino, Y. and Seki, H., "Preparation of Fine Shirasu-balloons from Vitric Volcaniclastic Materials," *Journal of the Japan Society of Powder and Powder Metallurgy*, **42**, 1128 (1995).

Tsuji, T., Uemaki, O. and Kugo, M., "Calcination of Perlite from Volcanic Ashes in Hokkaido using a Pneumatic Conveyer Calciner," Research Report of Faculty of Engineering, Hokkaido University, **121**, 34 (1984).

Uemura, Y., Nezu, S., Hamakawa, N., Ijichi, K., Ohzuno, Y. and Hatate, Y., "Application of High-Velocity Fluidized Bed Reactor for Producing Hollow Inorganic Micro-spheres from Volcanic Glass Particles," *J. Chem. Eng. Japan*, **31**, 298 (1998).