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Instrument for ceramic particle dispersion

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ABSTRACT

Agglomerated sub-micrometer-sized alumina particles were pulverized using a novel method. A high-density polyethylene (HDPE) cup equipped with stainless steel mesh turned at a 500–2000 rpm revolution rate and a 200–800 rpm rotation rate. A suspension passes through the small mesh openings, and turbulent flow and high shear stress was generated. The sample's particle size distribution before mesh treatment exhibited a broad peak at 2–70 μm, reflecting the particles' agglomeration. This suspension's viscosity was 19.8 mPa s. After mesh treatment at 2000 rpm revolution rate for 10 min, the distribution showed two peaks at 0.2 and 2–70 μm. The alumina agglomerates shrank concomitantly with increased treatment time and dispersed completely after 30 min mesh treatment. The resultant suspension's viscosity was 9.2 mPa s, which is half that of the pre-treatment suspension.

1. Introduction

Nano-sized and submicrometer-sized ceramic particles are widely used as photocatalysts [1] sonophotocatalysts [2], fillers [3,4], films [5–8], and so on. The particles must be well dispersed for these applications. However, their dispersion is difficult because of their high agglutinability. For pulverization of ceramic particles, ball milling is useful [9] and preferred for micrometer-sized particles. Nevertheless, long treatment time is needed for that method. Very recently, the wet-jet milling method was used for the homogeneous and rapid dispersion of ceramic particles [5,9–11]. It is an innovative method in powder science. However, the wet-jet milling apparatus is expensive because its pulverization unit is made of diamond. A novel pulverization method with short treatment time and low cost is necessary.

Good dispersion of ceramic particles is accomplished by providing high collision energy. To obtain high collision energy, we specifically examined the unique commercial mixer (AR-250; Thinky Corp., Tokyo, Japan) schematically presented in Fig. 1(a). Its shape and procedures resemble that of a centrifugal separator. The difference from a centrifugal separator is that a container is also rotated at an appropriate speed. The particles in a suspension move to the sidewall of the container by rotation and become sediment by revolution. These two centrifugal forces produce a whirlpool in the fluid. Consequently, the suspension in the container is stirred and mixed. This method presents several benefits over conventional mixing methods, which use a screw-shaped stirring rod. For instance, large volumes of air bubbles remain in the material. The mixer rotates the container holding the material while revolving it. Because the container revolves and rotates at very high rates (500–2000 rpm), homogeneous mixtures are obtained in several minutes, which is a shorter treatment time than those of previous stirring methods. However, sufficient shear stress for pulverization is unobtainable using this system [10]. For that reason, the equipment as applied in this study was remodeled to yield great collision energy. Fig. 1 (b) portrays a schematic illustration of the remodeled apparatus. A mesh is attached in a container and is also rotated. A suspension passes through the small mesh openings and turbulent flow and high shear stress are thought to be generated. This energy engenders high collision energy.

In this study, a mesh was installed in a container to enhance collision energy. Furthermore, the relation between the stirring condition and properties of the obtained suspension was evaluated.

2. Experimental procedures

High purity α-alumina (TM-DAR; Taimei Chemicals Co. Ltd., Nagano, Japan) depicted in Fig. 2 was used for this experiment. It was mixed with 70 vol.% distilled water and 0.62 mass% ammonium poly (acrylic acid) (PAA) (Seruna D-305; Chukyo Yushi Co. Ltd., Aichi, Japan) as a dispersant. Mixing was done using a planetary mixer (AR-250; Thinky Corp., Tokyo, Japan) without stainless steel mesh for 1 min, rotated at 800 rpm and revolved at 2000 rpm for 1 min (Fig. 1). The mixing conditions are presented in Table 1. The mixtures were treated using the mixer with the mesh for 1–30 min. The revolution rate was 500–2000 rpm; the rotation rate was 2/5 times the revolution rate. The container and the stainless steel mesh were made of high-density polyethylene (HDPE; Thinky Corp., Tokyo, Japan) and SUS 316 (P-25; Nippon Filcon Co. Ltd., Tokyo, Japan), respectively. The mesh wire diameter was 0.375 mm ϕ; the opening area

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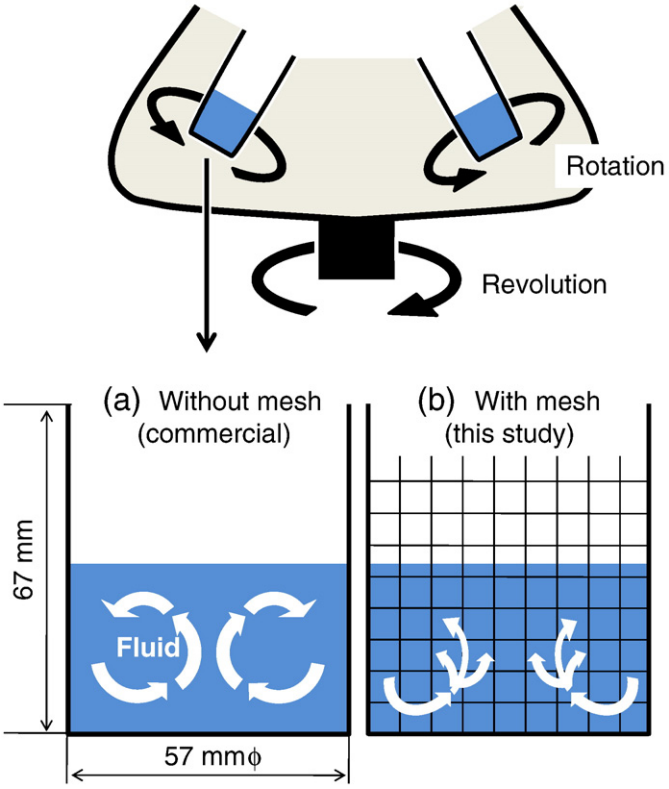

Fig. 1. Schematic model of the instrument for particle dispersion.

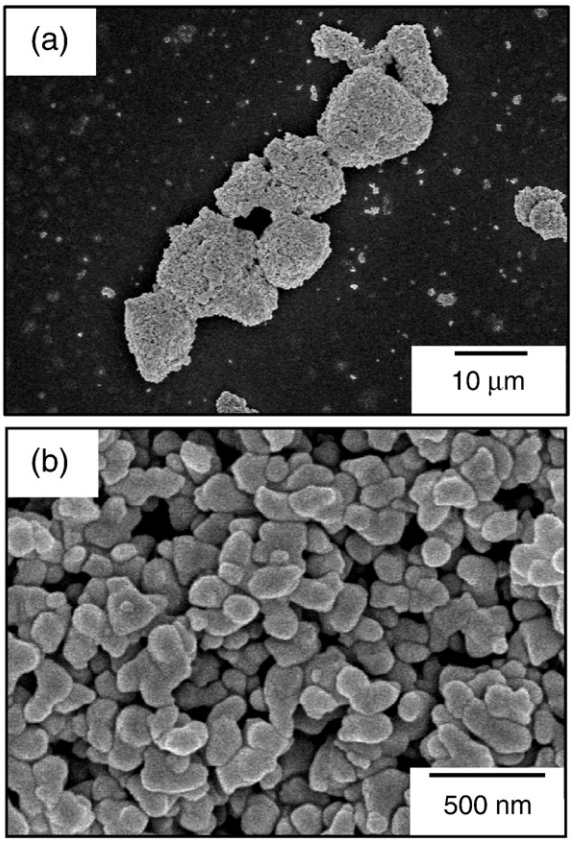

Fig. 2. SEM images of the α-alumina particles observed at (a) = low magnification and (b) = high magnification.

Table 1
Experimental conditions of the planetary mixer.

	Revolution rate dependence test	Time dependence test
Mesh opening [mm^2]	0.64 × 1.04	0.64 × 1.04
Revolution rate [rpm]	500–2000	2000
Rotation rate [rpm]	2/5 times the revolution rate (200–800)	800
Treatment time [min.]	10	1–30

All samples were pre-mixed without stainless steel mesh for 1 min, rotated at 800 rpm and revolved at 2000 rpm for 1 min.

was 0.64 × 1.04 mm^2. After mesh treatment, the suspensions were re-mixed without mesh for 1 min to remove bubbles. For this purpose, the rotation and revolution rates were 60 and 2000 rpm, respectively.

The apparent viscosity of the suspension was measured at 20 °C using a rotational cylinder viscometer (RT20TI; Thermo Fisher Scientific Inc., Massachusetts, USA) under a 2 min shear stress cycle of 0.54–6–0.54 Pa. The particle size distribution of the alumina

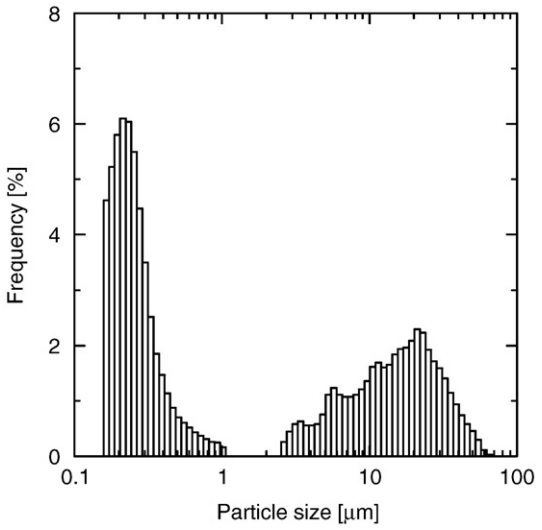

Fig. 3. Particle size distribution of the suspension before mesh treatment.

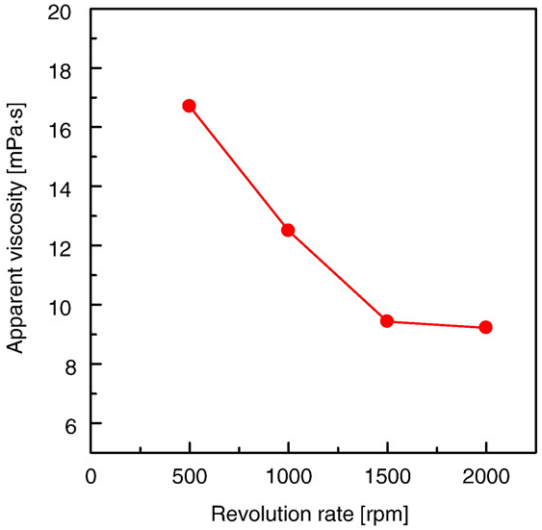

Fig. 4. Apparent viscosity of the suspension after mesh treatment as a function of the revolution rate.