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Particle shape modification and related property improvements

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Abstract

The increasing sophistication of powder metallurgy processing, together with the greater demands on final product quality have led to an increased demand for metal powders of high quality. In this paper we report the successful preparation of two spheroidized metal powders, — electrolytic copper powder mixed with Al_2O_3 particles and hydrogenation–dehydrogenation (HDH) titanium powder — produced by high speed impact using a particle composite system (PCS). Experimental results show that irregularly shaped metal particles can be processed into spherical particles by use of this process. The spheroidizing process increases bulk density of Ti powder from 1.15 g/cm^3 to 1.73 g/cm^3 and its fluidity index from 46 to 71, improves surface morphology of either single Ti particles or composite Al_2O_3/Cu particles and molding properties of bulk powders. The characteristics of sintered parts made from spheroidized powders are superior to those of products made from the untreated irregular powders.

Keywords: Metal powders; Particle composite system (PCS); Shape modification; Spheroidizing process

1. Introduction

With the development of increasingly sophisticated powder metallurgy production techniques, there is also an increased demands for powders of higher purity, with finer particle sizes and a narrower size distribution. Additionally there is a demand for particles with better surface morphology and with a spherical shape, as such particles will have increased packing density and improved bulk powder properties, such as flowability expressed by fluidity index and molding properties.

Particle spheroidization provides a homogeneous, free-flowing character to the subject powder. This facilitates powder handling and allows precise control of powder feed rates in a wide range of applications, including powder metallurgy and various thermal processing processes. Spherical particles allow denser particle packing and give a smoother macroscopic surface. These properties are beneficial for applications requiring low inter-particle friction coefficients [1–7]. Material made from spherical tungsten powder has a more homogeneous pore distribution, and the air permeability of the product can be easily controlled because the spherical particles are well suited to thermal spraying, so that the spraying layer is more symmetrical and homogeneous [8]. Metal powder injection molding (PIM) [9] or hot pressed sintering (i.e. hot pressing) applications can also benefit from spherical particles by the improvement of powder flowability. Spheroidization of metal particles can therefore play an important role in the substantial improvement of both powder properties as well as the quality of final sintered products. To illustrate the particle spheroidization process, we report in the following the results of our experiments on composite Al_2O_3/Cu powder and titanium powder.

2. Experimental

2.1. Materials

Commercially available normal electrolytic copper powder, with average size of 25 μm and hydrogenation–dehydrogenation (HDH) Ti powder with 99.25% Ti including the impurity elements of 0.01 wt.% Fe, 0.04 wt.% Si, 0.04 wt.% Cl, 0.02 wt.

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% C, 0.03 wt.% N, 0.53 wt.% O and 0.08 wt.% H and a maximum particle size of less than 38 μm, were sourced from Gripm Advanced Materials Co., Ltd, the General Research Institute of Nonferrous Metals (Beijing). α-Al_2O_3 powder, with an average size of 150 nm, was supplied by Zhoushan Mingri Nano Materials Co., Ltd, Zhejiang Province.

2.2. Experimental characterisation

Particle size distributions were measured using a laser diffraction particle size analyzer (BT-9300H, Dandong, China). About 0.1 g of sample was put in 100 ml water and given on ultrasonic dispersion treatment for about 5 min. The specific surface areas were automatically calculated by the particle size distributions. The bulk density and tap density as well as other characteristics of the powders were measured using a powder characteristic tester (BT-1000, Dandong, China). A JSM-6301F (JEOL, Japan) scanning electron microscope (SEM) was used to observe the surface morphology of the particles before and after treatment, and to observe the morphology of the sintered products.

2.3. Spheroidization of particles and preparation of products

2.3.1. Pcs

A particles composite system (PCS) which uses high speed mixer blending and impacting was used to treat the powders [10,11].

The PCS can convert irregularly shaped particles into spherical ones and allow the coating of fine particles on the surface of larger particles by the use of high speed rotary impact blades in a ring-shaped chamber. The system is operated at 2000–8000 rpm at temperatures from 45 to 75 °C. Less than 200 g of sample was used for each batch. The treatment time is less than 20 min with high efficiency and low energy consumption. It has been shown previously that longer times are not beneficial [10,11]. The wear of parts and contamination to product may be ignored because of short treatment time.

2.3.2. HDH Ti powder

For shape modification of the HDH Ti powder, the rotating speed of PCS was 5000 rpm, and the processing time was 15 min under nitrogen, argon or helium atmosphere. The Ti powders were then mixed with wax-based binders in a Brabender PLE 651 blender and then compacted into samples by hot pressing at 180 °C, respectively. After solvent and thermal debinding, the samples were sintered in a vacuum furnace (vacuum degree: $4-6\times10^{-3}$) at 1250 °C lasting for 90 min. A HAAKE Reomix rheometer made in Germany was used to test the rheological characteristics of the powder sample. A versamet-2 metallographic microscope made in Japan was used to observe the structure of the final product [12,13].

2.3.3. Composite Al_2O_3/Cu powder

In order to prepare reinforced Cu-based composite material, the composite Al_2O_3/Cu powder was made by mechanical dispersion (MD) in a ball mill running at 40 rpm for 2 h of the 98.5–100 wt.% Cu powder mixed with 0–1.5 wt.% Al_2O_3 superfine powder. 150 g composite powder was put into the PCS and spheroidized under an argon atmosphere at 5000 rpm for 15 min. This process can make Al_2O_3 particles dispersed homogeneously inside Cu particles, and spheroidized afterward. The shape modified Al_2O_3/Cu composite powder was molded by hot pressing, carried out using a HIGH-MULIT 5000 multifunctional sintering furnace produced by Fuji Airwaves Co. Ltd., Japan. The sintered sample was 50 mm in diameter, 8 mm in thickness and 100 g in weight. The sintering parameters were 920 °C, 15 °C/min heating rate, 20 MPa sintering pressure, and 30 min thermostatic control. Argon protection was used in the process [10,11].

3. Results and discussion

3.1. The effect of shape modification on powder characteristics

3.1.1. Particle surface morphology

Fig. 1 shows example scanning electron micrographs of both the untreated and the shape modified spheroidized HDH Ti powder. It can be seen from Fig. 1 that the irregular edges of the original HDH Ti particles disappeared after the impacting,

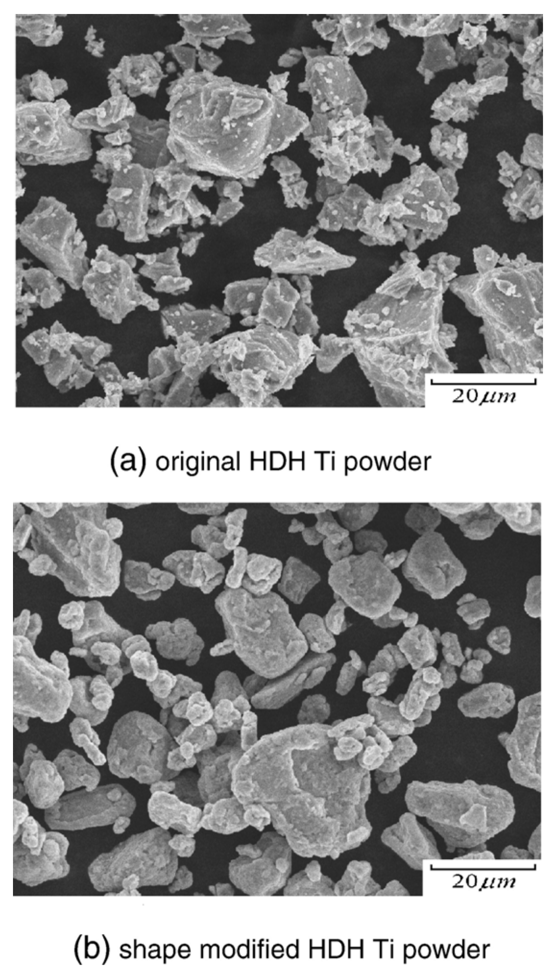

Fig. 1. SEM photograph of surface morphology of Ti powder.