Hydrodynamic particle-size classification of aluminum alloy powders


Powder fractionation is an essential part of powder metallurgy processes. However, powder particles smaller than 40 \( \mu \text{m} \) can hardly be classified. Meshes with openings smaller than 40 \( \mu \text{m} \) are not used in conventional sieving because of very low effectiveness since powder is suspended above the sieve as a result of vibration, which makes it difficult for the particles to pass through the mesh. Powders with particles smaller than 40 \( \mu \text{m} \) can be fractionated by hydroclassification. The hydroclassification of aluminum alloy powders and distribution of powder particle sizes are studied, and efficient hydroclassification methods are developed. Water-atomized aluminum powders and alloys have not been produced until recently because of the explosion hazard as hydrogen releases when aluminum interacts with water. A method is proposed for the hydroclassification and, thus, fractionation of powders over a wide range of particle sizes, including those smaller than 40 \( \mu \text{m} \), beginning with 0–10 \( \mu \text{m} \).

Keywords: powder fraction, hydrocyclone, inhibitor, grain-size composition, aluminum alloys.

INTRODUCTION

The disintegration of a material (for example, melt atomization) usually results in powders whose grain-size composition is only close to what is needed. Hence, the starting powder is fractionated, the fractions are dosed in a ratio needed and then mixed.

Sieves with openings smaller than 40 \( \mu \text{m} \) are not commonly used in powder production because of very low efficiency. The clear area of a 400-mesh (37.5 \( \mu \text{m} \)) sieve with \( \Omega 25 \mu \text{m} \) wire is just 35% [1]. In addition, powder particles cannot pass through openings smaller than 40 \( \mu \text{m} \) since they are suspended above the sieve because of vibration.

1Frantsevich Institute for Problems of Materials Science, National Academy of Sciences of Ukraine, Kiev, Ukraine.

2To whom correspondence should be addressed; e-mail: neiko@ipms.kiev.ua; 10@ipms.kiev.ua.

Powders with particles smaller than 40 µm may be fractionated in air and hydraulic classifiers. However, if active metal and alloy powders whose suspensions are explosive are to be air-classified, special explosion-proof means need to be used, but the cost substantially increases. By their effectiveness and accuracy of grading, hydraulic classifiers are superior to air classifiers [2]. They are especially suitable for wet processes, including the water atomization of metal powders. However, hydraulic classification is currently used in the production of iron powders. Suspensions are usually dehydrated and the resulting powders are dried and graded using vibratory sieves.

The objective of the paper is to examine the hydroclassification and grading of aluminum-based alloy powders and develop efficient hydroclassification methods.

Water-atomized aluminum powders and alloys have not been produced until recently because of the rapid oxidation of their surface in water and explosion hazard from hydrogen gas generation. The issue of explosion safety and oxidation protection of water-atomized aluminum powders was resolved at the Institute for Problems of Materials Science (National Academy of Sciences of Ukraine) [3–6]. This enables the commercial application of this powder production and hydroclassification process and will permit fractionation of powders over a wide range, including size fractions smaller than 40 µm.

**EXPERIMENTAL PROCEDURE**

To fractionate a water suspension, we selected a hydrocyclone (which is a simple device without moving parts) for grading finely ground materials in the centrifugal field induced by the rotating suspension (Fig. 1).

The powders are produced as follows. The charge prepared using master alloys and containing all alloying elements is molten in an induction furnace. The melt is poured into a hearth and then flows out through a calibration orifice in the bottom. The gravitational metal jet is dispersed with high-pressure jets of preliminary prepared water (its temperature and content of inhibitor and stabilizer being monitored) in a jet chamber. The water suspension with sprayed powder formed in the jet chamber in melt atomization is fed into a sedimentation tank, continuously pumped out from it, and supplied to a hydrocyclone to be graded (Fig. 2). The suspension with coarse particle fractions is returned to the sedimentation tank, the powder settles down in its lower section, and is mechanically dehydrated by filtration under vacuum. The suspension with fine fractions is settled down in a thickener or particles are separated on a filter. After dehydration, the wet powders are vacuum-dried.

To optimize the sedimentation and dehydration, we have examined the kinetics of gas release when atomized powders from aluminum-based alloys doped with scandium, titanium, and zirconium interact with water.

The kinetics of gas emission resulting from the interaction of aluminum alloy with water was examined depending on the suspension parameters (pH, temperature). The rate of gas emission, which characterizes the oxidation of powders in water, is represented by \( q \), ml/(kg ⋅ h), and is determined as the amount of gas per 1 ml formed within 1 h when 1 kg of powder interacts with water at room temperature. It was assumed that particles 0.25 µm at the most settled down in the thickener for 32 h. The suspension should have such parameters (inhibitor composition, hydrogen index) that particles settle down for a shorter period of time than the induction period of powder oxidation in water.

To examine the kinetics of gas emission, we used an original system that applies a force to balance the pressure of the gas accumulated under the measuring dome [7]. The experimental procedure allows for the peculiarities of the alloy powders used and is based on the following principles. The parameters of the measuring dome are determined from the expected rate of gas emission and the error (±1%) admissible in the measurement of the gas volume. Powder samples are taken from the sedimentation tank of the spraying apparatus in an amount sufficient to examine the chemistry and morphology of particles. If several samples cannot be measured in parallel, they are stored at a temperature no higher than 5°C.

The weight distribution of particles larger than 40 µm was studied by dry sieving according to ISO 4497. The grain-size composition of the minus material was determined using a laser granulometer and then checked by finding the diameters of particles in microphotographs taken with a scanning electron microscope (SEM). Therefore, the results were selectively checked with a laser granulometer. This was needed because particles of superfine powders prepared for laser granulometry may be nondiscretely distributed, and the device may regard interacting particles as one.