AERODYNAMIC ATOMIZATION OF METAL MELT JETS BY TRANSVERSE PULSED SHOCK AND DETONATION WAVES

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Abstract: A new method for producing metal powders for additive technologies by aerodynamic atomization of a freely falling melt stream by transverse pulsed shock or detonation waves is proposed. The method allows controlling the intensity of the shock/detonation wave (from Mach 4 to approximately 7) as well as the composition and temperature of detonation products by selecting the appropriate fuel and oxidizer. The method has been implemented on laboratory and industrial installations and has been preliminarily tested on melts of three metals: zinc, aluminum, and stainless steel, which have significantly different properties in terms of density, surface tension, and viscosity. Pulsed shock and detonation waves are generated by a pulse-detonation gun operating on the stoichiometric mixture of liquid hydrocarbon fuel and gaseous oxygen. The operation process of the setup is controlled by a video camera. The shape and size of solidified particles in the resulting powders are studied by dry fraction separation on sieves, optical microscopy, laser diffraction, and atomic force microscopy. The minimum and maximum particle size of produced powders is 0.1–1 and 400–800 μm, respectively. The latter is explained by the deficiency of shock/detonation wave energy for fine atomization of melt jets, especially dense and thick (8 mm) stainless steel melt jets. The mass fraction of the finest particles (0–10 μm) can be at least 20%. The shape of particles of the finest fractions (0–30 and 30–70 μm) is close to spherical (zinc and aluminum) or perfectly spherical (stainless steel). The shape of particles of larger fractions (70–140 μm and more) is mainly irregular. Zinc and aluminum powders contain agglomerates in the form of particles with small satellites. The content of agglomerates in stainless steel powders is very low. In general, preliminary experiments show that the proposed method for producing fine metal powders seems promising in terms of powder characteristics.

Keywords: metal powder; gas atomization; free-falling melt jet; pulse detonation gun; detonation wave; particle size distribution; zinc; aluminum; stainless steel; additive technologies

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Figure Captions

Figure 1 Schematic (*a*) and photograph (*b*) of the laboratory setup

Figure 2 Samples of aluminum powder: (*a*) on separator trays; and (*b*) after collection and drying

Figure 3 Example of records of three ionization probes in one operation cycle of the pulsed detonation gun

Figure 4 The mass-weighted size distribution function (SDF) for zinc powder in separator trays Nos. 1 to 4 obtained by dry sifting on sieves by fractions of 140–250, 70–140, 30–70, and 0–30 μm; sample weight is 313.8 g

Figure 5 Results of microscopic and atomic force microscopy (AFM) analyses of zinc powder fractions: (*a*) 140–250 μm; and (*b*) and (*c*) 0–30 μm

Figure 6 The granulometric analysis of zinc powder by the laser diffraction method for several particle fractions: *1* — 0–30 μm; *2* — 30–70; and *3* — 70–140 μm

Figure 7 The mass-related SDF for aluminum powder in separator trays Nos. 1 to 4 obtained by dry sifting on sieves by fractions of 140–250, 70–140, 30–70, and 0–30 μm; sample weight is 143.2 g

Figure 8 Results of microscopic and AFM analyses of aluminum powder fractions: (*a*) 140–800 μm; and (*b*) and (*c*) 0–30 μm

Figure 9 The granulometric analysis of aluminum powder by the laser diffraction method for several particle fractions: *1* — 0–30 μm; *2* — 30–70; and *3* — 70–140 μm

Figure 10 Video frames of the atomization process of the freely falling jet of molten stainless steel by a detonation wave in two consecutive operation cycles of the pulsed detonation gun

Figure 11 Mass-related SDFs for the stainless steel powder obtained by dry sieving on sieves for fractions > 1000, 800–1000, 400–800, 250–400, 140–250, 70–140, 30–70, and 0–30 μm; sample weight is 84.4 g

Figure 12 Results of microscopic and AFM analyses of the stainless-steel powder obtained on sieves: (*a*) 70–140 μm; and (*b*) and (*c*) 0–30 μm

Figure 13 The granulometric analysis of stainless-steel powder by the laser diffraction method for several particle fractions: *1* — 30–70 μm; *2* — 70–140; and *3* — 140–250 μm

Figure 14 Comparison of the mass-related SDFs obtained by the laser diffraction method for aluminum (*1*) and zinc (*2*) powders; fractions 0–30 μm

Figure 15 Comparison of the mass-related SDFs obtained by the laser diffraction method for zinc, aluminum, and stainless steel powders; fractions 30–70 μm

Table Captions

Table 1 Metals

Table 2 Properties of metals

Table 3 Fuel composition

Table 4 Fuel properties

Table 5 Measured and calculated detonation velocities and calculated composition of detonation products expanded to 0.1 MPa

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