Application of sprayed bronze powders of the BrSn10Ph1 and BrSn5Zn5Pb5 grades for applying protective coatings by gas-flame spraying

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Abstract: *Information on a small-size installation for production of atomized powders of copper-based alloys is presented. The process of obtaining pulverized powders of BrSn10Ph1 and BrSn5Zn5Pb5 grades by induction melting and melt gas atomization, intended for hardening of new and restoration of worn surfaces by gas-flame coating, as well as protection against corrosion of parts is studied. The quality of the coatings obtained using the manufactured powders has been confirmed.*

KEYWORDS*: EQUIPMENT FOR POWDER PRODUCTION, SPRAYED BRONZE BRSN10PH1 AND BRSN5ZN5PB5 POWDERS, INVESTIGATIONS, PROPERTIES, GAS-FLAME SPRAYING*

1. Introduction

The simplicity and cost-efficiency of the application of coatings by gas-flame spraying for strengthening new and restoring worn-out surfaces, as well as for the protection of parts of various functional purposes against corrosion, make this method attractive [1, 2]. Available equipment for gas-flame spraying of powders, consisting of a sprayer and a gas control panel, as well as powder materials for applying coatings are required to implement this method [3]. As materials, sprayed powders of bronze powders based on copper are widely used.

The purpose of the work is to obtain sprayed powders of tin-phosphorous bronze BrSn10Ph1 and lead bronze BrSn5Zn5Pb5 for applying protective coatings.

2. Results and discussion

To solve this problem, the small-sized equipment was developed to study the processes of powder production based on copper (Fig. 1).

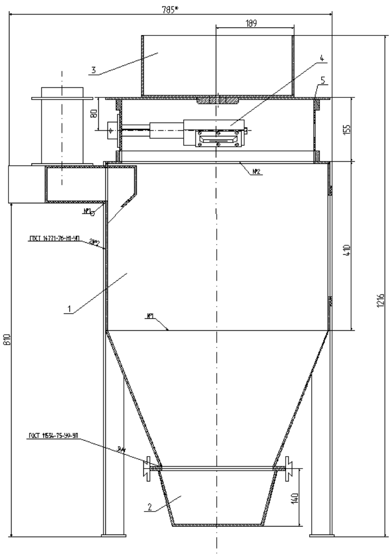


Fig. 1. *Equipment for production of metal powders by spraying a metal melt by gas flow: 1 – body; 2 – bottom plate; 3 – metal reservoir; 4 – nozzle; 5 – cover*

The production of experimental samples of sprayed bronze powders of BrSn10Ph1 and BrSn5Zn5Pb5 grades included the following basic operations [4]: weighing the initial components, loading the components into an induction melting furnace and heating, spraying a jet of the melt, removing the powder from the equipment and drying, sieving powder (Fig. 2).

Fig. 2. *Spraying process of copper-based powders by gas flow atomization of metal melt*

As a rule, powders of various fractions are obtained by air spraying. By varying the air pressure during spraying and the angle of inclination of the nozzles, it is possible to regulate the output of a given powder fraction to a certain extent. Studies have shown that the output of powder is 95%. Depending on the modes of spraying, the output of the sprayed powder of large fractions is 5-35% when using slot nozzles and fractions with a particle size less than 0.16 mm – up to 5-10%. Figure 3 shows the particle size distribution diagrams of tin-phosphorous bronze powders produced by means of this equipment.

When using these powders for the production of porous products, such a distribution is acceptable and almost all of the powder without remelting can be used at manufacturing site. However, for applying gas-thermal and gas-dynamic coatings onto worn-out surfaces or to protect them against corrosion, powders with particle sizes less than 100 μm are required. This leads to the remelting of powder with large particles and, accordingly, to significant additional energy costs. In this regard, a specialized spray unit was developed with a set of removable nozzles [5].

It is known that the main factors determining the powder dispersion are the viscosity, the surface tension of the melt and the gas flow energy [6]. The viscosity of the melt is regulated by the chemical composition of the alloy and the temperature of the melt, and the surface tension of the melt is regulated by the diameter of the flowing jet of the melt. To obtain powders with particles less than 100 μm, it was decided to increase the relative gas flow rate. To solve this problem, a nozzle design was developed for spraying a metal melt by air based on a de Laval nozzle. A set of removable nozzles makes it possible to change the angle of gas attack in a wide range and change the area of their cross section (Fig. 4) [5].

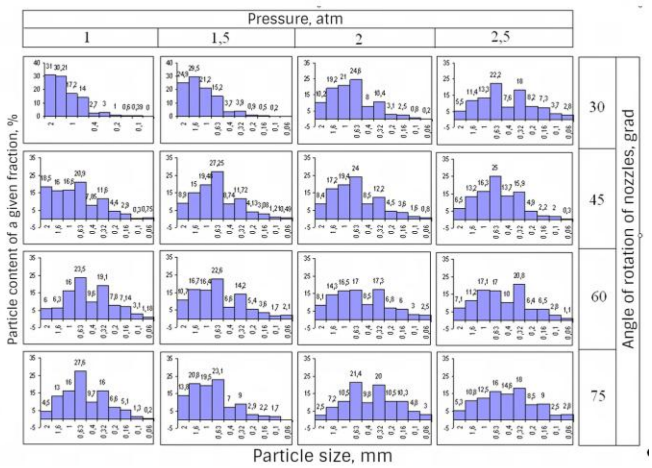


Fig. 3. Particle size distribution diagrams of the powder

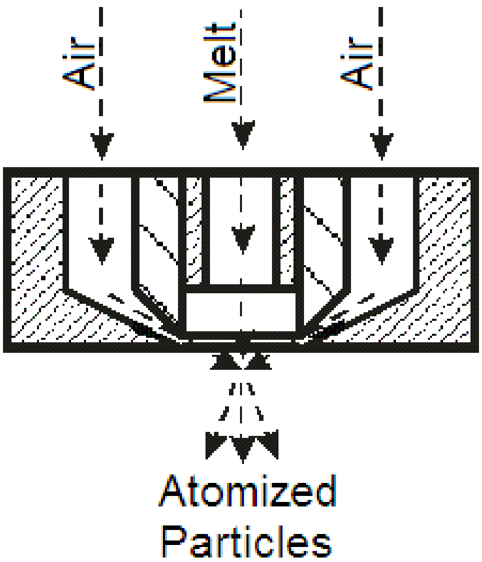


Fig. 4. *The nozzle for spraying based on the Laval nozzle*

The output of applicable powder with fractions less than 100 μm was more than 80% when using a specialized spraying unit to produce sprayed spherical powders of tin-phosphorous bronze BrSn10Ph1. Figure 5 shows the appearance of the particles of the manufactured BrSn10Ph1 brand bronze powder. The properties of tin-phosphorous bronze powders are shown in Table 1.

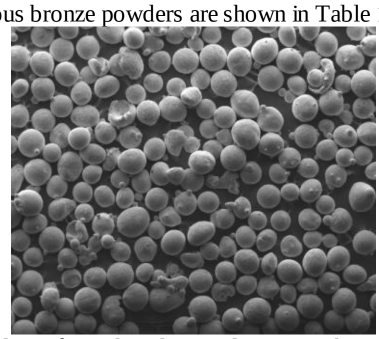


Fig. 5. *Powders of tin-phosphorous bronze with a particle size of less than 100 μm*

Table 1. *Properties of tin-phosphorous bronze BrSn10Ph1 powders.*

Fraction, μm	Bulk density, γ, g/cm^3	Flow rate τ, sec	Tap density, g/cm^3	Spherical shape factor
(-0.063+0.01)	5,30	9.80	5.70	0.95
(-0.1+0.063)	5,23	11.60	5.65	0,95
(-0.16+0.1)	5,10	12.10	5.52	0,95
(-0.2+0.16)	4,95	13.00	5.47	0,95
(-0.315+0.2)	4,90	17.10	5.40	0,95
(-0.4+0.315)	4,85	19.90	5.30	0,95
(-0.63+0.4)	4,80	28.00	5.25	0,95
(-1.0+0.63)	4,75	30.00	5,18	0,95

Similar results were obtained when studying the process of obtaining powders of the BrSn5Zn5Pb5, only taking into account the technological features when melting the melt in an induction furnace, namely the influence of carbon monoxide of one of the components – zinc [7-9]. The appearance of the bronze powder particles of the BrSn5Zn5Pb5 grade is shown in Figure 6, the properties are shown in Table 2.

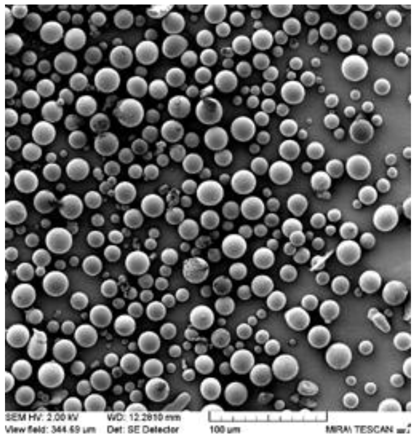


Fig. 6. *Appearance of the obtained bronze powder particles of the BrSn5Zn5Pb5 grade*

Table 2. *Values of bulk density, density after shaking, the ratio of density after shaking to the bulk density of BrSn5Zn5Pb5 powder.*

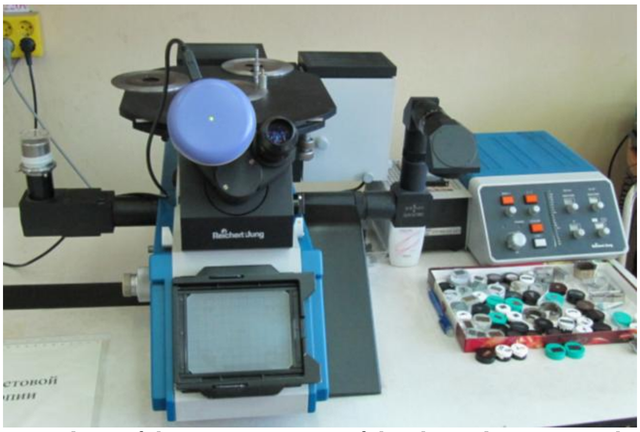
Fraction, μm	Bulk density, γ, g/cm^3	Flow rate τ, sec	Tap density, g/cm^3	The ratio of the density after shaking to the bulk density
(- 0,063 + 0,01)	5,26	9.80	5,60	1,065
(- 0,1 + 0,063)	5,16	11.60	5,55	1,076
(- 0,16 + 0,01)	5,11	12.10	5,51	1,078
(- 0,2 + 0,16)	5,06	13.00	5,49	1,085
(- 0,315 + 0,2)	4,90	17.10	5,42	1,106
(- 0,4 + 0,315)	4,85	19.90	5,38	1,109
(- 0,63 + 0,4)	4,80	28.00	5,36	1,117
(- 1,0 +0,63)	4,78	30.00	5,35	1,119

It should be noted that this equipment can produce powders of alloys based on copper and aluminum of other compositions used, for example, for restoring and strengthening the surfaces of crank-shaft necks, "fits" for rolling bearings, internal surfaces of slider bearings (provided that the coating length does not exceed the diameter of the hole), surfaces of transmission shafts, camshaft necks, wheel hubs, etc. [10].

The produced tin-phosphorus bronze and aluminum powders with a particle size of less than 100 μm were sprayed onto steel substrates by high-speed gas-flame spraying on TENA-Ppm equipment (Figure 7) using MAF (methyl-acetylene-allene fraction) as combustible synthetic gas.

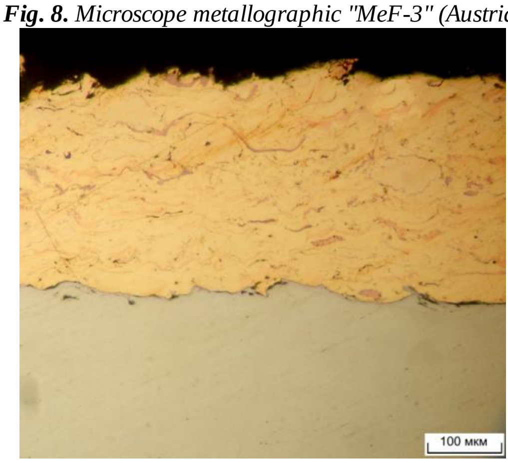
Fig. 7. *Chamber of semi-automatic spraying TENA-KPAN-1300 with the equipment of gas-flame spraying TENA-Ppm*

To study the strength of the joint of the coating with the surface of the steel plate, slots were made and metallographic studies were carried out on a metallographic high - temperature microscope "MeF-3" (Austria) (Figure 8). Studies of the structures have shown a strong formation of the coating and the absence of cracks and detachment. The structure of experimental coatings made of bronze powders BrSn10Ph1 and BrSn5Zn5Pb5 are shown in Figure 9.

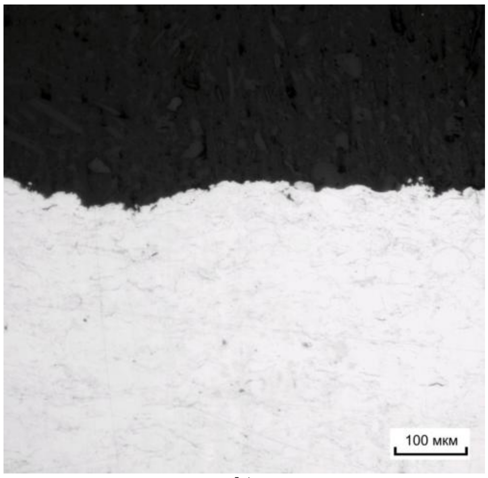


Analysis of the microstructures of the obtained coatings makes it possible to conclude that the quality of the sprayed coatings is high: the total porosity in the sprayed layer is much lower than the allowable 2%.

Fig. 8. *Microscope metallographic "MeF-3" (Austria)*



a)



b)

Fig. 9. *Microstructures of coatings applied to steel plates by gas-flame spraying from bronze powders of tin-phosphorous bronze BrSn10Ph1 ×100 (a) and lead BrSn5Zn5Pb5 (b)*

3. Conclusion

Information about the equipment design for producing sprayed powders based on copper and aluminum, intended for applying coatings by gas-flame spraying when strengthening new and restoring worn-out surfaces, as well as for the protection of parts for various functional purposes against corrosion, including crankshafts, transmission shafts, wheel hubs, camshafts, etc. is presented.

It is shown that the equipment provides powders with a high level of properties and powder output of fine fractions. The possibility of using the obtained powders of tin-phosphorous bronze BrSn10Ph1 and lead BrSn5Zn5Pb5 for applying high-quality sprayed coatings has been experimentally confirmed.

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