Production of powders of copper alloy (copper 85, tin 5, lead 5, zinc 5) by spraying a melt with a gas flow

Ilyushchanka A.[1, 2], Charniak I. [2], Kusin A. [2], Yarahovich D. [2], Kusin R. [3], Dechko M. [3], Marhanava V.[3]
State Research and Production Powder Metallurgy Association[1] – Minsk, Republic of Belarus
State Scientific Institution "O.V. Roman Powder Metallurgy Institute"[2] – Minsk, Republic of Belarus
Belarusian State Agriculture Technical University[3] – Minsk, Republic of Belarus
E-mail: alexil@mail.belpak.by, irinacharniak@tut.by, 2312444@mail.ru, 19081877@mail.ru

Abstract: *The study of the process of producing copper alloy (copper 85, tine 5, lead 5, zinc 5) powders of grade by the method of induction melting and spraying with a melt gas flow is presented.*

KEYWORDS: SPRAYING OF METAL MELT WITH A GAS FLOW, POWDER OF THE COPPER ALLOY (COPPER 85, TIN 5, LEAD 5, ZINC 5), INDUCTION MELTING, RESEARCH

1. Introduction

Bronze powders (copper alloy (copper 85, tin 5, lead 5, zinc 5) grade are widely used for spraying coatings by the gas-thermal method on the working surfaces of parts operating under friction and wear conditions. One of the main ways to produce spherical powders for spraying is spraying an overheated metal melt with a gas flow [1–3]. The method of producing metal powders by spraying a melt is technologically advanced, universal and highly efficient. However, in the process of induction melting, the copper alloy (copper 85, tin 5, lead 5, zinc 5) multicomponent alloy is significantly depleted in zinc due to the large difference in its melting temperatures with the melting points of the main component. A large number of techniques have been developed to reduce the loss of alloying components during melting and casting of the alloy. Their main recommendations are as follows [4–6]: to avoid overheating of the melt [7]; to use deoxidizers; to use fluxes.

Zinc and zinc-based alloys are very sensitive to overheating. Excessive overheating of zinc melts is always undesirable, since it causes the oxidation of zinc and alloying elements; it contributes to the saturation of the melts with hydrogen and oxide non-metallic inclusions. In addition, limitations on permissible overheating temperatures of zinc melts are due to the low boiling point of zinc and the evaporation of zinc. The losses of metals from evaporation depend on the pressure of the saturated vapor of the liquid metal: the higher the vapor pressure, the greater their losses during the preparation of alloys [8]. At the moment when the vapor pressure of the metal becomes equal to the external pressure, boiling of the metal begins, i.e. evaporation occurs not only from the surface, but throughout the entire volume. Deoxidizers are used to reduce the oxides that make up the alloy. One of the most common methods of deoxidation of power of copper alloy (copper 85, tin 5, lead 5, zinc 5) is melting the alloy in graphite crucibles. Fluxes are used to protect the alloy from oxidation and to separate non-metal impurities that enter the metal. For the protection of copper-zinc alloys, fluxes are used consisting of materials such as glass, sodium chloride, calcium sulfate, calcium fluoride, barium chloride, borax, and etc.

However, all the applications of the above methods are impractical in the implementation of processes for producing spherical powders by spraying the melt with a gas flow. Thus, the recommendation not to overheat the melt contradicts one of the main requirements of the powder spraying process, i.e. melt overheating by at least 250 °C [9]. The use of deoxidizers and fluxes in the process of spraying powder is possible with a significant complication of the process and a decrease in its productivity, since before supplying the melt to the spraying unit, it is necessary to completely remove the slag. It is technically difficult to implement. At the same time, if the slag gets into the spraying unit, it clogs the nozzle, which requires stopping the entire spraying process and spending a significant amount of time and additional resources. In addition to losses in value terms, zinc vapor brings a significant danger to human health. Thus, the development of ways to reduce zinc losses is an urgent and important task.

The purpose of the work is to study the effect of the melt overheating temperature, the diameter of its outflow jet and the gas pressure in the spray nozzle on zinc waste in the process of producing powders of copper alloy (copper 85, tin 5, lead 5, zinc 5) by induction melting and spraying the metal melt with a gas flow.

2. Experimental results and discussion

The production of experimental samples of sprayed copper alloy (copper 85, tin 5, lead 5, zinc 5) grade included the following basic operations [10, 11]: 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.

1) *Weighing the initial components* (scrap copper – 83.48 %, tin – 4.91 %, lead – 4.91 %, zinc – 6.7 %). Copper scrap without tinplate and soldering, plate zinc anodes, tin of O1 grade, lead sheets of C1 grade in the state of delivery were used as the initial components.

2) *Loading the components into an induction melting furnace and heating*. The melt was overheated with respect to the main component by 117 – 317 °C: the melt temperature was 1200, 1300, and 1400 °C. Two load variants were tried. According to the first variant, copper was heated to a specified temperature and melted. Then, slag was removed from the surface of the melt and tin and lead were introduced. When the melt reached the specified temperature, the most low-melting component, i.e. zinc, was introduced. According to the second variant, all the components were melted simultaneously: zinc sheets were twisted together with lead plates. Tin and copper were placed outside.

3) *Spraying a jet of the melt*. Within no more than 30 seconds from the moment of readiness, the melt entered the metal receiver. From the metal receiver, the melt freely flowed through a hole of a certain diameter in the form of a vertically falling jet into the spray zone, where it was dispersed into fine droplets by a gas flow. The sprayed droplets of the melt, due to the forces of gravity, moved into the water, where their final cooling took place. Figure 1 shows the equipment for spraying powders, and Figure 2 schematically shows a nozzle for spraying a jet of the melt. The hole diameter was 4, 6 and 8 mm; the pressure drop was 0.3 and 0.7 MPa.

4) *Removing the powder from the equipment and drying*. The sprayed powder was removed from the plate and dried at a temperature of 110 – 120 °C.

5) *Sieving powder*. The dried powder was sieved into fractions, and its chemical composition was examined.

Fig. 1 *Equipment for spraying powders*

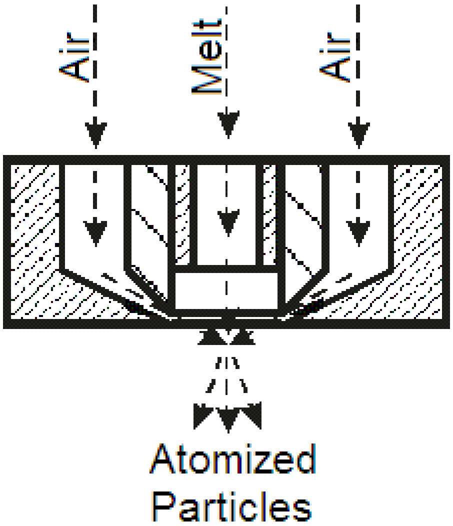

Fig. 2 *The nozzle for spraying*

According to the above technology, pilot batches of experimental samples of powders were produced and the effect of the melt overheating temperature, the diameter of the melt jet and the gas pressure on the value of zinc waste was investigated.

Table 1 shows the effect of overheating temperature on zinc waste at different sequence of introducing components into the melt.

Table 1 *Effect of overheating temperature on zinc waste*

Sequence of introducing components	Sequential introduction of components (variant 1)			Simultaneous introduction of components (variant 2)		
Overheating temperature, °C	117	217	317	117	217	317
Zinc content in the charge mixture, %	6,7	6,7	6,7	6,7	6,7	6,7
Zinc content in the powder, %	2,70	2,59	1,14	2,60	2,32	1,10
Waste, %	59,7	61,34	82,99	61,19	65,37	83,58

An analysis of the obtained data indicates that the overheating temperature has a primary effect on zinc waste. In this case, the powder spraying technology according to variant 1 is preferable due to lower zinc losses. Further, the experimental samples were produced according to variant 1, i.e. with the sequential introduction of the components. Moreover, taking into account that excessive zinc waste is observed at a melt temperature of 1400 °C (overheating temperature is 317 °C), and at a melt temperature of 1200 °C (overheating temperature is 117 °C), a low output of good powder is observed. Then the melt was heated to a temperature of 1300 °C (overheating temperature is 217 °C).

The effect of the overheating temperature on the form factor and the output of a good powder for experimental samples produced at overheating temperatures of 1200 and 1300 °C was determined (the temperature of 1400 °C was not considered according to the data in Table 2 due to the large waste of zinc). Form factor FF was assessed by the method described in Ref. [12]:

$$FF = \frac{4\pi A}{L_0^2}, \qquad (1)$$

where A – particle projection area, mm; L_0 – projection perimeter, mm.

The evaluation of the sphericity of the particles was carried out by determining the number of powder particles in the investigated fraction with a form factor of 0.8 or more on a certified automatic image analyzer “Mini-Magiscan” (“Joyce Loebl”, England) (Figure 3). The output of good powder was determined as a percentage in relation to the weight of the charge mixture for preparing the melt (Table 2).

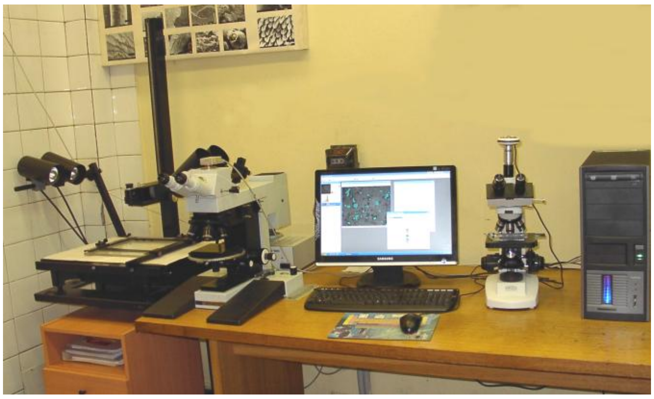

Fig. 3 *Automatic image analyzer “Mini-Magiscan” (“Joyce Loebl”, England)*

Table 2 *Effect of overheating temperature on a form factor and output of good powder*

Over-heating temperature, °C	Good powder output, %	Particle content with a form factor not less than 0.8, %		
		Powder particle size, μm		
		(-1000+630)	(-400+200)	(-1000+630)
1200	88,5	69,0	81,0	90,0
1300	94,0	93,0	94,0	96,0

Figure 5 shows the appearance of powder of copper alloy (copper 85, tin 5, lead 5, zinc 5), produced by the developed technology, and not dispersed into fractions.

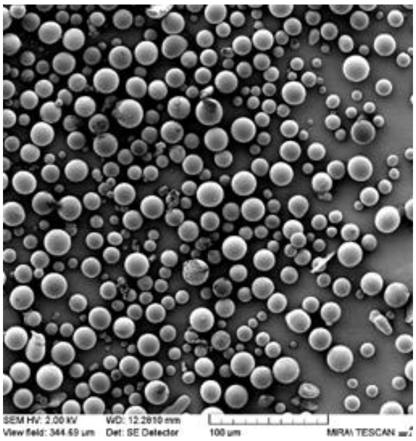

Fig. 5 *The appearance of the produced particles of powders of copper alloy (copper 85, tin 5, lead 5, zinc 5)*

The analysis of the obtained data indicates that the overheating temperature of 1300 °C is optimal for producing the required shape and chemical composition of the powder according to all parameters under study.

The effect of spraying modes of the melt (the diameter of the nozzle hole through which the melt flows and the gas pressure in the spray nozzle) by the gas flow on the zinc content was studied. The research results are presented in Table 3.

Table 3 *Effect of the diameter of the melt jet and the pressure drop of the gas on zinc waste*

Melt flow diameter, mm	4	4	8	8	6	6
Gas pressure in the nozzle, MPa	0,3	0,7	0,3	0,7	0,3	0,7
Zinc content in powder, %	2,58	2,6	2,58	2,59	2,6	2,6
Waste, %	61,49	61,19	61,49	61,34	61,19	61,19

The analysis of the obtained data has shown that the modes of the spraying process of the metal melt by a gas flow have practically no effect on the content (losses) of zinc in the process of producing a spherical sprayed powder.

Conclusion. It has been experimentally confirmed that when producing zinc-containing sprayed powders using the traditional technology of melting charge mixture materials, excessive zinc waste is observed, i.e. more than 60%. The optimal temperature 1300 ° C for heating the melt for further research has been established -. The melt flow diameter and gas pressure do not affect zinc losses.

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