Processing of steel galvanizing waste using the method of melt immersion

V I Gel\textsuperscript{1} and S B Sapozhkov\textsuperscript{1,2}

\textsuperscript{1}Yaroslav-the-Wise Novgorod State University, ul. B. St. Petersburgskaya, 41
173003, Veliky Novgorod, Russia

\textsuperscript{2}E-mail: ssb@novsu.ru

Abstract. The article describes the methods of steel galvanizing waste processing by immersion in a zinc melt, furnaces and devices for processing hard zink and drosses into usable products for zink pots, the methods for zinc extraction from waste and their use in industry. It is demonstrated that the hot-dip galvanizing wastes is a serious resource in reducing the consumption of primary zinc, what is more their use does not entail deterioration in the quality of the hot-dip zinc coating. However, not all technologies and types of equipment for processing zinc-containing waste are equally effective. It is appropriate to use vibro-deburring closed machines for processing dross (liming), and furnace with a “roof” heated for processing hard zink, and in the latter case, according to the technology of fractional loading of reagent – aluminum scrap – processing floating aluminum-iron intermetallic compounds carnallite-cryolite fluxing agent.

1. Introduction

In the last ten years, Russia has been actively developing the methods of galvanizing steel products by immersion in liquid zinc, including power line pylons, pipes, building bars, hardware items. Galvanizing of individual large products is carried out mainly in baths up to 13 meters long, 1.6 meters wide and up to 3 meters deep. At the same time, the average output of waste is: 7.5 kg/t of hard zinc, dross (liming) – up to 3.75 kg/t and zinc dust – up to 3–4 kg/t (for example, when flues blowing-down) of zinc items. The calculations show that, for example, when the production volume is 30,000 t/year of galvanized products, they form: 225 t of hard zinc and 112.5 t of dross, 30 t (averaged) of zinc dust, which contains a total of about 290 t of zinc.

For example, it is proposed to use hard zinc milled in a ball mill for thermodiffusion zinc coating of small products. It is also possible to prepare synthetic saturated mixture of dross for the same purpose. The dust produced by blowing flues contains only 0.1% of iron and 0.35% of lead and has various direct use options. It is proposed to melt the hard zinc in a gas-heated crucible with loading in three stages and with exposure at a temperature of up to 610 °C for several hours after each loading. The “Korner” distilling furnace for hard zinc regenerates 85–88% of the bonded zinc with a purity of 99.9%. The furnace brings hard zinc to the evaporation temperature of zinc. Then the zinc settles in the cooling retort.

According to the description of another method, the waste is loaded into the melt of an equimolar mixture of sodium and potassium chlorides with the addition of sodium or aluminum fluorides at a temperature of 740–790 °C. Then it is carried 15–30 minutes, then the metal zinc is removed, the
operation is repeated 3–5 times. Then the aluminum is added, 5–10% of molten salts weight, galvalume melt is taken away, and the oxides and intermetallic compounds with aluminum and zinc sediments are extracted from molten salts. After that, the operation is repeated [2].

The liming is processed by sieving in a rotating drum screen with the release of metal globules and their return to the hot-dip galvanizing bath. This allows reducing the volume of zinc purchases, and mechanizing the processing process.

The dross (liming) after each galvanizing operation is removed to the end of the galvanizing bath, where it is settled. The spread of dross on the surface of the melt is excluded due to its restriction by a metal partition. Heating of zinc dross pieces is performed at the expense of the temperature of molten zinc – 440–460 °C in the process bath for 20–30 minutes. The reduction of zinc losses with production waste is provided from 85% to 76–77% and a decrease in the yield of dross is from 6.1–6.2 kg/t to 5.6–5.7 kg/t of galvanized products.

In [4], an equipment analysis for processing zinc-containing waste is given. The equipment is patented in twenty countries and is operated in twenty-eight countries. The most common methods of processing zinc-containing waste involve placing them in cylindrical drums or retorts of various designs, heated to a temperature higher than the melting point of zinc. The drums are then rotated to intensify the separation of molten zinc from the sludge.

2. Research and development of new aggregates
One of the first was designed “Carousel melting furnace”, consisting of a powerful fixed furnace body, inside which rotates a non-removable metal melting drum, heated from the outside. Through the center of the drum passes a metal pipe that acts as bearing shafts, the ends of which go through the holes in the opposite walls of the furnace body and rotate in special supports. Inside the melting drum, between the main shaft and the walls of the drum, there are blades that perform the functions of a conveyor screw. The loading and unloading devices are made in the form of holes in the opposite ends of the melting drum [5].

The disadvantages of the furnace include the complexity of the design and the use of special heat-resistant materials in the construction of the furnace, as well as environmental pollution by waste flue gases, metal- and chlorine-containing dust, which requires the use of gas cleaning equipment.

In a tilted rotary furnace (figure 1), which is widely used worldwide for melting aluminum scrap, metalized zinc, lead, and copper wastes, the technology for melting zinc dross, there was tested the melting technique of zinc dross at the Taganrog Iron and Steel Factory. The furnace temperature is 500–520 °C, the waste oil consumption is 25–28 l/hour. The furnace charge of dross is 5 t, with a zinc content of 60%. There is collected 2940 kg of zinc and 2050 kg of slag with a residual zinc content of 2.92%. The operating time of the furnace is 2 hours [3].

![Figure 1. Rotary kiln for processing of metalized waste of Al, Pb, Zn.](image-url)
The article [6] describes the experience of processing hot-dip galvanizing, hard zinc and dross wastes in a closed vibration machine (which does not emit dust during operation). The technological scheme for processing zinc liming is demonstrated at the figure 2.

![Technological scheme of zinc ash processing in the vibration machine.](figure2.png)

The frequency of circular vibrations is 25 Hz, the amplitude is 5 mm, the drive power is 5.0 kWe, the processing time is 45–50 min (500 kg of dross). At the same time, the speed of particles of bulk loading reaches 1.0 m/s, acceleration is up to 150 m/sec², impact force is up to 30 N, contact pressure is up to 15 kN, and with an increase in the residence time of metal crowns, even grinding of their surfaces occurs while removing the oxycarbide part.

The yield of globule metal from dross (fractions – minus 4 mm) containing 50% zinc, is 160 kg, fraction 4.0–2.0 – 150 kg, fraction minus 2 mm – 190 kg. The yield of zinc in the remelting of the globule metal is 96.5%, in the remelting of the fraction minus 4.0–2.0 – 62.5%, and in the fraction minus 2 mm – 46%. The globule metal was returned to the hot-dip galvanizing bath, and the 4.0–2.0 fraction, containing less than 0.01% chlorine, was used to produce zinc oxide.

Figure 3 shows a photo of a working vibration machine with a loading capacity of 500 kg. During 45–60 minutes of machine operation, the complete separation of the globule metal from the liming is achieved.

![Vibro deburring machine separating metal globules from dross.](figure3.png)
The fraction minus 2 mm was studied for the preparation of a sulfate-chloride salt, applicable for correcting the composition of galvanizing baths, where the chlorine ion is a necessary component of the electrolyte, improving the adhesion of the coating, increasing the electrical conductivity of solutions, contributing to the uniform dissolution of anodes. The low cost of the solvent, the possibility of separating lead and zinc already at the leaching stage without the introduction of cementation treatment has determined the choice in favor of sulfuric acid leaching. The resulting salt corresponds to the standard for zinc sulfuric acid 7-water [7].

Hard zinc was processed in a furnace with a capacity of 2 t lump hard zink with vaulted electric heaters [10]. The choice of arch heating is due to the nature of Al-Fe-Zn intermetallic compounds' liquation to the surface of the melt bath and the possibility of their overheating when mixed with carnallite-cryolite fluxes in order to reduce the amount of liquid zinc in them and turn them into a loose condition [8].

Currently, in order to save energy, a gas furnace with a removable arch and melt mixing with the help of vertical mechanical pump is offered. The diagram of the hard zinc processing furnace is demonstrated at the figure 4.

![Figure 4. Diagram furnace for processing hard zinc. 1 – furnace cavity; 2 – removable arch; 3 – window for slag removal; 4 – impeller pump; 5 – window for receipt of the melt in the mixing zone; 6 – window for feeding the melt into the furnace cavity; 7 – window for loading reagents; 8 – burner; 9 – smoke removal; 10 – leaks for the metal release; 11 – slag tanks.](image)

The temperature of primary heating is determined by the composition of the initial hard zinc and peritectic lines in the diagram of the metals state. The temperature reduction in steps and a discrete aluminum feed together with the flux provide a minimum output of “drained” flux agents.

The time of processing the melt with aluminum scrap is 16–20 hours, depending on the iron content in the hard zinc. The ratio of aluminum lump scrap with fractional introduction of aluminum into the melt is 1.2:1, where: 1.2 – is the amount of aluminum scrap or chips, 1.0 – is the amount of iron in the load, the flux agent consumption is 2–4% adding to the hard zinc weight. As a result, the content of iron in secondary zinc should not exceed 0.05%, the content of aluminum – 1.2%, which on average amounted to 5.0–5.5% of the zinc consumption for coating and did not worsen its quality. The slag from the melt surface was sent to a vibration machine for processing.
Furnaces installation for processing hard zinc and vibration machines for dross allows to get the maximum zinc return in the form of commercial products, and it is possible to cross-use the resulting zinc intermediates.

3. Conclusion
Hot-dip galvanizing wastes are a significant resource in reducing primary zinc consumption. Many technologies exist and are used for processing zinc-containing waste, both by mechanical grinding and sieving, and by melting.

Not all offered and using waste processing technologies meet the requirements for emissions of harmful substances into the environment and complex processing for full use in the national economy.

Most sufficiently meets these requirements the processing technology of drossb (liming) vibro deburring closed machine, allowing to obtain high quality products: metal globules to return to the hot-dip galvanizing bath, the fraction minus 4 to plus 2 mm – for the production of zinc oxides, the fraction minus 2 mm – for the production of sulfate-chloride salts to stabilize the process in electroplating technology.

Processing of hard zinc occurs most fully in furnaces with arch heating using the technology of fractional loading of the reagent-aluminum scrap - with processing of floating aluminum-iron intermetallic compounds carnallite-cryolite fluxing agent.

References
[1] Alekseev A A 2005 Metallurgicheskaya pererabotka cinkosoderzhashchih othodov proizvodstva [Metallurgical processing of zinc-containing waste products] Vestnik Inzhekona. Seriya: Tekhnicheskie nauki 3(8) 125–128 [In Russ.]
[2] Kazantsev G F, Barbin N M, Moiseev G K and Vatolin N A 2000 Sposob pererabotki othodov cinka [Method for zinc waste processing] Patent RU 2147322 [In Russ.]
[3] Tarasov A V, Gel V I, Sheveleva L M 1989 Pererabotka othodov goryachego cinkovaniya [Processing of hot-dip galvanizing waste] Stal' 6 57–58 [In Russ.]
[4] Alekseev A A 2007 Organizaciya effektivnogo teknologicheskogo processa goryachego cinkovaniya [Organization of effective technological process of hot-dip galvanizing of wastes by implementing resource-saving technologies] (Sankt-Peterburg) p 129 [In Russ.]
[5] Gel V I 2013 Rotornaya pech [Rotary kiln] Patent RU 134620 [In Russ.]
[6] Gel V I and Samsonov A I 1991 Kompleksnaya tekhnologiya pererabotki cink- i hlorosoderzhashchih othodov [Complex technology of zinc-and chlorine-containing waste processing] Voprosy ekologii i resursospredezhdeniya v pererabotke othodov cvetnoj metallurgii: Sb. nauch. tr. ed A N Petrun'ko at al. 30–33 [In Russ.]
[7] Gel V I, Malyy E F, Makarenko E A and Prohorov S N 1989 a.s. SSSR № 1493855 [In Russ.]
[8] Tarasov A B, Besser A D and Maltsev V I 2004 Metallurgicheskaya pererabotka vtiorichnogo cinkovogo syr'ya [Metallurgical processing of secondary zinc raw materials] ed A V Tarasov (Moscow: Gincvetmet) p 219 [In Russ.]