Investigations of zinc recovery from metallurgical waste

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Abstract. Approximately 7 million tonnes of zinc is annually used for corrosion protection in processes of continuous galvanization and the hot dip processes. Two types of waste are obtained from the process: zinc ash and hard zinc and each of them constitute around 10% of the feed weight. Paper concerns the method of possible separation of metallic zinc from the non-metallic zinc compounds from the zinc ashes – the waste product of hot dip galvanization process. The investigative programme covered the comminution tests of the feed (zinc ash) in selected crushers: jaw crusher, roller crusher and impactor. Results of investigations show that application of individual crushing device results in various breakage of the feed sample. Impact force caused the highest increase in finest particles size fractions of the product, while metallic and non-metallic fractions were comminuted differently. The compression force, in turn, caused the selective comminution, i.e. the breakage of metallic zinc was observed in a higher degree.

1. Introduction and methodology

World production of metallic zinc during last decade shows a slight increase and in recent years its consumptions reach 14 million tonnes. Main directions of zinc utilization include processes of galvanization, production of zinc alloys, brass and bronze, chemicals, as well as other semi-products based on the zinc. The major share in global zinc consumption, however, constitute galvanization process[1]. Two main types of zinc galvanization are: hot-dip galvanizing (HDG) and electro-galvanizing.

In the HDG process two kinds of residues are occurring. The zinc ash, that is formed on the surface of the HDG bath, and hard zinc, formed on the bottom of galvanizing kettle [2,3,4]. The zinc ash consists mainly of metal oxides, sulphides and chlorides and it has to be removed continuously before the galvanized goods are extracted from the bath [5]. These residues contain up to 90% of metallic zinc, depending on particle size fraction (table 1).

The ash zinc waste contain the zinc in metallic and non-metallic forms. In order to recover the metal from ash zinc, the waste is directed to smelting process [6]. However, smelting the whole charge results in higher metal loss in the process. Therefore, it is advisable to separate the metallic form of zinc from the waste, in order to reach higher effectiveness of zinc recovery in further metallurgical processes. It is also worth to remember that finer material, with too much gangue and complex
compounds cannot be recovered with high effectiveness in pyrometallurgical processes. In such cases hydrometallurgical treatment might be the most suitable method of processing [7]. Both forms of zinc have different physical and mechanical properties. It was observed under microscope that light grey irregular particles of metallic zinc are bound with finer dark grey brownish areas that represent the zinc ash. On that basis it is assumed that grindability properties of both form of zinc could be different. The zinc ash particles can break more easily than particles of metallic zinc, and the crushing product may contain coarser particles of metallic zinc along with finer particles of zinc ash and non-metallic fractions. Further screen separation [8] can be applied for comminution products.

Taking into account the above, the main research aim of the paper is investigation of selective comminution of zinc ash waste, therefore comminution process should be properly adjusted in order to minimize the content of size fractions below 0.5 mm. Three different crushers were tested: jaw crusher, hammer crusher and roll crusher.

2. Experimental

The feed materials for experiments constitute the zinc ash waste from hot-dip process, with maximum particle size below 12 mm. Initial characteristics of the feed material was performed and results were presented in table 1.

| Particle size fraction [mm] | Yield [%] | Metallic zinc content [%] |
|---------------------------|-----------|--------------------------|
| >3                        | 35        | >90                      |
| 0.1 - 3                   | 50        | 60                       |
| Dust (<0.1 mm)            | 15        | 30-35                    |

Results of particle size analysis show that particles coarser than 3 mm constitute approximately 35-40%. Additionally, this material is of a very high purity in terms of metallic zinc content. This size fraction of material can be separated from the entire feed and proceed for the metal zinc recovery by means of pyrometallurgical methods [9]. The finest size fraction, in turn, contain 30% of zinc roughly, therefore processing of this part of feed material might be uneconomic. An average zinc content in the feed material equals 67%, approximately (figure 1).

![Figure 1. Metallic zinc content in individual particle size fractions in the feed material 0-3 mm.](image-url)
Summing up, the particle size fraction above 3 mm can be divided from the feed. Optionally also the dusts below 0.1 mm could be removed and only the size fraction 0.1 – 3 mm processed by means of crushing.

The Zn content in individual particle size fraction is different. The lowest content of metal can be observed in two finest particle size fractions, while in coarser ones the amount on zinc is higher. It is hard to notice a clear relationship between the size of material and zinc content, however coarser fractions in general contain more metallic zinc than finer ones. Similar data can be found in literature [9].

As it was mentioned above, the research aim of the paper is to test potential usefulness of comminution operations in zinc ash waste processing. Three types of crushers were used in tests, and the scheme of investigations was presented in figure 2.

![Figure 2. Scheme of investigations.](image)

![Figure 3. Crushing products from individual crushing devices.](image)
The feed material 0-3 mm was undergone the sieve analysis and the result was presented in figure 3. Then the sample was divided into four parts, three of them were crushed in different crushers, while the fourth one was secured as spare one. Crushing tests were then performed, and size analyses of crushing products were made.

Crushing product below 0.5 mm is treated as a final waste in this case. Two issues were taken into account in the work assessment of individual crushers: the yield of product below 0.5 mm and the zinc metal content in size fraction below 0.5 mm.

If the metal zinc content in crushing product below 0.5 is lower than in feed material, that might indicate, that in crushing process mainly non-metallic particles and ash pass into fine fraction. When, in turn, the zinc content in finest crushing product increases, that may indicate that more significant amount of metallic zinc is crushed, too.

3. Results of investigations

Each crushing product was undergone the sieve analysis and the results were presented in figure 3. Inspecting the figure, it might be seen that crushing products from jaw and roller crushers have very similar particle size compositions. The product of hammer crusher, in turn (figure 4), has a slightly higher content of finer particles. Comparing all crushing products below 0.5 mm it can be stated that hammer crusher produced nearly 8% more material. However, at this point it is not possible to strictly determine which crushing device is more favorable.

![Figure 4. Yields of products below 0.5 mm obtained for individual crushers.](image)

In the next stage of research program chemical analyses on each products were performed, and the content of metallic zinc in each sample was determined. Results are presented in table 2.

| Type of crusher | Jaw crusher | Roller crusher | Hammer crusher | Feed |
|----------------|-------------|---------------|----------------|------|
| Metallic zinc content, [%] | 63.2 | 70.0 | 60.8 | 63.2 |

Calculations of average content of metallic zinc in feed are presented in table 2. Analysis of data presented in the table shows that in the case of hammer crusher the content of metallic zinc in products has decreased, while in crushing product of roller crusher the higher zinc content was recorded. For the jaw crusher the zinc content was on the same level. It may indicate that impact forces cause comminution of non-metallic fractions in a higher degree than metallic ones. In turn, the pressing
force that predominates in the roller crusher, results in slight more intensive comminution of metallic zinc. Results of tests for jaw crusher show that both metallic and non-metallic fractions comminute in the same degree.

Results of investigations show that application of certain method of comminution may results in selective crushing of both zinc fractions. It is then possible to design the crushing circuit in which products with different contents of metallic and non-metallic zinc, can be obtained. The entire circuit should include sieving the material with particle size above 3 mm, crushing and size classification on a screen.

4. Summary and conclusions
Secondary resources of zinc constitute significant amount and are becoming more significant in terms of its recovery. It is especially important when the world zinc production from primary resources is on similar level since last decade and zinc demand increases. The method presented in the paper can increase effectiveness of zinc recovery from galvanizing process waste. Application of comminution operation helps in initial separation of non-metallic zinc fractions from the metallic ones. Results of investigation show that hammer crusher is the most favorable device among the three tested crushers. Impact forces increase selective comminution and, as a result, non-metallic fraction breaks more intensively, passing at the same time to the waste product.

The designed circuit can be modified, depending what cut size dT2 of the hammer crusher screen is accepted. It is possible to separate a coarser material (i.e. below 1 mm) and include further treatment of this fine size fraction in grinding operations. That would result in even more higher effectiveness of separation, but investigations within this scope will be the subject of further publications.

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