HYDROMETALLURGICAL TREATMENT OF ELECTIRIC ARC FURNACE DUST IN AIM OF ZINC SEPARATION

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Abstract

During the steel production from secondary raw materials in the electric arc furnace, generation of the main intermediate of the process- dust from the electric arc furnace (EAF dust) occurs. This dust contains significant amounts of Zn and Fe, as well as Pb, Ca, Mn, Ni, Cu, Cd, Mg, Si, Cr, F, Cl and other elements and is considered hazardous industrial solid waste since it contains heavy metals. In order to separate Zn as a valuable component, hydrometallurgical treatment of EAF dust was investigated.The treatment consists of two stages: 1st stageis water leaching of EAF dust performed in order to remove water-soluble compounds, and 2nd stage is acid leaching in order to leach ZnO from EAF dust and obtain a $ZnSO_4$*solution. With optimal parameters of the water leaching process of EAF dust, the achieved leachingrates of water-soluble compounds are as follows: 80.84% Cl, 60.63% K, 52.95% Na, 18.23% Ca, while with acid leaching of the solid residue obtained after water leaching at optimal parameters achieved leaching rate of Zn is 82.34%. In addition to the economic aspect of this treatment where the separation of Zn from EAF dust is performed, the treatment also has an ecological aspect because the transformation of hazardous waste into non-hazardous waste is performed, which has a positive effect on the environment.*

Keywords: *EAF dust, hydrometallurgical treatment, Zn separation, environment protection.*

1. INTRODUCTION

The total world steel production in 2019 amounted to 1869 million tons, of which the steel production in the electric arc furnace amounted to more than 30% of the world steel production [1-3]. Steel production from secondary raw materials, so-called scrap iron, is performed in an electric arc furnace (EAF) at a temperature of 1600°C, where during the melting of the batch the elements from the iron melt evaporate, which leads to the formation of the main intermediate of the process - electric arc furnace dust (EAF dust) [3-7]. In general, about 10-20 kg of EAF dust is generated during the production of 1 ton of crude steel[5, 8-10].Electric arc furnace dust contains significant amounts of zinc and solid iron oxides, as well as variable amounts of Pb, Ca, Mn, Ni, Cu, Cd, Mg, Si, Cr, F, Cl, etc. [1, 8-10]. The Zn content in EAF dust varies between 2 and 40% [2, 5, 6, 8-10]. Due to the fact that EAF dust is formed under oxidation conditions, most metals are present in the form of metal oxides. Zinc occurs in the form of ZnO and $ZnFe_2O_4$, while iron mainly occurs in the oxide form as Fe_3O_4 and Fe_2O_3 [3, 5, 8, 9]. The presence of heavy metals such as Pb and Cd in EAF dust can pose a threat to the environment and human health, and for this reason EAF dust is considered officially hazardous industrial solid waste in many countries [4, 5, 6, 9, 8, 10, 11].

In this paper, a laboratory experimental study of hydrometallurgical treatment of EAF dust originating from a steel plant in the Republic of Serbia was performed. Chemical characterization of EAF dust, laboratory experimental tests of EAF dust water leaching process in order to remove chlorides and other water-soluble compounds, as well as tests of acid leaching process of solid residue obtained after water leaching in order to separate zinc were performed.

2. EXPERIMENTAL

Chemical characterization was performed on a reference sample of EAF dust by the following methods: Atomic Absorption Spectrophotometry (AAS), Volumetry (V), Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES), Spectrophotometry(SF), Carbon/Sulfur Analyzer (ACS).

Laboratory experimental investigations of hydrometallurgical treatment of EAF dust include water leaching and acid leaching processes. The parameters of the water and acid leaching processesat ambient temperature were investigated. All leaching experiments were performed on an initial EAF dust sample in an amount of 100 g, in a glass reactor with volume of 1 L, equipped with a stirrer with speed control and a device for automatic temperature control. For acid leaching experiments with the addition of oxidants, O_2 from a pressurized bottle was used.

3. RESULTS AND DISCUSSION

The chemical composition of the initial EAF dust sample is presented in Table 1.

Table 1 - Chemical composition of the initial EAF dust sample

Element	Zn	Fe	Mn	Cu	Pb	Co	K	Ni	Cr	Ca	Cd
Content (%)	32.44	18.92	1.81	0.19	1.39	0.0017	0.87	0.036	0.25	3.85	0.04
Element	Cl	Mo	S	P	As	Sb	Sn	Al	Si	Na	Mg
Content (%)	2.85	<0.005	0.51	0.15	0.0041	0.022	0.037	0.73	1.0	1.28	0.93

3.1.Water leaching of EAF dust

The following parameters of the EAF dust water leaching process were investigated: pulp density 5-20%, ambient temperature-80ºC and pH correction to <11. Process parameters such as the leaching process duration of 60 min and the mixing speed of 750 rpm remain constant in all experiments.

The 1ststage of hydrometallurgical treatment of EAF dust was performed in order to remove chlorides and other water-soluble compounds from EAF dust, such as Ca, Mg, K, and Na. The effects of water leaching EAF dust are a reduction in the consumption of sulfuric acid and chlorine ions in the second stage of leaching. The test results of the water leaching process confirm the removal of chloride from EAF dust, as well as other water-soluble elements. The leaching rates of chlorides and soluble compounds from EAF dust in water are shown in Figure 1 and amount to 80.84% Cl, 60.63% K, 52.95% Na, 18.23% Ca, 0.14% Zn and <0.0006% Pb.

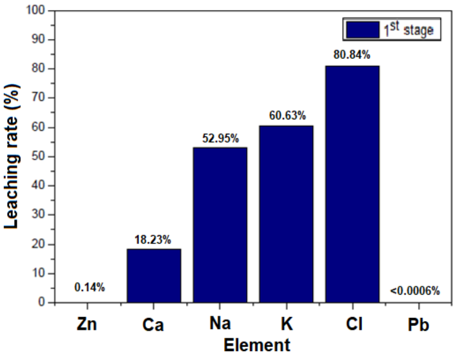


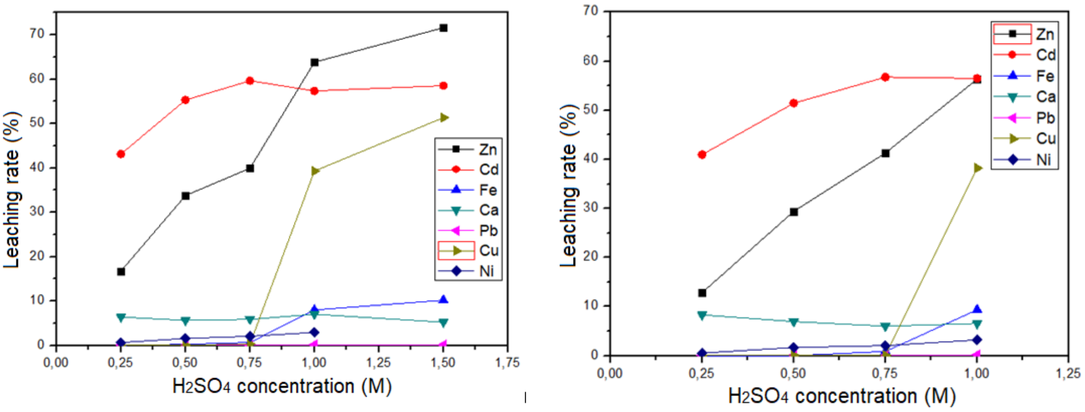
Figure 1 - Leaching rates of chlorides and water-soluble compounds

In water leaching experiments without pH correction, the pH of the suspension is above 11 at the end of leaching, which causes an increase in the concentration of Pb and Zn in the pregnant leaching solution. In order to prevent leaching of Pb and Zn with water, the pH of the suspension was corrected to <11 by adding concentrated HNO_3. The mass of the solid residue after water leaching without heating is reduced by about 10% compared to the initial mass of the EAF dust sample. The same percentage of weight reduction was shown in the experiment performed at a temperature of 80ºC, which means that the increased temperature is not necessary during water leaching process. Also, no significant influence of pulp density on the metal concentration in the solution after leaching was observed, so that the pulp density of 20% was taken as the optimal parameter.

3.2.Acid leaching of the solid residue

After the 1stat stage of hydrometallurgical treatment of EAF dust, the obtained solid residue was leached in the 2ndstage with sulfuric acid at ambient temperature in order to leach ZnO from EAF dust and obtain a solution of $ZnSO_4$. The following process parameters were examined: H_2SO_4 concentration (0.25M, 0.5M, 0.75M, 1.0M and 1.5M), leaching process time (10 and 20 min), as well as oxidant addition (O_2), while a pulp density of 20% and a stirring speed of 750 rpm were constant.

Leaching rate of the tested elements depending on the concentration of H_2SO_4 without addition of oxidant is presented in Figure 2. From the obtained results it can be concluded that the leaching rate of Zn increases with increasing H_2SO_4 concentration for both tested leaching times (10 and 20 min). The highest Zn leaching rate of 71.63% was achieved by leaching with 1.5M H_2SO_4 over a time of 10 min. Leaching rate of Cu and Fe increases significantly at H_2SO_4 concentrations above 0.75M H_2SO_4. With increasing concentration of H_2SO_4, the leaching rate of Ca and Ni does not change significantly. Leaching rate of Cd leaching increases with increasing H_2SO_4 concentration from 0.25M to 0.75M. With a further increase in the concentration of H_2SO_4 from 0.75M to 1.5M, no significant change in the leaching rate of Cd was observed.



a) Leaching time 10 min b) Leaching time 20 min

Figure 2 - Leaching rate depending on the concentration of H_2SO_4 at a leaching time of 10 min and 20 min (leaching reagent 0.25-1.5M H_2SO_4, pulp density 20%, mixing speed 750 rpm, ambient temperature, without oxidant addition)

Investigation resultsof the addition of O_2influence as an oxidant on Zn leaching showed that the Zn leaching rate significantly increases with the addition of oxidant during the acid leaching process. The achieved Zn leaching rate with the addition of oxidant is 10% higher than the leaching rate without the addition of oxidant at the same tested process parameters (leaching with

1.5M H_2SO_4, pulp density of 20%, leaching time 10 min, mixing speed 750 rpm, ambient temperature) and amounts to 82.34%.

After acid leaching, the obtained solid residue showed the characteristics of non-hazardous waste based on TCLP and LP tests.

4. CONCLUSION

In order to separate Zn from EAF dust as a valuable component, hydrometallurgical treatment of EAF dust was investigated. The treatment consists of two stages: 1st stage of leaching with water was performed in order to remove water-soluble compounds, and 2nd rate of leaching with sulfuric acid in order to leach ZnO from EAF dust and obtain a solution of $ZnSO_4$. The achieved leaching rates of water-soluble compounds from EAF dust are 80.84% Cl, 60.63% K, 52.95% Na, and 18.23% Ca at the following optimal process parameters: pulp density 20%, ambient temperature, time 60 min, stirring speed 750 rpm and pH correction to pH <11.

The best results of acid leaching were achieved by leaching the solid residue obtained after water leaching EAF dust at the following parameters: 1.5M H_2SO_4 with the addition of O_2 as oxidant, pulp density 20%, leaching time 10 min, stirring speed 750 rpm at ambient temperature. Leaching rate of Zn at these leaching parameters is 82.34%. Apart from the economic one, the investigated treatment has also ecological significance because it transforms the starting material which represents hazardous industrial solid waste into non-hazardous waste, which can be disposed of at a non-hazardous waste landfill without risk to the environment.

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