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A Study on the Reduction of Zinc Dust using Methane Gas

Jei-Pil Wang[*]

Department of Metallurgical Engineering, Pukyong National University, Busan, Republic of Korea.

[*]*First and Corresponding author*

Abstract

A study on the recovery of zinc from wasted sludge generated from molten process of scrap in foundry was conducted at elevated temperature over 1000°C. The raw material from wasted sludge from foundry was almost composed of ZnO with minor impurities such as FeO, MnO and Cr_2O_3. It was reduced by methane gas(CH_4) with following reaction: $2ZnO + CH_4(g) = 2Zn + CO_2(g) + 2H_2(g)$. The zinc oxide was reduced by methane gas and metallic zinc was transformed to zinc gas which can be attached to the condenser. Once reduction reaction was completed, zinc powder attached in the condenser was taken off and it was examined by X-ray diffraction (XRD), energy-dispersive X-ray spectroscopy (EDX) as well as inductively coupled plasma atomic emission spectroscopy (ICP-AES) to determine purity of zinc powder. It was noted that the purity of zinc powder obtained was observed to be over 99.5 wt.%.

Keywords: zinc dust, methane gas, recovery, powder

I. INTRODUCTION

Casting refers to the process of filling a metal, which was heated and melted in the furnace, into a mold and solidifying it to produce a certain type of product. The foundry industry, which is the basic material industry of all industrial sectors, is regarded as industrial rice, whether it is light industry or heavy industry. It is used as a key raw material in most industries such as machinery, automobile, and material industry, and the demand is increasing exponentially as the industry develops. Especially, in Korea, many castings plants have been built in accordance with the industrialization policy that started from the 1960s.

This study was conducted to recover the zinc from the dust casting furnace. As the industry develops, the amount of waste generated is gradually increasing, and some wastes become environmental pollutants. The Electric Arc Furnace Dust (EAFD), one of these typical wastes, is generated during the melting process of scrap iron. It is classified as hazardous waste, so it is landfilled or used as a filler of asphalt concrete [1]. This dust contains about 30-40% of zinc, so it can be used as a resource when appropriately treated. Zinc contained in EAFD is an important resource widely used as a key raw material for coatings, machinery, medicines, animal feeds, and paints to prevent oxidation of iron products [2-4]. Therefore, if the zinc contained in casting furnace dust in a larger amount than EAFD is recovered using an economical and efficient treatment method and used as zinc metal, it will contribute to recycling resources and inhibiting environmental pollutants. In March 2017, the LME market price of zinc is high at $2,872/ton, and it is expected to meet the environmental trend with the waste green circulation system through urban mines [5-7]. Globally, the process of recovering valuable metals in dust are divided into dry treatment and wet treatment. The dry treatment includes Waelz method and Plasma method [8-9]. The electrolytic method of the wet treatment includes a method of using alkaline leaching solution and a method of using acidic leaching solution [10-11]. Therefore, in this study, the author chose the dry process to recover the zinc contained in the casting furnace dust. The Waelz method recovered the zinc through the Imperial Smelting Process (ISP) process after the reduction process, but in this study, zinc can be recovered only by the reduction process. In addition, the conventional Plasma method has the advantage of directly recovering the metal zinc generated by melting and reduction, but has the disadvantage of high power consumption and low purity of zinc. Therefore, in this study, the author recovered zinc from the casting furnace dust only by a relatively inexpensive process and a simple reduction process.

II. EXPERIMENTAL METHOD

The casting furnace dust in power form used in this study was provided by “S” in Geyonggi-do. X-Ray Fluorescence Analysis and X-Ray Diffraction were used to analyze the properties of the casting furnace dust. X-ray fluorescence analysis was used to analyze the constituents of the top and bottom samples obtained through the recovery process. In the recovery process, 10g of dust was heated at a rate of 10°C /min, maintained at 900°C for 90 minutes, and then cooled at a rate of 10°C/min. A dry process was used to maintain a reducing atmosphere by injecting CH4 gas during heating, maintaining and cooling.

Fig. 1 is a schematic diagram of an experimental apparatus used in the recovery process. The reactor body was constructed in a box-type electric furnace so that the reactor body could be filled from above. The reactor body and cover used in this experiment were made of SUS301 material with high corrosion resistance and durability at high temperature, minimizing the potential thermal fatigue and fracture defects during the experiment. For complete sealing, rubber O-ring was installed between the reactor body and the cover to prevent outside and inside gas from entering and exiting. O-ring was protected from melting at high temperature by installing cooling line under the cover. Powder-type dusts were placed in the carbon crucible and charged in the center of the reactor, so that the inert gas reacted with the dust of the carbon crucible can be discharged easily through the off-gas line after the reaction.

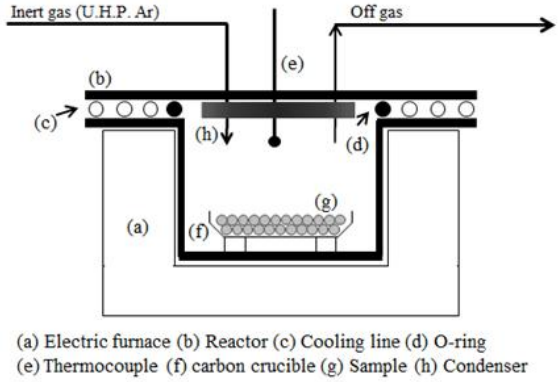

Fig. 1. Experimental apparatus for removal and recovery of arsenic from gold concentrate

III. RESULTS AND DISCUSSION

The main component of the casting furnace dust is Zn, and the content, in general, varies according to casting company, scrap iron, and operating conditions. The melting furnace dust used in this experiment was provided by "S" in Gyeonggi-do S, and the properties of the dust were analyzed before the experiment. Table 1 shows the results of XRF analysis of the casting furnace dust, and Fig. 2 shows the results of XRD analysis. The peak of ZnO was clearly observed, and it was judged that the dust was appropriate to recover zinc because it contained more than 90% of zinc.

Table 1. Chemical composition of the EAFD samples

Element	Weight(%)
Zn	92.16
Fe	3.57
Mg	2.56
Si	1.13
Al	0.24
S	0.21
Mn	0.09

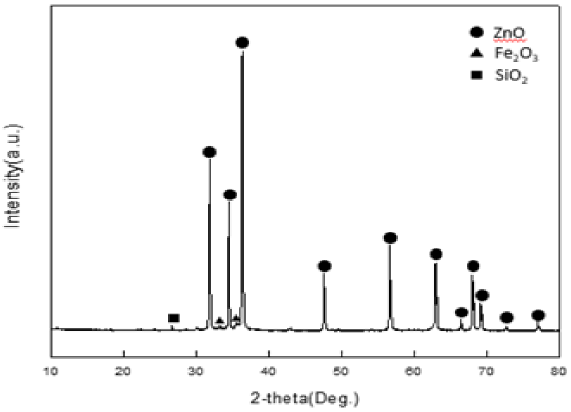

Fig. 2. The XRD pattern of the casting furnace dust in this study

In this experiment, zinc was vaporized at the same time as the reduction and recovered considering the boiling point was 907°C. In this experiment, CH_4 was used as a reducing gas to reduce ZnO. ZnO reacts with CH_4 at 900°C and is reduced to Zn, generating CO and H_2 gas are generated. And maintained for 90 minutes so that a sufficient reduction reaction can be achieved. The thermodynamic equation used in this experiment is as follows (1).

$$ZnO + CH_4(g) = Zn + CO(g) + 2H_2(g)$$

$$\Delta G_{900°C} = -5.87\text{kcal} \tag{1}$$

Therefore, in this study, the top sample deposited on the condenser by the scattering of zinc through the dry process was recovered. Due to the cooling line in the condenser, the scattered zinc at high temperature was deposited when it met with the low temperature condenser and the top sample was recovered. After the reduction and heat treatment in the dust, the unscattered samples were recovered from the carbon crucible. Fig. 3 is a photograph showing the results of XRD analysis of the top sample recovered from the condenser. Table 2 shows the results of analyzing the top and bottpm samples obtained from the recovery process using XRF. Zinc was scattered in the CH4 reducing atmosphere and 99.20% was confirmed as the top sample. In Fig. 3 the results of XRD analysis showed that ZnO became Zn. Also, it was confirmed that the zinc content (92.16 wt.%) of the dust sample was significantly reduced to the Zn content (5.31 wt.%), the bottom sample in the carbon crucible. Therefore, it was confirmed that the ZnO in the casting furnace dust was mostly scattered in the reducing atmosphere of 900°C and deposited on the condenser, implying that the holding time at 900°C was appropriate. Fe, Mg, Si, etc. were contained in the bottom samples remaining as residues and they did not scatter because the boiling point was higher than 900°C. The content of Fe was 32.44 wt.%; Mg was 24.46 wt.%; and Si was 20.43 wt.%. These results imply that it will be widely used as a resource if it goes through the process of recovering valuable metals once again from the bottom sample.

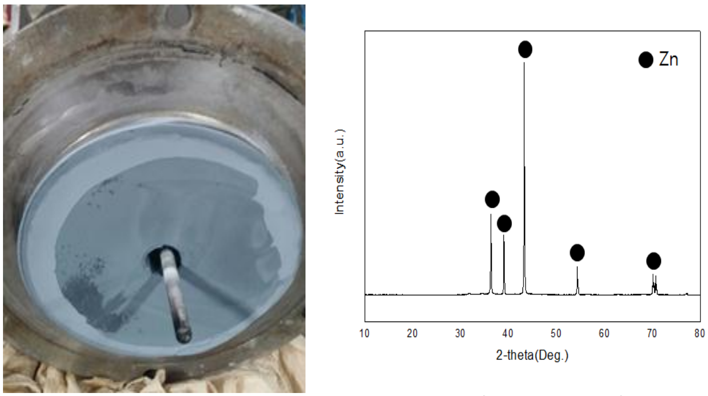

Fig. 3. Top sample and the XRD pattern of the casting furnace dust used in this study

Table 2. Chemical composition of top sample and bottom sample

Weight(%)	Zn	Ni	Cu	Fe	Si	Mg	Al	S	Ca
Top Sample	99.20	0.31	0.24	0.23	-	-	-	-	-
Bottom Sample	5.31	0.56	0.78	32.44	20.43	24.46	4.34	4.22	3.69

IV. CONCLUSION

This study recovered ZnO, which accounts for the largest portion of the casting furnace dust, as Zn through dry treatment method. The dry treatment method used in this experiment was a methane reduction atmosphere maintained at 900°C for 90 minutes, and most of the ZnO in the dust was scattered and recovered as Zn. All of these processes have been confirmed by XRD and XRF analysis and were accompanied by thermodynamic behaviors.

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