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Hydrometallurgical Extraction of Zinc and Iron from Electric Arc Furnace Dust (EAFD) using Hydrochloric Acid

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ABSTRACT: *Approximately 7.5 million tons of electric arc furnace dust (EAFD) are generated annually worldwide from steelmaking industry. EAFD is categorised as a hazardous waste due to the presence of heavy metals such as zinc, iron, nickel, lead and cadmium. Nevertheless, EAFD can be recycled through the extraction of zinc and iron, which constitute the greatest composition (8%–40% and 16%–60%, respectively) in EAFD. In this project, hydrometallurgical extraction of zinc and iron was performed using hydrochloric acid (HCl) as leaching agent. Factors such as temperature, acid concentration and dust-to-acid ratio on the extraction of zinc and iron were investigated. Results showed that zinc and iron extraction increased simultaneously as the temperature and acid concentration increased. The highest zinc and iron extractions were about 70% and 60%, respectively using 5 M HCl with dust-to-acid ratio of 3 g per 100 ml HCl at 70°C after 15 min of leaching. The result indicates the feasibility of zinc and iron extraction from EAFD through HCl hydrometallurgical process which will be beneficial for steelmaking industries in future.*

Keywords: Electric arc furnace dust (EAFD), hydrochloric acid leaching, hydrometallurgical process, zinc extraction, iron extraction

1. INTRODUCTION

In electric arc furnace (EAF) steelmaking process, about 15–20 kg of EAF dust (EAFD) is generated per ton of steel processed.[2,4,9] EAFD is categorised as hazardous waste as it contains heavy metals such as zinc, iron, cadmium and chromium.[2,4,9] Thus, proper disposal of EAFD needs to be implemented in order to prevent environmental pollution problem.[2] Instead of disposing EAFD, valuable zinc and iron can be extracted and recycled from the EAFD.[3] Generally, zinc and iron exist in the form of zinc ferrite ($ZnFe_2O_4$), zincite (ZnO), hematite (Fe_2O_3) and magnetite (Fe_3O_4) in EAFD.[4–6] In the past, pyrometallurgy, hydrometallurgy or hybrids of these methods have been developed to extract zinc and iron from EAFD.[5] In particular, hydrometallurgical process has the advantages of high flexibility, low energy consumption, low operating cost and environmental friendliness.[4,5] In hydrometallurgy, hydrochloric acid (HCl) is an effective lixiviant since Cl^- ions can act as strong activators to enable dissolution of zinc and iron as well as removal of other toxic elements.[7,8,10] Moreover, the filtration process for solid-liquid separation using HCl leaching is easier than sulphuric acid leaching.[8] Studies showed that in atmospheric HCl leaching of EAFD, maximum zinc extraction was about 23% using 5 M HCl at 50°C for 48 h, whereas, in pressure leaching (85 bar), about 93% of zinc extraction from synthetic zinc ferrite was achieved using 0.3 M HCl at 260°C after 100 min of leaching.[7,10] In pH-controlled HCl leaching (1–2 M), the highest iron extraction from EAFD was about 80% at 90°C after 2 h of leaching.[1] In this project, HCl was used as leaching agent to extract zinc and iron from EAFD obtained from local steelmaking industry. The factors affecting the extraction process such as temperature, acid concentration and dust-to-acid ratio were investigated for the extraction of zinc and iron from the EAFD.

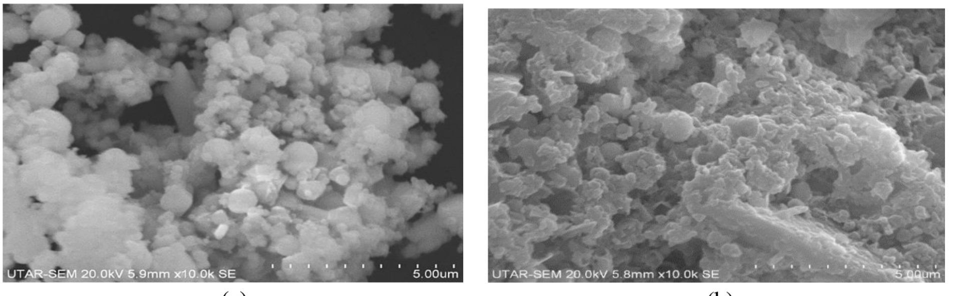
2. EXPERIMENTAL

Zinc and iron contents of EAFD were determined using inductively-coupled plasma optical emission spectroscopy (ICP-OES, Perkin Elmer OPTIMA 7000). The phases of the EAFD were analysed using X-ray diffractometer (XRD, Shidmazu XRD 6000). Scanning electron microscopy (SEM, Hitachi S3400N) was performed on the EAFD to investigate its morphology. Leaching experiment was conducted using different concentrations of HCl from 1.0 M to 5.0 M with temperatures variation from 25°C to 90°C. Leaching time for the experiment was set at 15 min. The dust-to-acid ratio was 3 g per 100 ml of HCl. Further investigation of dust-to-acid-ratio on the zinc and iron extraction was performed using 1 g to 8 g of dust per 100 ml of HCl. After leaching process, the filtered solution was subjected to ICP-OES analysis and the remaining solid residue was analysed using XRD and SEM.

3. RESULTS AND DISCUSSION

3.1 Characterisation of EAFD Before HCl Leaching

The zinc and iron contents in EAFD are ~26wt%, respectively. The morphology of EAFD in Figure 1(a) shows that EAFD consists of spherical particles with different sizes and the particles form agglomerates. In Figure 2(a), XRD analysis shows the presence of zinc ferrites ($ZnFe_2O_4$), zincite (ZnO), hematite (Fe_2O_3), magnetite (Fe_3O_4) and silicon dioxide (SiO_2) phases in EAFD.



(a) (b)

Figure 1: SEM images of (a) raw EAFD and (b) EAFD residue.

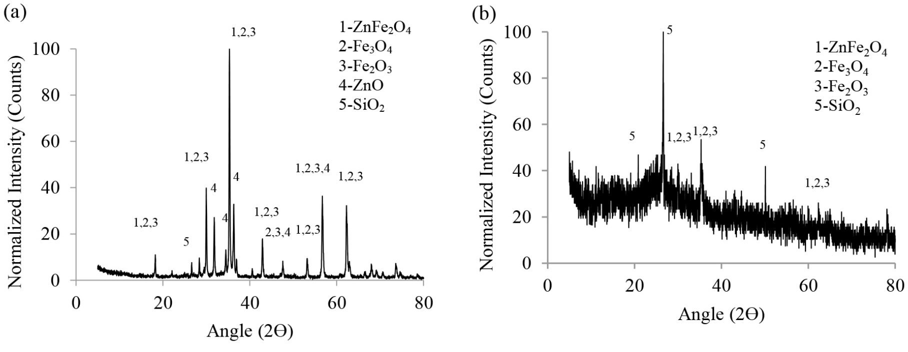


Figure 2: XRD pattern of (a) raw EAFD and (b) EAFD residue.

3.2 Effects of Acid Concentration, Temperature and Dust-to-Acid Ratio on Zinc and Iron Extraction

Figure 3(a) shows that zinc extraction increases as the HCl concentration increases. This is probably because the high acid concentration increases the amount of Cl^- ions which can act as strong activator to dissolve the zinc in EAF dust.[10] The increase in temperature also increases the amount of zinc extraction. This can be due to the elevated leaching temperature, which accelerates the reaction of EAFD with HCl. Nevertheless, the increase in zinc extraction from EAFD with increasing temperature did not apply for all samples. Depending on the acid concentration, further increase in temperature after a certain temperature can lead to a decrease in the zinc extraction from EAFD due to the evaporation of HCl.[11] From the investigation, the highest amount of zinc extraction from EAFD is around 70% using 5 M HCl with 3 g of dust to 100 ml of HCl after 15 min of leaching at 70°C. In the case of HCl leaching, iron can also be extracted simultaneously from EAFD during the extraction of zinc from EAFD. Figure 3(b) shows that iron extraction increases when acid concentration and temperature increase. However, depending on acid concentration, iron extraction also shows decrement at elevated temperature (80°C–90°C). The highest amount of iron extraction from EAFD is around 60% at 70°C using 3 g of dust per 100 ml of 5 M HCl after 15 min of leaching. In terms of dust-to-acid ratio, Figures 4(a) and 4(b) show that the highest amount of zinc and iron extractions are 70% and 60%, respectively when 3 g of EAFD to 100 ml of 5 M HCl was used. Further increase in the amount of EAFD (> 4 g) with constant HCl volume reduces the availability of acid to extract zinc and iron from EAFD.[5,6]

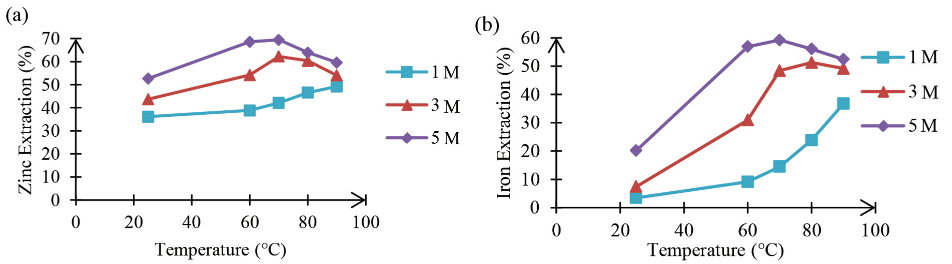


Figure 3: The effects of acid concentration and temperature on the extraction of (a) zinc and (b) iron from EAFD.

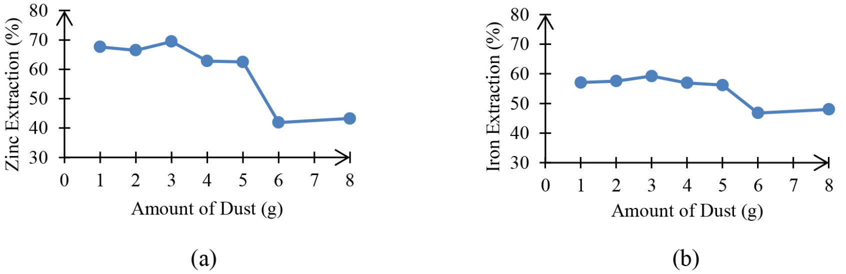


Figure 4: The effects of dust-to-acid ratio on the extraction of (a) zinc and (b) iron from EAFD.

3.3 Characterisation of EAFD Residue After HCl Leaching

Figure 1(b) shows that the morphology of EAFD residue has changed to irregular shape after HCl leaching. Pores are found among the agglomerates which can imply that EAFD has reacted with HCl during the leaching process. XRD analysis in Figure 2(b) shows that the zinc oxide peaks are not observed after leaching; whereas, the peaks of zinc ferrite, hematite and magnetite also decrease after leaching in comparison to the initial EAFD, shown in Figure 2(a). This can indicate that zinc and iron have been extracted from EAFD. However, the remaining zinc ferrite, hematite and magnetite in the EAFD residue after leaching can denote that zinc and iron are not completely leached from the EAFD.

4. CONCLUSION

Both acid concentration and temperature can affect the amount of zinc and iron extraction from EAFD. Present investigation shows that the highest zinc and iron extraction are around 70% and 60%, respectively using 5 M HCl with dust-to-acid ratio of 3 g to 100 ml after 15 min of leaching at 70°C. Further investigation on dust-to-acid ratio in terms of HCl volume and concentration can be performed in future to improve the zinc and iron extraction from EAFD.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

1. Baik, D. and Fray, D. (2000). Recovery of zinc from electric-arc furnace dust by leaching with aqueous hydrochloric acid, plating of zinc and regeneration of electrolyte. *Miner. Process. Extract. Metal.*, 109(3), 121–128, https://doi.org/10.1179/mpm.2000.109.3.121.
2. Dutra, A., Paiva, P. & Tavares, L. (2006). Alkaline leaching of zinc from electric arc furnace steel dust. *Miner. Eng.*, 19(5), 478–485, https://doi.org/10.1016/j.mineng.2005.08.013.
3. Ghani, A. et al. (2016). Study of zinc leaching of EAF flue dust using sodium hydroxide. *Pak. J. Anal. Environ. Chem.*, 17(1), 33–37, https://doi.org/10.21743/pjaec/2016.06.005.
4. Havlik, T. et al. (2012). Acidic leaching of EAF steelmaking dust. *World Metal. ERZMETALL*, 65(1), 48–56.
5. Havlik, T. et al. (2006). Hydrometallurgical processing of carbon steel EAF dust. *J. Haz. Mater.*, B135(1–3), 311–318, https://doi.org/10.1016/j.jhazmat.2005.11.067.
6. Havlik, T. et al. (2005). Atmospheric leaching of EAF dust with diluted sulphuric acid. *Hydrometal.*, 77(1–2), 41–50, https://doi.org/10.1016/j.hydromet.2004.10.008.
7. Langova, S., Lesko, J. & Matysek, D. (2009). Selective leaching of zinc from zinc ferrite with hydrochloric acid. *Hydrometal.*, 95(3–4), 179–182, https://doi.org/10.1016/j.hydromet.2008.05.040.
8. Lee, H., Baik, D. & Jo, H. (2002). Hydrometallurgical method for recovery of zinc from electric arc furnace dust. US Patent 6,338,748 B1.
9. Li, H., Wang, Y. & Cang, D. (2010). Zinc leaching from electric arc furnace dust in alkaline medium. *J. Centr. South Uni. Technol.*, 17(5), 967–971, https://doi.org/10.1007/s11771-010-0585-2.
10. Shawabkeh, R. (2010). Hydrometallurgical extraction of zinc from Jordanian electric arc furnace dust. *Hydrometal.*, 104(1), 61–65, https://doi.org/10.1016/j.hydromet.2010.04.014.
11. Wikipedia. (2017). Hydrochloric acid. Retrieved 11 December 2017, from https://en.wikipedia.org/wiki/Hydrochloric_acid.