Hydrometallurgical Recovery of Zinc from Electric Arc Furnace Dust by Using Acidic and Alkaline Leaching

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Abstract— ***Electric arc furnace is commonly used in secondary steel making which generates dust which is hazardous waste but it also contains zinc and other valuable metals. This dust is otherwise dumped into landfills which deteriorate the quality of land due to presence of toxic metals such as lead, arsenic and cadmium. In the present research the Electric arc furnace dust was first characterized with ICPMS for elemental analysis and XRD to determine the compounds present in the dust. In the elemental analysis it was found that zinc content was found to be 12.18% and iron content was 18.54% .It was also observed that zinc is present in the form of zinc ferrite ($ZnFe_2O_4$) and zinc oxide (ZnO). The objective of the study was to recover zinc from the EAFD. Zinc extraction was performed using sulphuric acid in acidic media and sodium hydroxide in basic media at various temperatures and different stirring speeds. In the research in acidic media high zinc extraction of 80.48% and is observed but the presence of iron which was observed to be 49.163% in the filtrate make this process unfit for electrowinning. Experiment on removal of iron from the acidic filtrate is also performed by precipitation by adding Ammonium hydroxide as a precipitating agent and it was observed that along with zinc, iron was also removed from the solution and the process was unable to remove iron from the solution. Therefore the whole research drifted towards caustic leaching. In experiments with caustic leaching although the zinc recovery was observed to be lesser than acidic media but iron as an impurity is found to be negligible. The process which was found to be most suitable for zinc recovery was caustic roasting and leaching of EAFD. In this process zinc recovery is found to be 70.91% and iron recovery was found 0.147%.Finally electrowinning was performed using stainless steel electrodes at 2.9V and 0.8A at room temperature of 27˚C .Zinc is found to be deposited at cathode as a grey colour deposit.***

Keywords— Electric arc furnace dust, Zinc, Leaching, precipitation, Electrowinning

I. INTRODUCTION

Today iron & steel industry has an important role in the development of a nation. The reason for their application is due to its high strength, high availability and low cost as compared to other materials available. Its properties could be varied by adding various alloying elements such as nickel, chromium and carbon etc. There are various types of furnaces which are used for their recycling such as Induction furnace and electric arc furnace. The furnace which is majorly used for secondary steel making at a larger level is electric arc furnace .A steel plant produces 30 tons of steel in 1 heat and a steel plant produces minimum 10 heats in a day which means a small steel industry using electric arc furnace produces at least 300 tons of steel every day. Out of the steel which is produced everyday 10-20 Kg of dust per ton of steel is produced[1] It means that an average production of dust in a small steel industry is at least 3000 Kg per day .

Electric arc furnace dust contains valuable metals such as Zinc, Manganese and Magnesium moreover this dust contains harmful elements such as Lead, Hexachrome and Cadmium. This dust is dumped otherwise into landfills which deteriorates the environment majorly polluting the ground water resources which can cause various diseases such as cancer moreover the steel industries have to pay heavy amount of money for its disposal which add up to the cost of steel increasing its price.

There are two methods to recover zinc from the electric arc furnace dust, one is pyrometallurgical and another is hydrometallurgical .The reason why this method is not applied for the recovery of zinc from electric arc furnace dust is that this process requires huge initial investment and high energy requirement .One of the possibilities is that centralised facilities for steel plants could be created for zinc extraction therefore this method is not suitable for study at laboratory scale.

II. CHARACTERIZATION

The dust was initially characterised by ICPMS and to determine the elemental analysis of the dust samples. The elemental analysis is shown in Table I as according to [2] each EAF dust has its individual elemental and mineralogical composition which implies that each dust has different optimum leaching parameters .The dust samples in this study are taken from Arora Steels, Ludhiana.

Table I
Result of Elemental analysis of the dust sample done by ICPMS

Element	Composition(in percentage)
Mg	1.15
Al	.417
Cr	.331
Mn	1.91
Fe	18.54
Ni	.024
Zn	12.18
Cd	.024
Pb	.542

The dust sample was also characterized by XRD and the results are depicted in Fig.1 show that the majority of the dust is in the form of zinc ferrite ($ZnFe_2O_4$) and zinc is present in the form of Zinc Oxide (ZnO) and zinc ferrite ($ZnFe_2O_4$)**.**Zinc ferrite is highly stable compound and it is difficult to recover zinc from zinc ferrite as compared to zinc oxide. From the results of elemental analysis it can be concludes that when the charge is heated in the electric arc furnace the zinc in the scrap reacts with iron to form highly stable zinc ferrite($ZnFe_2O_4$).remaining zinc reacts with oxygen to form zinc oxide.

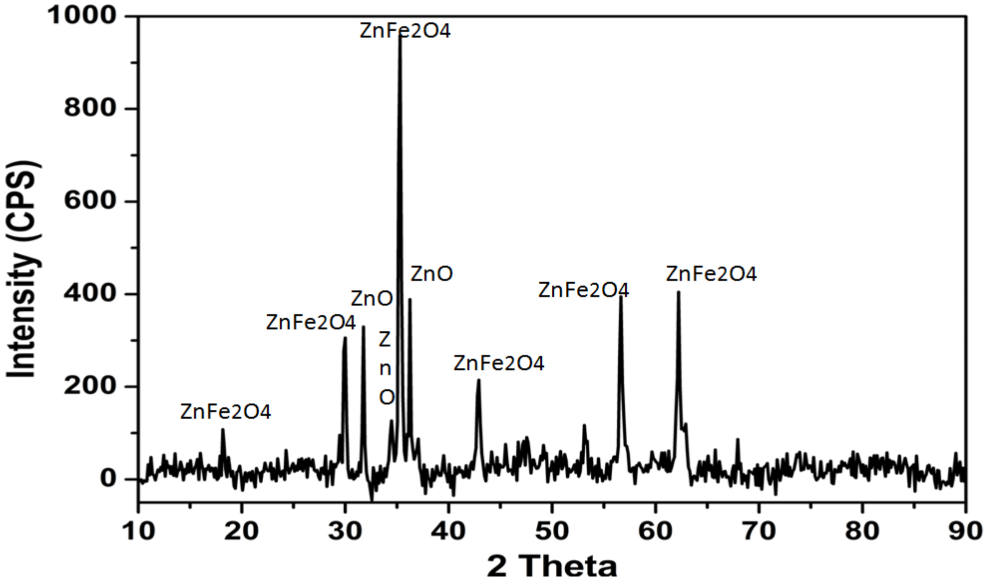

Fig. 1: X-ray diffraction spectra of the electric arc furnace dust

III. EXPERIMENTAL PROCEDURE

A. ACIDIC LEACHING

The dust was first treated with sulphuric acid as acidic reagents has high zinc recovery[3] .The experimental conditions. In the experiment dust was leached with 125ml of 1M sulphuric acid at 1000rpm with a liquid to solid ratio of 7.5
For a leaching time of 3 hours at room temperature to avoid iron dissolution into the solution .Then the solution was filtered by gravity filtration by using whatman42 filter paper and was analysed under atomic absorption spectrometer.

The results are shown in Table II. From Table II it can be concluded that although the zinc recovery is quite high but the iron content is also quite high in the solution which makes the process unsuitable for electrowinning.

TABLE II
PERCENTAGE RECOVERY OF ZINC AND IRON AFTER ACIDIC LEACHING

Elements	Recovery(%)
Zn	80.48
Fe	49.163

B. PRECIPITATION

After AAS analysis, for removing iron content precipitation reaction was conducted in which ammonium hydroxide was added as precipitant at pH of 1.7 at a temperature of 95˚C to precipitate out ammonium jarosite[4].The reaction for the precipitation are:

$$\mathbf{ZnO.Fe_2O_3 + 8H^+ \longrightarrow Zn^{2+} + 2Fe^{3+} + 4H_2O}$$

$$\mathbf{NH_4^+ + 3Fe^{3+} + 2SO_4^{2-} + 6H_2O \longrightarrow NH_4Fe_3(SO_4)_2(OH)_6 + 6H^+}$$

Which combines to give

$$\mathbf{3ZnO.Fe_2O_3 + 2NH_4^+ + 4SO_4^{2-} + 12H^+ \longrightarrow 3Zn^{2+} + 2NH_4Fe_2(SO_4)_2(OH)_6}$$

After precipitation blood red colour precipitates and solution was formed which was sent for analysis

Fig. 2

Filtration of sulphuric acid after precipitation

Fig. 3

After precipitation the residue left on the Filterpaper after precipitation

The solution was analysed by atomic absorption spectroscopy and from Table III although the recovery of iron dropped to 5.17% but the recovery of zinc also reduced to 33.19%.

TABLEIII
Percentage recovery of iron and zinc

Elements	Recovery(%)
Zn	33.19
Fe	5.17

TABLE IV
Comparison of analysis of acidic filtrate before and after precipitation by using AAS

Elements	Results(mg/l) Before Precipitation	Results(mg/l) After precipitation
Fe	12310	1280
Zn	13070	5390
Mg	1300	486
Ca	341	230

Before precipitation

Percentage of Zinc in the solution= (13070/(12310+13070+1300+341))*100=48.36%

Percentage of Iron in the solution = (12310/(12310+13070+1300+341))*100=45.557%

After precipitation

Percentage of Zinc in the solution= (5390/(1280+5390+486+230)*100=72.97%

Percentage of Iron in the solution= (1280/ (1280+5390+486+230))*100=17.33%

From the analysis of the solution it is concluded that addition of Ammonium Hydroxide (precipitating agent) is unable to remove iron completely from the solution moreover it also precipitate out zinc along with iron reducing the recovery of zinc in overall process. Therefore the acidic media is inappropriate to recover zinc from the solution as electrowinning of zinc require percentage of zinc above 90% in the solution.

Therefore the research moved towards caustic leaching process.

C. CAUSTIC ROASTING & LEACHING PROCESS

STEP 1: Hydrolysis of the dust

The dust was heated in distilled water at a temperature of 70˚C and stirred for 4 hours on a magnetic stirrer in a liquid to solid ratio of 4:1. It was then filtered with whatman 42 filter paper and dried in hot air oven at 80˚C for 4 hours and then at 150˚C for 4 hours.

STEP 2: Caustic roasting of the hydrolysed dust

A sample of 88g of hydrolysed dust was taken. Mixed NaOH with dust with NaOH: Dust in ratio of 1.27[5] therefore taken 112 g of NaOH in 100ml of distilled water, mixed the NaOH solution with hydrolysed dust, dried in a hot air oven at 150˚C to dry the water content. Then heated in programmable furnace for 1hour at 350˚C.This gives a hard solid greenish coloured structure. The image of the caustic roast is shown in Fig. 4. The zinc ferrite ($ZnFe_2O_4$) which is highly stable compound and difficult to break is broken down into sodium zincate (Na_2ZnO_2) and hematite (Fe_2O_3) by roasting electric arc furnace dust with NaOH.

STEP 5: Scrapping out the roasted residue
The roasted residue becomes quite hard to be directly scrapped out. Therefore added 5M NaOH solution prepared for leaching to scrap out the hard residue.

STEP 6: Leaching of caustic roast with NaOH solution.
Leaching of 800ml 5M NaOH solution at a stirring speed of 700rpm on a magnetic stirrer for 42 hours at room temperature at a liquid to solid ratio of 4:1 is done.

Fig. 4: After roasting at 350˚C the image of the caustic roast

STEP 7: Filtration of the solution
The solution after leaching was filtered with whatman 1 filter paper and the residue was washed with half the amount of solution taken and the residue was dried in hot air oven initially at 80˚C and then at 150˚C.

STEP 8: Electrowinning of zinc
The electrowinning of zinc was done using stainless steel electrodes in a one litre container at 2.9V at 0.8 A at room temperature of 27˚C. [6] The anode and cathode for electrowinning of NaOH was made up of stainless steel plates. The width of the plates was 40 mm and length was 120 mm, the thickness of the plate was 1.25 mm and out of 120 mm only 50 mm was immersed in the NaOH solution.
Result of Experiment III
The results of the experiment are shown in table V are analysed through microwave plasma atomic emission spectroscopy

Table V: Elemental analysis of 5M NaOH solution analysed through MPAES

Elements	**Results (mg/l)**
Zinc	6340

Iron	24
Copper	0.32
Lead	17.3
Aluminium	342

Recovery of zinc is found to be 70.9172% and recovery of iron is also found to be 0.147%

The zinc content in the sample is equal to 6340/(6340+24+0.32+17.3+342)=94.29%

The iron content of the sample is found to be 24/(6340+24+0.32+17.3+342)=.00356%

The iron content is found to be negligible in the solution in comparison to zinc content and the solution is found be fit for electrowinning. After electrowinning zinc is deposited as a grey colour solid at the cathode surface.

IV.CONCLUSIONS

From the characterisation it can be concluded that the dust mainly constitute zinc ferrite ($ZnFe_2O_4$) and zinc oxide (ZnO). Zinc ferrite is highly stable compound which is very difficult to break. It was also concluded that Sulphuric acid as a media has highest zinc dissolution as compared to basic media but it has low zinc selectivity as elements like iron also get dissolved in the solution which creates problem in electrowinning of zinc. Caustic leaching is found to have high zinc selectivity in terms of dissolution. Hydrolysis of dust removes impurities like Calcium, magnesium and other water soluble impurities. Roasting of the hydrolysed dust with NaOH helps to break the Zinc ferrite ($ZnFe_2O_4$) into sodium zincate (Na_2ZnO_2) and hematite (Fe_2O_3).The experiment in which caustic roasting with leaching is performed has maximum zinc recovery with 70.9172% with minimum amount of iron content in the solution 0.147% in which roasting with sodium hydroxide is performed at 350˚C and leaching is performed for 42 hours at room temperature.

V. References

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