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Recovery of zinc and iron from high iron-bearing zinc calcine by selective reduction roasting

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ABSTRACT

A novel method to recover zinc and iron from high iron-bearing zinc calcine by reduction roasting-low acid leaching-magnetic separation was proposed. The effects of roasting and leaching conditions were investigated and their optimum conditions were established. Meanwhile, the mineralogical changes during the processes were characterized by XRD, VSM, SEM and LPSA. The results show the $ZnFe_2O_4$ in the calcine was decomposed into ZnO and Fe_3O_4, and about 92.6% Zn was extracted from the roasted calcine with reporting most of iron as magnetite into the residue. Finally, more than 90% Fe was recovered from the residue by magnetic separation method.

Introduction

Zinc is a vital metal in the world and is mostly produced from zinc sulphide concentrates through the roast-leach-electrowinning process [1–3]. With the depletion of low iron-bearing zinc sulphide ores, the high iron-bearing ores, abundant in China, are becoming an important source for the production of zinc. In the roasting step, zinc sulphide is converted to oxide structure which is easier to dissolve in dilute sulphuric acid. However, a significant fraction of zinc oxide tends to react with iron impurities to form zinc ferrite ($ZnFe_2O_4$) [4–6], which poses a problem for extraction of zinc in subsequent leaching process, since it is a stable tetrahedral structure and cannot be dissolved under normal conditions and, as a result, is separated out as residue [7–10]. The presence of $ZnFe_2O_4$ therefore results in not only lower zinc leaching rate (<80%) but also considerable amount of leaching residue containing iron.

In order to solve this problem, the residue generated from neutral leaching procedure is subjected to hot acid leaching instead of low acid leaching to destroy the ferrite structure and thus improve the zinc leaching rate and reduce the amount of leaching residue [11,12]. Although the zinc leaching rate can reach 95%, the zinc sulphate solution obtained will still contain a high level of iron impurity. The dissolved iron must be removed from the solution prior to precipitation of other impurities for electrowinning of zinc metallic [13,14]. Up to now, three commercial technologies of removing iron viz. jarosite, goethite and haematite have been developed to precipitate iron as an easily filterable crystalline residue [15–17]. Precipitation methods are a well-established technology for iron removal, but considerable amount of iron residue is produced when they are applied in the industry of zinc production. Unfortunately, these iron residues contains soluble, toxic impurities such as Cd, Pb and As, and has never found any application and requires further disposal [18].

Concerns over the problems, such as iron release, energy consumption and environmental pollution, have been brought about by the oxidative roasting procedure, and consequently, direct acid leaching methods [19–21], including atmospheric leaching process and high pressure leaching process, have been developed to extract zinc from iron-bearing zinc sulphide concentrate. A fatal drawback of atmospheric pressure leaching process is that most of iron impurity is dissolved into the leach liquor with zinc extraction and thus it actually is no more economical than hot acid leaching. By contrast, the selective extraction of zinc can be achieved by high pressure process, but high investment cost makes it unsuitable to be applied widely. As

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Table 1
Chemical composition of the high iron-bearing zinc calcine (wt%).

Zn	Fe	S	Pb	Cu	Si	Ca	Mn	Cd	Ag
56.15	13.31	2.44	1.27	0.915	0.89	0.569	0.532	0.154	0.014

of present, there are no effective techniques within the industry to produce zinc from high iron-bearing zinc sulphide concentrate. Therefore, this investigation is set to develop an eco-friendly and cost-effective process for meeting the requirement of the zinc industry as whole.

In this study, a novel method, i.e., selective reduction roasting with low acid leaching followed by magnetic separation, was proposed to recover zinc and iron simultaneously from high iron-bearing zinc calcine (roasted high iron-bearing zinc sulphide concentrates). The reduction roasting process aims to selectively decompose the zinc ferrite contained in zinc calcine into zinc oxide and magnetite. After roasting, the zinc oxide generated will be extracted selectively by low acid leaching and the magnetite enriched in leaching residue will be able to be recovered using low intensity magnetic separation. The application of this method would simplify the process of zinc production, lower the quantity of leaching residue and reduce the requirement of leaching equipment. In addition, the reduction roasting can be performed taking full advantage of the heat carried by zinc calcine generated in the previous oxidative roasting process.

In this paper, the effects of roasting and leaching parameters on the transformation of $ZnFe_2O_4$ and the extraction of zinc, along with the recovery of iron from the leaching residue were investigated. The phase transformation and mineralogical changes during the process were also reported.

Experimental

Materials and analysis

The high iron-bearing zinc calcine used in this study was collected from a zinc hydrometallurgical plant in Inner Mongolia, China. The chemical and phase composition (wt%) of zinc and iron in the iron-bearing zinc calcine are depicted in Tables 1–3, respectively. It can be seen that the major elements present are zinc (56.15%), mainly distributed in zinc oxide (83.3%), and iron (13.31%) most of which exists in zinc ferrite (82.53%). Coal gas (CG), a good reductant in metallurgical industry for its reducibility can be controlled easily by adjusting the partial pressure of carbon monoxide (CO), was used as the reductant in the roasting process, the composition of which is shown in Table 4, indicating CO as the main reductive component. Carbon dioxide (CO_2) was also used in this investigation to control the reducibility of roasting atmosphere for the selective transformation of zinc ferrite to zinc oxide and magnetite. While nitrogen (N_2) was applied as a protective gas and H_2SO_4 used as the lixiviant in the leaching of the sample.

Table 2
Phase composition of zinc in the high iron-bearing zinc calcine.

Phase composition	ZnO	$ZnFe_2O_4$	$ZnSO_4$	ZnS	Zn_2SiO_4
Zn distribution (%)	83.30	12.84	2.01	1.38	0.47

Table 3
Phase composition of iron in the high iron-bearing zinc calcine.

Phase composition	$ZnFe_2O_4$	Fe_3O_4	FeS_2	Fe_2CO_3	Others
Fe distribution (%)	82.53	10.38	2.91	0.45	3.73

Table 4
Chemical composition of the coal gas.

Gas composition	CO	CO_2	H_2	N_2
Percentage (vol%)	28	5	13	54

Experimental methods

Experimental process

The schematic diagram of the airtight rotary kiln designed especially for this research was depicted in Fig. 1. About 150 g of dried zinc calcine was put into the rotary kiln and preheated to the required temperature (800 °C) at flow rate 1.0 L/min N_2. The reduction of the sample was conducted under the CG and CO_2, while the roasted zinc calcine cooled to room temperature at a flow rate of 1.0 L/min N_2. The calcine was then removed from the rotary kiln, weighed and stored for analysis and subsequent leaching experiment. During leaching process, the roasted zinc calcine obtained under the optimum roasting conditions was ground to -74 μm before it was dried at 105 °C for 8 h. Exactly 100 g of the prepared samples was put into a three-neck flask containing dilute sulfuric acid solution (110 g/L) prepared previously, which was heated by a thermostatic mantle and provided with a mechanical stirrer. After the required time, the leachate was separated from the residue by vacuum filtration and analyzed for zinc and iron. The zinc leaching residue was dried, weighed, and preserved in closed vessel for analyses and subsequent magnetic separation. Finally, the iron recovery test was performed in a low intensity magnetic separator (model: XCGS-Φ50) to investigate the magnetic separation performance of iron from the leaching residue.

Characterization techniques

In the present study, the percentage composition of zinc and iron were determined by inductively coupled plasma (ICP-AES, IRIS Intrepid II XSP) while the percentage composition of other elements were analyzed by X-ray fluorescence (XRF, Rigaku, ZSX Primus II), and the qualitative and quantitative information about crystalline phases were determined by X-ray powder diffraction (XRD, Rigaku, TTR-III) and chemical methods, respectively. The changes of magnetism, morphology and particle size were

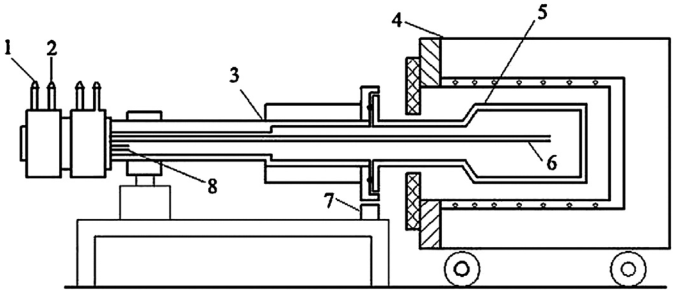

Fig. 1. Schematic diagram of the airtight rotary kiln: (1) water inlet, (2) water outlet, (3) cooling system, (4) electric resistance furnace, (5) corundum tank, (6) admitting pipe, (7) rotating wheel, and (8) escape pipe.