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# Pelletizing and alkaline leaching of powdery low grade zinc oxide ores

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**Abstract**

Low grade powdery zinc oxide ores (5.2% Zn, <2 mm) are mixed with cement 5 wt.%, pelletized and solidified. The diameters of the pellets obtained are between 5 mm to 8 mm. When the pellet solidification periods are 3 days, 10 days and 45 days respectively, the alkaline leaching rates of zinc in the pellets are up to 92.2%, 87.3% and 72.9% respectively. Decreasing the solidification time can reduce reaction time, increase dissolution of zinc in pellets and lower the effect of initial zinc concentration on leaching rate. The experiment results show that the minimum solidification time is three days, and the kinetic study indicates that alkaline leaching of the low grade zinc oxide pellets is controlled by the diffusion of the leach liquor through the gangue layer in the whole leach process, and the apparent rate constants are $3.51\times10^{-2}$ day$^{-1}$, $8.09\times10^{-3}$ day$^{-1}$, $4.74\times10^{-3}$ day$^{-1}$ respectively.


*Keywords:* Pelletizing; Ammonia leaching; Low grade powdery ores; Zinc oxide ores; Column reactor

## 1. Introduction

The processing of zinc oxide ores is becoming more attractive due to the depletion of zinc sulfide ores as well as the restriction on sulfur emissions during their processing. There is very abundant zinc oxide ores in Yunnan province (China). The zinc oxide ores usually contains a low grade zinc, high grade calcium magnesium carbonate and silica. Leaching of zinc can be performed either by hydrometallurgical or pyrometallurgical routes. The low grade zinc of the ores results in high consumption of energy in pyrometallurgical processing due to the necessity of heating high contents of gangue materials. The high content of silica usually enters solution as silica gel with zinc when acid leaching method is used. The formation of silica gel makes filtration difficult. To overcome the filtration difficulty, a new flocculating agent (Magnafloc 156) was used by Bodas (1996) and the quantity required was very small compared to the other flocculating agents used. A method proposed by Ikenobu (2000) made it possible to precipitate silica in a form having excellent solid–liquid separation characteristics by feeding a compound containing pre-adjusted silica contents. Perry (1966) used Al2(SO4)3 as the flocculating agent to prevent clogging of the filters with silicic acid. Matthew and Elsner (1977) adjusted the pH of the leaching solution to 4.0–5.5, using a neutralizing agent, to precipitate and coagulate the

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colloidal SiO2. In those processes the operating parameters must be properly controlled, otherwise colloidal silica will not be effectively precipitated from the solution. For the effective control of silica gel, Dufresne (1976) presented a method of treating zinc silicate ores, called the quick leaching. It was also applied to an Egyptian zinc silicate ore by Abdel Aal and Shukry (1997). Microwave irradiation by Hua et al. (2002) was applied to the quick leaching of zinc silicate ore. The leaching percentage of zinc was 99% and the dissolution of silica and iron was as low as 0.30% and 0.10%. Those investigations show that hydrometallurgical methods are more attractive than pyrometallurgical ones for the treatment of zinc oxide ores, especially for the low grade ores. Mineralogical studies showed that smithsonite can be completely leached but hemimorphite is relatively difficult to leaching by alkaline liquor. To this day, little has been published as related to an alkaline treatment of low grade powdery ores. Zhao and Stanforth (2000) studied the production of zinc powder by alkaline treatment of smithsonite ores. The best leaching results were obtained in presence of 5 M NaOH, at 90–95 °C and a reaction time of 90 min. Frenay (1985) studied leaching of zinc oxide ores in various solution media and obtained the best leaching results with alkaline media. In previous paper, directly leaching the ores was discussed whose diameter is between 2.0 mm–10.0 mm. But when the ores size is −2.0 mm, they could not be directly leached in a column reactor because they are too fine and the leaching liquor is difficult to go through the ores layer. In order to overcome the effect by silica gel, reduce the acid consumption, shorten technical process and economically utilize the ores, in this paper, as a fundamental study, powdery zinc oxide ores are mixed with cement, pelletized by disc balling machine, solidified and leached by ammonium sulphate solutions in a column reactor.

## 2. Experimental

### 2.1. Materials

The zinc oxide ores used in the present study was from Lanping town in Yunnan Province of China. The raw ores ground was analyzed by chemical method and examined by X-ray powder diffraction (XRD). The chemical composition is given in Table 1 and the XRD pattern is shown in Fig. 1. The chemical method shows that the sample contains 9.6% Zn, 8.5% Fe, 25.3% CaO, 1.1% MgO, 15.1% $SiO_2$, 0.7% $Al_2O_3$ and 0.02% Cu. X-ray diffraction (XRD) analysis shows smithsonite($ZnCO_3$) (8.4%), calcite ($CaCO_3$) (42.6%) and quartz ($SiO_2$) (15.1%) as the major components, Franklinite {(Zn, Fe, Mn)(Fe,Mn)$_2$O$_4$} (0.1%) as the minor ones and marmatite (nZnS·mFeS) (0.08%) is present in trace amounts in raw ores. Zinc is mainly in the form of smithsonite (86.0%) whose distribution shows in Table 2. Low grade powdery zinc oxide ores (5.2% Zn, <2 mm) are separated from the raw ores, mixed with cement 5 wt.%, pelletized and solidified. The diameters of the pellets obtained are between 5 mm to 8 mm and the pellet solidification periods are 3 days, 10 days and 45 days respectively in order to get enough compressive strength.

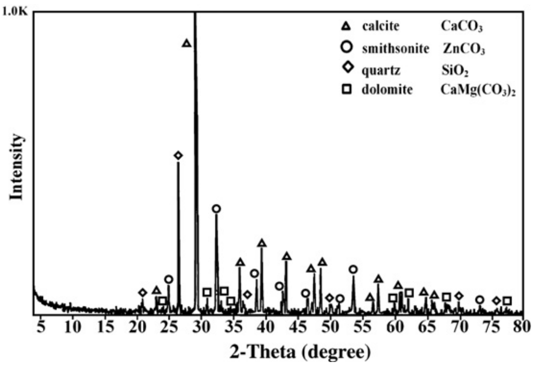


Fig. 1. XRD pattern of raw ores.

According to the result of previous paper, nine experiments are designed. In all experiments, the liquor and solid ratio is 4:1.Other different experiment parameters such as solidification time, concentration of $(NH_4)_2SO_4$, pH and initial zinc concentration are showed in Table 3. Those chemical reagents such as $(NH_4)_2SO_4$ and $NH_3 \cdot H_2O$ are of analytical purity.

### 2.2. Procedure

The experiments are carried out in a column reactor that is fabricated from 5 mm thick glass. The column showed in Fig. 2 is 650 mm high with an internal diameter of 45 mm, which is filled with pellets and fed with the leaching liquor at the rate of 95 L/(m$^2$ h); The leaching liquor immerged all pellets in column passes through the pellets sample slowly by gravity and then re-circulates through a side loop with a pump. A container with a capacity of 10.0 L collects the solution draining from the column. When the zinc concentration in solution doesn't increase, the leaching is the end. In the leaching process, the column system is comprised of 850 g pellets and the liquid and solid ratio is always 3400: 850 cm$^3$/

Table 1
Chemical composition of raw ores (wt.%)

| Zn | Fe | CaO | MgO | $SiO_2$ | $Al_2O_3$ | Cu |
|---|---|---|---|---|---|---|
| 9.6 | 8.5 | 25.3 | 1.1 | 15.1 | 0.7 | 0.02 |

Table 2
Mineral components of raw ore (wt.%)

| Smithsonite | Willemite | Blende | Franklinite |
|---|---|---|---|
| 86.0 | 12.6 | 1.1 | 0.4 |