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Research on Comprehensive Utilization of Efficient Extraction of Aluminum Oxide from Fly Ash

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Abstract

With the rapid development of industrialization, the output of fly ash has increased greatly, and the heavy metals and harmful substances it contains pose a serious threat to the environment and human health. However, fly ash is also rich in resources, especially alumina (Al_2O_3), and its effective recovery and utilization is of great significance for environmental protection and economic development. In this study, the acid-base combined extraction method was designed and optimized, which significantly improved the extraction efficiency of Al_2O_3 and reduced the production cost. Firstly, Al_2O_3 in fly ash was converted into soluble sodium aluminate by alkali treatment, then sodium aluminate was converted into aluminum hydroxide precipitate by acid treatment, and finally the extraction rate of Al_2O_3 was calculated by drying and weighing. The experimental results show that under the optimized conditions, the extraction rate of Al_2O_3 reaches a high level of 82.6% to 83.3%, which is significantly better than the traditional alkali method and acid method. In addition, this paper also discusses the comprehensive utilization of the extracted Al_2O_3 in electrolytic preparation of aluminum metal, production of ceramics and refractories, mechanical processing, production of high-purity transparent ceramics and as a catalyst carrier. These studies not only open up a new road for the resource utilization of fly ash, but also help to promote the sustainable development of related industries, reduce environmental pollution and achieve a win-win situation for economy and environment.

Keywords

Fly Ash; Comprehensive Utilization; Aluminum Oxide.

1. Introduction

Fly ash, as the waste after coal combustion, is an important solid waste produced in industrial production. With the rapid development of global industrialization, the output of fly ash is increasing year by year, which brings great challenges to environmental protection. Fly ash contains a lot of heavy metals and harmful substances, which will pose a serious threat to the environment and human health if it is not handled properly. However, there are many valuable resources in fly ash, such as alumina (Al_2O_3). The effective recovery and utilization of these resources can not only solve environmental problems, but also bring economic benefits [1-2].

Among the many components of fly ash, the content of Al_2O_3 is relatively high, and Al_2O_3 is widely used in industry [3]. Efficient extraction of Al_2O_3 from fly ash can not only realize the resource utilization of waste, but also relieve the pressure of bauxite resources and reduce the dependence on natural resources [4-5]. Therefore, it is of great practical significance and long-term development value to study the efficient extraction technology of Al_2O_3 from fly ash.

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At present, the research on extracting Al_2O_3 from fly ash has made some progress, but there are still some problems such as low extraction efficiency and high cost. The purpose of this study is to improve the extraction efficiency of Al_2O_3 and reduce the production cost through in-depth exploration and optimization of extraction technology, and to further explore the comprehensive utilization of the extracted Al_2O_3 in various fields. Through such research, a new road is opened up for the resource utilization of fly ash, which promotes the sustainable development of related industries, reduces environmental pollution and realizes a win-win situation for economy and environment.

2. Extraction Method of Al_2O_3 from Fly Ash

The core goal of this study is to significantly improve the extraction efficiency of Al_2O_3 from fly ash through in-depth exploration and optimization of extraction technology, and to reduce the production cost [6-7]. In order to achieve this goal, an innovative acid-base combined extraction method was designed, which combined the advantages of alkali method and acid method to maximize the extraction rate of Al_2O_3 and simplify the subsequent processing steps.

Firstly, the fly ash was pretreated by alkali treatment. In this step, sodium hydroxide (NaOH) reacts with Al_2O_3 in fly ash to form soluble sodium aluminate. The dissolution rate of Al_2O_3 can be maximized by controlling the reaction temperature, time and alkali concentration [8]. The next step is acid treatment, in which sulfuric acid (H_2SO_4) is used to acidify the alkali-treated solution to convert sodium aluminate into $Al(OH)_3$ precipitate. High-efficient precipitation of hydrogen Al_2O_3 can be achieved by adjusting the pH value of acid solution.

In order to improve the extraction efficiency of Al_2O_3, the acid-base combined extraction method was optimized. Specifically including:

(1) Optimization of reaction conditions. The effects of reaction temperature, reaction time, concentration of alkali liquor and acid liquor and pH value on the extraction rate of Al_2O_3 were systematically studied by orthogonal experimental design. Through these experiments, the best combination of reaction conditions was determined [9].

(2) Improvement of solid-liquid separation technology. In the extraction process, solid-liquid separation is a key step. Efficient centrifugal separation technology is adopted to improve the speed and efficiency of solid-liquid separation, thus reducing the loss of Al_2O_3 [10].

(3) Waste liquid recycling. Considering environmental protection and cost factors, the waste liquid generated in the extraction process is recycled. Through proper treatment, these waste liquids can be reused in the extraction process, thus reducing the production cost and reducing environmental pollution.

The acid-base combined extraction method designed in this study has the following innovations: high efficiency, and the extraction rate of Al_2O_3 is significantly improved by optimizing reaction conditions and solid-liquid separation technology. Environmental protection, through the recycling of waste liquid, environmental pollution is reduced, and the consumption of water resources is reduced. Economical, by optimizing the process and recycling the waste liquid, the production cost is reduced and the economy of the whole extraction process is improved.

3. Experimental Part

3.1 Experimental Materials and Methods

3.1.1 Source and Pretreatment of Fly Ash

Fly ash comes from a large local thermal power plant, which uses coal as the main fuel. The collected fly ash is first dried to remove the water in it, so as to facilitate the subsequent chemical reaction. After grinding, the dried fly ash can reach a certain fineness and increase its contact area with the reaction reagent, thus improving the reaction efficiency.

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3.1.2 Experimental Reagents and Instruments

The experimental reagents mainly include NaOH, H_2SO_4, etc., which are used in the alkali treatment and acid treatment steps of acid-base combined extraction method. In addition, deionized water is used as a solvent.

Experimental instruments include electronic balance, constant temperature water bath pot, centrifuge, pH meter, oven, etc. Electronic balance is used to accurately weigh reagents and samples; Constant temperature water bath pot is used to control the reaction temperature; Centrifuges are used for solid-liquid separation; The pH meter is used to monitor and adjust the pH of the solution; The oven is used to dry the treated samples.

3.1.3 Experimental Methods and Steps

(1) Alkali treatment step: the pretreated fly ash is mixed with NaOH solution with a certain concentration, heated to a set temperature in a constant temperature water bath pot, and stirred continuously for a certain period of time, so that Al_2O_3 and NaOH fully react to generate soluble sodium aluminate.

(2) Solid-liquid separation: centrifuge the reacted mixture to obtain supernatant containing sodium aluminate and residual solid.

(3) Acid treatment step: transfer the supernatant to another container, gradually add H_2SO_4 for acidification, and monitor the pH of the solution with a pH meter. When the pH value reaches a predetermined value, the addition of acid is stopped, and stirring is continued for a period of time, so that sodium aluminate is completely converted into hydrogen Al_2O_3 precipitate.

(4) Solid-liquid separation again: centrifuge the acidified mixture to obtain hydrogen Al_2O_3 precipitate and supernatant. The hydrogen Al_2O_3 precipitate was taken out and washed with deionized water several times to remove residual acid and sodium ions.

(5) Drying and weighing: put the washed hydrogen Al_2O_3 precipitate into an oven to dry to a constant weight, then take it out and weigh it, and calculate the extraction rate of Al_2O_3.

Through the above experimental steps, the effects of various factors in the acid-base combined extraction method on the extraction rate of Al_2O_3 were systematically studied, so as to optimize the extraction process, improve the extraction efficiency and reduce the production cost.

3.2 Experimental Results and Discussion

3.2.1 Al_2O_3 Extraction Rate of different Extraction Methods

In order to verify the effectiveness of the acid-base combined extraction method designed in this study, a comparative experiment was carried out with the traditional alkali method and acid method. In the experiment, three methods were used to extract Al_2O_3 from the same batch of fly ash, and the Al_2O_3 extraction rate of each method was calculated. The experimental results show that the extraction rate of Al_2O_3 by acid-base combined extraction method is obviously higher than that by traditional alkali method and acid method. The specific data are shown in Table 1 below.

Under the conditions of NaOH concentration of 4 mol/L, temperature of 90°C, treatment time of 2 hours and solid-liquid ratio of 1:10, the extraction rate of Al_2O_3 reached 52.7%. This shows that Al_2O_3 can be effectively extracted from fly ash by alkaline method under this condition, but the extraction rate is not the highest.

Under the conditions of H_2SO_4 concentration of 2 mol/L, temperature of 80°C, treatment time of 3 hours and solid-liquid ratio of 1:12, the extraction rate of Al_2O_3 was 47.3%. Compared with alkali method, the extraction rate of acid method is slightly lower under experimental conditions, which may be related to the types, concentrations and treatment time of acid.

Under the conditions of NaOH concentration of 3 mol/L, temperature of 95°C, acidification pH of 3.5, treatment time of 2.5 hours, solid-liquid ratio of alkali treatment of 1:10 and solid-liquid ratio of acid treatment of 1:8, the combined extraction method showed the highest Al_2O_3 extraction rate, up to 78.6%. This data is obviously higher than the extraction rate of alkali method and acid method,

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which shows that the acid-base combined extraction method can extract Al_2O_3 from fly ash more efficiently under optimized conditions.

Table 1. Comparison of Al_2O_3 extraction rates by different extraction methods

Extraction method	experiment condition	Al_2O_3 extraction rate (%)
Alkali method	NaOH concentration: 4 mol/L, temperature: 90°C.	52.7
	Time: 2 hours, solid-liquid ratio: 1:10.	
acid method	H_2SO_4 concentration: 2 mol/L, temperature: 80°C.	47.3
	Time: 3 hours, solid-liquid ratio: 1:12.	
acid-base combined extraction method	NaOH concentration: 3 mol/L, temperature: 95 °C.	78.6
	Acidification pH: 3.5, time: 2.5 hours.	
	Solid-liquid ratio (alkali treatment): 1:10	
	Solid-liquid ratio (acid treatment): 1:8	

By comparing the Al_2O_3 extraction rates of three extraction methods under experimental conditions, it can be found that the acid-base combined extraction method has higher extraction efficiency. This method combines the advantages of alkali method and acid method. By optimizing the treatment conditions and steps, the extraction rate of Al_2O_3 is significantly improved, which provides a more efficient method for the resource utilization of fly ash.

3.2.2 Determination of Optimum Extraction Conditions

In order to determine the best extraction conditions of acid-base combined extraction method, several groups of single factor experiments were carried out. In the experiment, the parameters such as reaction temperature, reaction time, alkali concentration, acid concentration and pH value were changed respectively, and the effects of these parameters on the extraction rate of Al_2O_3 were observed.

Through the analysis and comparison of experimental data, the following optimum extraction conditions were determined: reaction temperature was 85℃, reaction time was 3 hours, alkali concentration was 3 mol/L, acid concentration was 1.5 mol/L, and pH value was 4.5.

Table 2. The extraction rate of Al_2O_3 in repeated experiments under the optimum extraction conditions

Experimental serial number	Reaction temperature (℃)	Reaction time (hours)	Alkaline solution concentration (mol/L)	Acid concentration (mol/L)	pH value	Al_2O_3 extraction rate (%)
1	85	3	3	1.5	4.5	82.6
2	85	3	3	1.5	4.5	83.1
3	85	3	3	1.5	4.5	82.9
4	85	3	3	1.5	4.5	83.3
5	85	3	3	1.5	4.5	82.8

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Repeated experiments were carried out under the optimum extraction conditions, and it was found that the extraction rate of Al_2O_3 was stable and reached the highest value. This shows that the extraction efficiency of acid-base combined extraction method can be further improved by optimizing the extraction conditions. The results are shown in Table 2.

It can be seen that under the optimum extraction conditions (reaction temperature is 85℃, reaction time is 3 hours, alkali concentration is 3 mol/L, acid concentration is 1.5 mol/L, and pH value is 4.5), five repeated experiments have been carried out. The extraction rate of Al_2O_3 is stable between 82.6% and 83.3%, and the average extraction rate is high, which shows the efficiency and stability of acid-base combined extraction method under optimized conditions.

By comparing the extraction rate of Al_2O_3 with different extraction methods and determining the best extraction conditions, the effectiveness and superiority of the acid-base combined extraction method designed in this study in extracting Al_2O_3 from fly ash are verified. This method not only improves the extraction efficiency of Al_2O_3, but also provides a new way for the resource utilization of fly ash.

4. Comprehensive Utilization of Al_2O_3

As an important inorganic nonmetallic material, Al_2O_3 has been widely used in many fields. Its high chemical stability, excellent mechanical and thermal properties make it a key raw material in many industrial processes.

Al_2O_3 is the main raw material for preparing aluminum by electrolysis. In the electrolytic cell, molten Al_2O_3 is decomposed into aluminum and oxygen after electrolysis. In this process, the purity of Al_2O_3 and electrolytic conditions have a crucial influence on the quality and output of aluminum. High purity Al_2O_3 can improve electrolysis efficiency and reduce the influence of impurities on aluminum quality. In the production of ceramics and refractory products, Al_2O_3 is widely used because of its high melting point, high hardness and excellent wear resistance. It can increase the hardness and high temperature resistance of ceramics and make ceramic products more durable. At the same time, adding Al_2O_3 to the refractory can improve the refractory temperature and slag resistance of the material.

The hardness of Al_2O_3 is second only to that of diamond and silicon carbide, so it is often used as grinding material and cutting tool. In the field of machining, Al_2O_3 abrasive can be used to grind metal surface and improve its smoothness. In addition, Al_2O_3 can also be made into cutting blades for cutting various hard materials. High-purity Al_2O_3 has a special application in the fields of translucent Al_2O_3 sintered body, phosphor carrier and so on. Its excellent light transmission performance can be used to make transparent ceramics, such as the light transmission tube of high-pressure sodium lamp. At the same time, high-purity Al_2O_3 is also an important carrier for making phosphors, which is widely used in lighting and display industries.

Active Al_2O_3 has high specific surface area and adsorption capacity, so it is often used as catalyst, adsorbent, dehydrating agent and catalyst carrier. Active Al_2O_3 plays an important role in petrochemical, fine chemical and environmental protection fields. It can accelerate the rate of chemical reaction and improve the purity and yield of products; At the same time, it can also effectively adsorb and remove harmful substances in gas or liquid. Al_2O_3 has a wide range of application values in many fields. With the continuous progress of science and technology and the growth of industrial demand, the comprehensive utilization of Al_2O_3 will be more in-depth and diversified.

5. Conclusion

In this study, the extraction efficiency of Al_2O_3 from fly ash was significantly improved by designing and optimizing the acid-base combined extraction method, and its comprehensive application potential in many fields was discussed. The results show that the acid-base combined extraction method combines the advantages of alkali method and acid method, and maximizes the extraction rate of Al_2O_3 by optimizing the key parameters such as reaction temperature, time, alkali and acid

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concentration and pH value. Compared with the traditional method, this method not only improves the extraction efficiency, but also simplifies the subsequent processing steps and reduces the production cost. In addition, through the recycling of waste liquid, this study also achieved a double promotion of environmental protection and economic benefits. In the aspect of comprehensive utilization, it is pointed out that Al_2O_3, as the main raw material for preparing aluminum by electrolysis, has a wide range of application values in the fields of ceramic and refractory products production, mechanical processing, translucent materials and catalyst carriers. These applications not only promote the development of related industries, but also open up a new road for the resource utilization of fly ash. In this study, by efficiently extracting alumina from fly ash, the resource utilization of waste was realized, the dependence on natural resources was reduced, and the environmental pollution was reduced. The research results not only have important practical significance, but also provide new ideas and methods for the comprehensive utilization of fly ash in the future.

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