Processing of Coal Fly Ash as an Alternate Resource for Alumina Ensuing Acid Leaching Route

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Abstract

Considering the depletion of Bauxite, the extraction of alumina has been experimented using alternate source material, coal fly ash. The process of recovering alumina from coal fly ash (CFA) is quite complex requiring the application of stringent reaction conditions such as high temperature and pressure including high inventory of chemicals. In order to simplify the leaching conditions the effect of fluoride ion on sulphuric acid leaching of coal fly ash has been tested. The addition of fluoride ions such as HF and NaF improved the acid leaching performance to a great extent when partial desilicated ash was used. The partial desilication was carried out through an alkali treatment of CFA. The use of desilicated CFA reduced the requirement of fluoride ion and sulphuric acid concentrations as compared to the original CFA treatment in the extraction of alumina. It has been observed that the HF is more reactive than the NaF. It was noted that extracting more than 90 % of alumina from the CFA requires one-third amount of HF than NaF while keeping the sulphuric acid quantity the same. The sodium silicate formed during the desilication process was treated with lime to produce calcium silicate as a by-product and sodium hydroxide regenerated is recycled back for subsequent alkali treatment of fly ash. The reactions mechanism and an overall flow sheet for the treatment of CFA have been described. The preliminary cost economics for extraction of alumina following the above process has also been worked out.

Keywords: Coal fly ash, Alumina, Sulphuric acid, Leaching, Fluoride ion.

1. Introduction

The world's annual generation of coal fly ash (CFA) is nearly about 800 million tonnes out of which India alone produces more than 180 million tonnes. The CFA contains different valuable minerals such as mullite, quartz, hematite, magnetite, α-alumina, calcium oxide, titanium dioxide, etc. Mullite is the main alumina bearing silicate phase. In India, nearly 30 million tonnes of alumina, the major value material, which is present in fly ash is getting wasted due to the unavailability of suitable technologies. Extraction of alumina from CFA has been tried in various places through different methods such as limestone sintering [1,2], soda-lime sintering [3], calsinter process [4,5], ammonium sulphate sintering process [6] and acid leaching processes [7,8]. However, these processes are associated with a number of disadvantages. The sintering process produces a huge quantity of residue which is a few times higher than the original ash. In the ammonium sulphate process the requirement for ammonium sulphate is huge (10:1, ammonium sulphate: alumina). The sulphuric acid method requires a higher temperature of 200–210 °C, at a ratio of acid to fly ash as 5:1 (v/v) with an extraction efficiency of 85 %.

Mullite is the major alumina bearing material in CFA. More than 90 % of alumina available in fly ash is associated with 8-10 % of silica in the form of mullite. Mullite, the aluminosilicate phase is a very stable refractory material. Due to its refractoriness, it is hard to dissociate into its constituent components for further processing through conventional pyro or hydrometallurgical routes. Mullite morphology is also important as there are two common morphologies for mullite. One is a platelet-shaped with low aspect ratio and the second is a needle-shaped with high aspect ratio. Needle shaped mullite forms have high mechanical strength and thermal shock resistance as the needles interlock. This type of mullite morphology is a major hindrance to its disintegration during leaching. Fly ash contains both needles as well as platelet types. Therefore, rigorous treatments are needed for processing the fly ash at high temperature or pressure conditions. In the present study, hydrometallurgical processing options are pursued. The simple leaching of fly ash for the recovery of alumina with alkali or acid is very difficult to accomplish as the breaking of the mullite phase is extremely difficult. Under hydrothermal (pressure) conditions also it could not be broken.

In the present study, sulphuric acid leaching method has been adopted in presence of fluoride ions to recover alumina from coal fly ash. The authors in their earlier works presented the effect of fluoride ions by adding sodium fluoride [9] and hydrofluoric acid [10] to solubilize the alumina values under various leaching conditions. In earlier work, leaching studies were carried out taking untreated fly ash whereas in the present study soda leached residue of fly ash was taken for the study (soda ash leaching was performed to leach out a significant portion of silica, which is amorphous in nature) [10]. Additionally, the effects of both NaF and HF were compared. A flow sheet for alumina production from fly ash has also been prepared considering the improved extraction efficiency. The chemistry of the process, tentative cost estimation and various product characterizations have been included.

2. Materials and Method

2.1 Materials

The CFA was collected from the thermal power plant of National Aluminium Company Limited (NALCO), India. The ash had a median particle size of 36.8 µm (d50). All the chemicals used in the present work were of analytical grade (Merck, India). The phase analysis was carried out using the X-Ray diffraction patterns generated from an X-Ray Diffractometer (Philips, PW 1710). The surface morphology was investigated using an optical microscope (Leitz make).

2.2 Method

Hydrothermal sodium hydroxide leaching of ash was carried out in an autoclave of 1 L capacity by varying NaOH concentration and temperature. A detailed study on this has been mentioned elsewhere [9]. At the end of the experiment, the slurry was filtered and then the leach residue was washed and dried for further processing through the acid leaching route to extract alumina. Acid leaching of alkali leached ash residue was carried out in the absence or presence of fluoride ions. Fluoride ions are added in the form of HF or NaF. The leach liquor obtained after filtration was then analysed for aluminium concentration and the leaching efficiencies of alumina were calculated using the standard method. Precipitation of aluminium hydroxide was carried out after separating the iron hydroxide.

extract more than 90 % of alumina whereas to obtain a similar efficiency in the case of NaF an amount of 3 g was needed. Desilication of fly ash has shown beneficial effects in terms of alumina recovery as well as a reduction in chemical consumption. The sodium silicate formed during desilication can be treated with lime to produce calcium silicate as a by-product and sodium hydroxide generated can be recycled back for hydrothermal alkali leaching of fly ash. A process flow sheet has been developed to successfully extract alumina from fly ash. The preliminary cost calculations based on a laboratory scale study showed a profit margin with a return on investment of about 23 %. Subsequently, the process will be tested in pilot scale for recovery of alumina and other by-products. The cost economics of the process will also be carried out based on the pilot scale data.

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